APPLICATION DATA SHEET

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Number of Copies of CDs::	
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exocad GmbH, et. al.
Exhibit 1004 - Part 2

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Name	William C. Rowland	Registration No.	30888

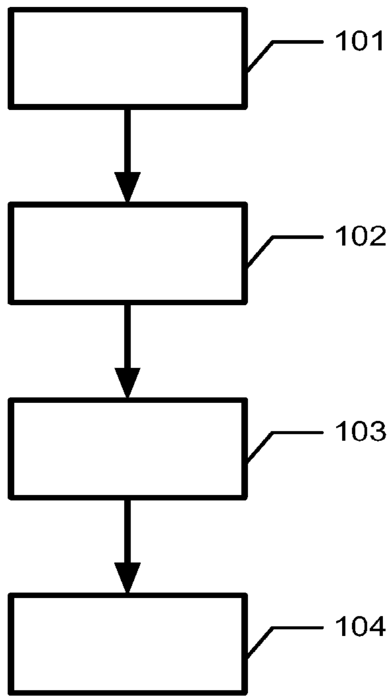


Fig. 1

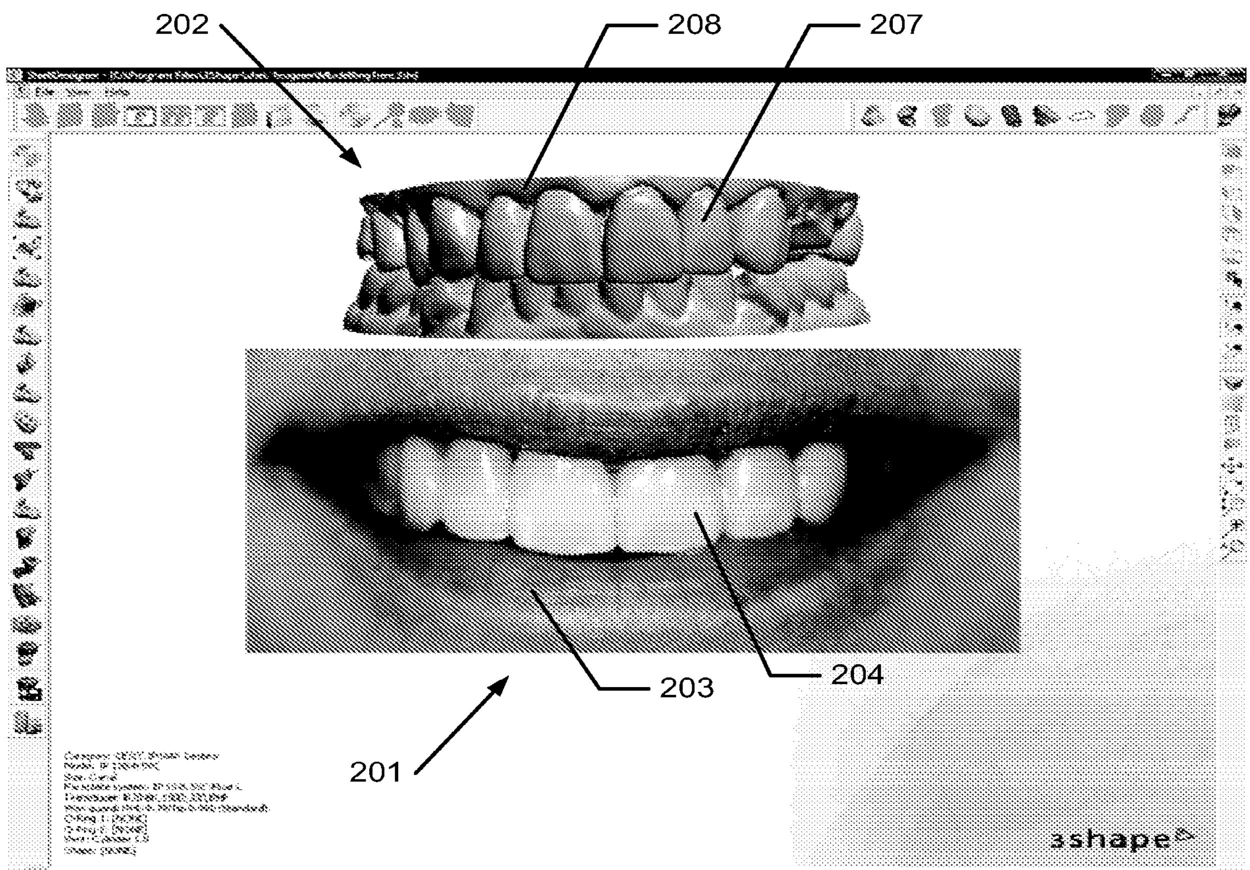


Fig. 2a)

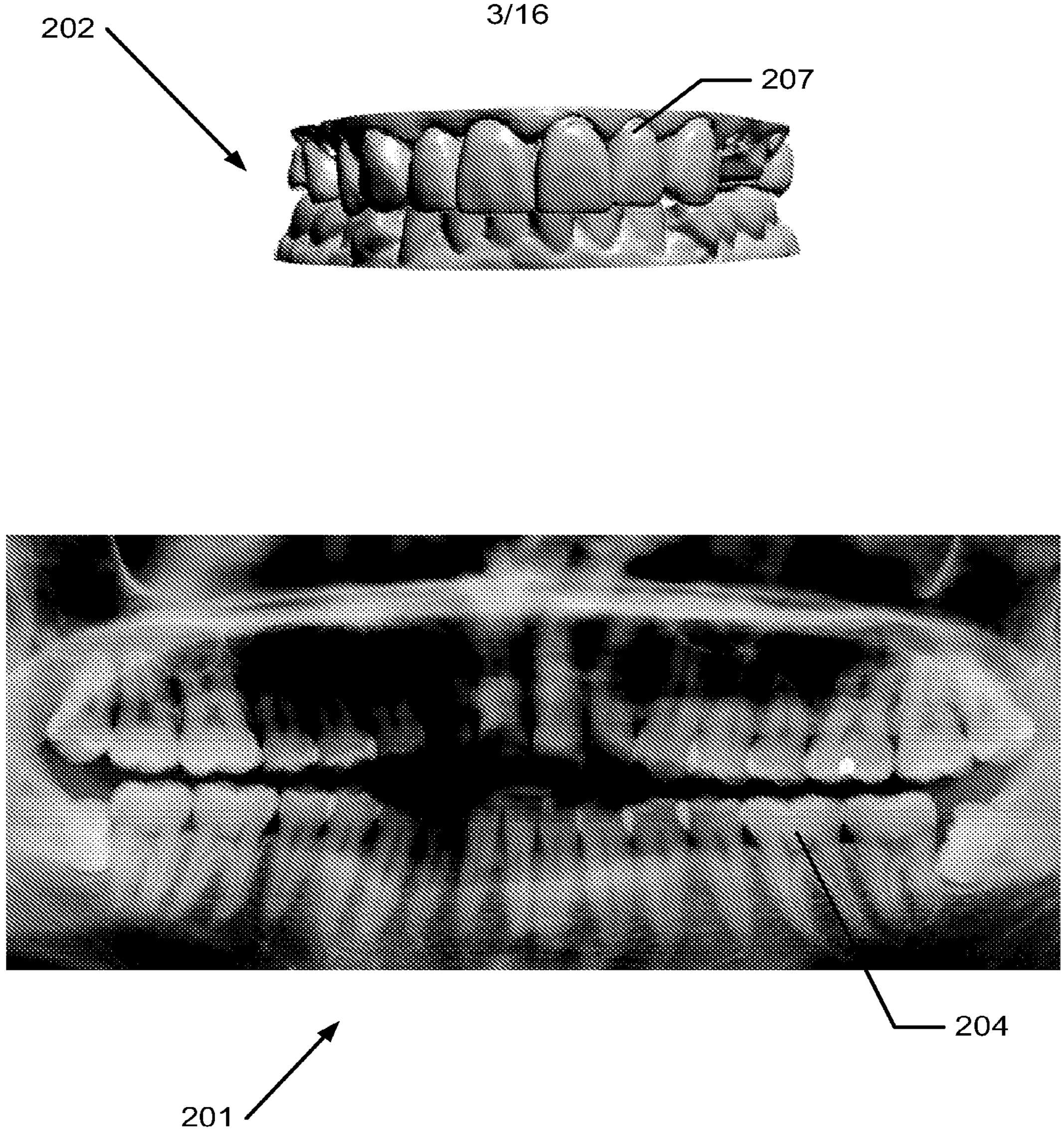


Fig. 2b)

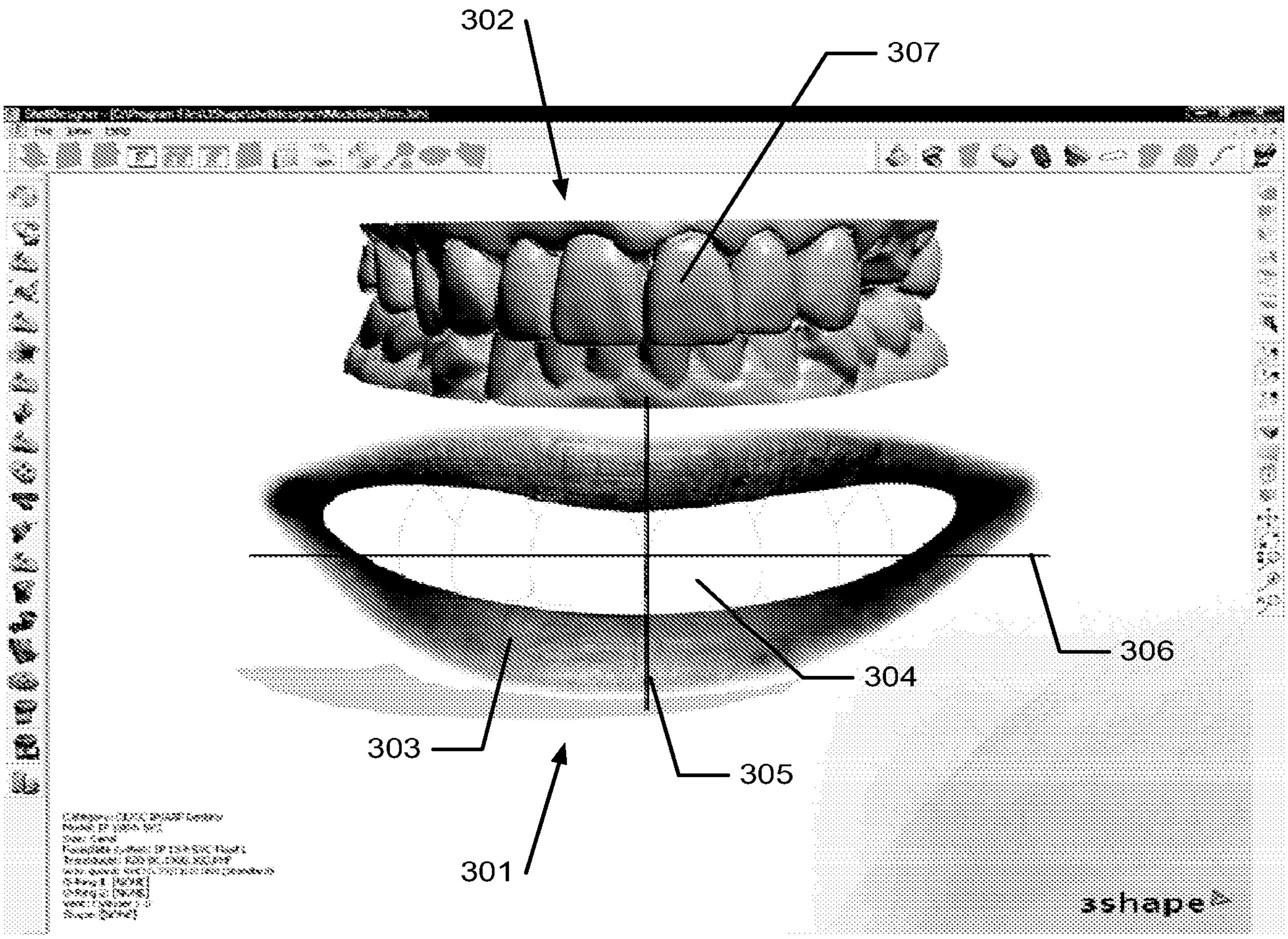


Fig. 3a)

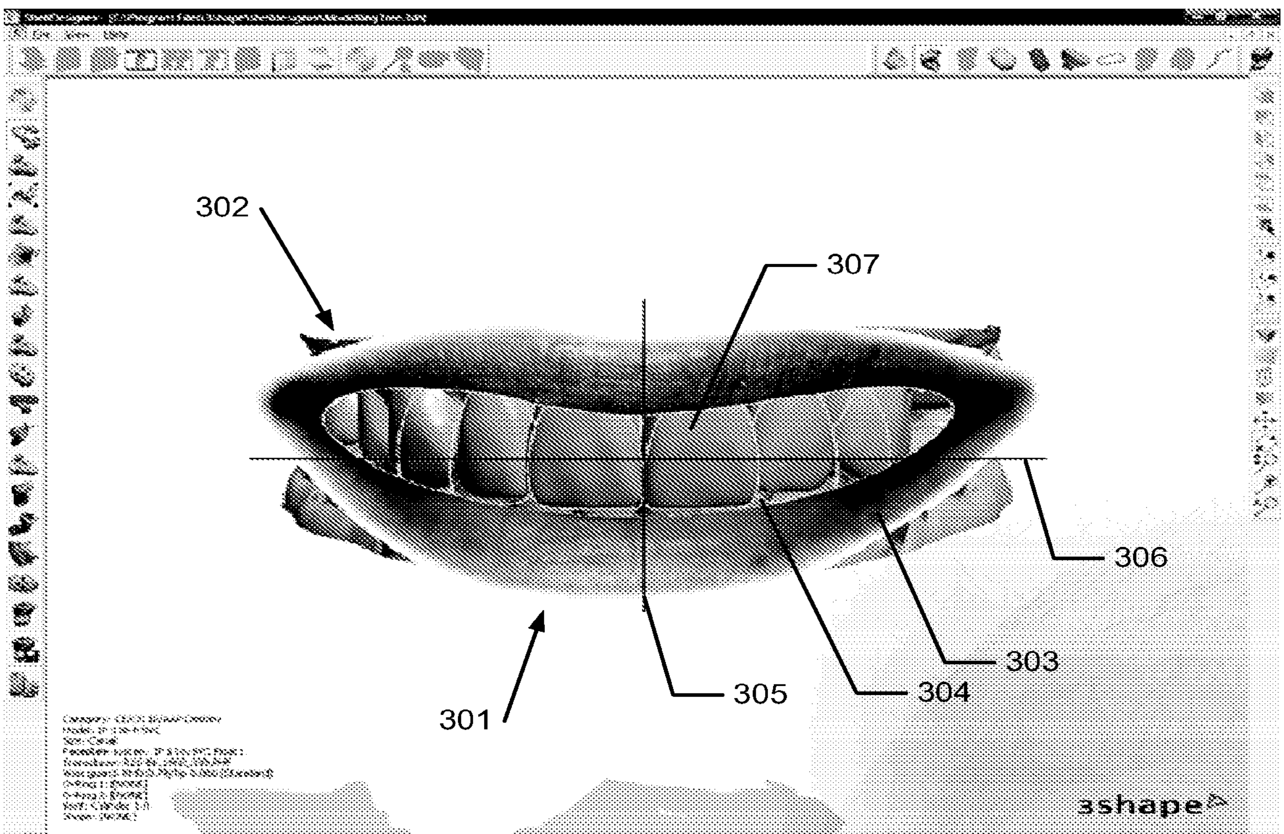


Fig. 3b)

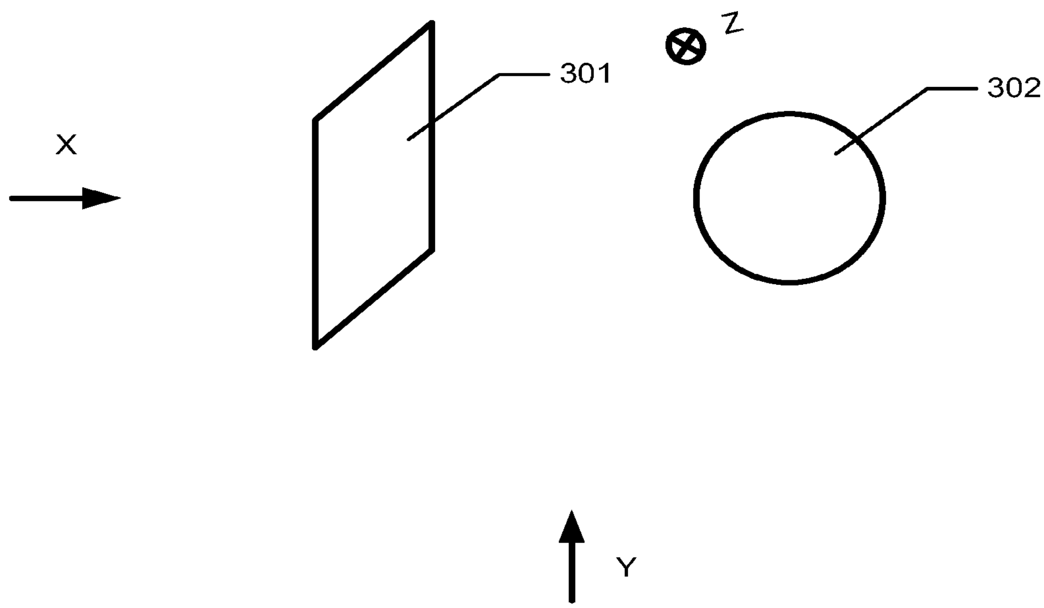


Fig. 3c)

Fig. 4a)

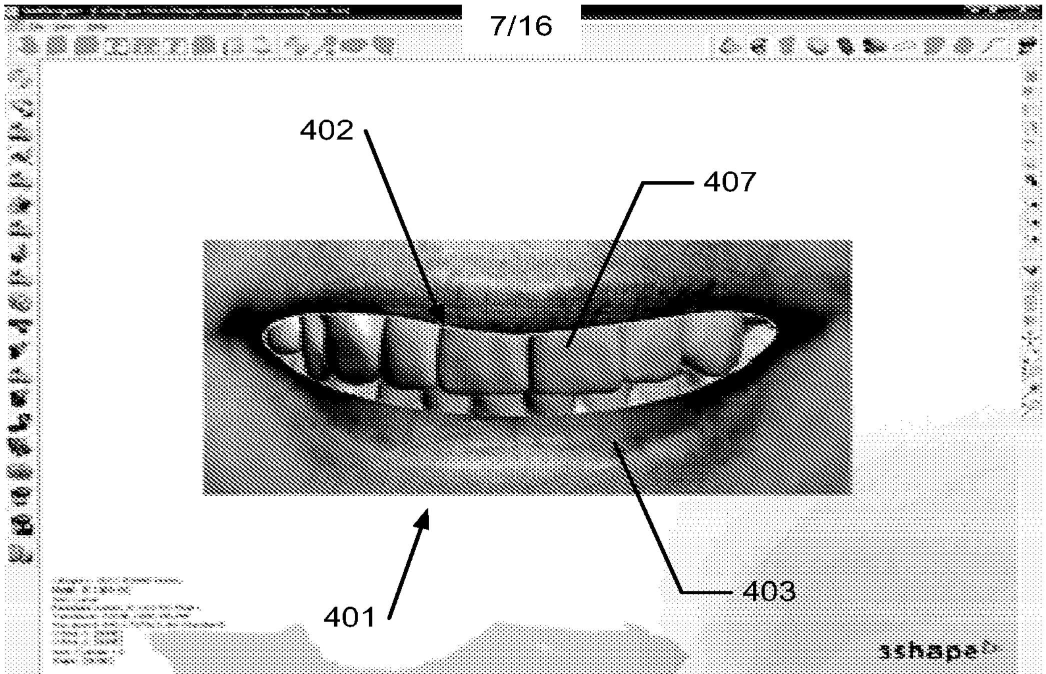
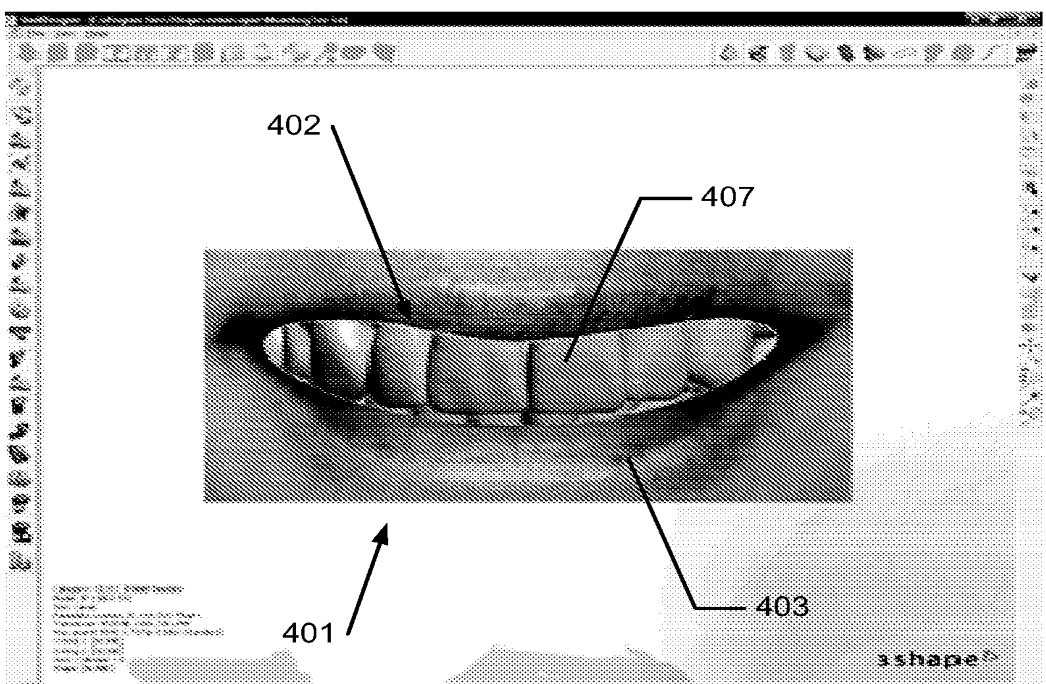


Fig. 4b)



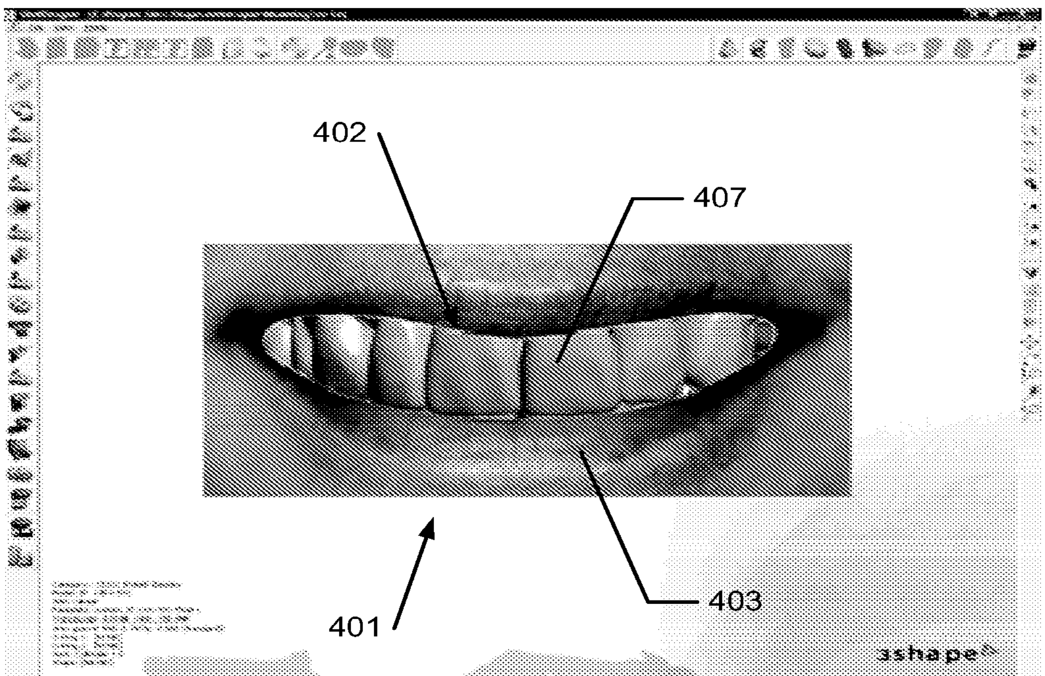


Fig. 4c)

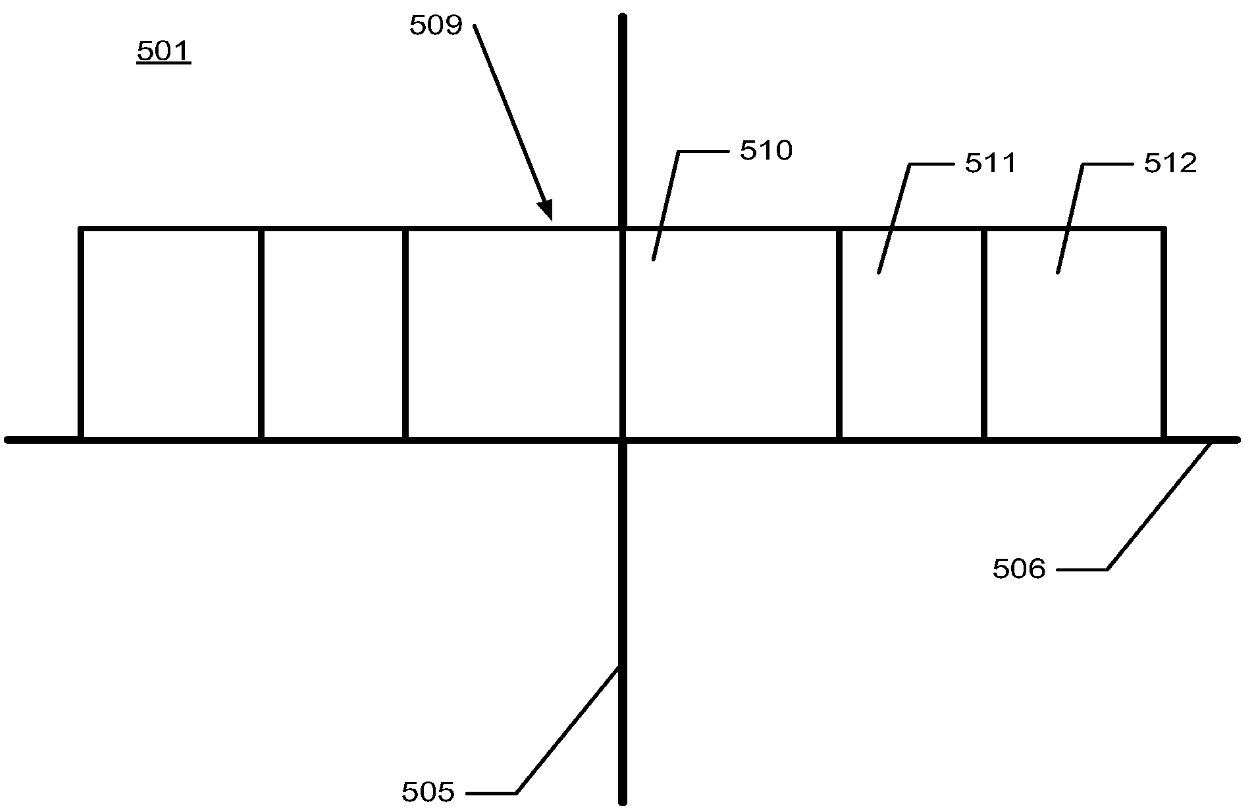
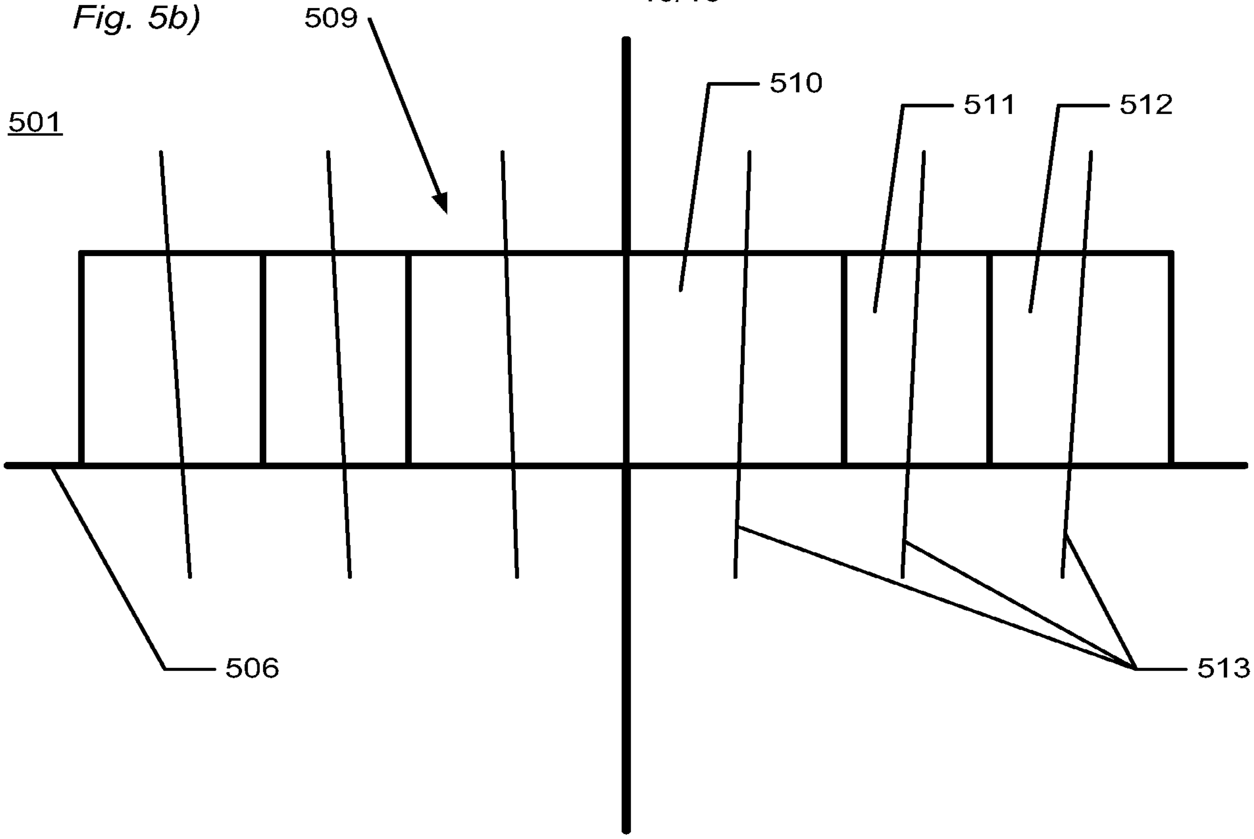


Fig. 5a)

Fig. 5b)



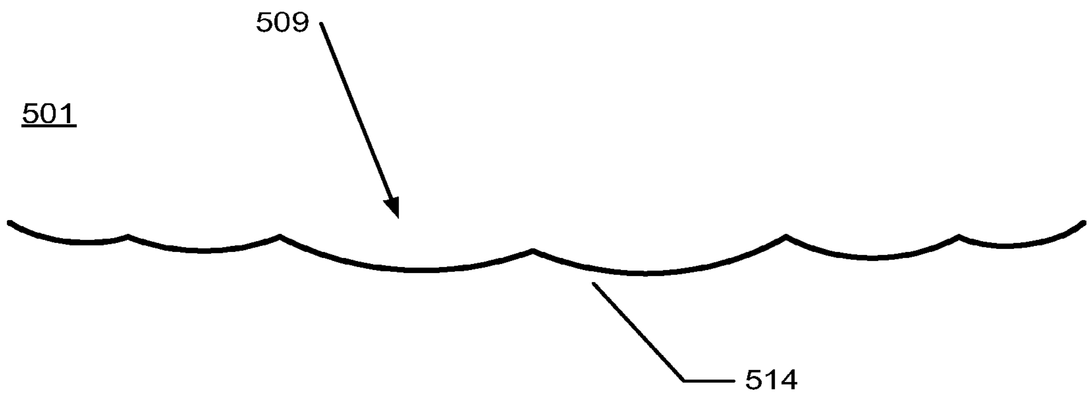
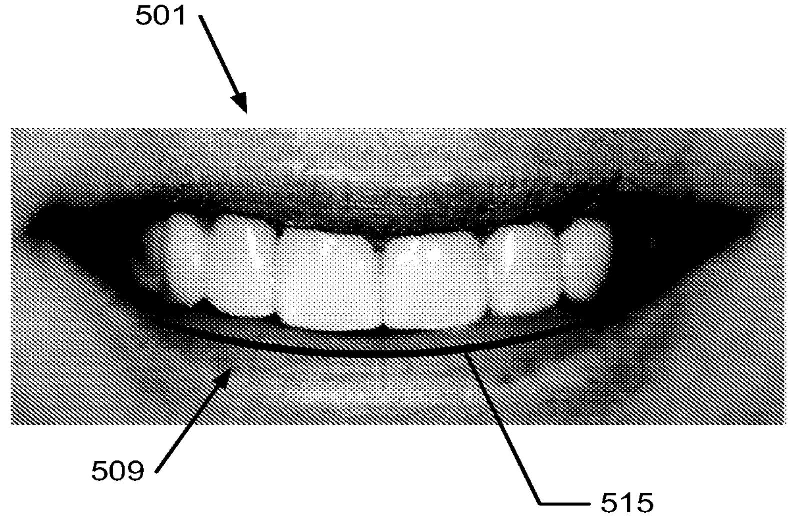


Fig. 5c)

Fig. 5d)



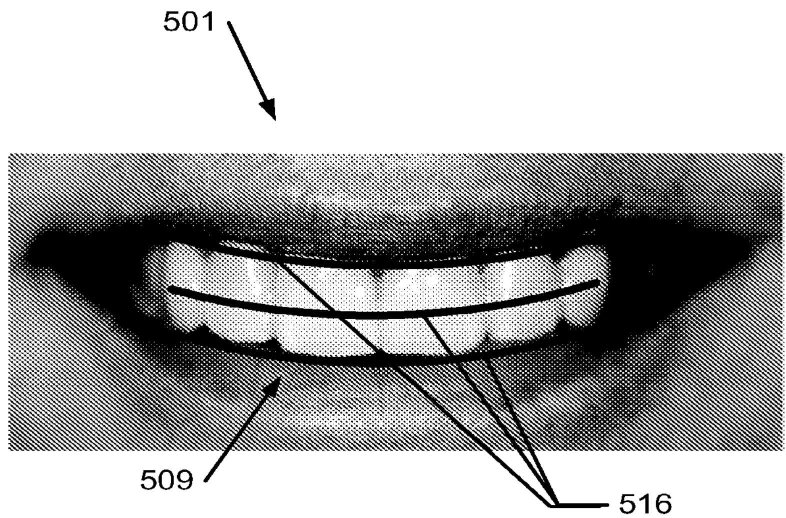


Fig. 5e)

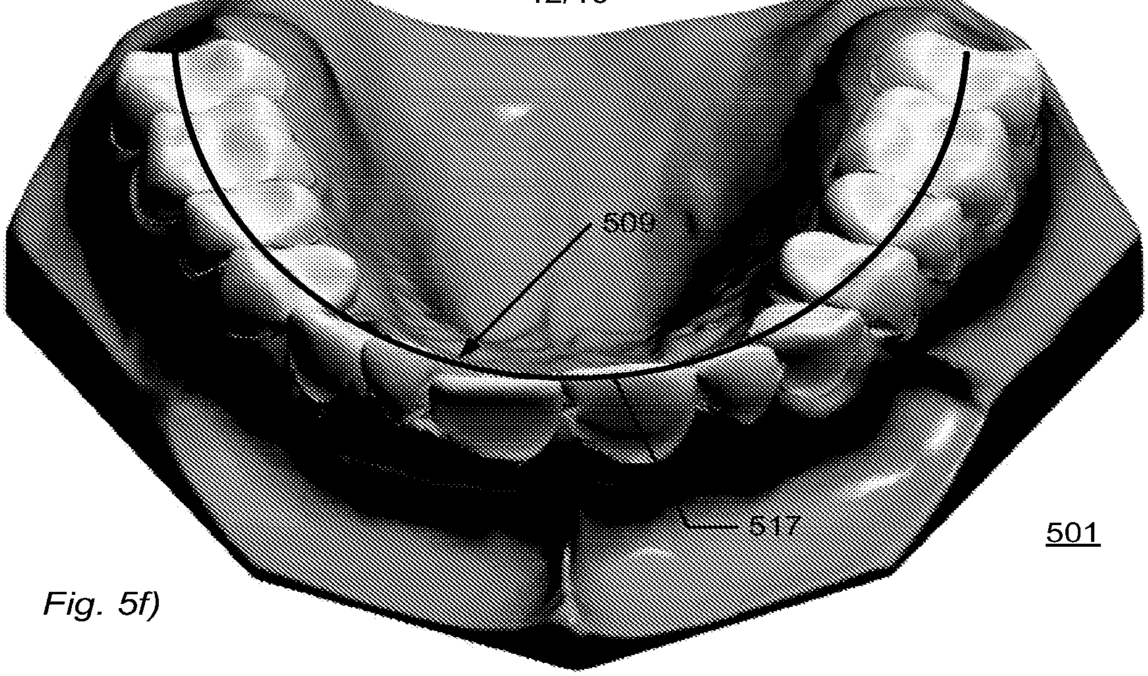
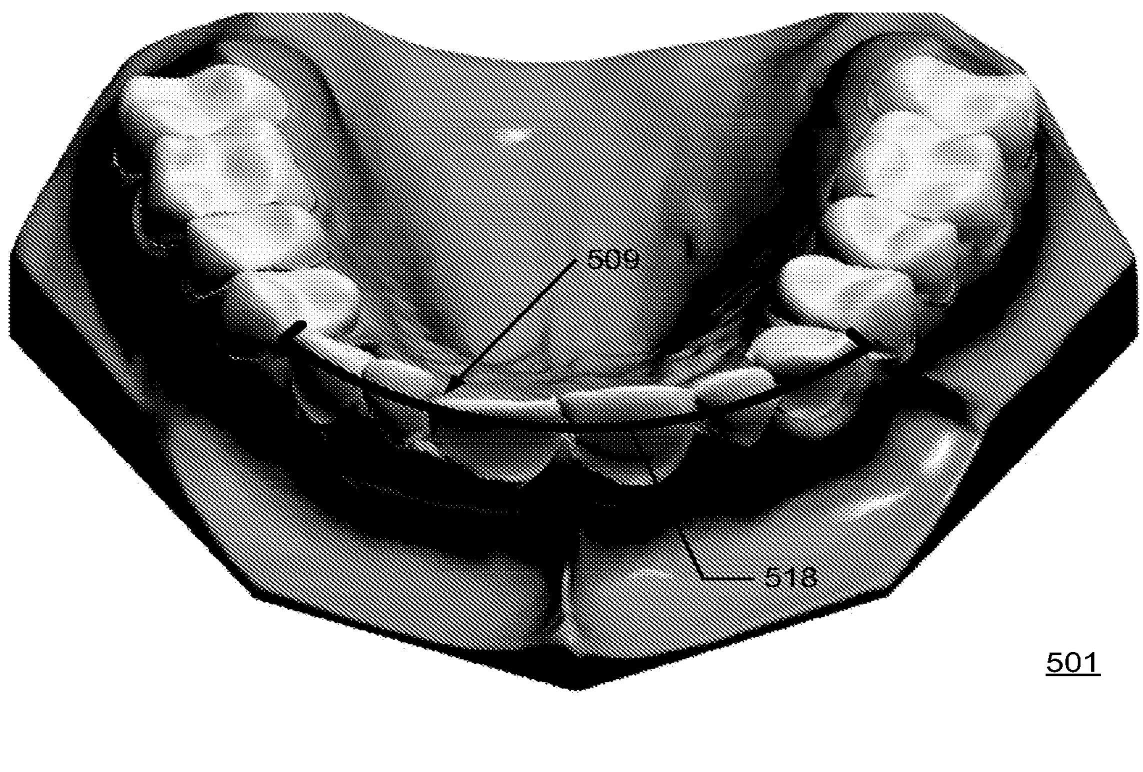


Fig. 5f)

Fig. 5g)



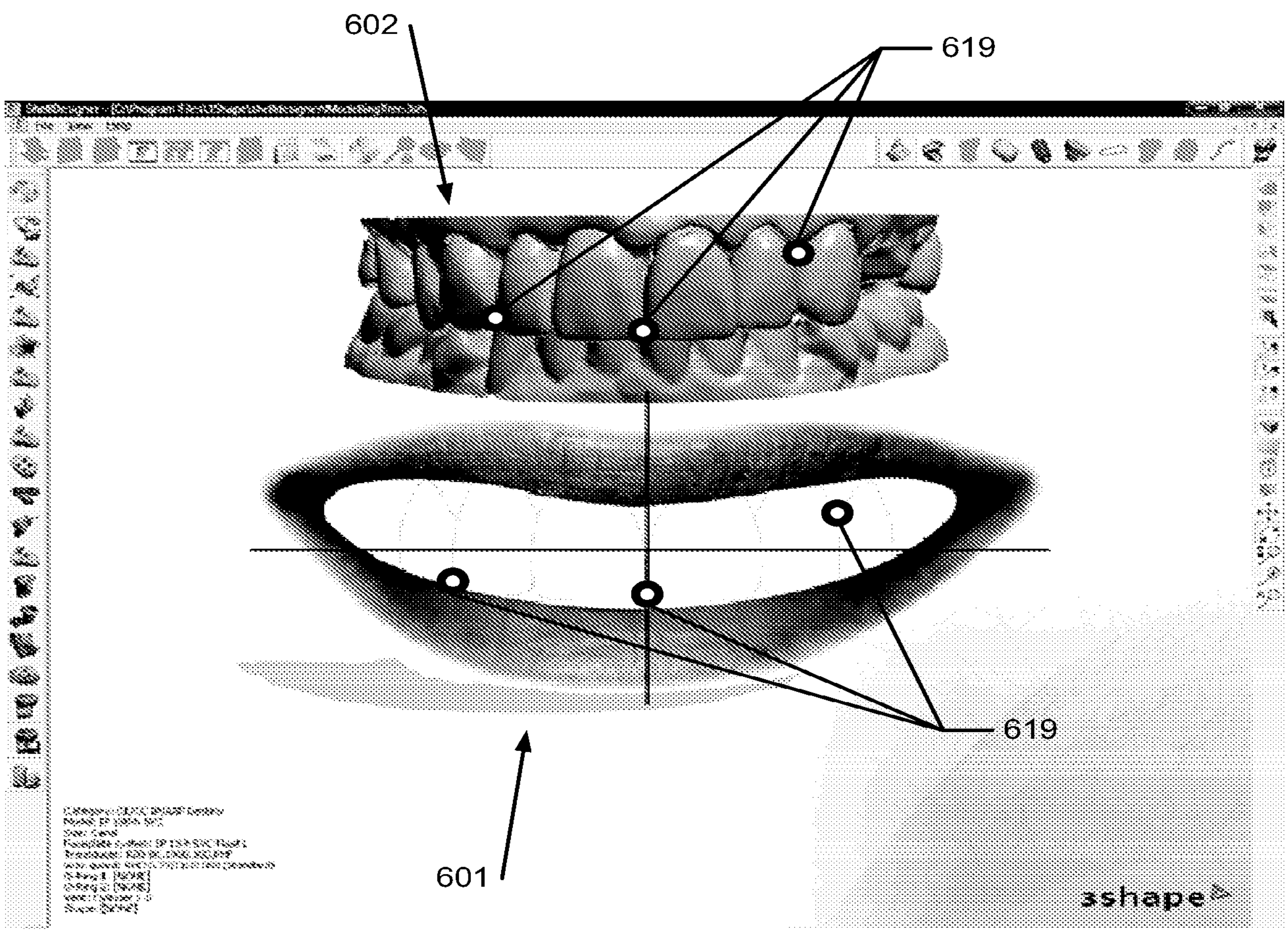


Fig. 6a)

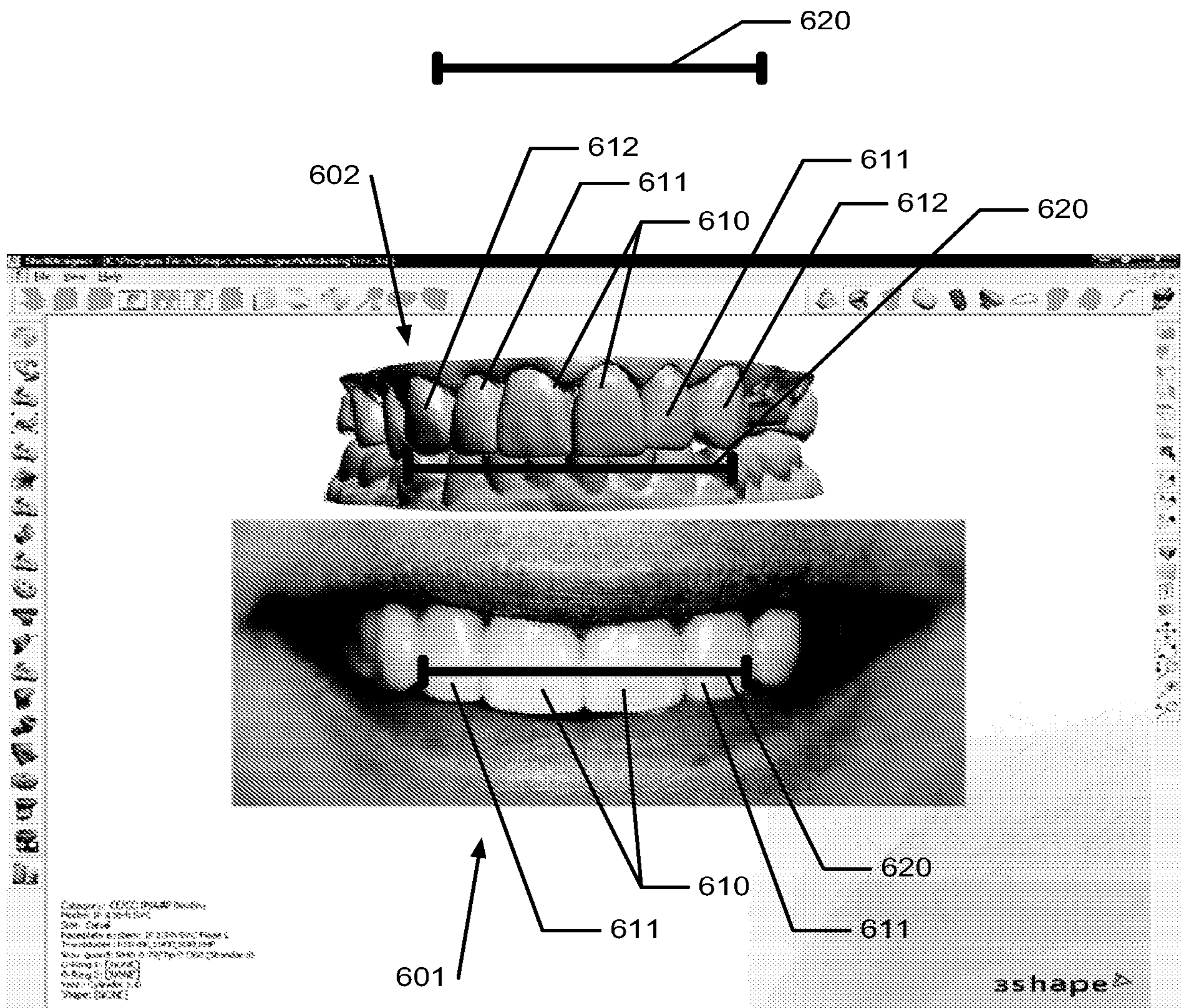
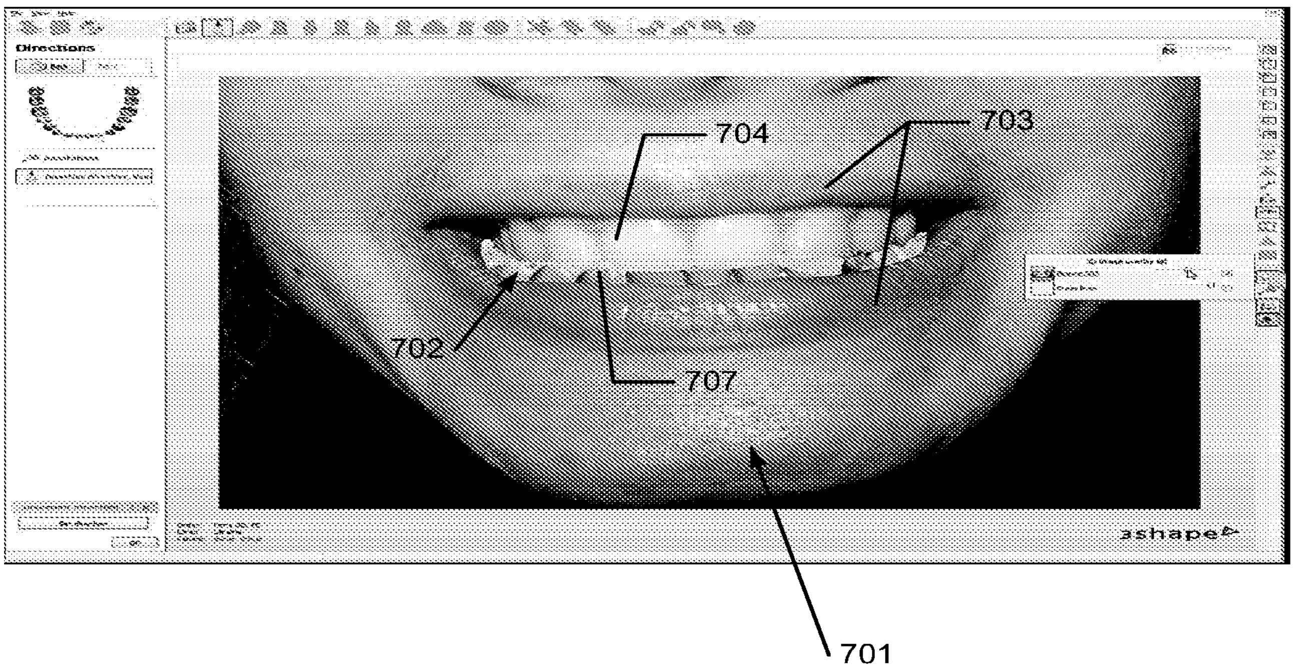


Fig. 6b)

Fig. 7


704
703
702
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Directions
3shape

Fig. 8

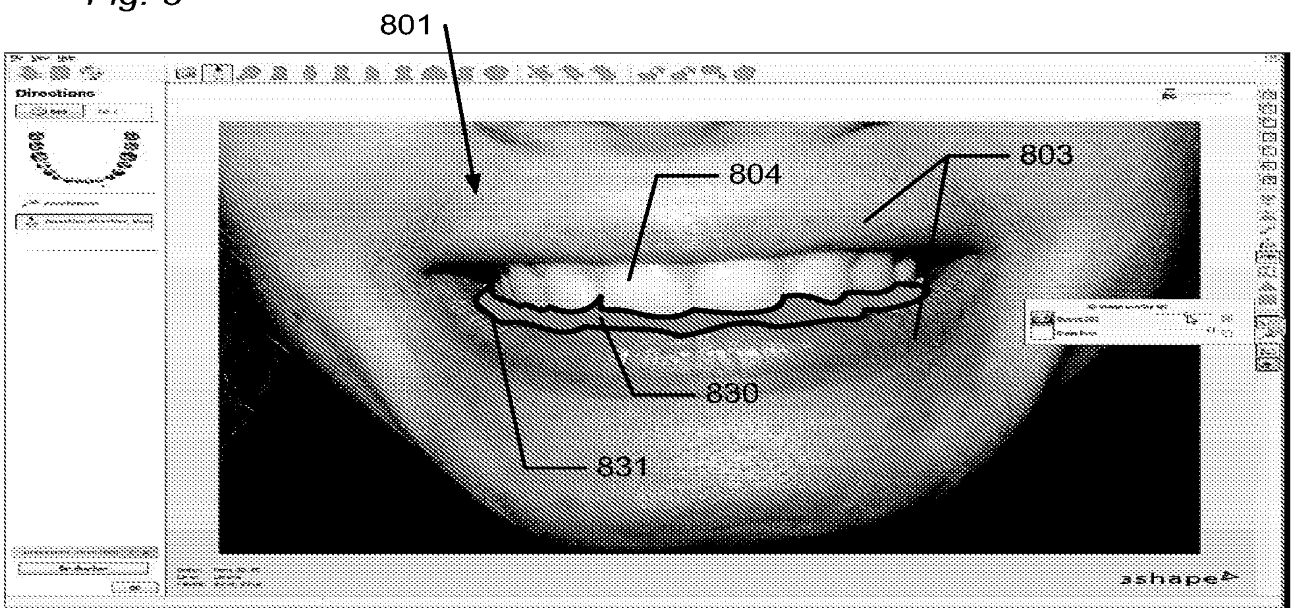
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Fig. 9

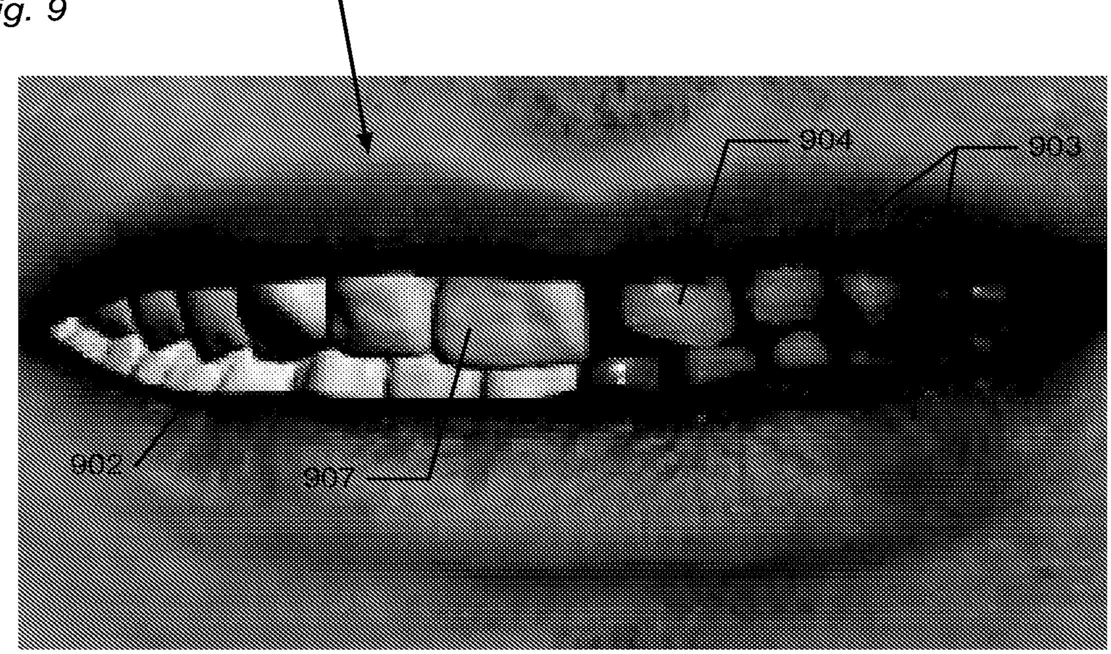
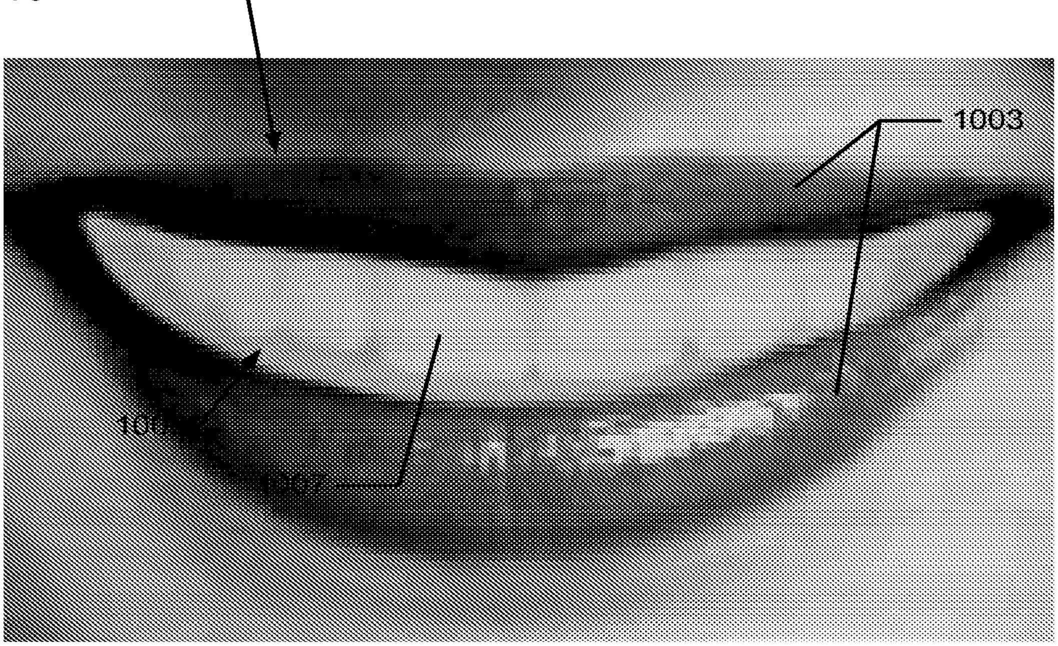


Fig. 10



2D image arrangement

Field of the invention

This invention generally relates to a computer-implemented method of visualizing and modeling a set of teeth for a patient. More particularly, the invention relates to providing a 3D virtual model of the patient's set of teeth.

Background of the invention

Visualization and modeling or design of teeth are known in the field of dental restorations.

When a patient requires a dental restoration, such as crowns, bridges, abutments, or implants, the dentist will prepare the teeth e.g. a damaged tooth is grinded down to make a preparation where a crown is glued onto. An alternative treatment is to insert implants, such as titanium screws, into the jaw of the patient and mount crowns or bridges on the implants. After preparing the teeth or inserting an implant the dentist can make an impression of the upper jaw, the lower jaw and a bite registration or a single impression in a double-sided tray, also known as triple trays. The impressions are sent to the dental technicians who manufacture the restorations e.g. the bridge. The first step to manufacture the restoration is traditionally to cast the upper and lower dental models from impressions of the upper and the lower jaw, respectively. The models are usually made of gypsum and often aligned in a dental articulator using the bite registration to simulate the real bite and chewing motion. The dental technician builds up the dental restoration inside the articulator to ensure a nice visual appearance and bite functionality.

CAD technology for manufacturing dental restoration is rapidly expanding improving quality, reducing cost and facilitating the possibility to manufacture in attractive materials otherwise not available. The first step in the CAD manufacturing process is to create a 3-dimensional model of the patient's teeth. This is traditionally done by 3D scanning one or both of the dental gypsum models. The 3-dimensional replicas of the teeth are imported into a CAD program, where the entire dental restoration, such as a bridge substructure, is designed. The final restoration 3D design is then manufactured e.g. using a milling machine, 3D printer, rapid prototyping manufacturing or other manufacturing equipment. Accuracy requirements for the dental restorations are very high otherwise the dental restoration will not be visual appealing, fit onto the teeth, could cause pain or cause infections.

WO10031404A relates to tools in a system for the design of customized three-dimensional models of dental restorations for subsequent manufacturing, where the dental restorations are such as implant abutments, copings, crowns, wax-ups, and bridge frameworks. Moreover, the invention relates to a computer-readable medium for implementing such a system on a computer.

Visualizing and modeling teeth for a patient based are also known from the field of orthodontics.

US2006127836A discloses orthodontic systems and methods for determining movement of a tooth model from a first position to a second position by identifying one or more common features on the tooth model; detecting the position of the common features on the tooth model at the first position; detecting the position of the common features on the tooth model at the second position; and determining a difference between the position of each common feature at the first and second positions.

Thus orthodontics relates to movement of teeth, so the desired position of a tooth or teeth is determined, and based on the present position of that tooth or teeth, the movement from the present position to the desired position is determined. Thus within orthodontics the desired or resulting position of a tooth or teeth is/are is known before planning the steps of the movement.

It remains a problem to provide an improved method and system for providing esthetically beautiful and/or physiologically suitable results of modeling teeth, both within the field of restorations, implants, orthodontics etc.

Summary

Disclosed is a computer-implemented method of visualizing, designing and modeling a set of teeth for a patient, wherein the method comprises the steps of:

- providing one or more 2D digital images;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- modeling the 3D virtual model based on at least one of the one or more 2D digital images.

Consequently, it is an advantage that the 3D CAD modeling of the 3D virtual model is based on a 2D digital image, since the 2D image determines or indicates what kind of modeling is suitable, where the expression suitable may comprise physiologically suitable or esthetically suitable or appealing. Thus the 2D image is used to perform a correct modeling of the 3D model, since the 2D image functions as a benchmark or rule for what kind of modeling is possible or how the modeling can be with the limits provided by the 2D image. Thus the modeling of the 3D virtual model is decided and performed based on the one or more 2D image, i.e. such as that the modeling of the 3D virtual model is based on the visualization of the 2D image.

The patient's oral cavity may comprise at least the patient's present set of teeth, such as prepared teeth or unprepared teeth, if the patient is not toothless, and maybe part of the gums. If the patient is toothless, then the oral cavity may comprise the gums of the patient.

It is an advantage that the 2D digital image and the 3D virtual model are aligned when viewed from one viewpoint, since hereby the user or operator of the system performing the method, can view the 2D image and the 3D model from a viewpoint where they are aligned, since this enables and facilitates that modeling of the 3D model is based on the 2D image. That the 2D image and 3D model are aligned when seen from a viewpoint means that at least some structures of the 2D image and the 3D model are coinciding when seen from a viewpoint. Thus the 2D image and 3D model may not be aligned when seen from any viewpoint, thus there may be only one viewpoint from which the 2D image and the 3D model are aligned.

Furthermore, it is an advantage that the 2D image and the 3D model are arranged and remain as separate data representations which are not merged or fused together into one representation. By keeping the data representations as separate representations, time is saved and data processing time and capacity is reduced. Thus the 2D image is not superimposed or overlaid onto the 3D virtual model for creating one representation with all data included. Prior art documents describe that the data from e.g. a color image is added to the 3D model, such that the color

content from the image is transferred to the 3D model, whereby the result is one representation, i.e. the 3D model including color. Creating such models requires more time and exhaustive data processing.
Thus, it is an advantage that the present method may be performed faster than prior art methods.

The method is for use when modeling teeth, but can of course also with advantage be used by students within the dental field when learning how to model teeth and what to take into consideration when modeling teeth.

Modeling of teeth is defined as comprising modeling of one or more dental restorations, modeling of one or more implants, modeling orthodontic movement of one or more teeth, modeling one or more teeth in a denture, e.g. a fixed or removable denture, to provide a visually pleasing appearance of the set of teeth etc.
Thus the modeling may comprise modeling of restorations, orthodontic planning and/or treatment, modeling of implants, modeling of dentures etc. When the CAD modeling comprises for example restorations, the virtually modeled restorations, such as crowns and bridges, can be manufactured by means of CAM, and the manufactured restorations can then eventually be inserted onto the patient's teeth by a dentist.

Arranging, placing, or positioning the 2D digital image on the 3D virtual model is performed digitally on a computer and shown on a user interface such as a screen, such that the user or operator obtains a visual representation of the 2D image and the 3D model together in the same field of view, whereby the operator can perform the modeling based on the simultaneous view of the 2D image and the 3D model instead of based on either one combined representation or separate views of the 2D image and/or the 3D model.

For facilitating the arrangement of the 2D image and the 3D model relative to each other, edge detection may be performed, whereby the contour of the teeth on the 2D image and/or on the 3D model is automatically derived. Edge detection can be performed by means of a software algorithm. Edges are points where there is a boundary or edge between to image regions, and edges can thus be defined as sets of points in the image which have a strong gradient magnitude. The contour of the teeth may thus be detected by detecting the edge between image portions showing the teeth and the gingival.

One or more 2D images may be provided in the method, and the 2D images may e.g. show the patient's face from different directions, show different parts of the patient's face, such as the lips and the eyes or nose for example for determining facial lines, show different examples of new teeth which the teeth of the 3D model can be modeled to look like, show the patient's teeth before preparing the teeth for restorations and after preparing the teeth, etc.

When aligning the 2D image and the 3D model, the 2D image may be of the patient's unprepared teeth, since it may be easier to align the 2D image and the 3D model, when the teeth on the 2D image are unprepared. When modeling the teeth of the 3D model, the 2D image may then be of the patient's prepared teeth, since e.g. restorations normally are modeled after having prepared the teeth by cutting part of the teeth such that crowns etc. can be attached to the prepared part of the teeth.

In some embodiments the 3D virtual model is generated by scanning a physical model of the patient's teeth, by scanning an impression of the patient's teeth, and/or by performing a direct scanning of the patient's teeth. If the patient is toothless, then the gums, a model or an impression of the gums may be scanned for creating a 3D model of the oral cavity.

In 3D scanning the object is analyzed to collect data on its shape. The collected data can then be used to construct digital, three dimensional models. In 3D scanning usually a point cloud of geometric samples on the surface of the subject is created. These points can then be used to extrapolate the shape of the subject.

In some embodiments the one or more 2D digital image comprises a patient-specific image of at least part of the patient's face.
An advantage of this embodiment is that the modeling can be based on an image of the patient, such that the modeling is performed with respect to the look or appearance of the patient, or with respect to some, a few or a single, specific visual features of the patient, such as the lips.

In some embodiments the one or more 2D digital image comprises a generic image of at least part of a human face.
An advantage of this embodiment is that the modeling can be based on a generic image, whereby it is not patient-specific features which determine the modeling, but instead it is a general image, e.g. of some visually pleasing teeth from another person, or a drawing of some ideal teeth.

In some embodiments the one or more 2D digital image is retrieved from a library comprising a number of images of teeth.
An advantage of this embodiment is that the 2D image, such as a generic image, can be selected from a library which contains for example several images of teeth, so that the patient e.g. can choose his/her desired new set of teeth from the library. The library may be a so called smile guide library comprising images of teeth and/or mouths which are shown while smiling, since visually pleasing teeth may be most important when smiling, since this may be when most teeth are shown to the surroundings.
The images of teeth in the library may be photos of teeth, may be drawings of teeth, etc.

In some embodiments the one or more 2D digital image is a template for supporting designing and/or modeling the patient's teeth.
An advantage of this embodiment is that when the 2D image is a template, then the operator can arrange and model teeth using this template for obtaining a visually pleasing result of the modeling.

In some embodiments the template comprises the midline of a face.

In some embodiments the template comprises a horizontal line passing along the anterior teeth.

In some embodiments the template comprises the occlusal plane of a face.

An advantage of the embodiments where the template comprises some feature, such as the midline of the face, a horizontal line, an occlusal plane etc, is that these features may assist in arranging the 2D image and the 3D model relative to each other and in modeling of the 3D model.

In some embodiments the template comprises boxes adapted to fit the centrals, the laterals and the cuspids.
An advantage of this embodiment is that it enables the operator to easily model the different anterior teeth to be visually pleasing. For example the laterals can with advantage be 2/3 of the width of the centrals, and the cuspids or canines can with advantage be slightly narrower than the centrals.

In some embodiments the template comprises one or more long axes of anterior teeth.
An advantage of this embodiment is that the long axes can be used for indicating the long axis alignment of teeth and/or the vertical direction of teeth for support in modeling.

In some embodiments the long axes of at least the upper anterior teeth converge toward the incisal edge or biting edge.
An advantage of this embodiment is that it is visually pleasing when the long axes of at least the upper anterior teeth converge toward the incisal.

In some embodiments the template comprises a contour of teeth.

In some embodiments the contour comprises a shape of one or more teeth seen from the front.

An advantage of the embodiments relating to the contour of teeth is that using the visually pleasing contour of some suitable teeth may be a simple and easy way to model the teeth of the 3D model.

In some embodiments the template comprises a curve.
An advantage of this embodiment is that by means of a curve, distances and angles can be measured or viewed. For example a distance can be measured from the centre of the curve, and in one example the operator may measure x mm from a certain point on the curve, and at this distance something specific may be arranged, such as a distal point on a lateral. Furthermore the curve may a symmetry curve for ensuring that the modeled teeth will be symmetric.

In some embodiments the curve comprises an arch following the upper and/or lower anterior teeth seen from the front or from above.

In some embodiments the curve comprises a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper teeth.

In some embodiments the template comprises one or more curves for indicating the position of the gingival tissue.

An advantage of these embodiments relating to curves of the teeth and/or of the mouth and lips is that using some kind of curve(s) may be a simple and easy way to model the teeth of the 3D model.

In some embodiments the one or more 2D digital image shows at least a number of front teeth.

In some embodiments the one or more 2D digital image is a photograph showing at least the patient’s lips and teeth seen from the front.
An advantage of this embodiment is that when the 2D image shows the patient’s lips and existing teeth, then the modeling of the teeth can be performed such that they suits the patient’s lips and unchanged teeth providing a visually pleasing result of the modeling.

In some embodiments the method further comprises virtually cutting at least a part of the teeth out of the one or more 2D digital image, if the 2D image comprises teeth, such that at least the lips remains to be visible in the 2D digital image.
An advantage of this embodiment is that when the lips and no or only some teeth are visible in the 2D image then it is easy to visualize the modeled teeth with the patient’s lips and determined whether it is a good result of modeling.
The cutting of teeth out of the 2D image may be performed virtually or digitally such that the information in the 2D image relating to the teeth is removed, deleted, made invisible etc..

In some embodiments the 3D virtual model is visible behind the lips.

An advantage of this embodiment is that when the 3D model can be seen behind the lips, then the modeling of the teeth can be performed while viewing the lips for determining if the modeling is satisfactory.

In some embodiments the one or more 2D digital image shows the face of the patient such that facial lines, such as the midline and the bi-pupillar line, are detectable.
An advantage of this embodiment is that facial lines determines the geometry of the patient's face, and for obtaining a visually pleasing result of modeling, the teeth should fit with this overall geometry.

In some embodiments the one or more 2D digital image is an X-ray image of the patient's teeth.
An advantage of this embodiment is that when using or applying an X-ray image of the patient's teeth, the entire teeth with roots under the gingival can be seen, and thus broken or weak teeth or roots can be detected. Hereby for example implants exerting force on the teeth and roots can be planned to be arranged to exert force on non-broken or strong teeth and teeth roots instead of on the broken and weak teeth and roots.

In some embodiments the method further comprises providing a 3D computed tomography scan of the patient's face for facilitating aligning the one or more 2D image and the 3D model and/or for modeling the 3D virtual model.

In some embodiments the one or more 2D digital image is a still image from a video recording.

In some embodiments the one or more 2D digital image is derived from a 3D face scan.

In some embodiments the method further comprises providing a 3D face scan of the patient for facilitating aligning the one or more 2D image and the 3D model and/or for modeling the 3D virtual model.

In some embodiments a face scan of the patient provides a measure of the distance that the upper and/or lower lip moves when the patient smiles, and the distance is adapted to be used for measuring the ideal length of at least some of the teeth.
An advantage of this embodiment is that at least the length of the front teeth is important for the visual appearance of the teeth.

In some embodiments the method further comprises providing at least part of the one or more 2D digital image to be at least partly transparent, such that the 3D virtual model is visual through the 2D digital image.

In some embodiments the one or more 2D digital image is adapted to be smoothly faded in and out of the view.
An advantage of this embodiment is that when smoothly fading the 2D image in and out of view this provides that the visualization of the 2D digital image changes from being entirely visible to be partly visible and then maybe invisible and vice versa. Hereby the 2D image can be viewed as the user wishes.

In some embodiments the 3D virtual model comprises the patient's set of teeth.

In some embodiments the method further comprises scaling the one or more 2D digital image and the 3D virtual model to show at least part of the teeth in the same size.
An advantage of this embodiment is that the 2D image and the 3D model should be shown in the same scale in order for optimally performing the

modeling. The scaling may be an automatic modification of the size of e.g. the 3D virtual model to the size of the 2D digital image or vice versa. Alternatively, the scaling may be of both the 2D image and the 3D model to resize them to a predetermined scale.

In some embodiments the method further comprises aligning the one or more 2D digital image and the 3D virtual model.
An advantage of this embodiment is that when the 2D image and the 3D model are aligned then modeling may be performed easier and with a better result. Alignment may be defined as the adjustment of an object in relation with another object, such that structures of the objects are coinciding. Thus common or alike structures of the 2D image and the 3D model are aligned.

In some embodiments the silhouette of the biting edge of at least the upper anterior teeth on the one or more 2D image and on the 3D virtual model is used to perform the alignment of the 2D image and the 3D virtual model.
An advantage of this embodiment is that in many cases the biting edge of the upper anterior teeth are seen on both the 2D image and on the 3D model, and therefore this biting edge may be an advantageous physical point of alignment.

In some embodiments the method further comprises projecting the plane of the one or more 2D digital image to the 3D virtual model.
An advantage of this embodiment is that when projecting the plane of 2D image to the 3D model or to a plane of the 3D model, the 3D model and the 2D image can be viewed in the same plane which may be an advantage when modeling the teeth. The viewing of the 3D model and the 2D image in the same plane may otherwise be complex.

In some embodiments the method further comprises changing the perspective view of the one or more 2D digital image and/or of the 3D virtual model to obtain the same perspective view.
An advantage of this embodiment is that modeling may be facilitated when the 2D image and the 3D model can be seen in the same perspective view.

In some embodiments the method further comprises de-warping the perspective view of the one or more 2D image for visually aligning the 2D image and the 3D virtual model.
An advantage of this embodiment is that when de-warping or correcting the perspective view of the 2D image, then the view is digitally manipulated, and hereby points on the perspective view of the 2D image can be mapped to points on the 3D model or its plane. After de-warping or correcting the perspective of the 2D image, the 3D model can be re-aligned, such that the 2D image and the 3D model are aligned again.

In some embodiments scaling, aligning, projecting to a plane, de-warping perspective and changing perspective are defined as virtual actions for arrangement.

In some embodiments one or more of the virtual actions for arrangement comprises rotations and translations left/right and back/forth of the one or more 2D digital image and/or of the 3D virtual model.
An advantage of this embodiment is that by providing rotations, translations etc. then different movements of the 2D image and/or of the 3D model may be performed for facilitating the scaling, aligning, perspective changing and ultimately for facilitating the modeling of the teeth.

In some embodiments the method further comprises the steps of:

- detecting anatomical points on the teeth, where the anatomical points are present and detectable both on the one or more 2D digital image and the 3D virtual model, and
- performing the virtual actions for arrangement based on these corresponding anatomical points.

An advantage of this embodiment is that using common or mutual anatomical points on the 2D image and the 3D model may be an easy way to perform alignment of the 2D image and the 3D model, where after modeling of the teeth can be performed.

In some embodiments at least one corresponding anatomical point is selected to perform the virtual actions for arrangement.

An advantage of this embodiment is that one common or mutual point on the 2D image and the 3D model may be sufficient for arranging the 2D image and the 3D model relative to each other. However in other cases the 2D image and the 3D model should be aligned using more points, such as two, three or four points. In general three points may be suitable. Four points can be used for performing an even better arrangement or for use in more difficult cases.

In some embodiments the method further comprises the steps of:
- providing a virtual measurement bar, and
- performing the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of adjustment to the virtual measurement bar.

An advantage of this embodiment is that it may be easy and fast to use a virtual measurement bar to perform the virtual actions for arrangement such as scaling, where the sizes of the 2D image and the 3D model are adjusted to correspond to each other.

In some embodiments the method further comprises that a user performs the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of eye measure.
An advantage of this embodiment is that just by using simple eye measure, the operator can very quickly and reliably perform the arrangement of the 2D image and the 3D model relative to each other or perform a rough starting point for a more detailed adjustment.

In some embodiments the anatomical points are upper and/or lower distal and/or mesial points on a number of specific anterior teeth.
An advantage of this embodiment is that anatomical point on the upper and/or lower distal and/or mesial parts of the anterior teeth are normally easy to detect both on the 2D image and on the 3D model.

In some embodiments the modeling of the 3D model is performed automatically based on the one or more 2D digital image.
An advantage of this embodiment is that the user does not need to perform any manual modeling of the 3D model on the screen, when the modeling can be performed fully automatic. However, typically if an automatic modeling takes place, then the user may check that the modeling is satisfying, and maybe perform small corrections to the modeling.

In some embodiments the method further comprises automatically selecting one or more 2D digital image which provides an optimal fit to the 3D virtual model.
An advantage of this embodiment is that a 2D image with an optimal, good or the best fit to the 3D model can automatically be selected, and hereby a good result of modeling can be obtained, and furthermore the time used for performing the modeling can be reduced, since no person needs to spend time on looking through a larger number of 2D images. The 2D image may be selected from a library of 2D digital images, or from any source

comprising a number of images of teeth and smiles. The library may comprises templates, photos, drawings etc.

In some embodiments the optimal fit is determined based on specific parameters for providing an esthetically, visually pleasing appearance.
An advantage of this embodiment is that the optimal, best or just a good fit can be determined based on different parameters, such as the present size of the patient's teeth, on the curves of the patient's present teeth set, etc. New teeth which are very big may not suit a person who used to have very small teeth or a person who has thin lips. Likewise a new teeth set with a strong composition may not suit a person who used to have a teeth set with a soft composition or a person who has full lips etc. So based on the present structures, features, shapes etc. of the patient's teeth, new teeth which will look natural and suit the patient can be determined from e.g. a template library of photos, drawings etc.

In some embodiments the alignment of the at least one 2D image and the 3D model is performed automatically.

In some embodiments the method further comprises providing at least part of the 3D virtual model to be at least partly transparent, such that at least one of the one or more 2D digital images is visual through the 3D virtual model.

In some embodiments the method comprises fading the 3D model smoothly in and out of the view.

In some embodiments the 3D model and two or more of the 2D images are aligned relative to each other, when there are more than one 2D image.

In some embodiments the 3D model and each of the 2D images are aligned relative to each other.

It is an advantage that the 3D model is aligned specifically to each of the 2D images, such that if shifting between the different 2D images, the correct alignment of the 3D model relative to the selected 2D image may automatically be presented on the user interface.

In some embodiments the different alignments of the 3D model relative to the two or more 2D images are stored in a data storage.

In some embodiments the alignment of the 3D model and a specific 2D image is retrieved from the data storage, when the specific 2D image is selected for view.

In some embodiments two or more of the 2D images are 2D images of at least part of the patient’s face seen from different directions.

In some embodiments the method further comprises sectioning at least two or more of the teeth in the 3D model and/or in the one or more 2D images.

In some embodiments the method further comprises modeling a restoration, such as a virtual crown, a virtual preparation, and/or an area of virtual gingival on the 3D model.

In some embodiments the 2D image and the 3D model are adapted to be arranged and/or viewed from one or more perspective views.
The perspective views may be from the front, from behind, from the side, from above, from below, and any combination of these view. A visual or non-visual point e.g. a center point, a line e.g. a centerline or a region e.g. a center region in the 3D model and/or in the 2D image may determine the point of reference for the perspective views.

In some embodiments the method comprises determining an angle of one or more of the perspective views.
The angle may be the angle relative to a center point of the 2D image and/or the 3D model. The angle may be an angle relative to a horizontal plane, and/or a vertical plane etc which virtually intersects the teeth in the 2D image and/or in the 3D model.

In some embodiments the method comprises predefining an angle of one or more of the perspective views.

In some embodiments at least one of the one or more 2D image is from a video stream of 2D images.

In some embodiments the 2D images from the video stream are from different perspective views.

In some embodiments the 3D model is configured to be aligned relative to one or more 2D images in the video stream.

In some embodiments the alignment of the 3D model and one or more 2D images for one or more perspective view is performed by means of interpolation and/or extrapolation of other perspective views.
It is an advantage that already determined perspective views can be used for alignment of other perspective views. The perspective views may be present or arranged on a virtual trajectory or curve and/or on a virtual view point sphere. Thus if two perspective views are already determined, a third perspective view located between the two perspective views can be determined by extrapolation or interpolation and the 3D model and the 2D image can be aligned relative to this or based on this. The perspective views or angles may be provided by a shift in angles, view directions etc, and the shifts may be smooth and continuous or in discrete steps.

In some embodiments the method comprises zooming at least one of the one or more 2D images and the 3D model in/out of view.

In some embodiments the 2D image and the 3D virtual model are adapted to be zoomed in/out simultaneously.
It is an advantage that the 2D image and the 3D model can be zoomed in/out simultaneously, and/or jointly, and/or together, and/or concurrently, and/or synchronously. Thus the increase or decrease in the size of the 2D image and the 3D model may be similar when zooming, the 2D image and the 3D model may follow each other when zooming, and the center point or center region of the zoom may be coinciding in the 2D image and the 3D model.

In some embodiments the zooming in/out is configured to be performed from one or more perspective views.

In some embodiments the zooming in/out is configured to be performed from one or more predefined angles.

In some embodiments the predefined angles determine the perspective views.

In some embodiments the method comprises providing the predefined angles in discrete steps.

In some embodiments the method comprises providing the predefined angles in a continuous sequence.

In some embodiments the 2D image and the 3D model are snapped together in their correct alignment.

It is an advantage that if for example the 2D image is seen from a side perspective, then the 2D image is automatically snapped to the correct angle relative to the 3D model.

In some embodiments the snapping together of the 2D image and the 3D model is performed automatically.

In some embodiments each of the one or more 2D images is configured to be snapped together with the 3D model in their correct alignment.

In some embodiments the 2D image and the 3D model are aligned based on one or more unprepared teeth, if unprepared teeth are present in the 3D model.

In some embodiments the 2D image and the 3D model are aligned based on the teeth in the upper jaw.
It is an advantage to align based on the upper teeth because these are typically the most visible teeth on a 2D image, in particular the front teeth in the upper jaw are normally most visible and the alignment may therefore be improved if these teeth are used for the alignment.
Alternatively and/or additionally the teeth in the lower jaw of the 3D model can also be moved e.g. downwards to obtain a suitable alignment.

In some embodiments the angle which the 3D model and the 2D image are seen from as default is determined by the perspective view of the 2D image.
The angel can also be denoted view, view point, perspective view etc.

In some embodiments the angle of the 3D model and the 2D image is configured to adapt relative to the perspective view of the 2D image.
The angel can also be denoted view, view point, perspective view etc.

In some embodiments the view of the 3D model is configured to adapt to the perspective view of a second 2D image, if this second 2D image is replacing a first 2D image. It is an advantage that the view may change automatically when a second 2D image is selected for view, alignment etc.

In some embodiments the method further comprises generating a 3D image by combining at least three of the 2D images.

In some embodiments the method further comprises rendering the 3D model. It is an advantage to perform rendering of the teeth in the 3D model, such as photo-realistic rendering, since hereby the 3D model is made to look more realistic and nicer. The 3D model may be for example yellow or gray by default, so by rendering the teeth in the 3D model to be for example more white, the 3D model teeth looks better and realistic.
The rendering can be performed by means of well-known methods performed using well-known computer programs.

In some embodiments the method further comprises providing textural features on the 3D model.
It is an advantage to provide textural features on the 3D model for making the teeth of the 3D model look more realistic and real. The textural features of the teeth may be obtained from a 2D image of the patient's existing teeth, the textural features may be from a standard template, may be generated specifically to the specific 3D model based on size, shape etc of the teeth. Furthermore, other parameters such as shadow, geometry, viewpoint, lighting, and shading information can be provided to the 3D model for making the teeth of the 3D model look more realistic and possibly look more esthetic.

In some embodiments the rendering is a photo-realistic rendering.

In general it is an advantage of the method and the embodiments that it/they enable(s) dental laboratories (labs) to superimpose a patient's actual face and smile images in the design process and utilize both directly to produce optimally esthetic and personalized restorations. Labs can show the dentist's patients exactly how a new restoration will transform their smiles and get feedback. The smile visualization is highly realizable because it may be solidly backed by the manufacturable 3D model and not just 2D image manipulations.

Personalized designs with patient specific 2D-image overlays can be obtained by importing 2D images of the patient's lips, teeth and smile to design restorations that exactly suit the patient's personal look. Image manipulation tools may be applied to mask away the teeth, and alignment tools may be used to bring lips and new teeth design together as a perfect personalized design guide.

High esthetics with generic 2D-image overlays can be obtained by using 2D-image libraries that help in achieving high esthetics, even without pictures of the actual patient's smile. By means of the method it is possible to select from a variety of smile-guides and design-templates to recreate complete smile compositions to apply with the restoration design.

Before-and-after visualization can be obtained for example by continuously interchanging between situation views through gradual fading in-and-out, whereby technicians, dentists and patients are easily able to detect even the smallest alterations and smile details for optimal comparisons.

The present invention relates to different aspects including the method described above and in the following, and corresponding methods, devices, systems, uses and/or product means, each yielding one or more of the benefits and advantages described in connection with the first mentioned aspect, and each having one or more embodiments corresponding to the embodiments described in connection with the first mentioned aspect and/or disclosed in the appended claims.

In particular, disclosed herein is a system for visualizing, designing and modeling a set of teeth for a patient, wherein the system comprises:
- means for providing one or more 2D digital images;
- means for providing a 3D virtual model of at least part of the patient's oral cavity;
- means for arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- means for modeling the 3D virtual model based on at least one of the one or more 2D digital images.

Furthermore the present invention relates to a computer program product comprising program code means for causing a data processing system to perform the above method, when said program code means are executed on the data processing system, and a computer program product according to the previous claim, comprising a computer-readable medium having stored there on the program code means.

Brief description of the drawings

The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

Fig. 1 shows an example of a flowchart of a computer-implemented method of visualizing and modeling a set of teeth for a patient.

Fig. 2 shows examples of visualizing a 2D image and a 3D model together.

Fig. 3 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 4 shows examples of arranging the 3D model and the 2D image relative to each other.

Fig. 5 shows examples of 2D images as templates.

Fig. 6 shows examples of how to perform virtual actions for arrangement of the 2D image and the 3D model.

Fig. 7 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 8 shows an example of how a 3D model can be arranged in a 2D image, or how a 2D image can be laid over a 3D model.

Fig. 9 shows an example of a before-and-after visualization.

Fig. 10 shows an example of rendering of a 3D model of teeth arranged relative to a 2D image.

Detailed description

In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced.

Fig. 1 shows an example of a flowchart of a computer-implemented method of visualizing and modeling a set of teeth for a patient.

In step 101 a 2D digital image is provided. The 2D image may be photograph of at least part of the patients face, a template of teeth, a drawing of teeth, a photo or image of an esthetic set of teeth etc. The 2D digital image may be shown on a user interface, such as a computer screen.

In step 102 a 3D virtual model of the patient's oral cavity comprising the patient's set of teeth, if there are any teeth, is provided. The 3D model of the patient's set of teeth may be generated by scanning a physical model of the patient's teeth, by scanning an impression of the patient's teeth, and/or by performing a direct scanning of the patient's teeth. If the patient is toothless, then the gums, a model or an impression of the gums may be scanned for creating a 3D model of the oral cavity. The 3D virtual model may be shown on a user interface, such as a computer screen.

In step 103 the 2D digital image is arranged or positioned relative to the 3D virtual model for visualizing the 3D virtual model relative to the 2D digital image. The arrangement or positioning is a digital, virtual arrangement, performed by means of software, such that the 2D image and the 3D model can be viewed together.

In step 104 the 3D virtual model of the patient's set of teeth is digitally or virtually modeled based on the visualization of the arrangement of the 2D image. Thus the 3D model of the patient's existing teeth is modeled using CAD, and the modeling may comprise restorations, orthodontic planning and/or treatment, prosthetics, removable dentures etc. When the CAD modeling comprises restorations, the virtually modeled restorations, such as crowns and bridges, can be manufactured by means of CAM, and the manufactured restorations can then be inserted onto the patient's teeth by a dentist.

Fig. 2 shows examples of visualizing a 2D image and a 3D model together. Fig. 2a) shows a screen shot on which both a 2D image 201 and a 3D model 202 are seen simultaneously. The 2D image 201 is a photograph of a part a person's face showing the mouth with lips 203 and teeth 204 behind the lips 203. The photograph may be of the patient himself or of another person. Using a photograph of the patient may be advantageous if the patient's teeth have been broken and the patient then wishes to have his teeth restored to look like they did before the damage. Using a photograph of another person may be an option if the patient wishes to have his teeth restored, exchanged by a new teeth set or treated by orthodontics in order for them to look different than they do at present.
The 3D model 202 of the patient's teeth comprises gingival 208 and teeth 207.
Fig. 2b) shows an example where the 2D image 201 is an X-ray image of the patient's teeth. The X-ray image shows the teeth 204 of the patient. Since the X-ray image shows the teeth approximately on lines, i.e. not on curves as in real-life, the plane of the X-ray image may be bended to be arranged relative to the 3D model 202 with teeth 207.

Fig. 3 shows an example of visualizing and arranging a 2D image and a 3D model.
Fig. 3a) shows a screen shot on which both a 2D image 301 and a 3D model 302 of teeth are seen simultaneously. The 2D image 301 is a photograph or drawing of a pair of lips 303 and an outline of teeth 304 behind the lips. A vertical line 305 and a horizontal line 306 are drawn through the 2D image 301, and they may be used as guiding lines for modeling.
Fig. 3b) shows a screen shot on with the 2D image 301 is arranged and aligned relative to the 3D model 302. The teeth 307 of the 3D model 302 can

be seen through and between the lips 303 and the outline of teeth 304 of the 2D image 301. When arranging and aligning the 2D image relative to the 3D model, modeling of the 3D model is facilitated. The vertical line 305 and the horizontal line 306 are also seen in fig. 3b).

Fig. 3c) shows a sketch of a 2D image 301 and a 3D model 302 seen in a perspective side view illustrating alignment from a viewpoint.

The 2D image 301 and the 3D model are in this figure attempted to be drawn in a perspective side view to show that if the 2D image and the 3D model are viewed from this viewpoint then they are not aligned. In the other figures, e.g. fig. 3b) the 2D image and the 3D model are viewed from a front viewpoint in which they are aligned. As seen there is a distance between the 2D image and the 3D model to indicate that the 2D image and the 3D model are separate representations and not one representation containing data from two representations. The distance can be any distance, such as shorter or longer than illustrated in the proportion here.

The arrow denoted X illustrates the front view in which the 2D image and the 3D model are aligned, as seen in e.g. fig. 3b).

The arrow denoted Y illustrates a bottom view where the 2D image and the 3D model are viewed from below, and as can be derived from the figure, the 2D image and the 3D model are not aligned when viewed from the Y viewpoint.

The end of an arrow, circle with cross, denoted Z illustrates a side view, and as explained above with respect to the perspective side view, the 2D image and the 3D model are not aligned when viewed from this viewpoint.

Fig. 4 shows examples of arranging the 3D model and the 2D image relative to each other.

Fig. 4a), b) and c) show examples of different arrangements of the 3D model 402 relative to the 2D image 401. The teeth 407 of the 3D model 402 is seen to be moved relative to the lips 403 of the 2D image 401 in the fig. 4a), b) and c). When the arrangement of the 3D model 402 has become suitable relative to the 2D image 401, the actual modeling of the teeth 407 of the 3D model 402 may be performed.

Fig. 5 shows examples of 2D images as templates.
Fig. 5a) shows an example of a 2D digital image 501, which is a reference frame for arranging and/or modelling the patient’s teeth. The reference frame comprises a template 509 for the upper anterior or front teeth. The template 509 comprises the midline of a face 505 and a horizontal line 506 passing along the incisal edge of the anterior teeth.
The template 509 comprises boxes adapted to fit the centrals 510, the laterals 511 and the cuspids 512, also known as canines. The laterals 511 may ideally be 2/3 of the width of the centrals 510, and the cuspids 512 may ideally be slightly narrower than the centrals 510.

Fig. 5b) shows an example where the 2D image 501 is a template 509 comprising the long axes 513 of the centrals 510, the laterals 511, and the cuspids 512. The long axes 513 converge toward the incisal edge indicated by the horizontal line 506.

Fig. 5c) shows an example where the 2D image 501 is a template 509 showing a contour 514 of anterior or front teeth seen from the front.

Fig. 5d) shows an example where the 2D image 501 comprises a template 509 comprising a curve 515 of a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper anterior teeth 510, 511, 512, as seen from the front.

Fig. 5e) shows an example where the 2D image 501 comprises a template comprising three curves 516 for indicating the position of the gingival tissue.

Fig. 5f) shows an example where the 2D image 501 comprises or is a template 509 comprising a curve in the form of an arch 517 which follows the upper teeth as seen from above.

Fig. 5g) shows an example where the 2D image 501 comprises or is a template 509 comprising a curve 518 which follows the upper anterior teeth as seen from above.

Fig. 6 shows examples of how to perform virtual actions for arrangement of the 2D image and the 3D model relative to each other.
Virtual actions for arrangement can comprise the following:
- scaling the 2D digital image and the 3D virtual model to show at least part of the teeth in the same size on both of them;
- aligning the 2D digital image and the 3D virtual model;
- projecting the 3D virtual model to a/the plane of the 2D digital image;
- changing the perspective view of the 2D digital image and/or of the 3D virtual model to obtain the same perspective view for both of them when visualizing the positioning;
- de-warping the perspective view of the 3D virtual model for visually aligning the 2D image and the 3D virtual model.
The virtual actions for arrangement can be performed by means of rotations and translations to the left and right and back and forth of the 2D digital image and/or of the 3D virtual model.
In one example (not shown) the silhouette of the biting edge of at least the upper anterior teeth on the 2D image and on the 3D virtual model is used to perform the aligning of the 2D image and the 3D virtual model.

Fig. 6a) shows an example where a virtual action for arrangement such as alignment is performed using detected corresponding anatomical points 619 on the teeth on the 2D digital image 601 and on teeth on the 3D virtual model 602. The anatomical points 619 shown in fig. 6a) are at the upper anterior teeth. One anatomical point is on the incisal edge at the distal side of the left lateral tooth, where left is left as seen in the figure, but right for the patient. Another anatomical point is on the incisal edge between the left and the right central teeth. The third anatomical point is at the gingival between the right lateral tooth and right cuspid tooth, where right is right as seen in the figure, but left for the patient.

When the corresponding anatomical points 619 are detected and e.g. marked as in the figure on both the 2D image 601 and the 3D model 602, the 2D image 601 and the 3D model 602 can be arranged relative to each other and aligned to each other by providing that the corresponding anatomical points 619 on the 2D image 610 and on the 3D model 602 cover, overlap, match or fit together. When corresponding anatomical points 619 are selected on the screen, the software may automatically arrange the 2D image 601 and the 3D model 602 such that the points 619 are overlapping.

Fig. 6b) shows an example where a virtual action for arrangement such as scaling is performed using a virtual measurement bar 620. The virtual measurement bar 620 is seen on both the 2D image 601 and the 3D model 602. On the 2D image 601, the measurement bar 620 has a length corresponding to the length across the upper two centrals 610 and the two laterals 611. However, on the 3D model, the measurement bar 620 has a length corresponding to both the upper two centrals 610, the two laterals 611 and the two cuspids 612. Thus in order to have matching sizes of the 2D image 601 and the 3D model 602, the 3D model should be scaled up or enlarged to fit the size of the 2D image.

Alternatively and/or additionally, the user can perform virtual actions of arrangement of the 2D digital image and/or of the 3D virtual model by means of eye measure.

Fig. 7 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 7 shows a screen shot from a user interface in which both a 2D image 701 and a 3D model 702 of teeth are seen simultaneously. The 2D image 701 is a photograph of a part of a patients face comprising the patient's lips 703 and the patient's existing upper teeth 704 behind the lips. In the place of the lower teeth the 3D model comprising the lower teeth 707 is arranged.

The 3D model 702 is arranged and aligned relative to the 2D image 701.

Fig. 8 shows an example of how a 3D model can be arranged in a 2D image, or how a 2D image can be laid over a 3D model.

Fig. 8 shows a screen shot from a user interface in which a 2D image 801 is seen. The 2D image 801 is a photograph of a part of a patients face comprising the patient's lips 803 and the patient's existing upper teeth 804 behind the lips.

If a 3D model of teeth should be arranged in the place of the lower teeth, the area of the lower teeth in the 3D image can be marked and hidden or deleted by means of a non-transparent area 830. The marked area 830 can be marked by drawing a line 831 along the edge of the upper teeth and the lower lips. The marking of the line 831 can be performed automatically by means of automatic contour and/or color detection of the 2D image. Alternatively and/or additionally, the operator can draw the line 831 or otherwise mark the area 830.

The same may apply if more or less, e.g. all the teeth in the 2D image should be replaced with the teeth of a 3D model.

Fig. 9 shows an example of a before-and-after visualization.

A before-and-after visualization can be obtained by continuously interchanging between situation views through gradual fading in-and-out, whereby technicians, dentists and patients are easily able to detect even the smallest alterations and smile details for optimal comparisons.

Fig. 9 shows an example in which both a part of a 2D image 901 and part of a 3D model 902 of teeth are seen simultaneously. The 2D image 901 is a photograph of a part of a patients face comprising the patient's lips 903 and the patient's existing teeth 904 behind the lips. In the place of the lower and upper teeth in the left side of the patient's mouth (right side for the patient) the 3D model comprising teeth 907 is seen.
The 3D model 902 is arranged and aligned relative to the 2D image 901.
The existing teeth 904 in the 2D image 901 correspond to the situation before restoring one or more of the teeth. The 3D model 902 with teeth 907 corresponds to a possible situation after restoration. Since the view can be interchanged between before and after visualization, e.g. by gradual fading in-and-out, the suggested changes can very clearly be seen and evaluated.

Fig. 10 shows an example of rendering of a 3D model of teeth arranged relative to a 2D image.
Fig. 10 shows an example in which both a 2D image 1001 and a 3D model 1002 of teeth are seen simultaneously. The 2D image 1001 is a photograph of a part of a patients face comprising the patient's lips 1003. In the place of the teeth in the 2D image, a 3D model comprising modeled and rendered teeth 1007 is arranged. The teeth 1007 in the 3D model have been rendered, such as a photo-realistic rendering.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In particular, it is to be understood that other embodiments may be utilised and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

When a claim refers to any of the preceding claims, this is understood to mean any one or more of the preceding claims.

The features of the method described above and in the following may be implemented in software and carried out on a data processing system or other processing means caused by the execution of computer-executable instructions. The instructions may be program code means loaded in a memory, such as a RAM, from a storage medium or from another computer via a computer network. Alternatively, the described features may be implemented by hardwired circuitry instead of software or in combination with software.

Electronic Acknowledgement Receipt

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International Application Number:	
Confirmation Number:	4632
Title of Invention:	2D IMAGE ARRANGEMENT
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Payment Type	Credit Card
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2	Authorization to access Appl. by Trilateral Office	PTO_SB_39.pdf	86155 aebee94a6e3bb221fac4923a6b18b40d2bcd402c	no	1
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2D image arrangement

Abstract

Disclosed is a computer-implemented method of visualizing, designing and modeling a set of teeth for a patient, wherein the method comprises the steps of:

- providing one or more 2D digital images;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- modeling the 3D virtual model based on at least one of the one or more 2D digital images.

(fig. 3b) should be published)

Claims:

1. A computer-implemented method of visualizing, designing and modeling a set of teeth for a patient, wherein the method comprises the steps of:
- providing one or more 2D digital images;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- modeling the 3D virtual model based on at least one of the one or more 2D digital images.

2. The computer-implemented method according to the preceding claim, wherein the one or more 2D digital image comprises a patient-specific image of at least part of the patient's face.

3. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image comprises a generic image of at least part of a human face.

4. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is retrieved from a library comprising a number of images of teeth.

5. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is a template for supporting designing and/or modeling the patient's teeth.

6. The computer-implemented method according to the preceding claim, wherein the template comprises the midline of a face.

7. The computer-implemented method according to claims 5 or 6, wherein the template comprises a horizontal line passing along the anterior teeth.

8. The computer-implemented method according to any of claims 5-7, wherein the template comprises the occlusal plane of a face.

9. The computer-implemented method according to any claims 5-8, wherein the template comprises boxes adapted to fit the centrals, the laterals and the cuspids.

10. The computer-implemented method according to any claims 5-9, wherein the template comprises one or more long axes of anterior teeth.

11. The computer-implemented method according to the preceding claim, wherein the long axes of at least the upper anterior teeth converge toward the incisal edge.

12. The computer-implemented method according to any claims 5-11, wherein the template comprises a contour of teeth.

13. The computer-implemented method according to the preceding claim, wherein the contour comprises a shape of one or more teeth seen from the front.

14. The computer-implemented method according to any of claims 5-13, wherein the template comprises a curve.

15. The computer-implemented method according to the preceding claim, wherein the curve comprises an arch following the upper and/or lower anterior teeth seen from the front or from above.

16. The computer-implemented method according to claims 14 or 15, wherein the curve comprises a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper teeth.

17. The computer-implemented method according to any of claims 5-16, wherein the template comprises one or more curves for indicating the position of the gingival tissue.

18. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image shows at least a number of front teeth.

19. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is a photograph showing at least the patient's lips and teeth seen from the front.

20. The computer-implemented method according to the preceding claim, wherein the method further comprises virtually cutting at least a part of the teeth out of the one or more 2D digital image, such that at least the lips remains to be visible in the 2D digital image.

21. The computer-implemented method according to the preceding claim, wherein the 3D virtual model is visible behind the lips.

22. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image shows the face of the

patient such that facial lines, such as the midline and the bi-pupillar line, are detectable.

23. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is an X-ray image of the patient's teeth.

24. The computer-implemented method according to any of the preceding claims, wherein the method further comprises providing a 3D computed tomography scan of the patient's face.

25. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is a still image from a video recording.

26. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is derived from a 3D face scan.

27. The computer-implemented method according to any of the preceding claims, wherein the method further comprises providing a 3D face scan of the patient.

28. The computer-implemented method according to any of the preceding claims, wherein the method further comprises providing at least part of the one or more 2D digital image to be at least partly transparent, such that the 3D virtual model is visual through the 2D digital image.

29. The computer-implemented method according to any of the preceding claims, wherein the one or more 2D digital image is adapted to be smoothly faded in and out of the view.

30. The computer-implemented method according to any of the preceding claims, wherein the method further comprises aligning the one or more 2D digital image and the 3D virtual model.

31. The computer-implemented method according to any of the preceding claims, wherein the silhouette of the biting edge of at least the upper anterior teeth on the one or more 2D image and on the 3D virtual model is used to perform the alignment of the one or more 2D image and the 3D virtual model.

32. The computer-implemented method according to any of the preceding claims, wherein the 3D virtual model comprises the patient’s set of teeth.

33. The computer-implemented method according to any of the preceding claims, wherein the method further comprises scaling the one or more 2D digital image and the 3D virtual model to show at least part of the teeth in the same size.

34. The computer-implemented method according to any of the preceding claims, wherein the method further comprises projecting the plane of the one or more 2D digital image to the 3D virtual model.

35. The computer-implemented method according to any of the preceding claims, wherein the method further comprises changing the perspective view of the one or more 2D digital image and/or of the 3D virtual model to obtain the same perspective view.

36. The computer-implemented method according to any of the preceding claims, wherein the method further comprises de-warping the perspective view of the one or more 2D image for visually aligning the one or more 2D image and the 3D virtual model.

37. The computer-implemented method according to any of the preceding claims, wherein scaling, aligning, projecting to a plane, and changing perspective are defined as virtual actions for arrangement.

38. The computer-implemented method according to the preceding claim, wherein one or more of the virtual actions for arrangement comprises rotations and translations left/right and back/forth of the one or more 2D digital image and/or of the 3D virtual model.

39. The computer-implemented method according to claims 37 or 38, wherein the method further comprises the steps of:
- detecting anatomical points on the teeth, where the anatomical points are present and detectable both on the one or more 2D digital image and the 3D virtual model, and
- performing the virtual actions for arrangement based on these corresponding anatomical points.

40. The computer-implemented method according to the preceding claim, wherein at least one corresponding anatomical point is selected to perform the virtual actions for arrangement.

41. The computer-implemented method according to any of claims 37-40, wherein the method further comprises the steps of:
- providing a virtual measurement bar, and
- performing the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of adjustment to the virtual measurement bar.

42. The computer-implemented method according to any claims 37-41, wherein the method further comprises that a user performs virtual actions for

arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of eye measure.

43. The computer-implemented method according to claims 39 or 40, wherein the anatomical points are upper and/or lower distal and/or mesial points on a number of specific anterior teeth.

44. The computer-implemented method according to any of the preceding claims, wherein the modeling of the 3D model is performed automatically based on the one or more 2D digital image.

45. The computer-implemented method according to any of the preceding claims, wherein the method further comprises automatically selecting one or more 2D digital image which provides an optimal fit to the 3D virtual model.

46. The computer-implemented method according to the previous claim, wherein the optimal fit is determined based on specific parameters for providing an esthetically, visually pleasing appearance.

47. The computer-implemented method according to any of the preceding claims, wherein the 3D virtual model is generated by scanning a physical model of the patient's teeth, by scanning an impression of the patient's teeth, and/or by performing a direct scanning of the patient's teeth.

48. The computer-implemented method according to any of the preceding claims, wherein the alignment of the at least one 2D image and the 3D model is performed automatically.

49. The computer-implemented method according to any of the preceding claims, wherein the method further comprises providing at least part of the

3D virtual model to be at least partly transparent, such that at least one of the one or more 2D digital images is visual through the 3D virtual model.

50. The computer-implemented method according to any of the preceding claims, wherein the method comprises fading the 3D model smoothly in and out of the view.

51. The computer-implemented method according to any of the preceding claims, wherein the 3D model and two or more of the 2D images are aligned relative to each other, when there are more than one 2D image.

52. The computer-implemented method according to any of the preceding claims, wherein the 3D model and each of the 2D images are aligned relative to each other.

53. The computer-implemented method according to any of the preceding claims, wherein the different alignments of the 3D model relative to the two or more 2D images are stored in a data storage.

54. The computer-implemented method according to any of the preceding claims, wherein the alignment of the 3D model and a specific 2D image is retrieved from the data storage, when the specific 2D image is selected for view.

55. The computer-implemented method according to any of the preceding claims, wherein two or more of the 2D images are 2D images of at least part of the patient's face seen from different directions.

56. The computer-implemented method according to any of the preceding claims, wherein the method further comprises sectioning at least two or more of the teeth in the 3D model and/or in the one or more 2D images.

57. The computer-implemented method according to any of the preceding claims, wherein the method further comprises modeling a restoration, such as a virtual crown, a virtual preparation, and/or an area of virtual gingival on the 3D model.

58. The computer-implemented method according to any of the preceding claims, wherein the 2D image and the 3D model are adapted to be arranged and/or viewed from one or more perspective views.

59. The computer-implemented method according to any of the preceding claims, wherein the method comprises determining an angle of one or more of the perspective views.

60. The computer-implemented method according to any of the preceding claims, wherein the method comprises predefining an angle of one or more of the perspective views.

61. The computer-implemented method according to any of the preceding claims, wherein at least one of the one or more 2D image is from a video stream of 2D images.

62. The computer-implemented method according to any of the preceding claims, wherein the 2D images from the video stream are from different perspective views.

63. The computer-implemented method according to any of the preceding claims, wherein the 3D model is configured to be aligned relative to one or more 2D images in the video stream.

64. The computer-implemented method according to any of the preceding claims, wherein the alignment of the 3D model and one or more 2D images for one or more perspective views is performed by means of interpolation and/or extrapolation of other perspective views.

65. The computer-implemented method according to any of the preceding claims, wherein the method comprises zooming at least one of the one or more 2D images and the 3D model in/out of view.

66. The computer-implemented method according to any of the preceding claims, wherein the 2D image and the 3D virtual model are adapted to be zoomed in/out simultaneously.

67. The computer-implemented method according to any of the preceding claims, wherein the zooming in/out is configured to be performed from one or more perspective views.

68. The computer-implemented method according to any of the preceding claims, wherein the zooming in/out is configured to be performed from one or more predefined angles.

69. The computer-implemented method according to any of the preceding claims, wherein the predefined angles determine the perspective views.

70. The computer-implemented method according to any of the preceding claims, wherein the method comprises providing the predefined angles in discrete steps.

71. The computer-implemented method according to any of the preceding claims, wherein the method comprises providing the predefined angles in a continuous sequence.

72. The computer-implemented method according to any of the preceding claims, wherein the 2D image and the 3D model are snapped together in their correct alignment.

73. The computer-implemented method according to any of the preceding claims, wherein the snapping together of the 2D image and the 3D model is performed automatically.

74. The computer-implemented method according to any of the preceding claims, wherein each of the one or more 2D images is configured to be snapped together with the 3D model in their correct alignment.

75. The computer-implemented method according to any of the preceding claims, wherein the 2D image and the 3D model are aligned based on one or more unprepared teeth, if unprepared teeth are present in the 3D model.

76. The computer-implemented method according to any of the preceding claims, wherein the 2D image and the 3D model are aligned based on the teeth in the upper jaw.

77. The computer-implemented method according to any of the preceding claims, wherein the angle which the 3D model and the 2D image are seen from as default is determined by the perspective view of the 2D image.

78. The computer-implemented method according to any of the preceding claims, wherein the angle of the 3D model and the 2D image is configured to adapt relative to the perspective view of the 2D image.

79. The computer-implemented method according to any of the preceding claims, wherein the view of the 3D model is configured to adapt to the

perspective view of a second 2D image, if this second 2D image is replacing a first 2D image.

80. The computer-implemented method according to any of the preceding claims, wherein the method further comprises generating a 3D image by combining at least three of the 2D images.

81. The computer-implemented method according to any of the preceding claims, wherein the method further comprises rendering the 3D model.

82. The computer-implemented method according to any of the preceding claims, wherein the method further comprises providing textural features on the 3D model.

83. The computer-implemented method according to any of the preceding claims, wherein the rendering is a photo-realistic rendering.

84. A computer program product comprising program code means for causing a data processing system to perform the method of any one of the preceding claims, when said program code means are executed on the data processing system.

85. A computer program product according to the previous claim, comprising a computer-readable medium having stored there on the program code means.

86. A system for visualizing, designing and modeling a set of teeth for a patient, wherein the system comprises:

- means for providing one or more 2D digital images;
- means for providing a 3D virtual model of at least part of the patient’s oral cavity;

- means for arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- means for modeling the 3D virtual model based on at least one of the one or more 2D digital images.

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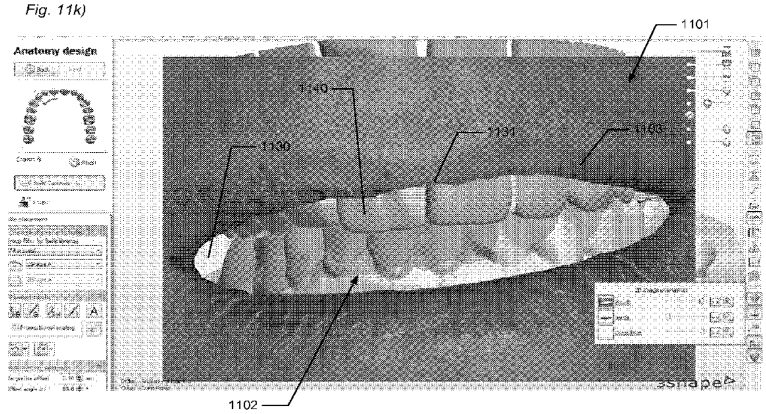
(54) **Title**: 2D IMAGE ARRANGEMENT

Fig. 11k)



(57) **Abstract**: Disclosed is a method of designing a dental restoration (1140) for a patient, wherein the method comprises: -providing one or more 2D images (1101), where at least one 2D image (1101) comprises at least one facial feature (1103); -providing a 3D virtual model (1102) of at least part of the patient's oral cavity; -arranging at least one of the one or more 2D images (1101) relative to the 3D virtual model (1102) in a virtual 3D space such that the 2D image (1101) and the 3D virtual model (1102) are aligned when viewed from a viewpoint, whereby the 3D virtual model (1102) and the 2D image (1101) are both visualized in the 3D space; and -modeling a restoration (1140) on the 3D virtual model (1102), where the restoration is designed to fit the facial feature (1103) of the at least one 2D image (1101).

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2D image arrangement

Field of the invention

This invention generally relates to a method of visualizing and modeling a set of teeth for a patient. More particularly, the invention relates to providing a 3D virtual model of the patient's set of teeth. The method is at least partly computer-implemented.

Background of the invention

Visualization and modeling or design of teeth are known in the field of dental restorations.
When a patient requires a dental restoration, such as crowns, bridges, abutments, or implants, the dentist will prepare the teeth e.g. a damaged tooth is grinded down to make a preparation where a crown is glued onto. An alternative treatment is to insert implants, such as titanium screws, into the jaw of the patient and mount crowns or bridges on the implants. After preparing the teeth or inserting an implant the dentist can make an impression of the upper jaw, the lower jaw and a bite registration or a single impression in a double-sided tray, also known as triple trays. The impressions are sent to the dental technicians who manufacture the restorations e.g. the bridge. The first step to manufacture the restoration is traditionally to cast the upper and lower dental models from impressions of the upper and the lower jaw, respectively. The models are usually made of gypsum and often aligned in a dental articulator using the bite registration to simulate the real bite and chewing motion. The dental technician builds up the dental restoration inside the articulator to ensure a nice visual appearance and bite functionality.

CAD technology for manufacturing dental restoration is rapidly expanding improving quality, reducing cost and facilitating the possibility to manufacture in attractive materials otherwise not available. The first step in the CAD manufacturing process is to create a 3-dimensional model of the patient's teeth. This is traditionally done by 3D scanning one or both of the dental gypsum models. The 3-dimensional replicas of the teeth are imported into a CAD program, where the entire dental restoration, such as a bridge substructure, is designed. The final restoration 3D design is then manufactured e.g. using a milling machine, 3D printer, rapid prototyping manufacturing or other manufacturing equipment. Accuracy requirements for the dental restorations are very high otherwise the dental restoration will not be visual appealing, fit onto the teeth, could cause pain or cause infections.

WO10031404A relates to tools in a system for the design of customized three-dimensional models of dental restorations for subsequent manufacturing, where the dental restorations are such as implant abutments, copings, crowns, wax-ups, and bridge frameworks. Moreover, the invention relates to a computer-readable medium for implementing such a system on a computer.

Visualizing and modeling teeth for a patient based are also known from the field of orthodontics.

US2006127836A discloses orthodontic systems and methods for determining movement of a tooth model from a first position to a second position by identifying one or more common features on the tooth model; detecting the position of the common features on the tooth model at the first position; detecting the position of the common features on the tooth model at the second position; and determining a difference between the position of each common feature at the first and second positions.

Thus orthodontics relates to movement of teeth, so the desired position of a tooth or teeth is determined, and based on the present position of that tooth or teeth, the movement from the present position to the desired position is determined. Thus within orthodontics the desired or resulting position of a tooth or teeth is/are is known before planning the steps of the movement.

It remains a problem to provide an improved method and system for providing esthetically beautiful and/or physiologically suitable results of modeling teeth, both within the field of restorations, implants, orthodontics etc.

Summary

Disclosed is a method of designing a dental restoration for a patient, wherein the method comprises:

- providing one or more 2D images, where at least one 2D image comprises at least one facial feature;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D images relative to the 3D virtual model in a virtual 3D space such that the 2D image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the 2D image are both visualized in the 3D space; and
- modeling a restoration on the 3D virtual model, where the restoration is designed to fit the facial feature of the at least one 2D image.

The terms designing and modeling are used interchangeably in this document to describe what is done to the restoration to make it fit to the patient. The user, e.g. a dental technician, may be digitally designing or modeling a restoration on the 3D virtual model.

It is an advantage that the 3D CAD modeling of the 3D virtual model is based on a 2D digital image, since the 2D image determines or indicates what kind of modeling is suitable, where the expression suitable may comprise physiologically suitable or esthetically suitable or appealing. Thus the 2D image is used to perform a correct modeling of the 3D model, since the 2D image functions as a benchmark or rule for what kind of modeling is possible or how the modeling can be with the limits provided by the 2D image. Thus the modeling of the 3D virtual model is decided and performed based on the one or more 2D image, i.e. such as that the modeling of the 3D virtual model is based on the visualization of the 2D image.

The patient’s oral cavity may comprise at least the patient’s present set of teeth, such as prepared teeth or unprepared teeth, if the patient is not toothless, and maybe part of the gums. If the patient is toothless, then the oral cavity may comprise the gums of the patient.

The 2D image(s) may typically be a digital image, and the term 2D digital image may be used interchangeably with the term 2D image in the specification.

It is an advantage that there may be one or more 2D images. If there are more 2D images, one 2D image may be used for alignment relative to the 3D virtual mode, and another 2D image may be used for designing the restoration. However, even if there are more 2D images, the same 2D image may be used both for alignment and for designing the restoration. The other 2D images may then just be used for visualization and presentation etc. If there is only one 2D image, that 2D image is used both for alignment with the 3D virtual model and for designing the restoration.
Thus the 2D image comprising the facial features may be denoted the first 2D image, and the 2D image which is used for alignment relative to the 3D virtual model may be denoted the second 2D image. If there is only one 2D

image, then the first 2D image and the second 2D image is the same 2D image. If there are more 2D images, then the first 2D image and the second 2d image may be the same 2D image, but they may also be two different 2D images.

The restoration is configured to be manufactured, such as by rapid manufacturing, such as by milling, printing etc. The restoration may be veneered, such as by adding porcelain to the surface of it after machine manufacturing. When the restoration is finished, it may be inserted in the patient’s mouth.

It is an advantage that the 2D digital image and the 3D virtual model are aligned when viewed from one viewpoint, since hereby the user or operator of the system performing the method, can view the 2D image and the 3D model from a viewpoint where they are aligned, since this enables and facilitates that modeling of the 3D model is based on the 2D image. That the 2D image and 3D model are aligned when seen from a viewpoint means that at least some structures of the 2D image and the 3D model are coinciding when seen from a viewpoint. Thus the 2D image and 3D model may not be aligned when seen from any viewpoint, thus there may be only one viewpoint from which the 2D image and the 3D model are aligned.

Furthermore, it is an advantage that the 2D image and the 3D model are arranged and remain as separate data representations which are not merged or fused together into one representation. By keeping the data representations as separate representations, time is saved and data processing time and capacity is reduced. Thus the 2D image is not superimposed or overlaid onto the 3D virtual model for creating one representation with all data included. Prior art documents describe that the data from e.g. a color image is added to the 3D model, such that the color content from the image is transferred to the 3D model, whereby the result is

one representation, i.e. the 3D model including color. Creating such models requires more time and exhaustive data processing.
Thus, it is an advantage that the present method may be performed faster than prior art methods.

The method is for use when modeling teeth, but can of course also with advantage be used by students within the dental field when learning how to model teeth and what to take into consideration when modeling teeth.

Modeling of teeth is defined as comprising modeling of one or more dental restorations, modeling of one or more implants, modeling orthodontic movement of one or more teeth, modeling one or more teeth in a denture, e.g. a fixed or removable denture, to provide a visually pleasing appearance of the set of teeth etc.
Thus the modeling may comprise modeling of restorations, orthodontic planning and/or treatment, modeling of implants, modeling of dentures etc. When the CAD modeling comprises for example restorations, the virtually modeled restorations, such as crowns and bridges, can be manufactured by means of CAM, and the manufactured restorations can then eventually be inserted onto the patient's teeth by a dentist.

Arranging, placing, or positioning the 2D digital image on the 3D virtual model is performed digitally on a computer and shown on a user interface such as a screen, such that the user or operator obtains a visual representation of the 2D image and the 3D model together in the same field of view, whereby the operator can perform the modeling based on the simultaneous view of the 2D image and the 3D model instead of based on either one combined representation or separate views of the 2D image and/or the 3D model.

For facilitating the arrangement of the 2D image and the 3D model relative to each other, edge detection may be performed, whereby the contour of the teeth on the 2D image and/or on the 3D model is automatically derived. Edge detection can be performed by means of a software algorithm. Edges are points where there is a boundary or edge between to image regions, and edges can thus be defined as sets of points in the image which have a strong gradient magnitude. The contour of the teeth may thus be detected by detecting the edge between image portions showing the teeth and the gingival.

One or more 2D images may be provided in the method, and the 2D images may e.g. show the patient's face from different directions, show different parts of the patient's face, such as facial features in the form of the lips and the eyes or nose for example for determining facial lines, show different examples of new teeth which the teeth of the 3D model can be modeled to look like, show the patient's teeth before preparing the teeth for restorations and after preparing the teeth, etc.

In some embodiments the restoration is designed on at least one prepared tooth in the 3D virtual model.

In some embodiments the 2D image and the 3D model are aligned based on one or more unprepared teeth.

In some embodiments the prepared tooth in the 3D virtual model is a physical preparation of the patient's teeth.

In some embodiments the prepared tooth in the 3D virtual model is a virtual preparation modeled on the 3D virtual model.

In some embodiments the 3D virtual model comprises at least one prepared tooth.

In some embodiments the 3D virtual model comprises no prepared teeth, and where the 3D virtual model is of the patient's oral cavity before at least one tooth is prepared.

In some embodiments the method comprises providing two 3D virtual models, where the first 3D virtual model comprises at least one prepared tooth and the second 3D virtual model comprises no prepared teeth, and where the first and the second 3D virtual models are aligned.

In some embodiments the 2D image and the second 3D virtual model comprising no prepared teeth are aligned.

In some embodiments the 2D image and the first 3D virtual model comprising at least one prepared tooth are aligned based on the alignment between the first and the second 3D virtual model and based on the alignment between the 2D image and the second 3D model.

When aligning the 2D image and the 3D model, the 2D image may be of the patient's unprepared teeth, since it may be easier to align the 2D image and the 3D model, when the teeth on the 2D image are unprepared. When modeling the restoration e.g. new teeth of the 3D model, the 2D image may then be of the patient's prepared teeth, since e.g. restorations normally are modeled after having prepared the teeth by cutting part of the teeth such that crowns etc. can be attached to the prepared part of the teeth.

The 2D image of the prepared teeth may be aligned to the 2D image of the unprepared teeth before the restoration on the 3D model is designed/modeled based on the 2D image with the prepared teeth, since it may be easier to align the 2D images of the prepared and unprepared teeth, e.g. using the lips and other features of the face or teeth, than to align the 2D image of the prepared teeth with the 3D model, since here it may be difficult to find corresponding features on these.

However, the method may also be used before the dentist prepares any tooth or teeth, e.g. for presenting and showing the patient how his set of teeth may look if a restoration is made on one or more of the teeth.

The method may be used for designing a diagnostic wax-up used to visualize the results of a restoration prior to the treatment being executed.
When designing a diagnostic wax-up, a virtual margin line and a virtual preparation may be made for designing the diagnostic wax-up, even though no real preparation is made.

The method may be used for designing a temporary, which the patient can wear after the dentist has prepared a tooth and before the final restoration is manufactured and placed on the prepared tooth.

The restoration may be designed, e.g. automatically, by selecting a tooth in the 2D image, e.g. the tooth in the position where the restoration should be placed or a different aesthetic tooth. In the 2D image the selected tooth is only seen from one viewpoint, so only the front side, the width and the height of the tooth may be seen in the 2D image. Thus the backside of the tooth cannot be seen. A standard model tooth may be selected from a library, and this model tooth may be shaped as the selected tooth in the 2D image. The model tooth or restoration can only be shaped as the selected tooth in the surfaces which are seen in the 2D image. The rest of the model tooth or restoration may be shaped according to some standard for a tooth in that respective location in a mouth. E.g. the backside or the distal surface of a central tooth may typically be flat, whereas the distal surface of a canine may typically be triangularly shaped, and the distal surface of a molar may typically resemble the mesial surface of the tooth. Or the distal surface of the neighbor teeth or the corresponding tooth on the other side of the midline in the mouth may be used to shape the surfaces of the restoration which cannot be derived from the 2D image. The restoration can be designed on the 3D virtual model, and the part of the restoration which is in contact with e.g. the preparation may be automatically designed to resemble the shape of the restoration.

The restoration can be a crown, a bridge, an abutment, an implant, a denture, such as a fixed or removable denture, a full denture or partial denture, a diagnostic wax-up, a temporary etc.
Designing a restoration may comprise designing at least part of a preparation, designing at least a part of the gingival surrounding the restoration in the patient’s mouth etc..

It is an advantage that the restoration is designed to fit or match the facial feature of the at least one 2D image, since this will provide a restoration which looks natural relative to the patient’s face and/or this will provide a restoration which is aesthetic, such as symmetrical. The dental technical rules for designing teeth, mathematical or algorithmic rules and/or rules for aesthetics may be programmed into the software or used in the software or method for designing the restoration to fit the facial features, and based on these rules the restoration may be designed, e.g. partly automatically. The dental technician or the dentist may use his/her experience and knowledge about dental aesthetics and rules to design and determine when the restoration fits the facial feature in the patient’s image or in a template or standard image of a face.
Designing the restoration to fit the facial features of the 2D image may be based on purely objective rules for restoration design. However designing the restoration to fit the facial features of the 2D image may alternatively and/or additionally be based on more subjective opinions and choices of the dental technician or dentist.

In some embodiments facial features are present in an image of the patient and/or in a generic image of a person.

In some embodiments the facial feature is one or two lips, one or more teeth, and/or the shape and/or size of the face.

In some embodiments the facial features comprise one or more imaginary lines of a face adapted to be detected in the 2D image, such as the midline, the horizontal line, and/or the bi-pupillar line.

If the 2D image is an image of at least part of the patient’s face, then the facial features used for designing the restoration may be the lips of the patient, the smile line of the patient’s mouth, the symmetry lines in the patient’s face, the midline of the patient’s face, the horizontal line of the patient’s face, the patient’s anterior teeth etc. Thus the restoration may be designed by fitting the restoration to the lips of the patient, by fitting the restoration to the smile line of the patient’s mouth, by fitting the restoration to the patient’s anterior teeth etc.

If the 2D image is an image, such as a drawing, of a generic template face, then the facial features used for designing the restoration may be symmetry lines of the template face, shapes and sizes of the teeth on the template face etc.

When designing the restoration to fit the facial features, the restoration may be designed such that there is a certain distance from the edge of the upper lip to the incisal edge of the anterior teeth, e.g. the centrals, when the patient smiles a natural smile; and/or such that a certain percentage or amount of the centrals are visible when the patient smiles.

Furthermore, when designing the restoration to fit the facial features, the restoration may be designed by considering the shape of the patient's face, the gender of the patient, the phenotypic characteristics of the patient, i.e. whether the patient is Asian, African, Caucasoid etc.. For example Asians typically has smaller teeth, men typically have bigger teeth than women, oval teeth typically suit an oval face shape etc.

Furthermore, if the patient has a small dental arch or jaw, then the distance between the canines will typically be smaller, and the anterior teeth should then typically be more narrow, than the teeth in a patient with a large arch and a larger distance between the canines.

In some embodiments the restoration is a crown, a bridge, an abutment, an implant, a denture, a diagnostic wax-up, and/or a temporary.

In some embodiments the designing of the restoration is performed to automatically fit the facial features of the at least one 2D digital image.

In some embodiments the restoration is designed by selecting a tooth in the 2D image, and modeling the restoration to have the same shape as the selected tooth.

In some embodiments the 3D virtual model is generated by scanning a physical model of the patient's teeth, by scanning an impression of the patient's teeth, and/or by performing a direct scanning of the patient's teeth. If the patient is toothless, then the gums, a model or an impression of the gums may be scanned for creating a 3D model of the oral cavity.

In 3D scanning the object is analyzed to collect data on its shape. The collected data can then be used to construct digital, three dimensional models. In 3D scanning usually a point cloud of geometric samples on the surface of the subject is created. These points can then be used to extrapolate the shape of the subject.

In some embodiments the one or more 2D digital image comprises a patient-specific image of at least part of the patient's face.
An advantage of this embodiment is that the modeling can be based on an image of the patient, such that the modeling is performed with respect to the facial features forming the look or appearance of the patient, or with respect to some, a few or a single, specific visual facial features of the patient, such as the lips.

In some embodiments the one or more 2D digital image comprises a generic image of at least part of a human face.
An advantage of this embodiment is that the modeling can be based on a generic image, whereby it is not patient-specific facial features which determine the modeling, but instead it is a general image, e.g. the facial features may be some visually pleasing teeth from another person, or the facial feature may be a drawing of some ideal teeth etc..

In some embodiments the one or more 2D digital image is retrieved from a library comprising a number of images of teeth.
An advantage of this embodiment is that the 2D image, such as a generic image, can be selected from a library which contains for example several images of teeth, so that the patient e.g. can choose his/her desired new set of teeth from the library. The library may be a so called smile guide library comprising images of teeth and/or mouths which are shown while smiling, since visually pleasing teeth may be most important when smiling, since this may be when most teeth are shown to the surroundings.
The images of teeth in the library may be photos of teeth, may be drawings of teeth, etc. and thus the facial features are then teeth.

In some embodiments the 2D image comprises a cross for providing a visual symmetry which is adapted to be used for designing the restoration.

In some embodiments the one or more 2D digital image is a template for supporting designing the patient's teeth.
An advantage of this embodiment is that when the 2D image is a template, then the operator can arrange and model teeth using this template for obtaining a visually pleasing result of the modeling. Thus the template may comprise facial features in the form of guiding lines, rough blocks for arranging the teeth etc.

Thus facial feature, such as imaginary lines, in a patient's face, such as the midline, the horizontal line, the bi-pupillar line etc. may be used to determine how the restored teeth should look, i.e. the features, such as lines, may be used for designing the restoration(s).

In some embodiments the template comprises a facial feature in the form of the midline of a face.

In some embodiments the template comprises a a facial feature in the form of horizontal line passing along the anterior teeth.

In some embodiments the template comprises a facial feature in the form of the occlusal plane of a face.

An advantage of the embodiments where the template comprises some facial feature, such as the midline of the face, a horizontal line, an occlusal plane etc, is that these features may assist in both arranging the 2D image and the 3D model relative to each other and in modeling of the restoration of the 3D model.

In some embodiments the template comprises a facial feature in the form of boxes adapted to fit the centrals, the laterals and the cuspids.
An advantage of this embodiment is that it enables the operator to easily model a restoration of the different anterior teeth to be visually pleasing. For example the laterals can with advantage be 2/3 of the width of the centrals, and the cuspids or canines can with advantage be slightly narrower than the centrals.

In some embodiments the template comprises a facial feature in the form of one or more long axes of anterior teeth.
An advantage of this embodiment is that the long axes can be used for indicating the long axis alignment of teeth and/or the vertical direction of teeth for support in modeling the restoration.

In some embodiments the facial feature in the form of the long axes of at least the upper anterior teeth converge toward the incisal edge or biting edge.
An advantage of this embodiment is that it is visually pleasing when the long axes of at least the upper anterior teeth converge toward the incisal.

In some embodiments the template comprises a facial feature in the form of a contour of teeth.

In some embodiments the contour comprises a shape of one or more teeth seen from the front.

An advantage of the embodiments relating to the contour of teeth is that using the visually pleasing contour of some suitable teeth may be a simple and easy way to model the restoration teeth of the 3D model.

In some embodiments the template comprises a facial feature in the form of a curve.
An advantage of this embodiment is that by means of a curve, distances and angles can be measured or viewed. For example a distance can be measured from the centre of the curve, and in one example the operator may measure x mm from a certain point on the curve, and at this distance something specific may be arranged, such as a distal point on a lateral. Furthermore the curve may be a symmetry curve for ensuring that the modeled restoration teeth will be symmetric.

In some embodiments the facial feature in the form of the curve comprises an arch following the upper and/or lower anterior teeth seen from the front or from above.

In some embodiments the facial feature in the form of the curve comprises a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper teeth.

In some embodiments the template comprises a facial feature in the form of one or more curves for indicating the position of the gingival tissue.

An advantage of these embodiments relating to curves of the teeth and/or of the mouth and lips is that using some kind of curve(s) may be a simple and easy way to model the restoration teeth of the 3D model.

In some embodiments the one or more 2D digital image shows at least a number of front teeth.
It is an advantage to have a facial feature in the form of front teeth, since front teeth may be good starting points for designing other restoration teeth.

In some embodiments the one or more 2D digital image is a photograph showing at least a facial feature in the form of the patient's lips and teeth seen from the front.
An advantage of this embodiment is that when the 2D image shows the patient's lips and existing teeth, then the modeling of the restoration teeth can be performed such that they suit the patient's lips and unchanged teeth providing a visually pleasing result of the modeling.

In some embodiments the method further comprises virtually cutting at least a part of the teeth out of the one or more 2D digital image, if the 2D image comprises teeth, such that at least the lips remains to be visible in the 2D digital image.
An advantage of this embodiment is that when the lips and no or only some teeth are visible in the 2D image then it is easy to visualize the modeled restoration teeth of the 3D virtual model with the patient's lips and determine whether the restoration it is a good result of modeling. The cutting of teeth out of the 2D image may be performed virtually or digitally such that the information in the 2D image relating to the teeth is removed, deleted, made invisible etc..
If there is free space between the teeth, such as between the upper and lower teeth in the 2D image, then this free space may also be removed from the 2D image, such that everything inside the edge of the lips is removed so that the 3D model can be seen within the edge of the lips. The lips themselves should preferably not be cut out, since the lips should preferably be seen while designing the restoration of the teeth, such that the restoration is designed to fit the patient's lips or the standard, template, model lips from a template 2D image.

Virtually cutting the teeth out of the 2D image may be performed by segmenting the lips and the teeth in the 2D image. Segmentation may be performed by that the dental technician manually draws with a digital drawing tool along the edge or lines of the lips and/or teeth, and thereby performs the segmentation. The segmentation may also be performed automatically by means of well-known image processing algorithms. The segmentation may also be performed by means of analyzing the color difference in the 2D image, and using the criteria that teeth are normally white/yellow or grey colored, and that lips are normally red/pink/flesh colored. The segmentation may also be performed by defining one or more lip models or teeth models and then digitally searching the 2D image for features which match the lip models and/or teeth models.

The edge of the lips can be marked by means of image processing tools, digital drawing tools, such as manual tools, semi-automatic tools, full-automatic tools, standard image processing tools, a combination of different drawings tools etc.

One of the 2D images may be a 2D image of the patient where the teeth can be seen behind the lips, e.g. where as much as possible of the teeth is seen, e.g. in an image where the patient smiles, such as his/her natural smile.
It may be an advantage that the patient's present teeth can be seen in the 2D image, since this may be used when designing the restoration. In particular, how the patient's present teeth and lips look or appear relative to each other when the patient smiles, may be used when designing the restoration.

Another one of the 2D images may be a 2D image of the patient where the teeth cannot be seen, e.g. where the lips are closed together.

In some embodiments the 3D virtual model is visible behind the lips.
An advantage of this embodiment is that when the 3D model can be seen behind the lips, then the modeling of the restoration teeth can be performed while viewing the lips for determining if the modeling is satisfactory.

In some embodiments the method comprises cutting out the part of the 2D image which is inside the edge of the lips.

In some embodiments the edge of the lips is marked on the 2D image.

In some embodiments the edge of the lips is marked manually by means of digital drawing tools.

In some embodiments the edge of lips is marked by means of a digital spline curve.

In some embodiments the edge of the lips is marked by means of semi-automatic drawings tools.

When a part from the 2D image and a part from the 3D virtual model should be viewed/seen/be presented at the same time, then for example the pixels relating to the lips in the 2D image may be selected for view and the pixels relating to the teeth in the 3D virtual model may be selected for view, and the 2D image and the 3D virtual model may be combined in view this way.

As an alternative to cutting out the teeth of the 2D image, the teeth in the 2D image can be made transparent such that the teeth in the 3D model can be seen in the place of the 2D image teeth. Providing the teeth in the 2D image to be transparent can be performed similar to the cutting, e.g. by selecting some pixels to be viewed and selecting other pixels not to be viewed.

In some embodiments the one or more 2D digital image shows the face of the patient such that facial features in the form of facial lines, such as the midline and the bi-pupillar line, are detectable.

An advantage of this embodiment is that facial lines determines the geometry of the patient’s face, and for obtaining a visually pleasing result of modeling, the teeth should fit with this overall geometry.

In some embodiments the one or more 2D digital image is an X-ray image of the patient’s teeth.
An advantage of this embodiment is that when using or applying an X-ray image of the patient’s teeth, the entire teeth with roots under the gingival can be seen, and thus broken or weak teeth or roots can be detected. Hereby for example implants exerting force on the teeth and roots can be planned to be arranged to exert force on non-broken or strong teeth and teeth roots instead of on the broken and weak teeth and roots.

In some embodiments the method further comprises providing a 3D computed tomography scan of the patient’s face for facilitating aligning the one or more 2D image and the 3D model and/or for modeling the 3D virtual model.

In some embodiments the one or more 2D digital image is a still image from a video recording.

In some embodiments the one or more 2D digital image is derived from a 3D face scan.
When the 3D face scan is seen on the screen it may be seen from a certain perspective thereby yielding a certain 2D projection of the 3D scan. Thus a 2D image may be derived from the 2D projection of the 3D face scan.

In some embodiments the method further comprises providing a 3D face scan of the patient for facilitating aligning the one or more 2D image and the 3D model and/or for modeling the 3D virtual model.

The 3D face scan may be provided by means of aligning and/or combining multiple sub-scans of the face, such as sub-scans from different angles.
Furthermore, at least some of the sub-scans may be at least partly overlapping.
The face scan may also comprise texture, and at least a part of the sub-textures of at least part of the sub-scans may be color adjusted ad/or color interpolated, such as by texture weaving, to provide the texture of the 3D face scan or 3D model.
When performing a face scan of the patient, at least part of the patient's hair may be powdered with a reflective powder.
Furthermore, silhouettes from multiple sub-scans may be extruded and subsequently intersected to provide a visual hull approximation.

Texture, such as color, from the 2D image or a face scan may be mapped onto the 3D virtual model and/or mapped onto the restoration.
If the restoration resembles the original tooth which is being restored, then it may be an advantage to use the texture, e.g. color, from the 2D image. But if the restoration does not resemble the original tooth or if there is no original tooth, then the texture, e.g. color, from the 2D image may not be mapped to the restoration.
Mapping the texture, e.g. color, from the 2D image onto the 3D virtual model and/or the restoration may be an advantage for designing the restoration, since it may e.g. help in determining the color of the restoration and/or other textural features of the restoration.

The teeth and tissue, such as gingival, in the 3D model may be at least partially segmented. The segmentation may be provided by means of a computer implemented algorithm, such as a shortest path algorithm applied on a 3D matrix representing curvature of the tooth surface.
Segmentation may alternatively/additionally be at least partly based on color information in the 3D model.

In some embodiments a face scan of the patient provides a measure of the distance that the upper and/or lower lip moves when the patient smiles, and the distance is adapted to be used for measuring the ideal length of at least some of the teeth.

An advantage of this embodiment is that at least the length of the front teeth is important for the visual appearance of the teeth.

In some embodiments the method further comprises providing at least part of the one or more 2D digital image to be at least partly transparent, such that the 3D virtual model is visual through the 2D digital image.

Transparency may mean full transparency, e.g. meaning something is completely invisible, partial transparency or translucency, e.g. meaning that the graphics is partially transparent, e.g. like a colored glass. Partial transparency may be simulated at some level by mixing colors.

When the entire or a part from the 2D image and/or the entire or a part from the 3D virtual model should be transparent, then for example some of, such as every second, pixels in the 2D image may be selected for view and some of, such as every other second, pixels in the 3D virtual model may be selected for view, and the 2D image and the 3D virtual model may be combined in view this way, such that one of them or both become transparent, e.g. interchangeably transparent.

Fading may be obtained similar to transparency, e.g. by selecting certain pixels for view and other pixels not for view.

In some embodiments the one or more 2D digital image is adapted to be smoothly faded in and out of the view.

An advantage of this embodiment is that when smoothly fading the 2D image in and out of view this provides that the visualization of the 2D digital image changes from being entirely visible to be partly visible and then maybe invisible and vice versa. Hereby the 2D image can be viewed as the user wishes. The fading in-and-out may be gradual.

In some embodiments the method further comprises providing at least part of the 3D virtual model to be at least partly transparent, such that at least one of the one or more 2D digital images is visual through the 3D virtual model.

In some embodiments the method comprises fading the 3D model smoothly in and out of the view.

In some embodiments the 2D image and the 3D model are adapted to be alternately faded in and out of view.

In some embodiments the 2D image is adapted to be faded into view, when the 3D virtual model is faded out of view, and vice versa.

In some embodiments the 2D image and the 3D virtual model are adapted to faded in and out of view independently of each other.

In some embodiments the 3D virtual model comprises the patient’s set of teeth.

In some embodiments the 2D image and the 3D virtual model are aligned by means of scaling, translating and/or rotating the 2D image and/or the 3D model relative to each other.

In some embodiments the view of the 2D image is fixed, and the 3D virtual model is scaled and/or translated and/or rotated relative to the 2D image.

In some embodiments the method comprises selecting a viewpoint of the 3D virtual model which provides an optimal fit to the 2D digital image.

In some embodiments the dental articulation of the upper and lower teeth in the 3D virtual model is adapted to be adjusted to resemble the articulation of the upper and lower teeth in the 2D image.

In some embodiments the method further comprises scaling the one or more 2D digital image and the 3D virtual model to show at least part of the teeth in the same size.
An advantage of this embodiment is that the 2D image and the 3D model should be shown in the same scale in order for optimally performing the modeling. The scaling may be an automatic modification of the size of e.g. the 3D virtual model to the size of the 2D digital image or vice versa. Alternatively, the scaling may be of both the 2D image and the 3D model to resize them to a predetermined scale.

In some embodiments the method further comprises aligning the one or more 2D digital image and the 3D virtual model.
An advantage of this embodiment is that when the 2D image and the 3D model are aligned then modeling of the restoration may be performed easier and with a better result. Alignment may be defined as the adjustment of an object in relation with another object, such that structures of the objects are coinciding. Thus common or alike structures of the 2D image and the 3D model may be aligned.

In some embodiments the silhouette of the biting edge of at least the upper anterior teeth on the one or more 2D image and on the 3D virtual model is used to perform the alignment of the 2D image and the 3D virtual model.
An advantage of this embodiment is that in many cases the biting edge of the upper anterior teeth are seen on both the 2D image and on the 3D model,

and therefore this biting edge may be an advantageous physical point of alignment.

In some embodiments the method further comprises projecting the plane of the one or more 2D digital image to the 3D virtual model.
An advantage of this embodiment is that when projecting the plane of 2D image to the 3D model or to a plane of the 3D model, the 3D model and the 2D image can be viewed in the same plane which may be an advantage when modeling the restoration teeth. The viewing of the 3D model and the 2D image in the same plane may otherwise be complex.

In some embodiments the method further comprises changing the perspective view of the one or more 2D digital image and/or of the 3D virtual model to obtain the same perspective view.
An advantage of this embodiment is that modeling of the restoration may be facilitated when the 2D image and the 3D model can be seen in the same perspective view.

For aligning the 2D image and the 3D model, a 2D projection of the 3D model may be performed. The projection may be a perspective projection, a parallel projection such as an orthographic projection, etc. Corresponding points may be selected on the 2D image and the 3D model, a projection of the 3D model onto 2D space may be made, and the distance between the corresponding points on the 2D projected 3D model and the 2D image may be minimized until the location of the corresponding points are coincident or almost coincident. The location may be minimized by means of iteration, like in the iterative closest point (ICP) method for aligning 3D models.

In some embodiments the method further comprises de-warping the perspective view of the one or more 2D image for visually aligning the 2D image and the 3D virtual model.

De-warping may be used, if the 2D image of the patient's mouth is for example taken in an angle from above, below and/or from a side, but it is desired that the 2D image of the patient's mouth is seen from the front, since a front image may be easier to use when designing a restoration for the patient's teeth.

Warping or de-warping may be used for correcting image distortion. Warping or de-warping may comprise mapping points to points. This can be based mathematically on any function from (part of) the plane to the plane.

Thus an advantage of this embodiment is that when de-warping or correcting the perspective view of the 2D image, then the view is digitally manipulated, and hereby points on the perspective view of the 2D image can be mapped to points on the 3D model or its plane. After de-warping or correcting the perspective of the 2D image, the 3D model can be re-aligned, such that the 2D image and the 3D model are aligned again.

Thus de-warping may be performed by projecting the 2D image or the teeth from the 2D image onto the 3D virtual model. Since the 3D model may only comprises the teeth of the patient, a face model, such as the patient's own face or a generic face model, may be used to align the 2D image and the 3D virtual model. A new perspective view of the 3D virtual model may now be selected and a new 2D image can be derived from this. This new 2D image may be a corrected, undistorted version or view of the original distorted 2D image.

In some embodiments scaling, aligning, projecting to a plane, de-warping perspective and changing perspective are defined as virtual actions for arrangement or alignment.

In some embodiments one or more of the virtual actions for arrangement comprises rotations and translations left/right and back/forth of the one or more 2D digital image and/or of the 3D virtual model.

An advantage of this embodiment is that by providing rotations, translations etc. then different movements of the 2D image and/or of the 3D model may be performed for facilitating the scaling, aligning, perspective changing and ultimately for facilitating the modeling of the teeth.

In some embodiments the method further comprises the steps of:
- detecting anatomical points on the teeth, where the anatomical points are present and detectable both on the one or more 2D digital image and the 3D virtual model, and
- performing the virtual actions for arrangement based on these corresponding anatomical points.

An advantage of this embodiment is that using corresponding, common or mutual anatomical points on the 2D image and the 3D model may be an easy way to perform alignment of the 2D image and the 3D model, where after modeling of the restoration teeth can be performed.

For correctly aligning the 2D image and the 3D virtual model, the number of corresponding points on the 2D image and the 3D model may be similar to the number of degrees (DOF) of freedom for moving the 2D image and the 3D model relative to each other. The number of degrees of freedom may for example be seven; thus seven corresponding points may be required for performing a correct alignment of the 2D image and the 3D virtual model.
For calculating the number of degrees of freedom, a camera model may be estimated. The camera model may comprise a number of internal parameters and a number of external parameters. The internal parameters may be magnification, also known as enlargement or scaling, and perspective projection or distortion. The external parameters may be the placement and orientation of the camera relative to the object, e.g. the set of teeth.
The degrees of freedom may be translations in the three directions in space and rotations about the three axes in space.

For reducing the number of degrees of freedom, and thus e.g. for reducing the required number of corresponding points on the 2D image and the 3D model, it can be assumed that all the teeth lie in the same plane. Then the internal parameters should not comprise the perspective projection or distortion, but only the magnification. Thus a parallel projection may be assumed, and for example it can alternatively and/or additionally be assumed that the 2D image of a patient's face is captured exactly from the front.
If a patient's teeth are photographed from a distance of about 1 meter, which may typically be the case when photographing teeth for this method, then the assumption about parallel projection may be acceptable.
For some cases it may be a reasonable assumption that all teeth lie in the same plane, however in other cases this assumption may not be correct, and it may be difficult or even impossible to align the 2D image and the 3D virtual model using this assumption.

In practice, alignment may be performed by fixing the 2D image in position and then moving the 3D virtual model relative to the fixed 2D image by using e.g. a 3D motion controller, a 3D navigation device, a 6DOF device (six degrees of freedom) or a 3D mouse, such as a spaceball.

If the 3D virtual model can be reduced to a 2D model, then the 2D image and the 2D model may be aligned using three points, since the alignment may then comprise magnification or scaling, translation in one direction and rotation about one axis.

The difficult part of aligning a 2D image and a 3D virtual model may be performing the rotation, since translation and scaling or magnification may be more easy to perform.

Perspective projection can be activated in the software program where the restoration is designed, and when perspective projection is activated the 2D image and/or the 3D virtual model may comprise more depth.

Perspective may be a parameter which can be adjusted, activated, fixed etc. in the software program for performing the method.

In some embodiments at least one corresponding anatomical point is selected to perform the virtual actions for arrangement.
An advantage of this embodiment is that one common or mutual point on the 2D image and the 3D model may be sufficient for arranging the 2D image and the 3D model relative to each other. However in other cases the 2D image and the 3D model should be aligned using more points, such as two, three or four points. In general three points may be suitable. Four points can be used for performing an even better arrangement or for use in more difficult cases.

In some embodiments the method further comprises the steps of:
- providing a virtual measurement bar, and
- performing the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of adjustment to the virtual measurement bar.

An advantage of this embodiment is that it may be easy and fast to use a virtual measurement bar to perform the virtual actions for arrangement such as scaling, where the sizes of the 2D image and the 3D model are adjusted to correspond to each other.

In some embodiments the method further comprises that a user performs the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of eye measure.
An advantage of this embodiment is that just by using simple eye measure, the operator can very quickly and reliably perform the arrangement of the 2D image and the 3D model relative to each other or perform a rough starting point for a more detailed adjustment.

In some embodiments the anatomical points are upper and/or lower distal and/or mesial points on a number of specific anterior teeth.
An advantage of this embodiment is that anatomical point on the upper and/or lower distal and/or mesial parts of the anterior teeth are normally easy to detect both on the 2D image and on the 3D model.

In some embodiments the modeling of the 3D model is performed automatically based on the one or more 2D digital image.
An advantage of this embodiment is that the user does not need to perform any manual modeling of the 3D model on the screen, when the modeling can be performed fully automatic. However, typically if an automatic modeling takes place, then the user may check that the modeling is satisfying, and maybe perform small corrections to the modeling.

In some embodiments the method further comprises automatically selecting one or more 2D digital image which provides an optimal fit to or match with the 3D virtual model.
An advantage of this embodiment is that a 2D image with an optimal, good or the best match or fit to the 3D model can automatically be selected, and hereby a good result of modeling of the restoration can be obtained, and furthermore the time used for performing the modeling of the restoration can be reduced, since no person needs to spend time on looking through a larger number of 2D images. The 2D image may be selected from a library of 2D digital images, or from any source comprising a number of images of teeth and smiles. The library may comprise templates, photos, drawings etc with facial features.

In some embodiments the optimal fit or match is determined based on specific parameters for providing an esthetically, visually pleasing appearance.

An advantage of this embodiment is that the optimal, best or just a good match or fit can be determined based on different parameters, such as the present size of the patient's teeth, on the curves of the patient's present teeth set, etc. New teeth which are very big may not suit a person who used to have very small teeth or a person who has thin lips. Likewise a new teeth set with a strong composition may not suit a person who used to have a teeth set with a soft composition or a person who has full lips etc. So based on the present facial features such as structures, features, shapes etc. of the patient's teeth, new teeth which will look natural and suit the patient can be determined from e.g. a template library of photos, drawings etc.

In some embodiments the alignment of the at least one 2D image and the 3D model is performed automatically.

In some embodiments the 3D model and two or more of the 2D images are aligned relative to each other, when there are more than one 2D image.

In some embodiments the 3D model and each of the 2D images are aligned relative to each other.
It is an advantage that the 3D model is aligned specifically to each of the 2D images, such that if shifting between the different 2D images, the correct alignment of the 3D model relative to the selected 2D image may automatically be presented on the user interface.

In some embodiments the different alignments of the 3D model relative to the two or more 2D images are stored in a data storage.

In some embodiments the alignment of the 3D model and a specific 2D image is retrieved from the data storage, when the specific 2D image is selected for view.

In some embodiments two or more of the 2D images are 2D images of at least part of the patient's face seen from different directions.

In some embodiments the method further comprises sectioning at least two or more of the teeth in the 3D model and/or in the one or more 2D images.

In some embodiments the 2D image and the 3D model are adapted to be arranged and/or viewed from one or more perspective views.
The perspective views may be from the front, from behind, from the side, from above, from below, and any combination of these view. A visual or non-visual point e.g. a center point, a line e.g. a centerline or a region e.g. a center region in the 3D model and/or in the 2D image may determine the point of reference for the perspective views.

In some embodiments the method comprises determining an angle of one or more of the perspective views.
The angle may be the angle relative to a center point of the 2D image and/or the 3D model. The angle may be an angle relative to a horizontal plane, and/or a vertical plane etc which virtually intersects the teeth in the 2D image and/or in the 3D model.

In some embodiments the method comprises predefining an angle of one or more of the perspective views.

In some embodiments at least one of the one or more 2D image is from a video stream of 2D images.

In some embodiments the 2D images from the video stream are from different perspective views.

In some embodiments the 3D model is configured to be aligned relative to one or more 2D images in the video stream.

In some embodiments the alignment of the 3D model and one or more 2D images for one or more perspective view is performed by means of interpolation and/or extrapolation of other perspective views.
It is an advantage that already determined perspective views can be used for alignment of other perspective views. The perspective views may be present or arranged on a virtual trajectory or curve and/or on a virtual view point sphere. Thus if two perspective views are already determined, a third perspective view located between the two perspective views can be determined by extrapolation or interpolation and the 3D model and the 2D image can be aligned relative to this or based on this. The perspective views or angles may be provided by a shift in angles, view directions etc, and the shifts may be smooth and continuous or in discrete steps.

In some embodiments the method comprises zooming at least one of the one or more 2D images and the 3D model in/out of view.

In some embodiments the 2D image and the 3D virtual model are adapted to be zoomed in/out simultaneously.
It is an advantage that the 2D image and the 3D model can be zoomed in/out simultaneously, and/or jointly, and/or together, and/or concurrently, and/or synchronously. Thus the increase or decrease in the size of the 2D image and the 3D model may be similar when zooming, the 2D image and the 3D model may follow each other when zooming, and the center point or center region of the zoom may be coinciding in the 2D image and the 3D model.

In some embodiments the zooming in/out is configured to be performed from one or more perspective views.

In some embodiments the zooming in/out is configured to be performed from one or more predefined angles.

In some embodiments the predefined angles determine the perspective views.

In some embodiments the method comprises providing the predefined angles in discrete steps.

In some embodiments the method comprises providing the predefined angles in a continuous sequence.

In some embodiments the 2D image and the 3D model are snapped or locked together in their correct alignment.
It is an advantage that if for example the 2D image is seen from a side perspective, then the 2D image is automatically snapped or locked to the correct angle relative to the 3D model.

When the alignment of the 2D image and the 3D virtual model has been found, this alignment can be saved, and if the 2D image and the 3D model are then moved again relative to each other, the saved alignment can be used to snap or lock the 2D image and the 3D virtual together again the correct alignment.

In some embodiments the snapping together of the 2D image and the 3D model is performed automatically.

In some embodiments each of the one or more 2D images is configured to be snapped together with the 3D model in their correct alignment.

In some embodiments the 2D image and the 3D model are aligned based on one or more unprepared teeth, if unprepared teeth are present in the 3D model.

In some embodiments the 2D image and the 3D model are aligned based on the teeth in the upper jaw.
It is an advantage to align based on the upper teeth because these are typically the most visible teeth on a 2D image, in particular the front teeth in the upper jaw are normally most visible and the alignment may therefore be improved if these teeth are used for the alignment.
Alternatively and/or additionally the teeth in the lower jaw of the 3D model can also be moved e.g. downwards to obtain a suitable alignment.

In some embodiments the angle which the 3D model and the 2D image are seen from as default is determined by the perspective view of the 2D image.
The angle can also be denoted view, view point, perspective view etc.

In some embodiments the angle of the 3D model and the 2D image is configured to adapt relative to the perspective view of the 2D image.
The angle can also be denoted view, view point, perspective view etc.

In some embodiments the view of the 3D model is configured to adapt to the perspective view of a second 2D image, if this second 2D image is replacing a first 2D image.
It is an advantage that the view may change automatically when a second 2D image is selected for view, alignment etc.

In some embodiments the method further comprises generating a 3D image by combining at least three of the 2D images.

In some embodiments the method further comprises rendering the 3D model.

It is an advantage to perform rendering of the teeth in the 3D model, such as photo-realistic rendering, since hereby the 3D model is made to look more realistic and nicer. The 3D model may be for example yellow or gray by default, so by rendering the teeth in the 3D model to be for example more white, the 3D model teeth looks better and realistic.
The rendering can be performed by means of well-known methods performed using well-known computer programs.

In some embodiments the method further comprises providing textural features on the 3D model.
It is an advantage to provide textural features on the 3D model for making the teeth of the 3D model look more realistic and real. The textural features of the teeth may be obtained from a 2D image of the patient's existing teeth, the textural features may be from a standard template, may be generated specifically to the specific 3D model based on size, shape etc of the teeth. Furthermore, other parameters such as shadow, geometry, viewpoint, lighting, and shading information can be provided to the 3D model for making the teeth of the 3D model look more realistic and possibly look more esthetic.

In some embodiments texture from the 2D image is mapped onto the 3D virtual model and/or the restoration.

In some embodiments the rendering is a photo-realistic rendering.

In general it is an advantage of the method and the embodiments that it/they enable(s) dental laboratories (labs) to superimpose a patient's actual face and smile images in the design process and utilize that directly to produce optimally esthetic and personalized restorations. Labs can show the dentist's patients exactly how a new restoration will transform their smiles and get feedback. The smile visualization is highly realizable because it may be solidly backed by the manufacturable 3D model and not just 2D image manipulations.

Personalized designs with patient specific 2D-image overlays can be obtained by importing 2D images of the patient’s lips, teeth and smile to design restorations that exactly suit the patient’s personal look. Image manipulation tools may be applied to mask away the teeth, and alignment tools may be used to bring lips and new teeth design together as a perfect personalized design guide.

High esthetics with generic 2D-image overlays can be obtained by using 2D-image libraries that help in achieving high esthetics, even without pictures of the actual patient’s smile. By means of the method it is possible to select from a variety of smile-guides and design-templates to recreate complete smile compositions to apply with the restoration design.

Before-and-after visualization can be obtained for example by continuously interchanging between situation views through gradual fading in-and-out, whereby technicians, dentists and patients are easily able to detect even the smallest alterations and smile details for optimal comparisons.

The present invention relates to different aspects including the method described above and in the following, and corresponding methods, devices, systems, uses and/or product means, each yielding one or more of the benefits and advantages described in connection with the first mentioned aspect, and each having one or more embodiments corresponding to the embodiments described in connection with the first mentioned aspect and/or disclosed in the appended claims.

In particular, disclosed herein is a system for designing a dental restoration for a patient, wherein the system comprises:

- means for providing one or more 2D images, where at least one 2D image comprises at least one facial feature;
- means for providing a 3D virtual model of at least part of the patient's oral cavity;
- means for arranging at least one of the one or more 2D images relative to the 3D virtual model in a virtual 3D space such that the 2D image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the 2D image are both visualized in the 3D space; and
- means for modeling a restoration on the 3D virtual model, where the restoration is designed to fit the facial feature of the at least one 2D image.

Furthermore the present invention relates to a computer program product comprising program code means for causing a data processing system to perform the above method, when said program code means are executed on the data processing system, and a computer program product according to the previous claim, comprising a computer-readable medium having stored there on the program code means.

According to another aspect, disclosed is a computer-implemented method of visualizing, designing and modeling a set of teeth for a patient, wherein the method comprises the steps of:
- providing one or more 2D digital images;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space; and
- modeling the 3D virtual model based on at least one of the one or more 2D digital images.

Brief description of the drawings

The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

Fig. 1 shows an example of a flowchart of a method of visualizing and modeling a set of teeth for a patient.

Fig. 2 shows examples of visualizing a 2D image and a 3D model together.

Fig. 3 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 4 shows examples of arranging the 3D model and the 2D image relative to each other.

Fig. 5 shows examples of 2D images as templates.

Fig. 6 shows examples of how to perform virtual actions for arrangement of the 2D image and the 3D model.

Fig. 7 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 8 shows an example of how a 3D model can be arranged in a 2D image, or how a 2D image can be laid over a 3D model.

Fig. 9 shows an example of a before-and-after visualization.

Fig. 10 shows an example of rendering of a 3D model of teeth arranged relative to a 2D image.

Fig. 11 shows an example of aligning a 2D image and a 3D virtual model relative to each other, cutting out the mouth and teeth of the 2D image to see the 3D virtual model in place of the teeth, and designing a restoration on the 3D virtual model based on the 2D image.

Detailed description

In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced.

Fig. 1 shows an example of a flowchart of a method of designing a dental restoration for a patient.

In step 101 one or more 2D digital images is provided, where at least one 2D image comprises at least one facial feature. The 2D image may be photograph of at least part of the patients face, a template of teeth, a drawing of teeth, a photo or image of an esthetic set of teeth etc. The 2D digital image may be shown on a user interface, such as a computer screen.

In step 102 a 3D virtual model of the patient’s oral cavity comprising the patient’s set of teeth, if there are any teeth, is provided. The 3D model of the patient’s set of teeth may be generated by scanning a physical model of the patient’s teeth, by scanning an impression of the patient’s teeth, and/or by performing a direct scanning of the patient’s teeth. If the patient is toothless, then the gums, a model or an impression of the gums may be scanned for creating a 3D model of the oral cavity. The 3D virtual model may be shown on a user interface, such as a computer screen.

In step 103 a 2D digital image is arranged or positioned relative to the 3D virtual model for visualizing the 3D virtual model relative to the 2D digital image. The arrangement or positioning is a digital, virtual arrangement, performed by means of software, such that the 2D image and the 3D model can be viewed together. The 2D digital image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the 2D digital image are both visualized in the 3D space. The user of the software program may use digital tools to manually align the 2D image and the 3D virtual model, or the 2D image and the 3D virtual model may automatically be aligned by means of digital processing means, or the alignment of the 2D image and the 3D virtual model may be a combination of manually alignment performed by the user and automatic alignment. The 2D image used for alignment with the 3D virtual may the same 2D image comprising facial features or it may be a different 2D image.

In step 104 a restoration of the 3D virtual model is modeled, where the restoration is designed to fit the facial feature of the at least one 2D image. Thus the part of the 3D virtual model of the patient’s set of teeth comprising the restoration is digitally or virtually modeled or designed based on the visualization of the arrangement of the 2D image comprising the facial feature. Thus the 3D model of the patient’s existing teeth is modeled using CAD, and the modeling may comprise restorations, orthodontic planning and/or treatment, prosthetics, removable dentures etc. The virtually modeled restorations, such as crowns and bridges, can be manufactured by means of CAM, and the manufactured restorations can then be inserted onto the patient’s teeth by a dentist.

Fig. 2 shows examples of visualizing a 2D image and a 3D model together.

Fig. 2a) shows a screen shot on which both a 2D image 201 and a 3D model 202 are seen simultaneously. The 2D image 201 is a photograph of a part of a person’s face showing facial features in the form of the mouth with lips 203 and teeth 204 behind the lips 203. The photograph may be of the patient himself or of another person. Using a photograph of the patient may be advantageous if the patient’s teeth have been broken and the patient then wishes to have his teeth restored to look like they did before the damage. Using a photograph of another person may be an option if the patient wishes to have his teeth restored, exchanged by a new teeth set and/or treated by orthodontics in order for them to look and/or be arranged differently than they do at present.

The 3D model 202 of the patient's teeth comprises gingival 208 and teeth 207.

Fig. 2b) shows an example where the 2D image 201 is an X-ray image of the patient's teeth. The X-ray image shows facial features in form of the teeth 204 of the patient. Since the X-ray image shows the teeth approximately on lines, i.e. not on curves as in real-life, at least part of the plane of the X-ray image may be changed with regard to the perspective, warped, projected and/or bended to be arranged relative to the 3D model 202 with teeth 207.

Fig. 3 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 3a) shows a screen shot on which both a 2D image 301 and a 3D model 302 of teeth are seen simultaneously. The 2D image 301 is a photograph or drawing showing facial features in form of a pair of lips 303 and an outline of teeth 304 behind the lips. A vertical line 305 and a horizontal line 306 are drawn through the 2D image 301, and they may also be used as guiding lines for modeling a restoration.

Fig. 3b) shows a screen shot on with the 2D image 301 is arranged and aligned relative to the 3D model 302. The teeth 307 of the 3D model 302 can be seen through and between the lips 303 and the outline of teeth 304 of the 2D image 301. When arranging and aligning the 2D image relative to the 3D model, modeling of a restoration on the 3D model is facilitated. The vertical line 305 and the horizontal line 306 are also seen in fig. 3b).

Fig. 3c) shows a sketch of a 2D image 301 and a 3D model 302 seen in a perspective side view illustrating alignment from a viewpoint.

The 2D image 301 and the 3D model are in this figure attempted to be drawn in a perspective side view to show that if the 2D image and the 3D model are viewed from this viewpoint then they are not aligned. In the other figures, e.g. fig. 3b) the 2D image and the 3D model are viewed from a front viewpoint in which they are aligned. As seen there is a distance between the 2D image and the 3D model to indicate that the 2D image and the 3D model are separate representations and not one representation containing data from two representations. The distance can be any distance, such as shorter or longer than illustrated in the proportion here.
The arrow denoted X illustrates the front view in which the 2D image and the 3D model are aligned, as seen in e.g. fig. 3b).
The arrow denoted Y illustrates a bottom view where the 2D image and the 3D model are viewed from below, and as can be derived from the figure, the 2D image and the 3D model are not aligned when viewed from the Y viewpoint.
The end of an arrow, circle with cross, denoted Z illustrates a side view, and as explained above with respect to the perspective side view, the 2D image and the 3D model are not aligned when viewed from this viewpoint.

Fig. 4 shows examples of arranging the 3D model and the 2D image relative to each other.
Fig. 4a), b) and c) show examples of different arrangements of the 3D model 402 relative to the 2D image 401. The teeth 407 of the 3D model 402 is seen to be moved relative to the lips 403 of the 2D image 401 in the fig. 4a), b) and c). When the arrangement of the 3D model 402 has become suitable relative to the 2D image 401, the actual modeling of the teeth 407 of the 3D model 402 may be performed.

Fig. 5 shows examples of 2D images as templates comprising facial features.
Fig. 5a) shows an example of a 2D digital image 501, which is a reference frame for arranging the patient's teeth and/or modeling a restoration. The

reference frame comprises a template 509 for the upper anterior or front teeth. The template 509 comprises facial features in the form of the midline of a face 505 and a horizontal line 506 passing along the incisal edge of the anterior teeth.
The template 509 comprises facial features in the form of boxes adapted to fit the centrals 510, the laterals 511 and the cuspids 512, also known as canines. The laterals 511 may ideally be 2/3 of the width of the centrals 510, and the cuspids 512 may ideally be slightly narrower than the centrals 510.

Fig. 5b) shows an example where the 2D image 501 is a template 509 comprising facial features in the form of the long axes 513 of the centrals 510, the laterals 511, and the cuspids 512. The long axes 513 converge toward the incisal edge indicated by the horizontal line 506.

Fig. 5c) shows an example where the 2D image 501 is a template 509 showing facial features in the form of a contour 514 of anterior or front teeth seen from the front.

Fig. 5d) shows an example where the 2D image 501 comprises a template 509 comprising facial features in the form of a curve 515 of a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper anterior teeth 510, 511, 512, as seen from the front.

Fig. 5e) shows an example where the 2D image 501 comprises a template comprising facial features in the form of three curves 516 for indicating the position of the gingival tissue.

Fig. 5f) shows an example where the 2D image 501 comprises or is a template 509 comprising a curve in the form of an arch 517 which follows the upper teeth as seen from above.

Fig. 5g) shows an example where the 2D image 501 comprises or is a template 509 comprising a curve 518 which follows the upper anterior teeth as seen from above.
The arch 517 and the curve 518 may also be denoted facial features.

Fig. 6 shows examples of how to perform alignment or virtual actions for arrangement of the 2D image and the 3D model relative to each other.
Virtual actions for arrangement can comprise the following:
- scaling the 2D digital image and the 3D virtual model to show at least part of the teeth in the same size on both of them;
- aligning the 2D digital image and the 3D virtual model;
- projecting the 3D virtual model to a/the plane of the 2D digital image;
- changing the perspective view of the 2D digital image and/or of the 3D virtual model to obtain the same perspective view for both of them when visualizing the positioning;
- de-warping the perspective view of the 3D virtual model for visually aligning the 2D image and the 3D virtual model.

The virtual actions for arrangement can be performed by means of rotations and translations to the left and right and back and forth of the 2D digital image and/or of the 3D virtual model.
In one example (not shown) the silhouette of the biting edge of at least the upper anterior teeth on the 2D image and on the 3D virtual model is used to perform the aligning of the 2D image and the 3D virtual model.

Fig. 6a) shows an example where the alignment or a virtual action for arrangement such as alignment is performed using detected corresponding anatomical points 619 on the teeth on the 2D digital image 601 and on teeth on the 3D virtual model 602. The anatomical points 619 shown in fig. 6a) are at the upper anterior teeth. One anatomical point is on the incisal edge at the distal side of the left lateral tooth, where left is left as seen in the figure, but right for the patient. Another anatomical point is on the incisal edge between the left and the right central teeth. The third anatomical point is at the gingival between the right lateral tooth and right cuspid tooth, where right is right as seen in the figure, but left for the patient.

When the corresponding anatomical points 619 are detected and e.g. marked as in the figure on both the 2D image 601 and the 3D model 602, the 2D image 601 and the 3D model 602 can be arranged relative to each other and aligned to each other by providing that the corresponding anatomical points 619 on the 2D image 610 and on the 3D model 602 cover, overlap, match or fit together. When corresponding anatomical points 619 are selected on the screen, the software may automatically arrange the 2D image 601 and the 3D model 602 such that the points 619 are overlapping.

Fig. 6b) shows an example where a virtual action for arrangement such as scaling is performed using a virtual measurement bar 620. The virtual measurement bar 620 is seen on both the 2D image 601 and the 3D model 602. On the 2D image 601, the measurement bar 620 has a length corresponding to the length across the upper two centrals 610 and the two laterals 611. However, on the 3D model, the measurement bar 620 has a length corresponding to both the upper two centrals 610, the two laterals 611 and the two cuspids 612. Thus in order to have matching sizes of the 2D image 601 and the 3D model 602, the 3D model should be scaled up or enlarged to fit the size of the 2D image.

Alternatively and/or additionally, the user can perform virtual actions of arrangement of the 2D digital image and/or of the 3D virtual model by means of eye measure.

Fig. 7 shows an example of visualizing and arranging a 2D image and a 3D model.

Fig. 7 shows a screen shot from a user interface in which both a 2D image 701 and a 3D model 702 of teeth are seen simultaneously. The 2D image

701 is a photograph of a part of a patients face comprising facial features in the form of the patient's lips 703 and the patient's existing upper teeth 704 behind the lips. In the place of the lower teeth on the 2D image the 3D model comprising the lower teeth 707 is arranged.

The 3D model 702 is arranged and aligned relative to the 2D image 701.

A restoration on the 3D model can be modeled to fit the facial features in the 2D image such as the patient's lips, the upper anterior teeth etc.

Fig. 8 shows an example of how a 3D model can be arranged in a 2D image, or how a 2D image can be laid over a 3D model.

Fig. 8 shows a screen shot from a user interface in which a 2D image 801 is seen. The 2D image 801 is a photograph of a part of a patients face comprising the patient's lips 803 and the patient's existing upper teeth 804 behind the lips.

If a 3D model of teeth should be arranged in the place of the lower teeth, the area of the lower teeth in the 3D image can be marked and hidden or deleted by means of a non-transparent area 830. The marked area 830 can be marked by drawing a line 831 along the edge of the upper teeth and the lower lips. The marking of the line 831 can be performed automatically by means of automatic contour and/or color detection of the 2D image. Alternatively and/or additionally, the operator can draw the line 831 or otherwise mark the area 830.

The same may apply if more or less, e.g. all the teeth in the 2D image should be replaced with the teeth of a 3D model.

Fig. 9 shows an example of a before-and-after visualization.

A before-and-after visualization can be obtained by continuously interchanging between situation views through gradual fading in-and-out, whereby technicians, dentists and patients are easily able to detect even the smallest alterations and smile details for optimal comparisons.

Fig. 9 shows an example in which both a part of a 2D image 901 and part of a 3D model 902 of teeth are seen simultaneously. The 2D image 901 is a photograph of a part of a patients face comprising facial features in the form of the patient's lips 903 and the patient's existing teeth 904 behind the lips. In the place of the lower and upper teeth in the left side of the patient's mouth (right side for the patient) the 3D model comprising teeth 907 is seen.
The 3D model 902 is arranged and aligned relative to the 2D image 901.
The existing teeth 904 in the 2D image 901 correspond to the situation before restoring one or more of the teeth. The 3D model 902 with restored teeth 907 corresponds to a possible situation after restoration of the teeth. Since the view can be interchanged between before and after visualization, e.g. by gradual fading in-and-out, the suggested changes can very clearly be seen and evaluated.

Fig. 10 shows an example of rendering of a 3D model of teeth arranged relative to a 2D image.
Fig. 10 shows an example in which both a 2D image 1001 and a 3D model 1002 of teeth are seen simultaneously. The 2D image 1001 is a photograph of a part of a patients face comprising the patient's lips 1003. In the place of the teeth in the 2D image, a 3D model comprising modeled and rendered restored teeth 1007 is arranged. The restored teeth 1007 in the 3D model have been rendered, such as a photo-realistic rendering.

Fig. 11 shows an example of aligning a 2D image and a 3D virtual model relative to each other, cutting out the mouth and teeth of the 2D image to see the 3D virtual model in place of the teeth, and designing a restoration on the 3D virtual model based on the 2D image.
Fig. 11 shows a number of steps which may be performed for designing a restoration, but it should not be understood that all these steps should be performed for designing a restoration. In some cases aligning the 2D image and the 3D virtual model can be performed differently than shown in the

figures 11, and in some cases the mouth and teeth is not cut out of the 2D image as shown in the figures 11.

Fig. 11a) shows a 3D virtual model 1102 of a patient's set of teeth. A first design of the restoration 1140 in the form of a bridge comprising three teeth is designed. The restoration is white whereas the original teeth in the 3D model are brown/grey in the figure.

Fig. 11b) shows the 3D model 1102 with the restoration 1140. In the lower right corner a menu 1141 is shown which allows the user to select a 2D image to overlay on the 3D model 1102.

Fig. 11c) shows a 2D image 1101 of the patient's lower face showing the mouth including lips 1103 and existing teeth 1104. The menu 1102 is also seen in the lower right corner.

Fig. 11d) shows both the 2D image 1101 with lips 1103 and teeth 105, and the 3D virtual model 1102 with the restoration 1140. The 2D image 1101 has been made partially transparent such that both the 2D image and the 3D virtual model can be seen. A scale on the menu 1141 in the lower right corner can be changed to adjust the transparency of the 2D image and/or the 3D model.

Fig. 11e) shows the 2D image 1101 and the 3D virtual model, where the 2D image has been made partially transparent, such that both the 2D image and the 3D virtual model can be seen. The 2D image and the 3D virtual model have been aligned which can be seen in that the incisal edge of the three anterior teeth 1142, 1143 and 1144 matches on the 2D image and the 3D virtual model.

Furthermore, it can be seen that the first design of the restoration 1140 has been designed such that the new teeth in the restoration 1140 are a little bit shorter than the original teeth on the 2D image.

The patient may have required the restoration 1140 because the original teeth was broken, damaged, dead, caused problems with the occlusion, problems with the gingival etc.

Fig. 11f) shows the 2D image 1101 and the 3D virtual model 1102, where the transparency of the 2D image is a little bit different compared to the transparency in fig. 11e). In fig. 11f) the 2D image is less transparent than in fig. 11e). The transparency can be adjusted by means of the scale on the menu 1141.

Figs 11g), 11h) and 11i) show an example of virtually cutting out teeth of the 2D image.

Fig. 11g) shows the 2D image 1101 of the patient's lower face where the lips 1103 and the teeth 1104 can be seen. The line 1131 along the lips 1103 is marked and thereby the whole area 1130 within the lips can be marked.

Fig. 11h) shows the 2D image 1101 where the area 1130 within the line 1131 along the lips 1103 has been emptied, i.e. replaced with an empty space, a blank area etc. Thus the teeth 1104 in the area 1130 is removed from view, deleted, disregarded etc. The area 1130 has been made transparent such that the 3D virtual model arranged behind the 2D image can be seen in the area 1130.

Fig. 11i) shows the area 1130 which is the part of the 2D image 1101 within the line 1131 along the lips. Thus the teeth 1104 are seen in this cut-out part of the 2D image.

Fig. 11j) shows the 2D image 1101 with the cut-out area 1130 along the line 1131 of the lips 1103, and the 3D virtual model 1102 is now visible in the cut-our area 1130 of the 2D image. The restoration 1140 of the 3D model 1102 is seen, and it can be seen that the restoration 1140 has not been finally designed yet, as there is a rather large gap between the upper central teeth, where the left central tooth (as seen for the viewer, but the right central tooth) is part of the restoration 1140.

Fig. 11k) shows that the restoration 1140 has now been finally designed, since the restoration 1140 has been designed such that there is no big gap between the two central upper teeth. Thus the restoration 1140 has been designed based on and designed to match and fit facial features seen on the 2D image, such as the lips 1103.

In this case where the restoration is three of the upper anterior teeth, the restoration is partly designed also to be symmetrical with the corresponding teeth in the other side of the upper jaw. But in cases where e.g. the restoration is a full denture or the restoration is all the anterior teeth in e.g. the upper jaw, then the new teeth in the restoration can be designed to match and fit the facial features of the patient's face as seen on the 2D image, and the restoration may not be designed to be symmetrical with any existing teeth in the patient's mouth.

Although some embodiments have been described and shown in detail, the invention is not restricted to them, but may also be embodied in other ways within the scope of the subject matter defined in the following claims. In particular, it is to be understood that other embodiments may be utilised and structural and functional modifications may be made without departing from the scope of the present invention.

In device claims enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

When a claim refers to any of the preceding claims, this is understood to mean any one or more of the preceding claims.

The features of the method described above and in the following may be implemented in software and carried out on a data processing system or other processing means caused by the execution of computer-executable instructions. The instructions may be program code means loaded in a memory, such as a RAM, from a storage medium or from another computer via a computer network. Alternatively, the described features may be implemented by hardwired circuitry instead of software or in combination with software.

Claims:

1. A method of designing a dental restoration for a patient, wherein the method comprises:

- providing one or more 2D images, where at least one 2D image comprises at least one facial feature;
- providing a 3D virtual model of at least part of the patient's oral cavity;
- arranging at least one of the one or more 2D images relative to the 3D virtual model in a virtual 3D space such that the 2D image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the 2D image are both visualized in the 3D space; and
- modeling a restoration on the 3D virtual model, where the restoration is designed to fit the facial feature of the at least one 2D image.

2. The method according to any of the preceding claims, wherein facial features are present in an image of the patient and/or in a generic image of a person.

3. The method according to any of the preceding claims, wherein the facial feature is one or two lips, one or more teeth, and/or the shape and/or size of the face.

4. The method according to any of the preceding claims, wherein the facial features comprises one or more imaginary lines of a face adapted to be detected in the 2D image, such as the midline, the horizontal line, and/or the bi-pupillar line.

5. The method according to any of the preceding claims, wherein the restoration is a crown, a bridge, an abutment, an implant, a denture, a diagnostic wax-up, and/or a temporary.

6. The method according to any of the preceding claims, wherein the designing of the restoration is performed to automatically fit the facial features of the at least one 2D digital image.

7. The method according to any of the preceding claims, wherein the restoration is designed by selecting a tooth in the 2D image, and modeling the restoration to have the same shape as the selected tooth.

8. The method according to any of the preceding claims, wherein the restoration is designed on at least one prepared tooth in the 3D virtual model.

9. The method according to any of the preceding claims, wherein the 2D image and the 3D model are aligned based on one or more unprepared teeth.

10. The method according to any of the preceding claims, wherein the prepared tooth in the 3D virtual model is a physical preparation of the patient's teeth.

11. The method according to any of the preceding claims, wherein the prepared tooth in the 3D virtual model is a virtual preparation modeled on the 3D virtual model.

12. The method according to any of the preceding claims, wherein the 3D virtual model comprises at least one prepared tooth.

13. The method according to any of the preceding claims, wherein the 3D virtual model comprises no prepared teeth, and where the 3D virtual model is of the patient's oral cavity before at least one tooth is prepared.

14. The method according to any of the preceding claims, wherein the method comprises providing two 3D virtual models, where the first 3D virtual model comprises at least one prepared tooth and the second 3D virtual model comprises no prepared teeth, and where the first and the second 3D virtual models are aligned.

15. The method according to any of the preceding claims, wherein the 2D image and the second 3D virtual model comprising no prepared teeth are aligned.

16. The method according to any of the preceding claims, wherein the 2D image and the first 3D virtual model comprising at least one prepared tooth are aligned based on the alignment between the first and the second 3D virtual model and based on the alignment between the 2D image and the second 3D model.

17. The method according to any of the preceding claim, wherein the method comprises virtually cutting at least a part of the teeth out of the at least one 2D image, such that at least the lips remains to be visible in the 2D image.

18. The method according to any of the preceding claim, wherein the 3D virtual model is visible behind the lips of the at least one 2D image.

19. The method according to any of the preceding claims, wherein the method comprises cutting out the part of the 2D image which is inside the edge of the lips.

20. The method according to any of the preceding claims, wherein the edge of the lips is marked on the 2D image.

21. The method according to any of the preceding claims, wherein the edge of the lips is marked manually by means of digital drawing tools.

22. The method according to any of the preceding claims, wherein the edge of lips is marked by means of a digital spline curve.

23. The method according to any of the preceding claims, wherein the edge of the lips is marked by means of semi-automatic drawings tools.

24. The method according to any of the preceding claims, wherein the 2D image and the 3D virtual model are aligned by means of scaling, translating and/or rotating the 2D image and/or the 3D model relative to each other.

25. The method according to any of the preceding claims, wherein the view of the 2D image is fixed, and the 3D virtual model is scaled and/or translated and/or rotated relative to the 2D image.

26. The method according to any of the preceding claims, wherein the method comprises automatically selecting one or more 2D digital image which provides an optimal fit to the 3D virtual model.

27. The method according to any of the preceding claims, wherein the method comprises selecting a viewpoint of the 3D virtual model which provides an optimal fit to the 2D digital image.

28. The method according to the previous claim, wherein the optimal fit is determined based on specific parameters for providing an esthetically, visually pleasing appearance.

29. The method according to any of the preceding claims, wherein the silhouette of the biting edge of at least the upper anterior teeth on the one or

more 2D image and on the 3D virtual model is used to perform the alignment of the one or more 2D image and the 3D virtual model.

30. The method according to any of the preceding claims, wherein the method further comprises scaling the one or more 2D digital image and the 3D virtual model to show at least part of the teeth in the same size.

31. The method according to any of the preceding claims, wherein the 3D model and two or more of the 2D images are aligned relative to each other, when there are more than one 2D image.

32. The method according to any of the preceding claims, wherein the 3D model and each of the 2D images are aligned relative to each other.

33. The method according to any of the preceding claims, wherein the different alignments of the 3D model relative to the two or more 2D images are stored in a data storage.

34. The method according to any of the preceding claims, wherein the alignment of the 3D model and a specific 2D image is retrieved from the data storage, when the specific 2D image is selected for view.

35. The method according to any of the preceding claims, wherein two or more of the 2D images are 2D images of at least part of the patient's face seen from different directions.

36. The method according to any of the preceding claims, wherein the method further comprises sectioning at least two or more of the teeth in the 3D model and/or in the one or more 2D images.

37. The method according to any of the preceding claims, wherein the alignment of the 3D model and one or more 2D images for one or more perspective views is performed by means of interpolation and/or extrapolation of other perspective views.

38. The method according to any of the preceding claims, wherein the 2D image and the 3D model are aligned based on the teeth in the upper jaw.

39. The method according to any of the preceding claims, wherein the dental articulation of the upper and lower teeth in the 3D virtual model is adapted to be adjusted to resemble the articulation of the upper and lower teeth in the 2D image.

40. The method according to any of the preceding claims, wherein scaling, aligning, projecting to a plane, and changing perspective are defined as virtual actions for arrangement.

41. The method according to any of the preceding claims, wherein one or more of the virtual actions for arrangement comprises rotations and translations left/right and back/forth of the one or more 2D digital image and/or of the 3D virtual model.

42. The method according to any of the preceding claims, wherein the 2D image and the 3D model are snapped or locked together in their correct alignment.

43. The method according to any of the preceding claims, wherein the snapping or locking together of the 2D image and the 3D model is performed automatically.

44. The method according to any of the preceding claims, wherein each of the one or more 2D images is configured to be snapped together with the 3D model in their correct alignment.

45. The method according to any of the preceding claims, wherein the method further comprises rendering the 3D model.

46. The method according to any of the preceding claims, wherein the method further comprises providing texture or textural features on the 3D model.

47. The method according to any of the preceding claims, wherein the rendering is a photo-realistic rendering.

48. The method according to any of the preceding claims, wherein texture from the 2D image is mapped onto the 3D virtual model and/or the restoration.

49. The method according to any of the preceding claims, wherein the method further comprises projecting the plane of the one or more 2D image to the 3D virtual model.

50. The method according to any of the preceding claims, wherein the method further comprises changing the perspective view of the one or more 2D digital image and/or of the 3D virtual model to obtain the same perspective view.

51. The method according to any of the preceding claims, wherein the 2D image and the 3D model are adapted to be arranged and/or viewed from one or more perspective views.

52. The method according to any of the preceding claims, wherein the method comprises determining an angle of one or more of the perspective views.

53. The method according to any of the preceding claims, wherein the method comprises predefining an angle of one or more of the perspective views.

54. The method according to any of the preceding claims, wherein the predefined angles determine the perspective views.

55. The method according to any of the preceding claims, wherein the method comprises providing the predefined angles in discrete steps.

56. The method according to any of the preceding claims, wherein the method comprises providing the predefined angles in a continuous sequence.

57. The method according to any of the preceding claims, wherein the angle which the 3D model and the 2D image are seen from as default is determined by the perspective view of the 2D image.

58. The method according to any of the preceding claims, wherein the angle of the 3D model and the 2D image is configured to adapt relative to the perspective view of the 2D image.

59. The method according to any of the preceding claims, wherein the view of the 3D model is configured to adapt to the perspective view of a second 2D image, if this second 2D image is replacing a first 2D image.

60. The method according to any of the preceding claims, wherein the method further comprises de-warping the perspective view of the one or more 2D image for visually aligning the one or more 2D image and the 3D virtual model.

61. The method according to the preceding claim, wherein the one or more 2D digital image comprises a patient-specific image of at least part of the patient’s face.

62. The method according to any of the preceding claims, wherein the one or more 2D digital image comprises a generic image of at least part of a human face.

63. The method according to any of the preceding claims, wherein the one or more 2D digital image is retrieved from a library comprising a number of images of teeth.

64. The method according to any of the preceding claims, wherein the 2D image comprises a cross for providing a visual symmetry which is adapted to be used for designing the restoration.

65. The method according to any of the preceding claims, wherein the one or more 2D digital image is a template for supporting designing the patient’s teeth.

66. The method according to any of the preceding claim, wherein the template comprises a facial feature in the form of the midline of a face.

67. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of a horizontal line passing along the anterior teeth.

68. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of the occlusal plane of a face.

69. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of boxes adapted to fit the centrals, the laterals and the cuspids.

70. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of one or more long axes of anterior teeth.

71. The method according to any of the preceding claims, wherein the long axes of at least the upper anterior teeth converge toward the incisal edge.

72. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of a contour of teeth.

73. The method according to any of the preceding claims, wherein the contour comprises a facial feature in the form of a shape of one or more teeth seen from the front.

74. The method according to any of of the preceding claims, wherein the template comprises a facial feature in the form of a curve.

75. The method according to any of the preceding claims, wherein the curve comprises an arch following the upper and/or lower anterior teeth seen from the front or from above.

76. The method according to any of the preceding claims, wherein the curve comprises a facial feature in the form of a smile line adapted to follow the lower lip in a natural smile and the incisal edges of the upper teeth.

77. The method according to any of the preceding claims, wherein the template comprises a facial feature in the form of one or more curves for indicating the position of the gingival tissue.

78. The method according to any of the preceding claims, wherein the one or more 2D digital image shows a facial feature in the form of at least a number of front teeth.

79. The method according to any of the preceding claims, wherein the one or more 2D digital image is a photograph showing at least a facial feature in the form of the patient's lips and teeth seen from the front.

80. The method according to any of the preceding claims, wherein the one or more 2D digital image shows the face of the patient such that a facial feature in the form of facial lines, such as the midline and the bi-pupillar line, are detectable.

81. The method according to any of the preceding claims, wherein the method further comprises generating a 3D image by combining at least three of the 2D images.

82. The method according to any of the preceding claims, wherein the one or more 2D digital image is an X-ray image of the patient's teeth.

83. The method according to any of the preceding claims, wherein the method further comprises providing a 3D computed tomography scan of the patient's face.

84. The method according to any of the preceding claims, wherein the one or more 2D digital image is a still image from a video recording.

85. The method according to any of the preceding claims, wherein the one or more 2D digital image is derived from a 3D face scan.

86. The method according to any of the preceding claims, wherein the method further comprises providing a 3D face scan of the patient.

87. The method according to any of the preceding claims, wherein at least one of the one or more 2D image is from a video stream of 2D images.

88. The method according to any of the preceding claims, wherein the 2D images from the video stream are from different perspective views.

89. The method according to any of the preceding claims, wherein the 3D model is configured to be aligned relative to one or more 2D images in the video stream.

90. The method according to any of the preceding claims, wherein the method further comprises the steps of:
- detecting anatomical points on the teeth, where the anatomical points are present and detectable both on the one or more 2D digital image and the 3D virtual model, and
- performing the virtual actions for arrangement based on these corresponding anatomical points.

91. The method according to any of the preceding claims, wherein at least one corresponding anatomical point is selected to perform the virtual actions for arrangement.

92. The method according to any of the preceding of claims, wherein the method further comprises the steps of:
- providing a virtual measurement bar, and
- performing the virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of adjustment to the virtual measurement bar.

93. The method according to any of the preceding claims, wherein the method further comprises that a user performs virtual actions for arrangement of the one or more 2D digital image and/or of the 3D virtual model by means of eye measure.

94. The method according to any of the preceding claims, wherein the anatomical points are upper and/or lower distal and/or mesial points on a number of specific anterior teeth.

95. The method according to any of the preceding claims, wherein the 3D virtual model is generated by scanning a physical model of the patient's teeth, by scanning an impression of the patient's teeth, and/or by performing a direct scanning of the patient's teeth.

96. The method according to any of the preceding claims, wherein the method further comprises providing at least part of the one or more 2D digital image to be at least partly transparent, such that the 3D virtual model is visual through the 2D digital image.

97. The method according to any of the preceding claims, wherein the one or more 2D digital image is adapted to be smoothly faded in and out of the view.

98. The method according to any of the preceding claims, wherein the method further comprises providing at least part of the 3D virtual model to be at least partly transparent, such that at least one of the one or more 2D digital images is visual through the 3D virtual model.

99. The method according to any of the preceding claims, wherein the method comprises fading the 3D virtual model smoothly in and out of the view.

100. The method according to any of the preceding claims, wherein the 2D image and the 3D model are adapted to be alternately faded in and out of view.

101. The method according to any of the preceding claims, wherein the 2D image is adapted to be faded into view, when the 3D virtual model is faded out of view, and vice versa.

102. The method according to any of the preceding claims, wherein the 2D image and the 3D virtual model are adapted to faded in and out of view independently of each other.

103. The method according to any of the preceding claims, wherein the method comprises zooming at least one of the one or more 2D images and the 3D model in/out of view.

104. The method according to any of the preceding claims, wherein the 2D image and the 3D virtual model are adapted to be zoomed in/out simultaneously.

105. The method according to any of the preceding claims, wherein the zooming in/out is configured to be performed from one or more perspective views.

106. The method according to any of the preceding claims, wherein the zooming in/out is configured to be performed from one or more predefined angles.

107. A computer program product comprising program code means for causing a data processing system to perform the method of any one of the preceding claims, when said program code means are executed on the data processing system.

108. A computer program product according to the previous claim, comprising a computer-readable medium having stored there on the program code means.

109. A system for designing a dental restoration for a patient, wherein the system comprises:
- means for providing one or more 2D images, where at least one 2D image comprises at least one facial feature;
- means for providing a 3D virtual model of at least part of the patient’s oral cavity;
- means for arranging at least one of the one or more 2D images relative to the 3D virtual model in a virtual 3D space such that the 2D image and the 3D virtual model are aligned when viewed from a viewpoint, whereby the 3D virtual model and the 2D image are both visualized in the 3D space; and
- means for modeling a restoration on the 3D virtual model, where the restoration is designed to fit the facial feature of the at least one 2D image.

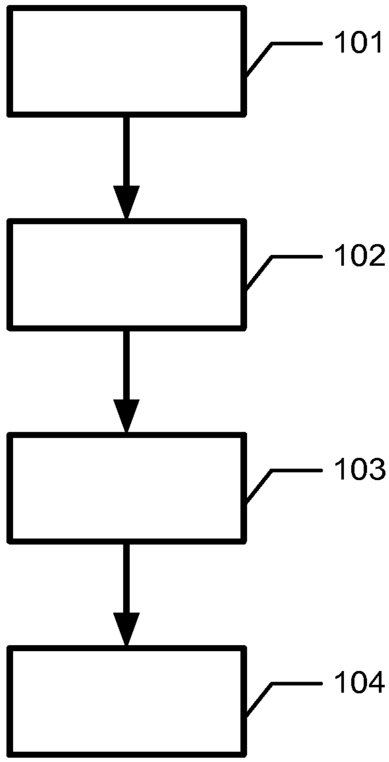


Fig. 1

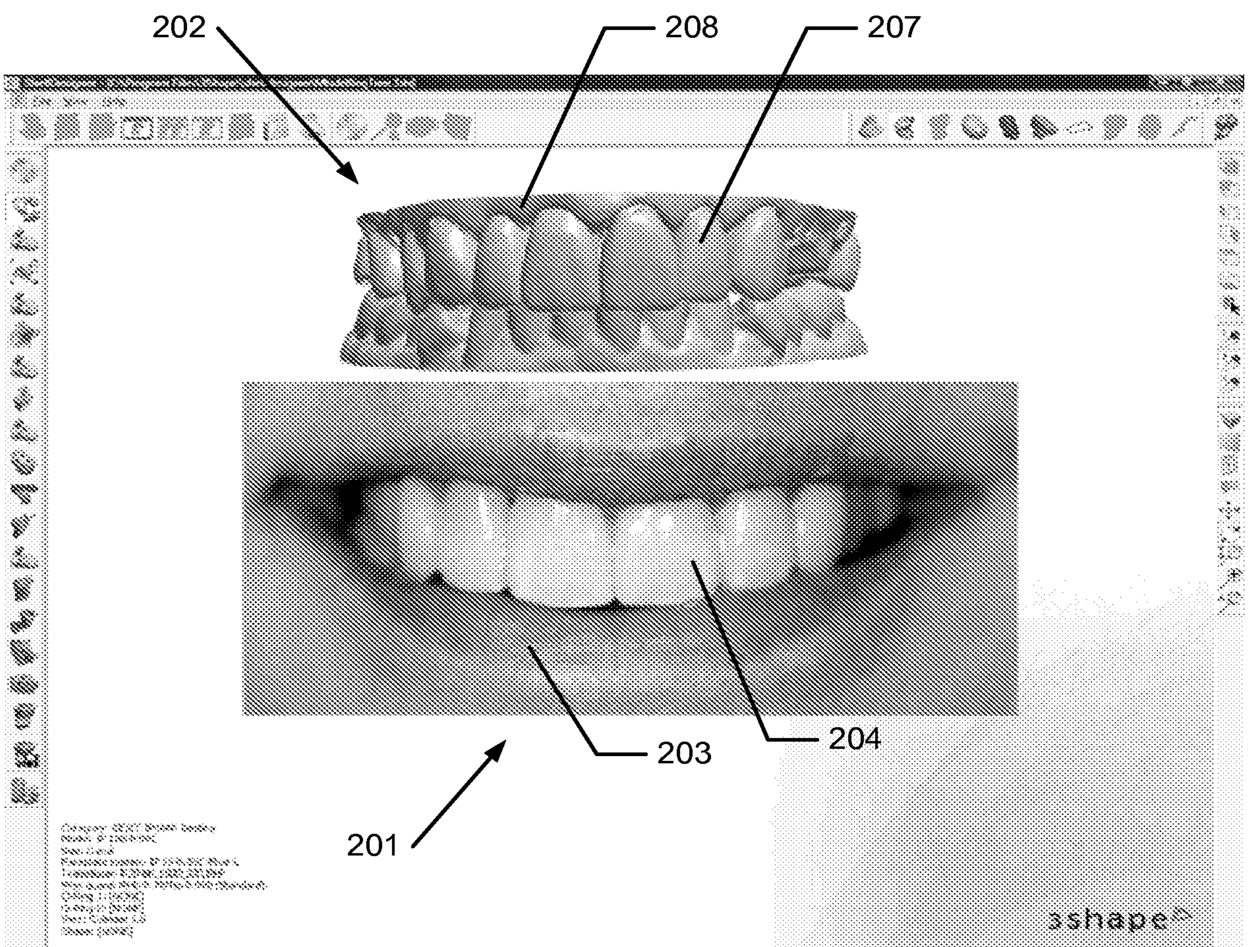
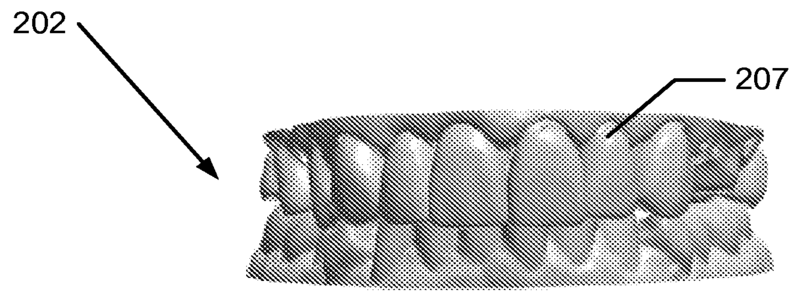


Fig. 2a)



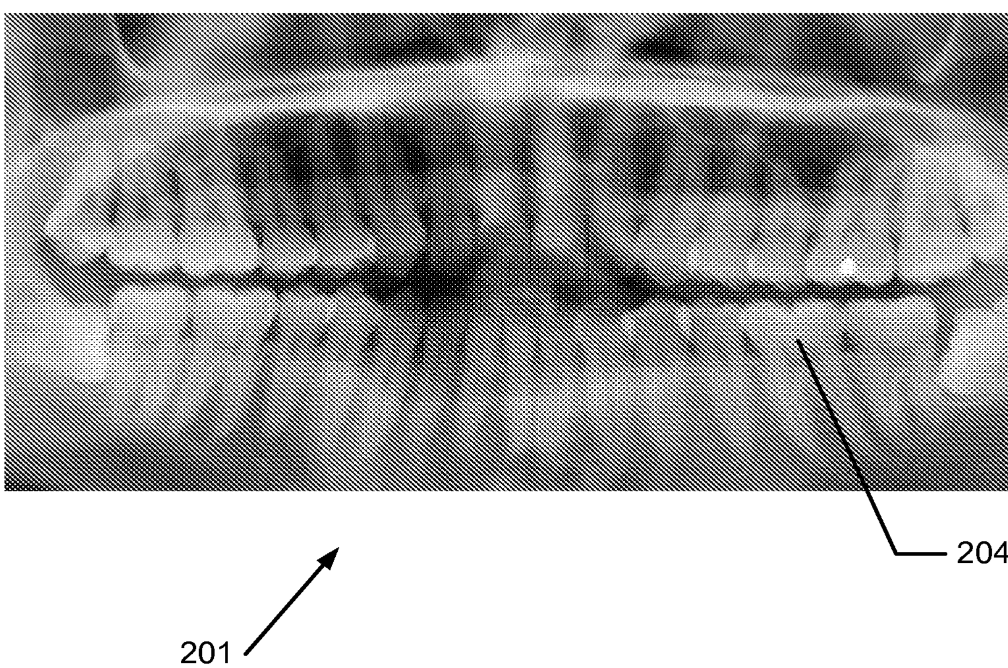


Fig. 2b)

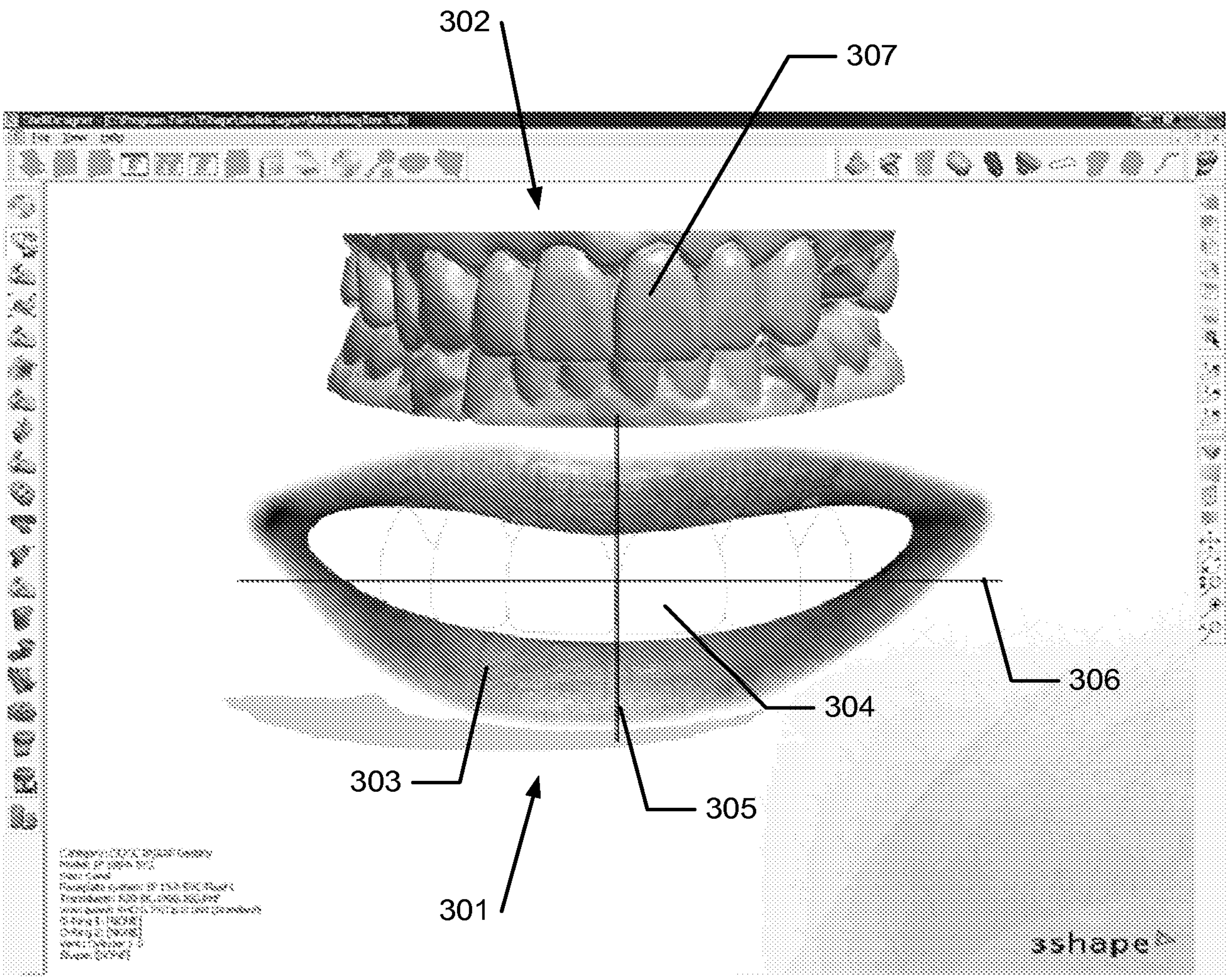


Fig. 3a)

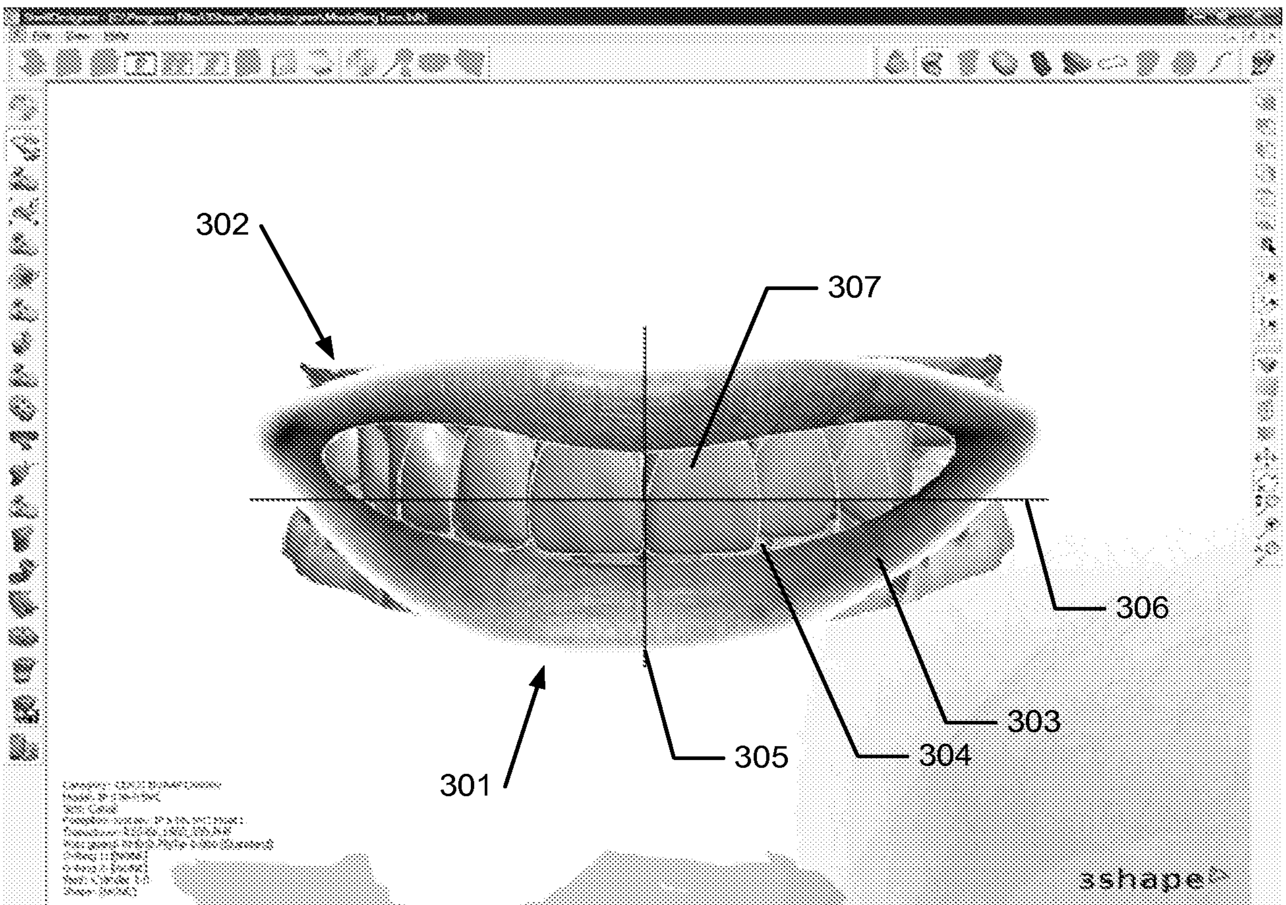


Fig. 3b)

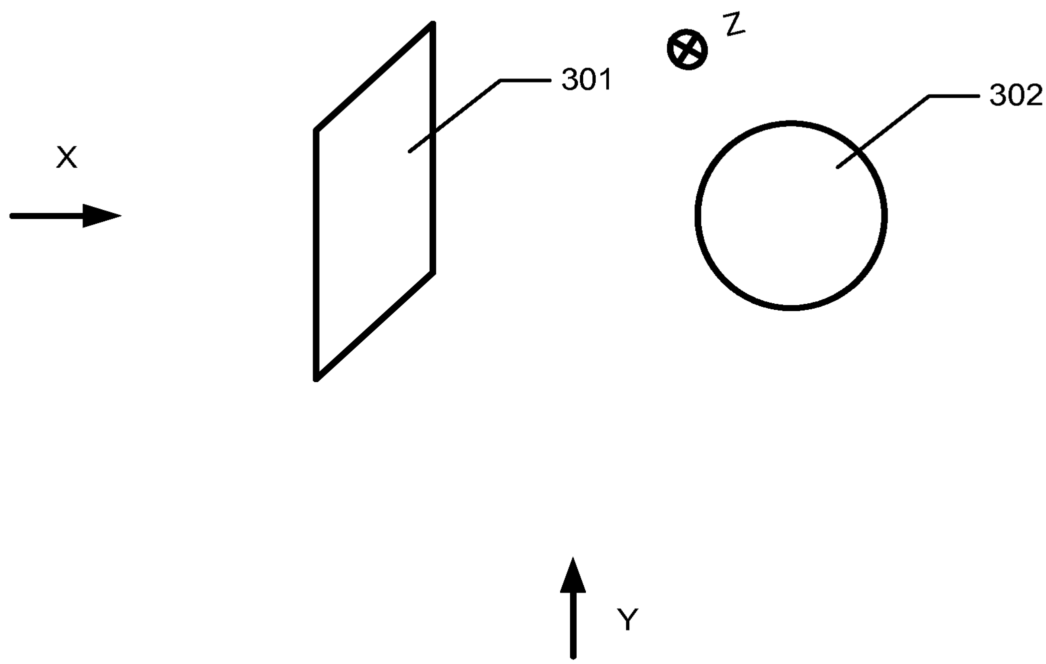


Fig. 3c)

Fig. 4a)

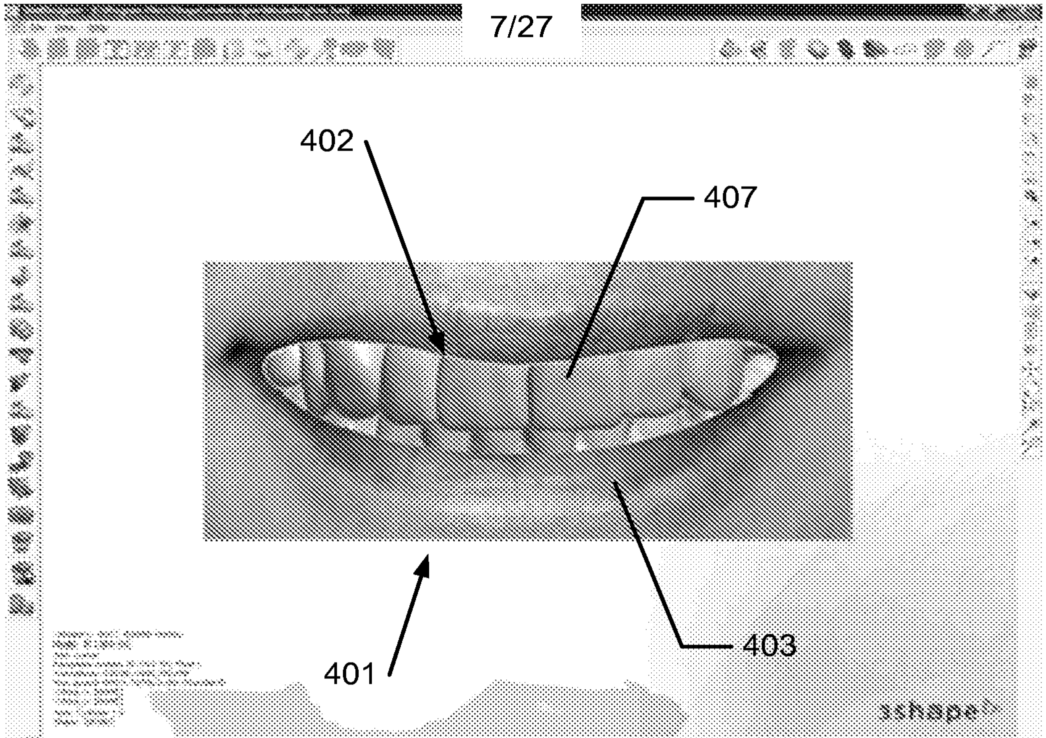
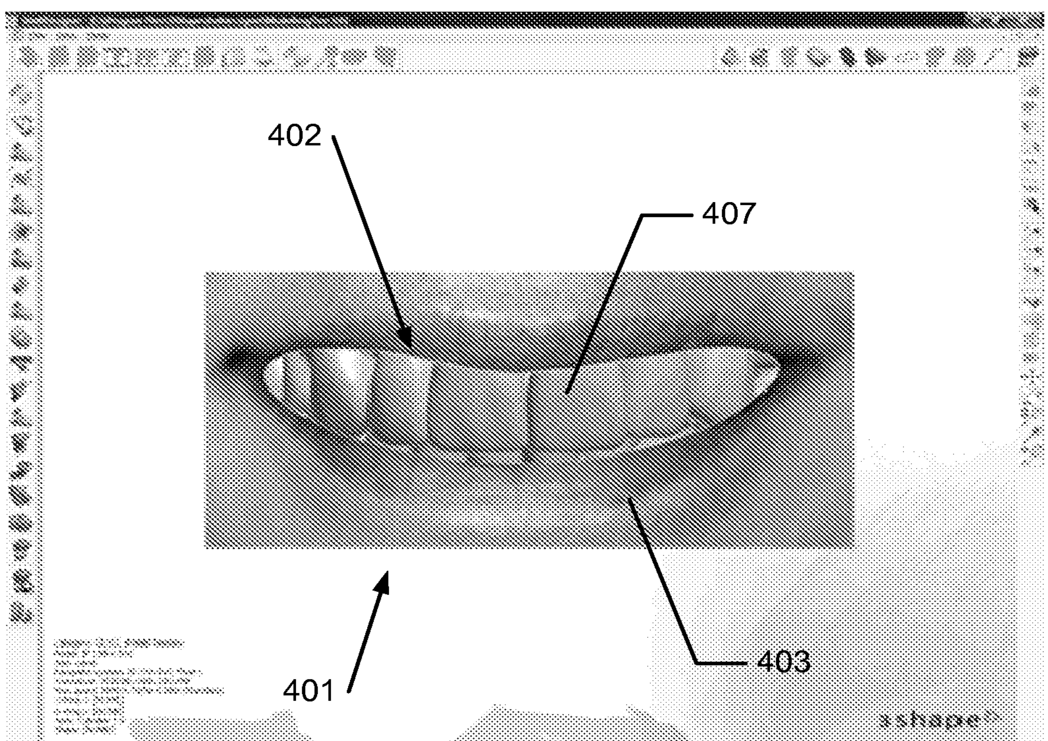


Fig. 4b)



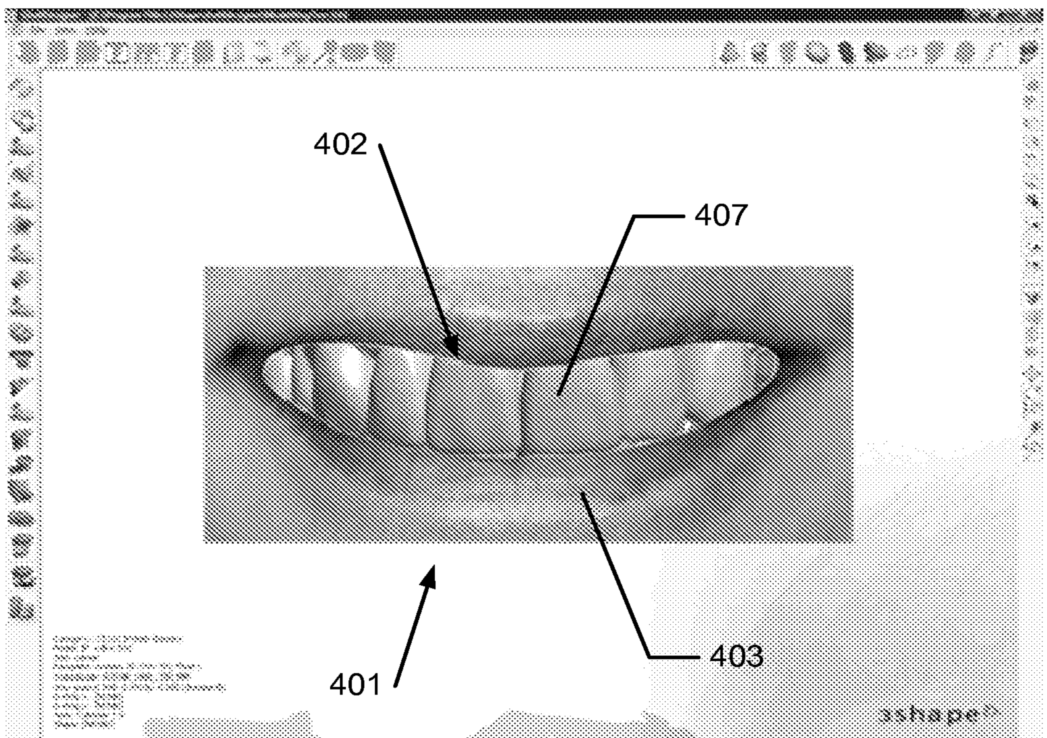


Fig. 4c)

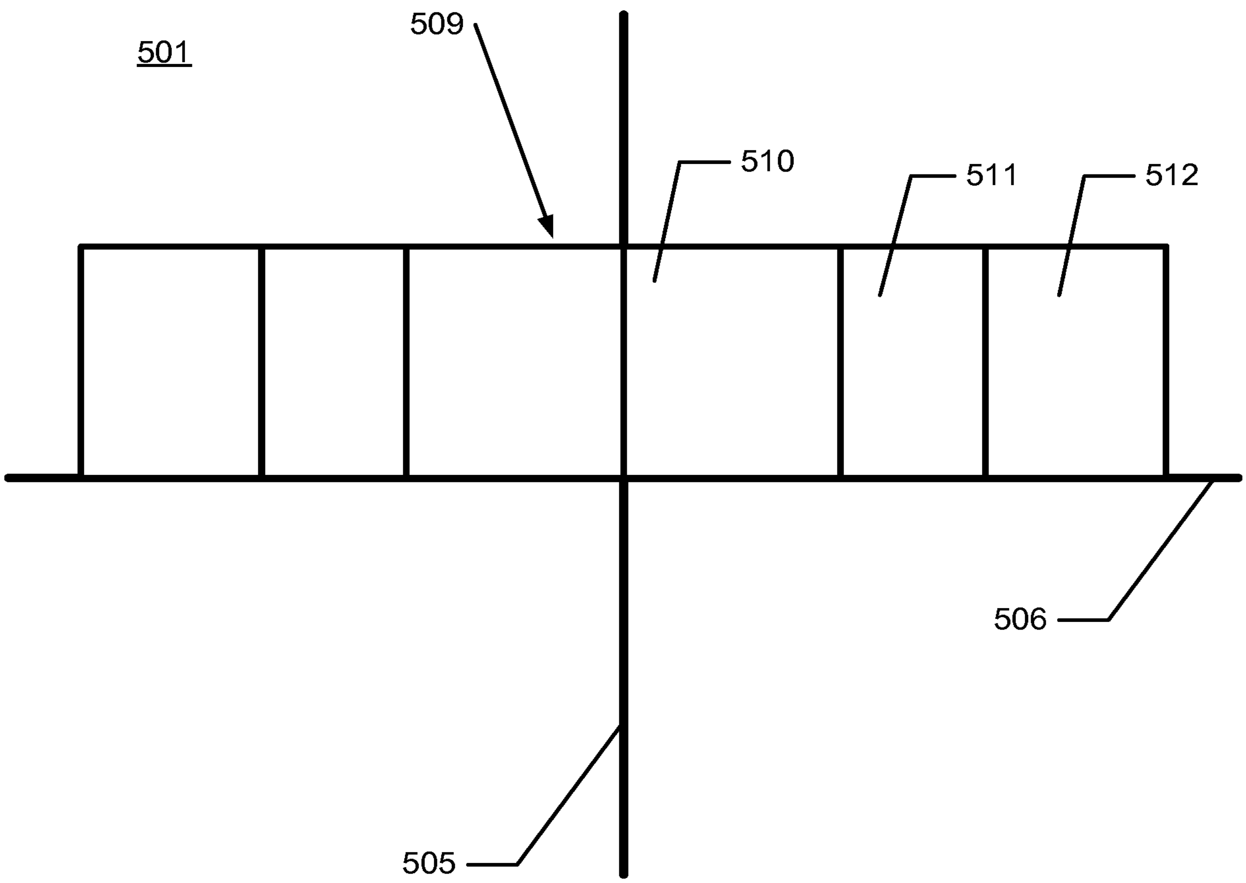
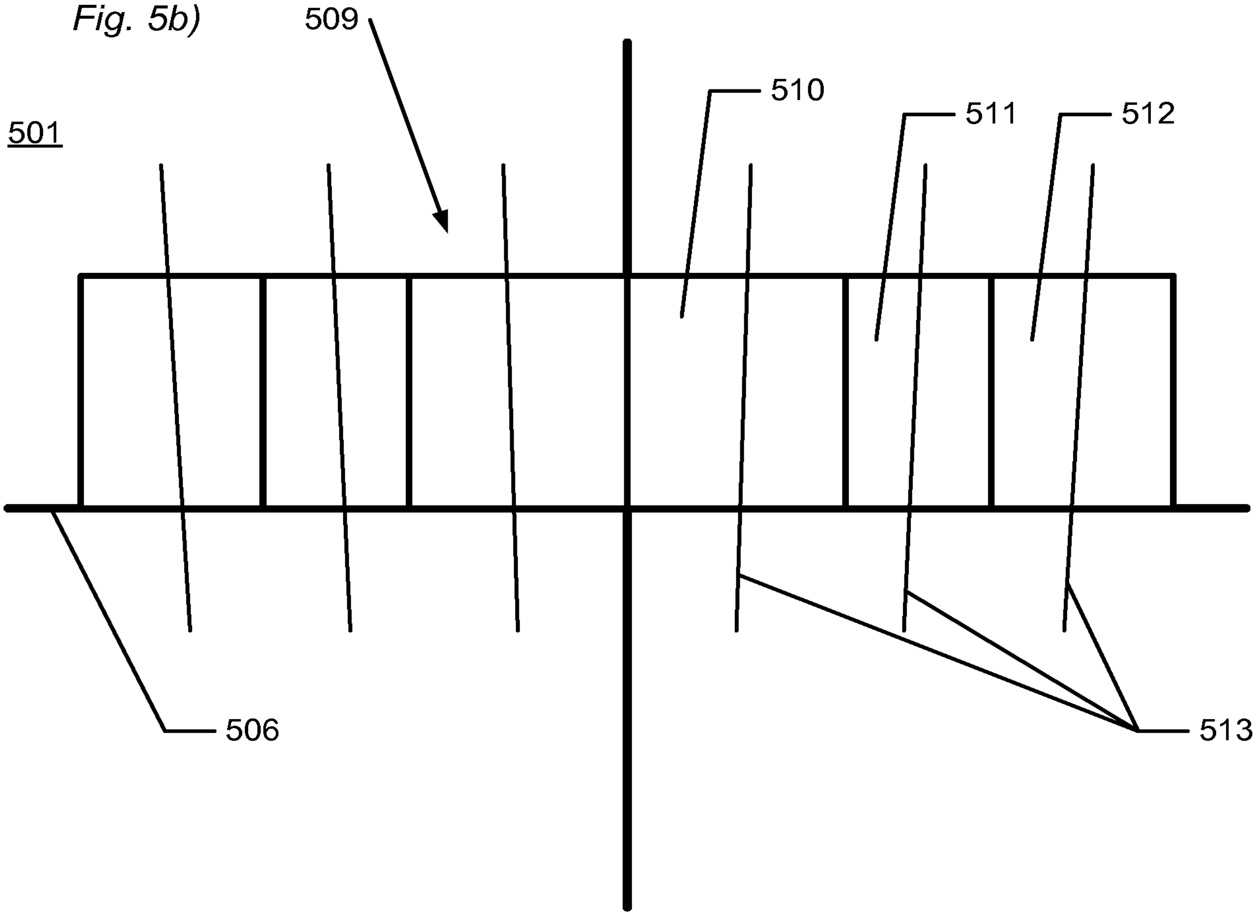


Fig. 5a)

Fig. 5b)



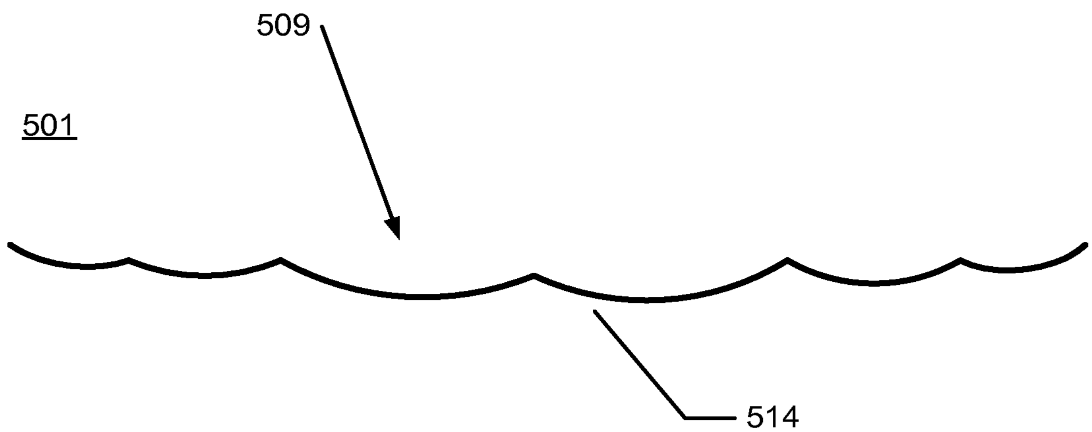
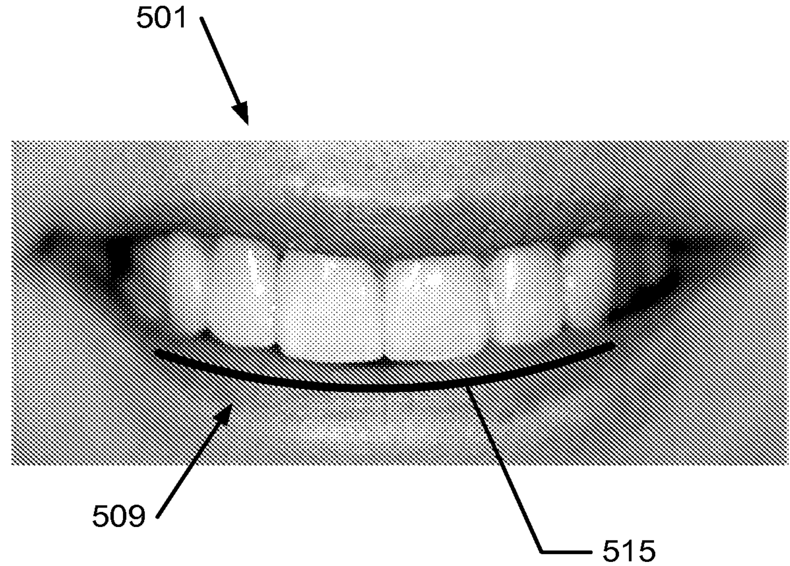


Fig. 5c)

Fig. 5d)



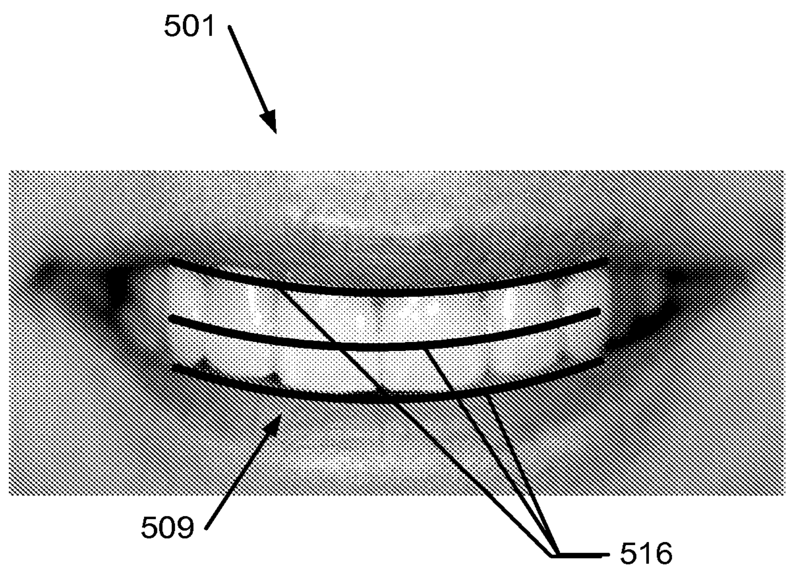


Fig. 5e)

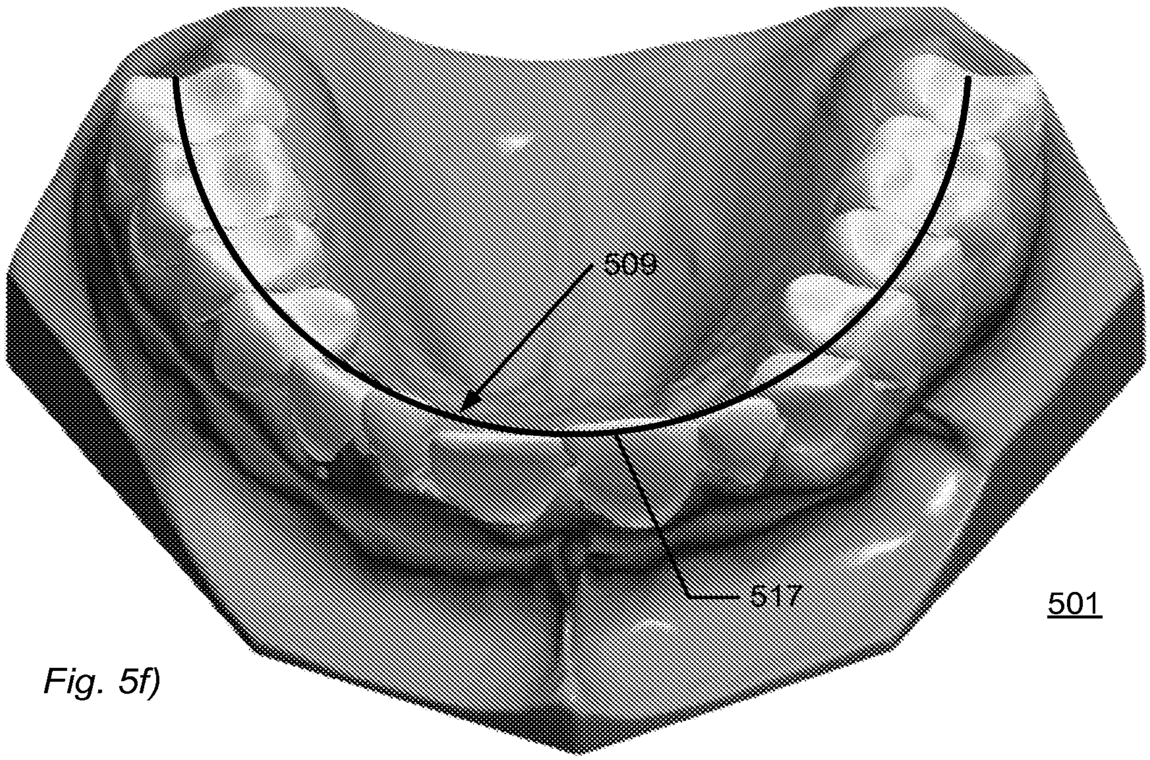
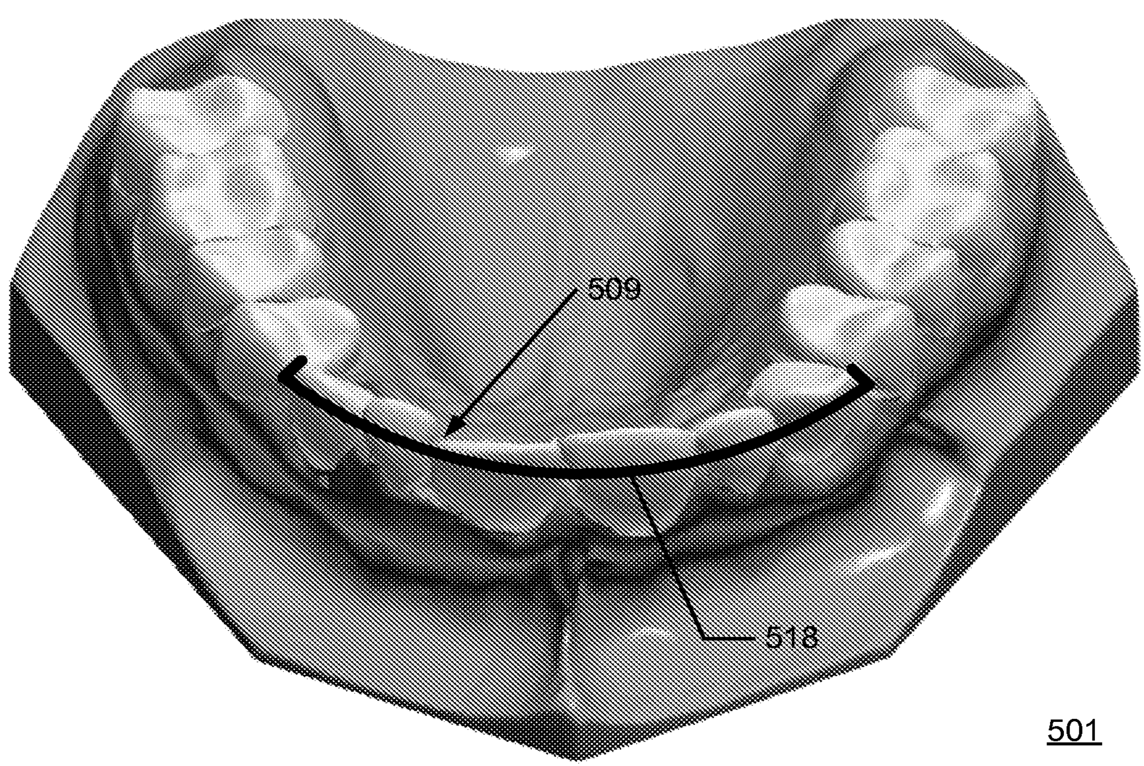


Fig. 5f)

Fig. 5g)



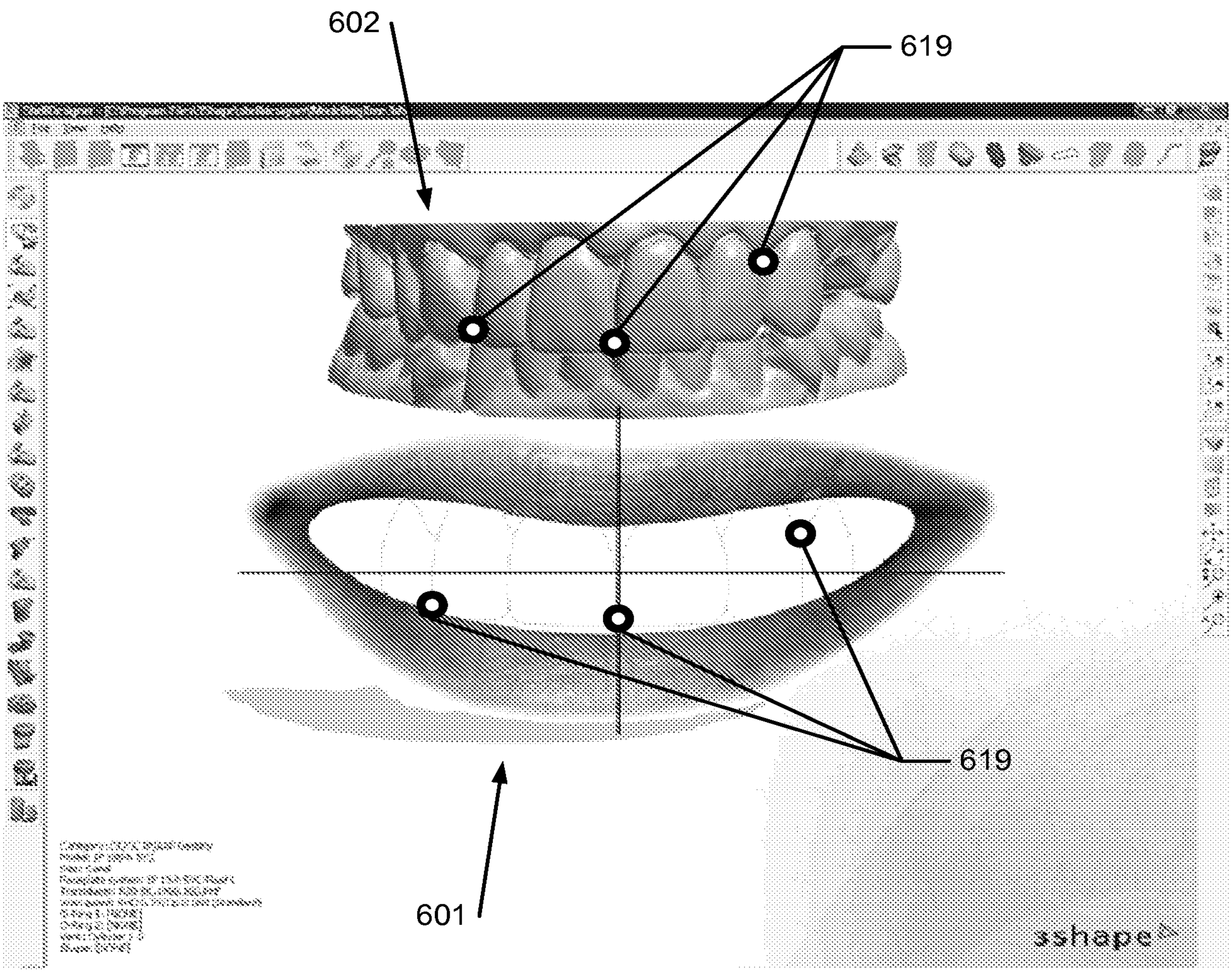


Fig. 6a)

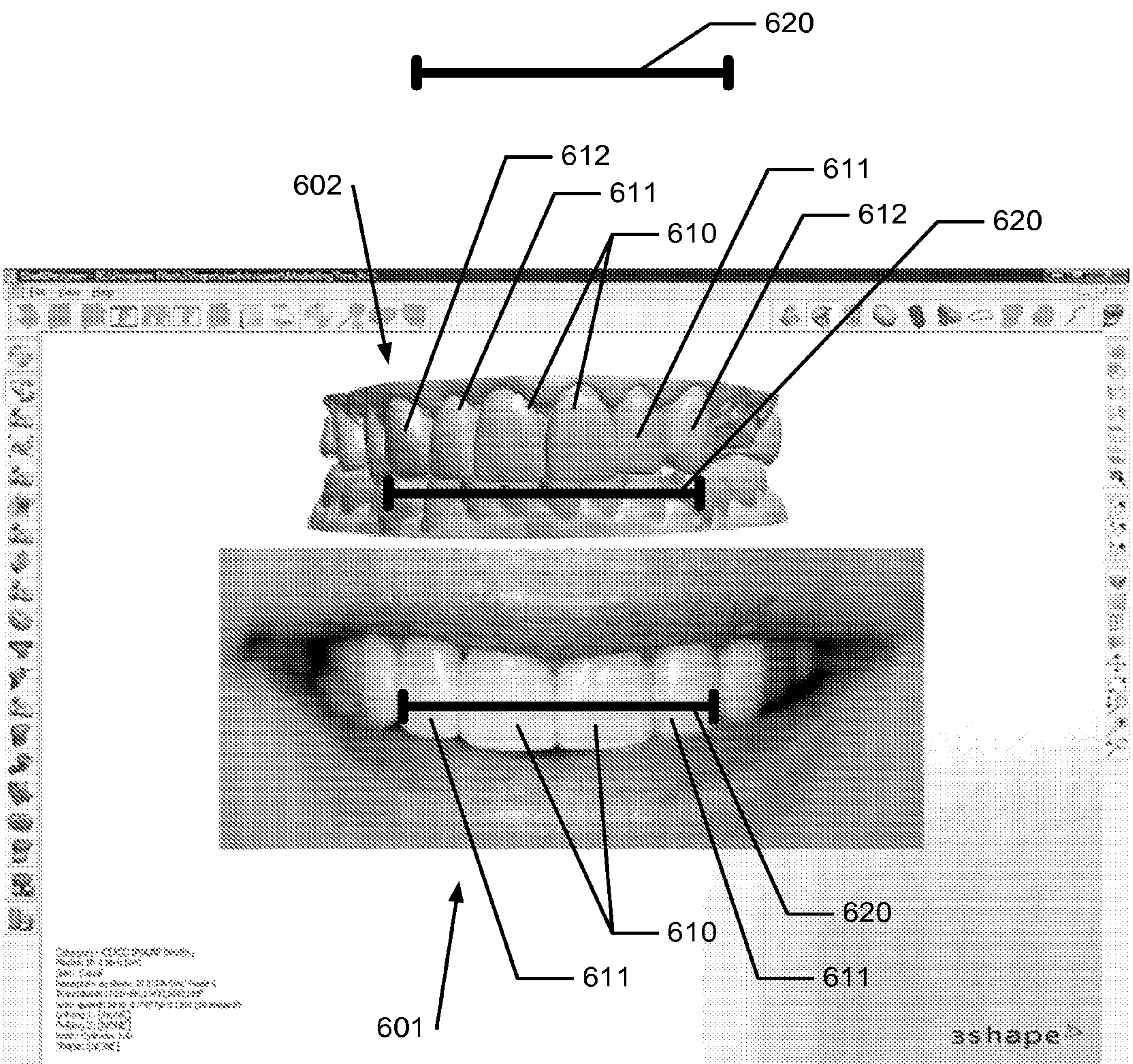


Fig. 6b)

Fig. 7

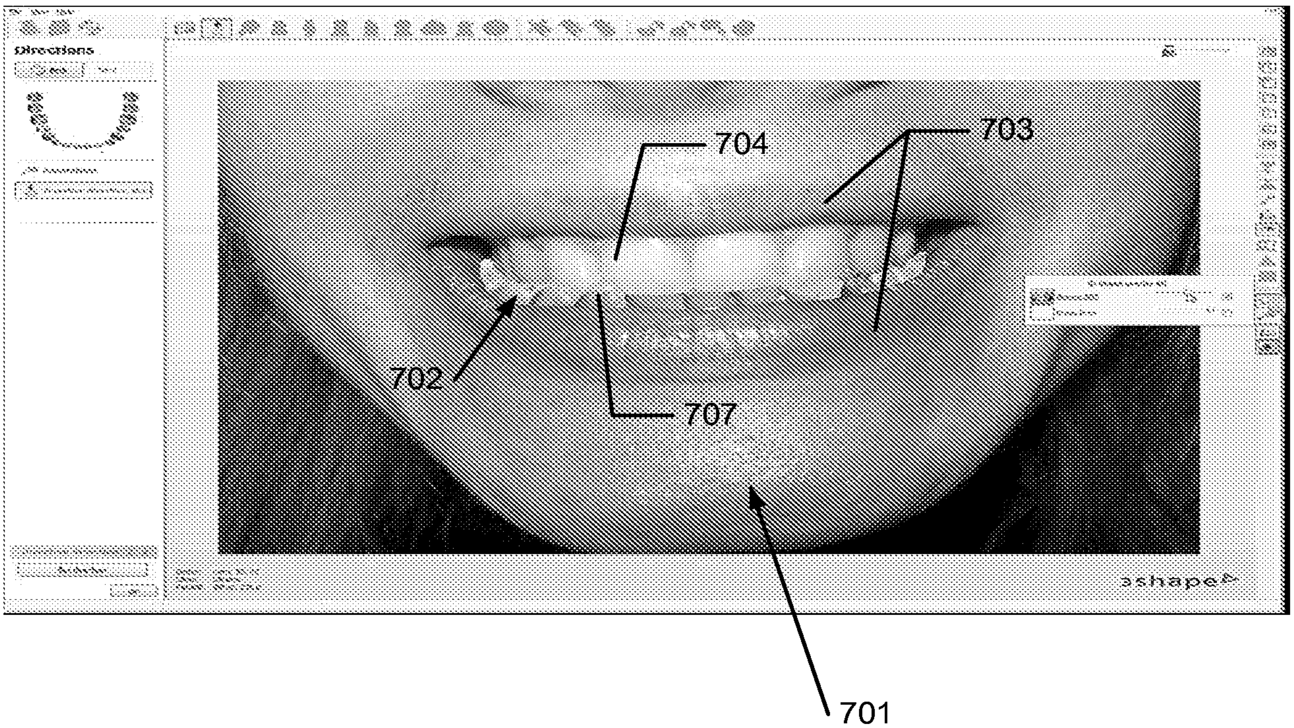

704
703
702
707
701
Directions
3shape

Fig. 8

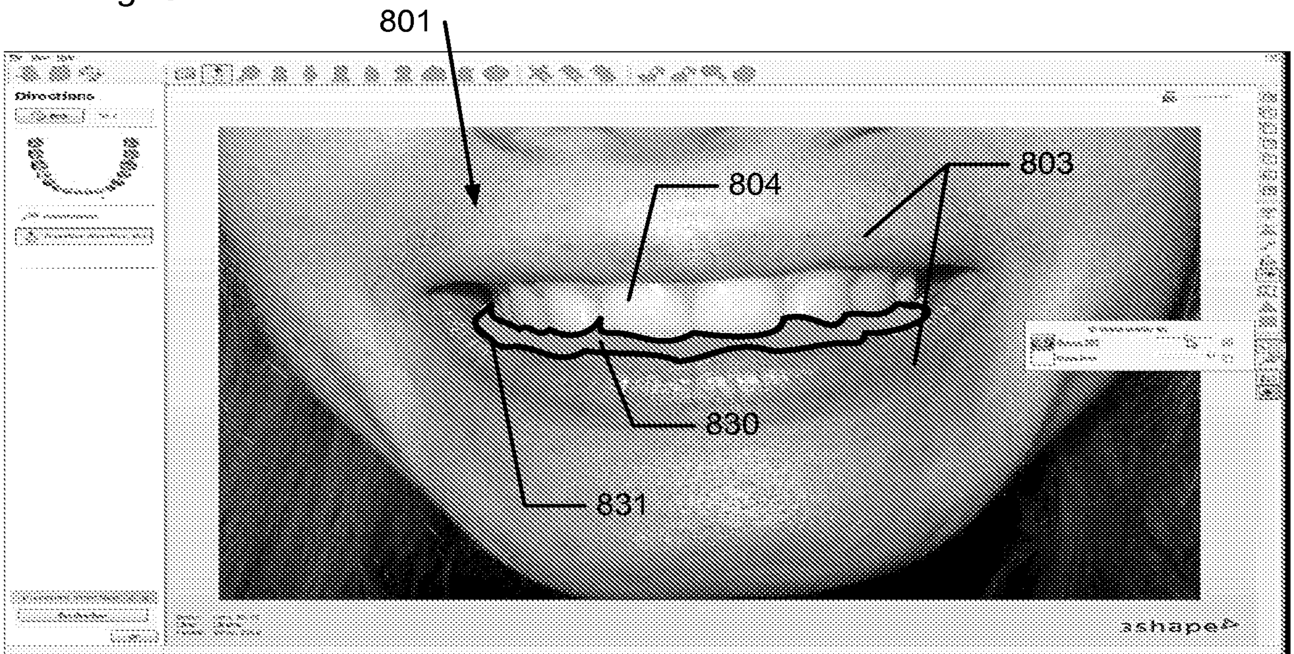

801
804
803
830
831
Directions
3shape

Fig. 9

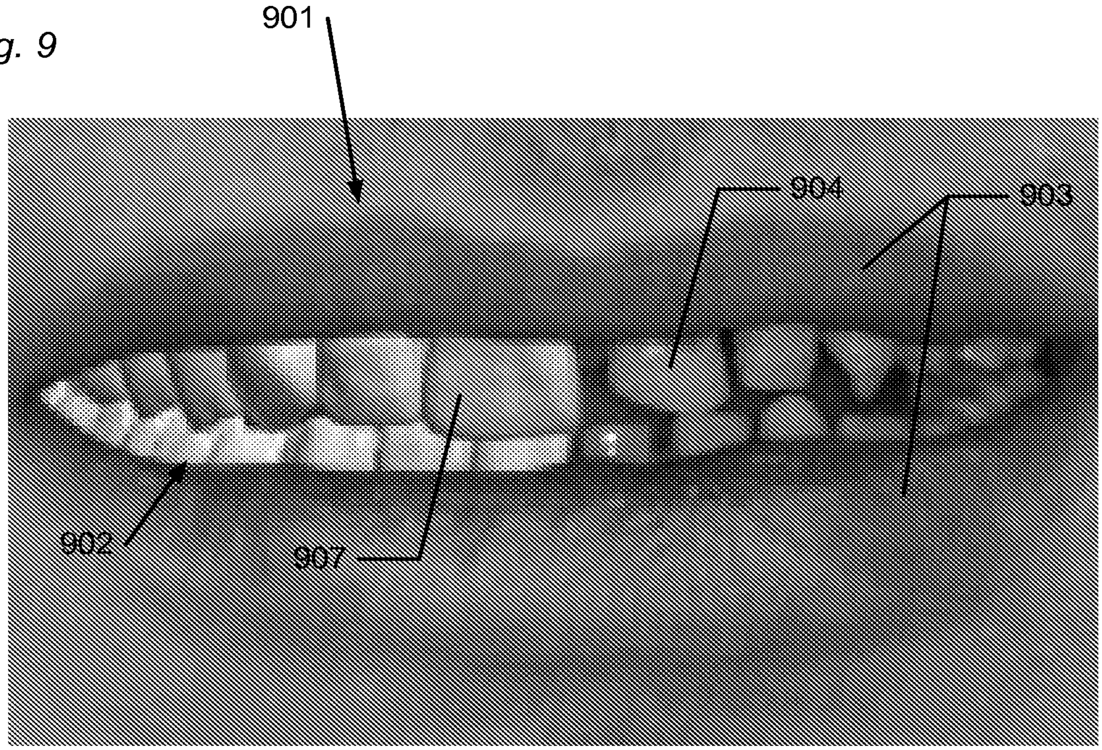


Fig. 10

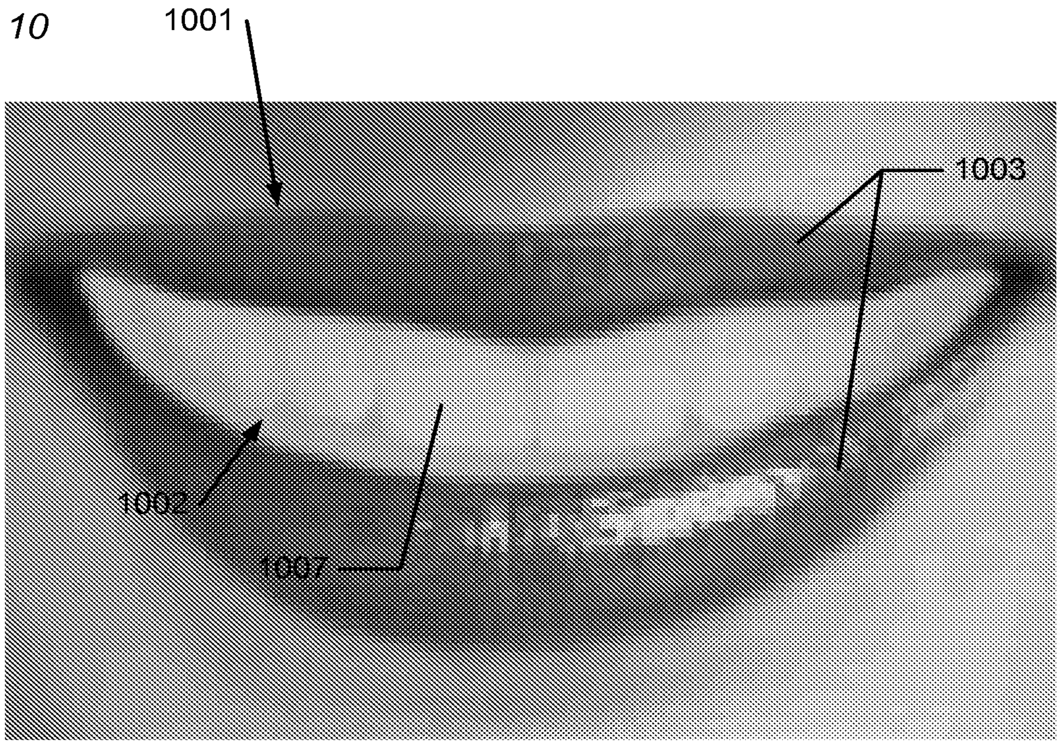
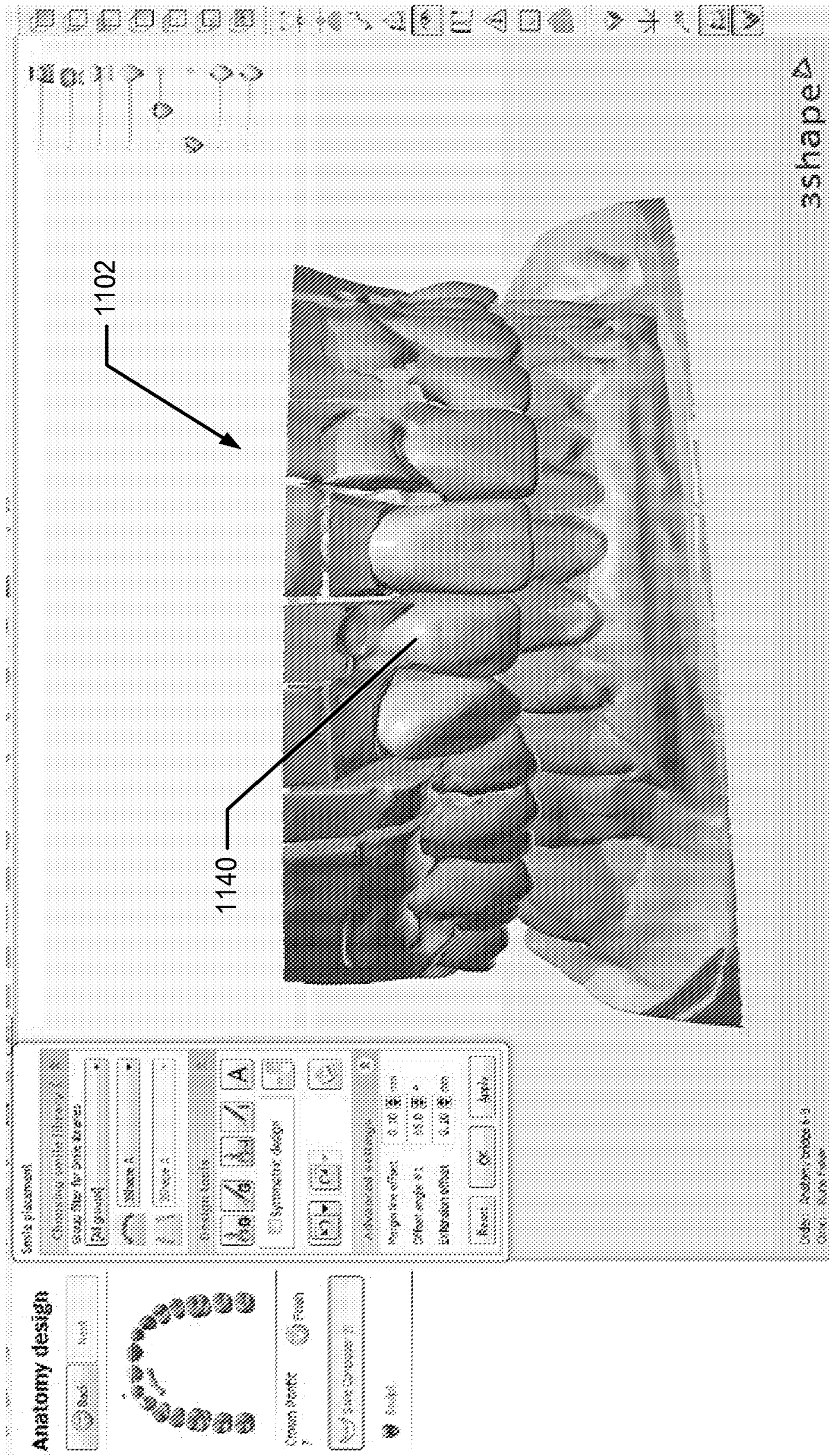


Fig. 11a)



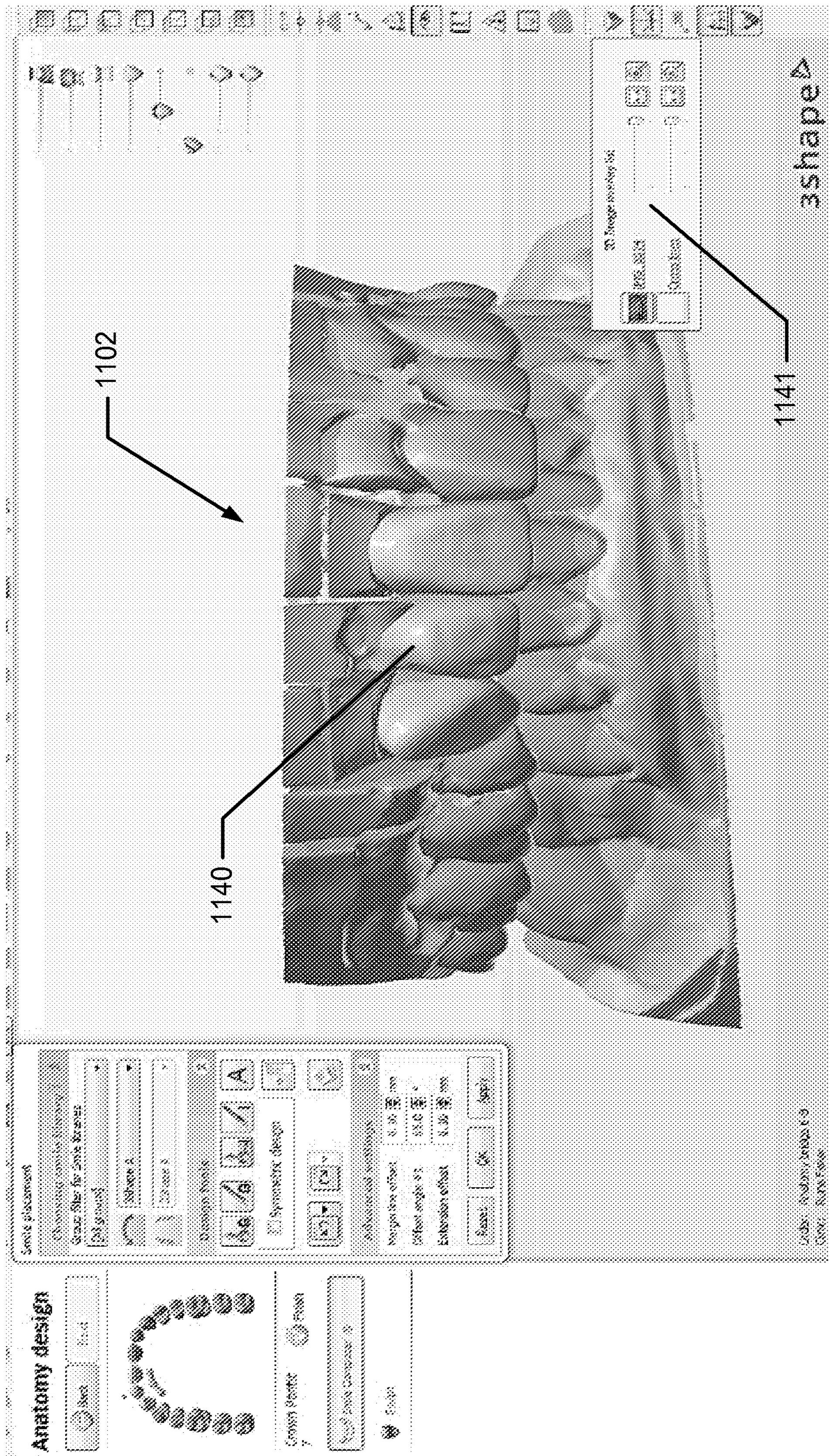


Fig. 11b)

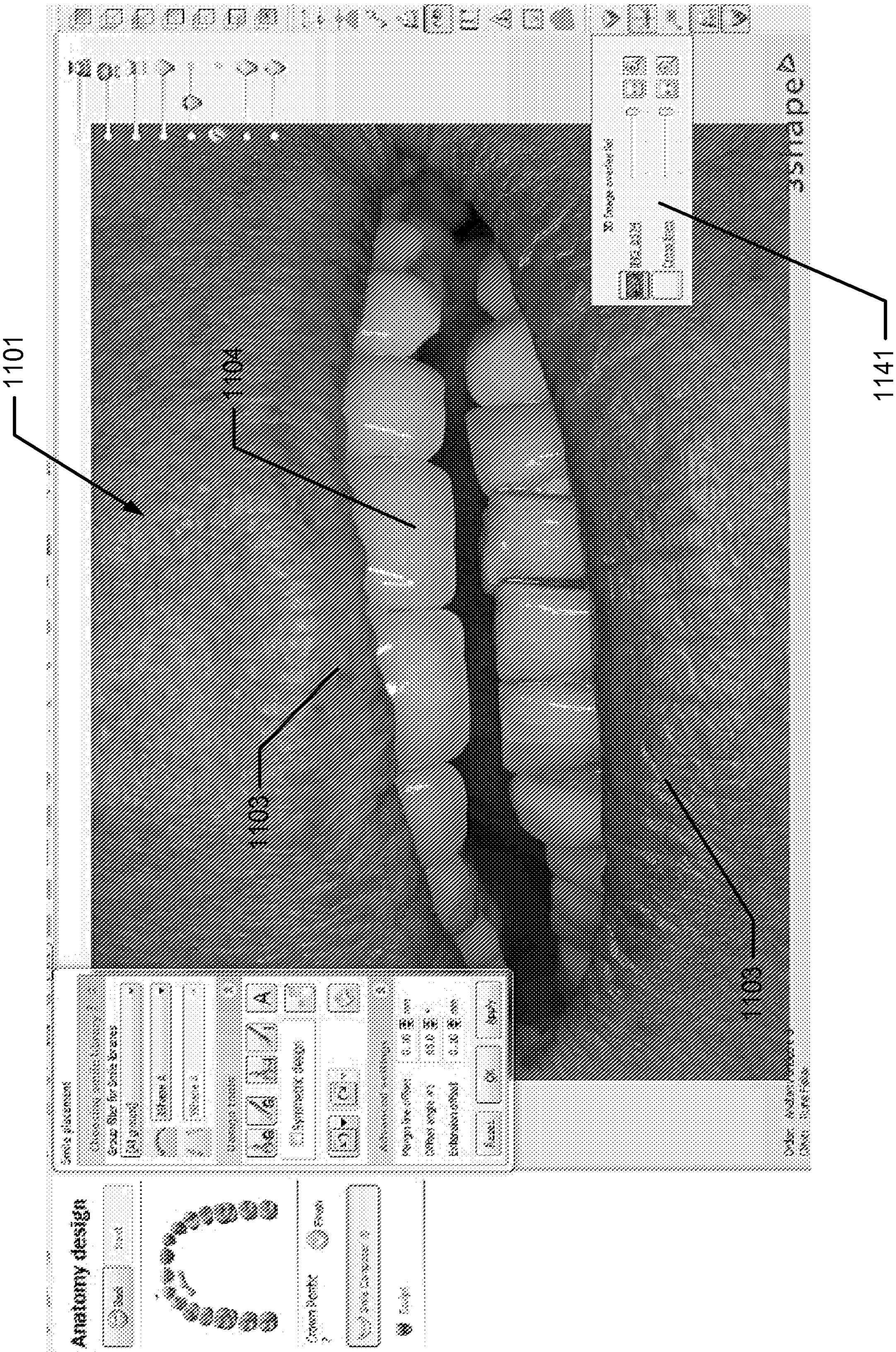


Fig. 11c)

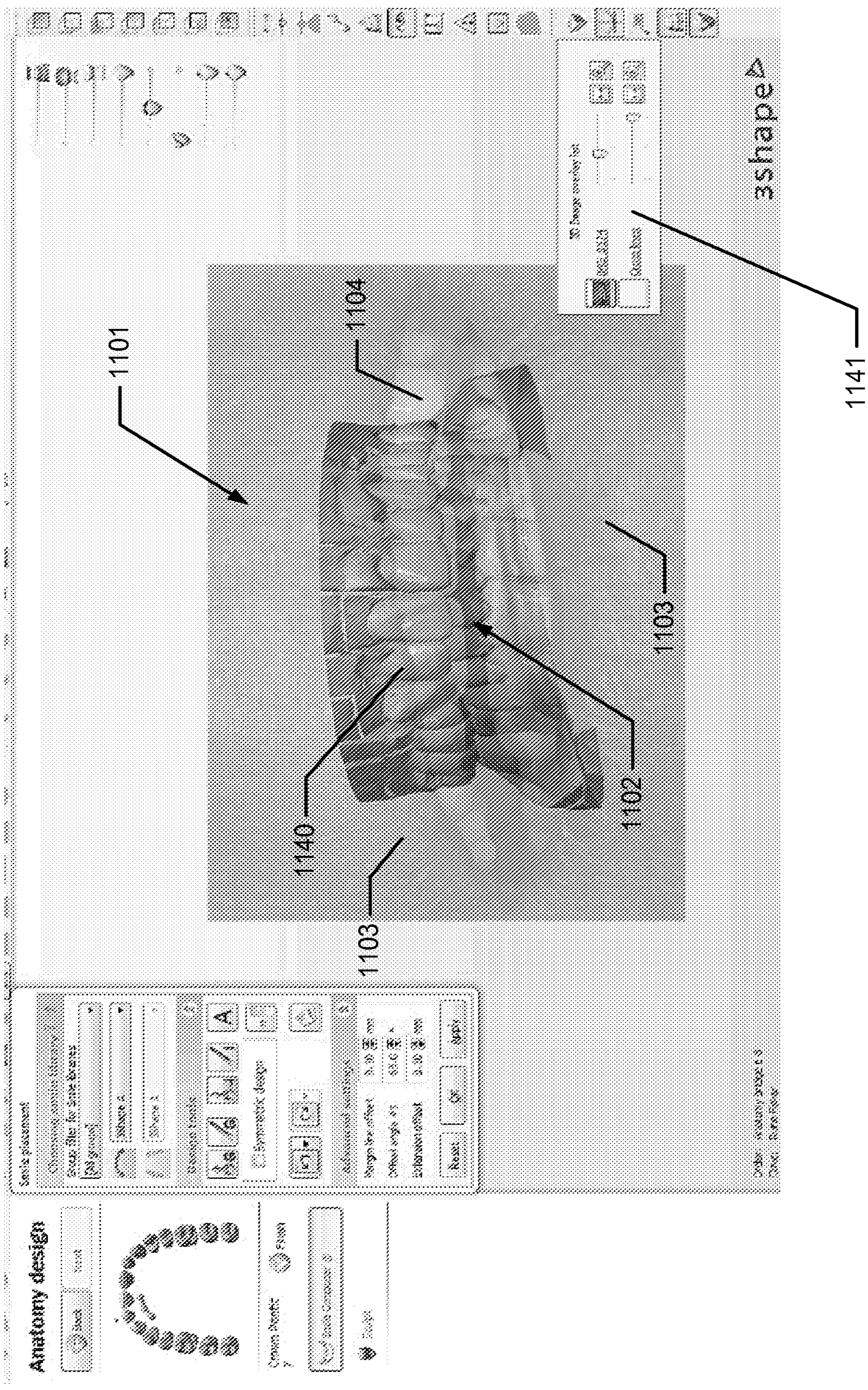

1101
1104
1103
1102
1140
1103
1141
3shape
Anatomy design
Symmetric design

Fig. 11d)

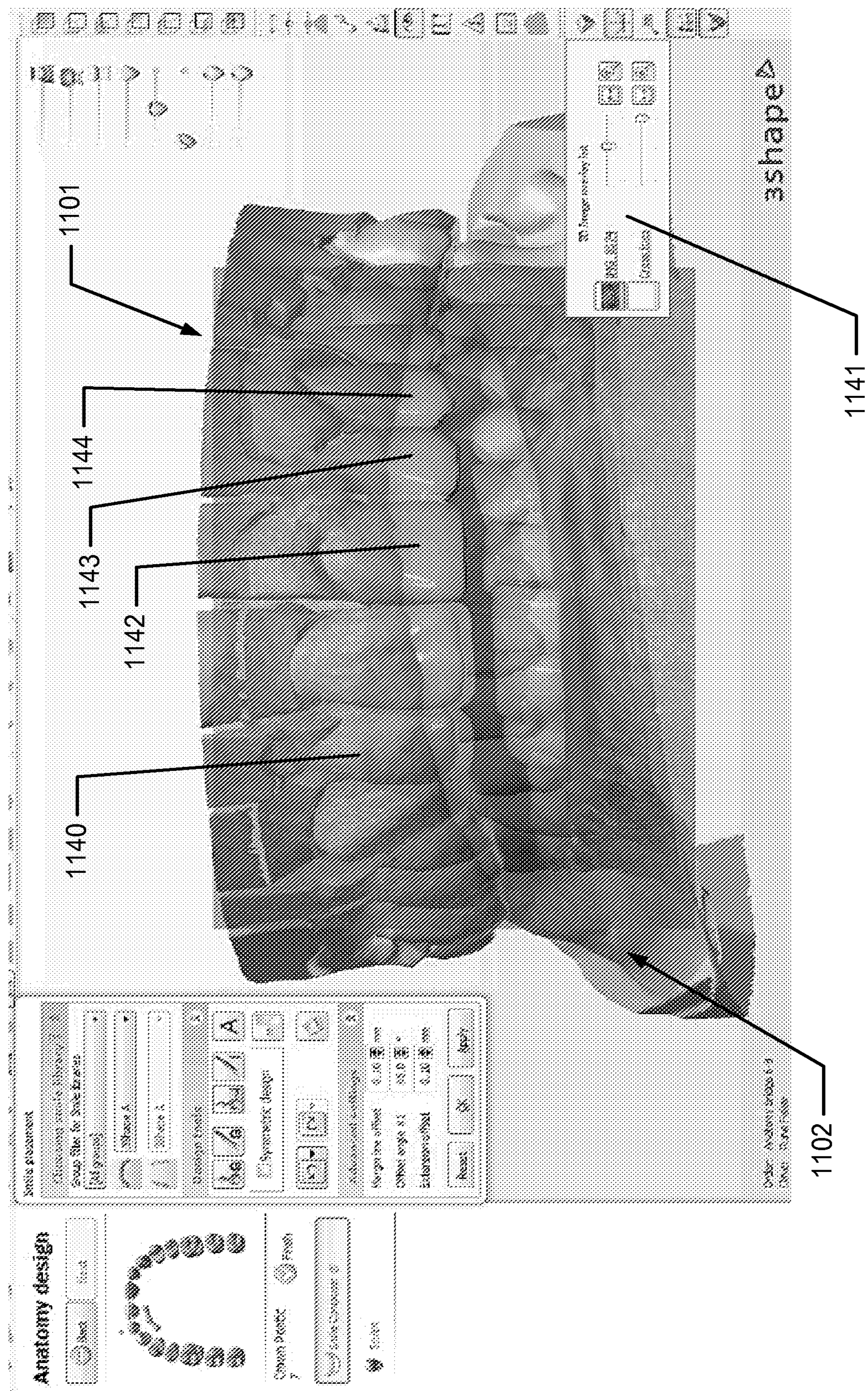


Fig. 11e)

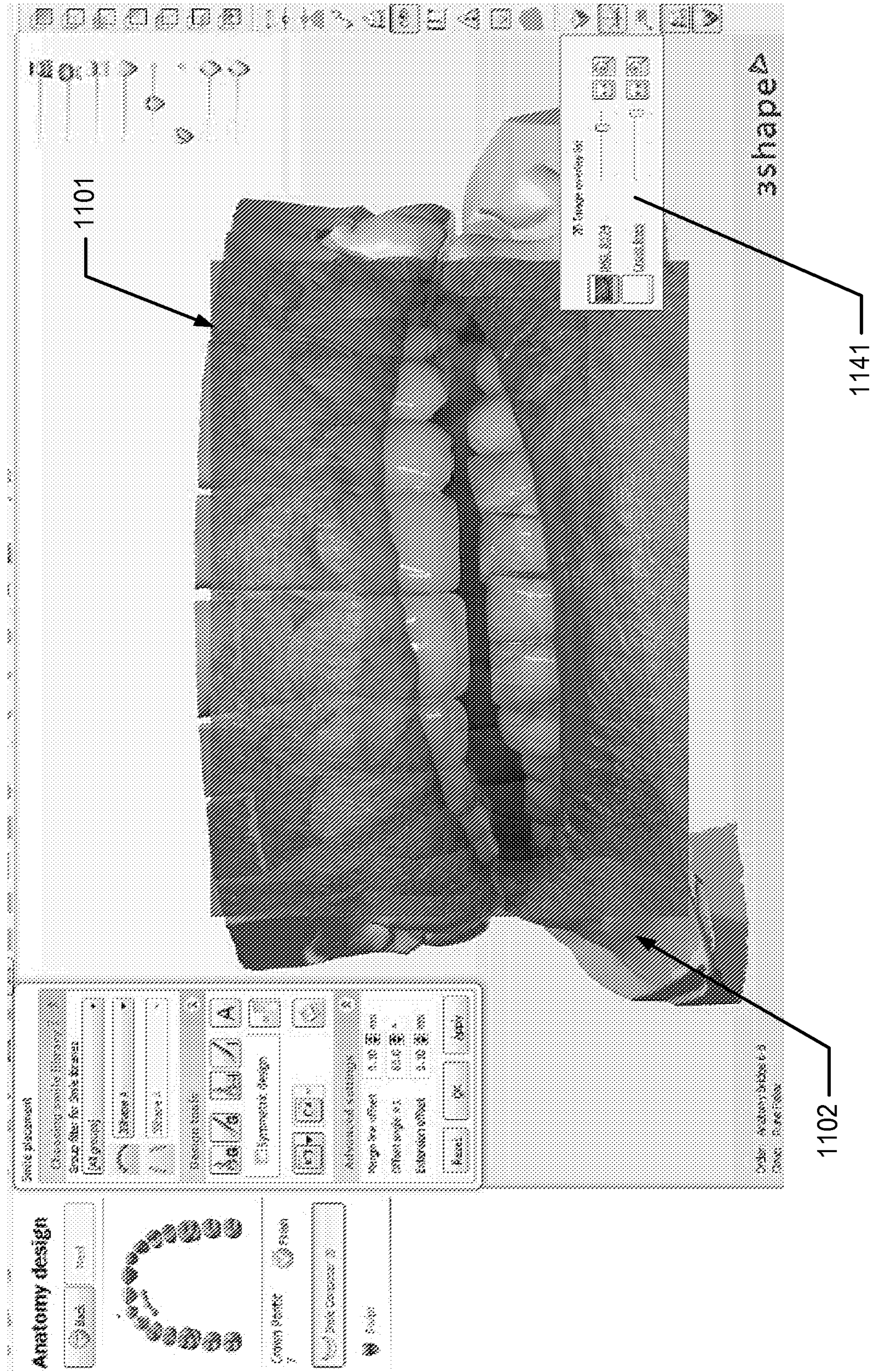


Fig. 11f)

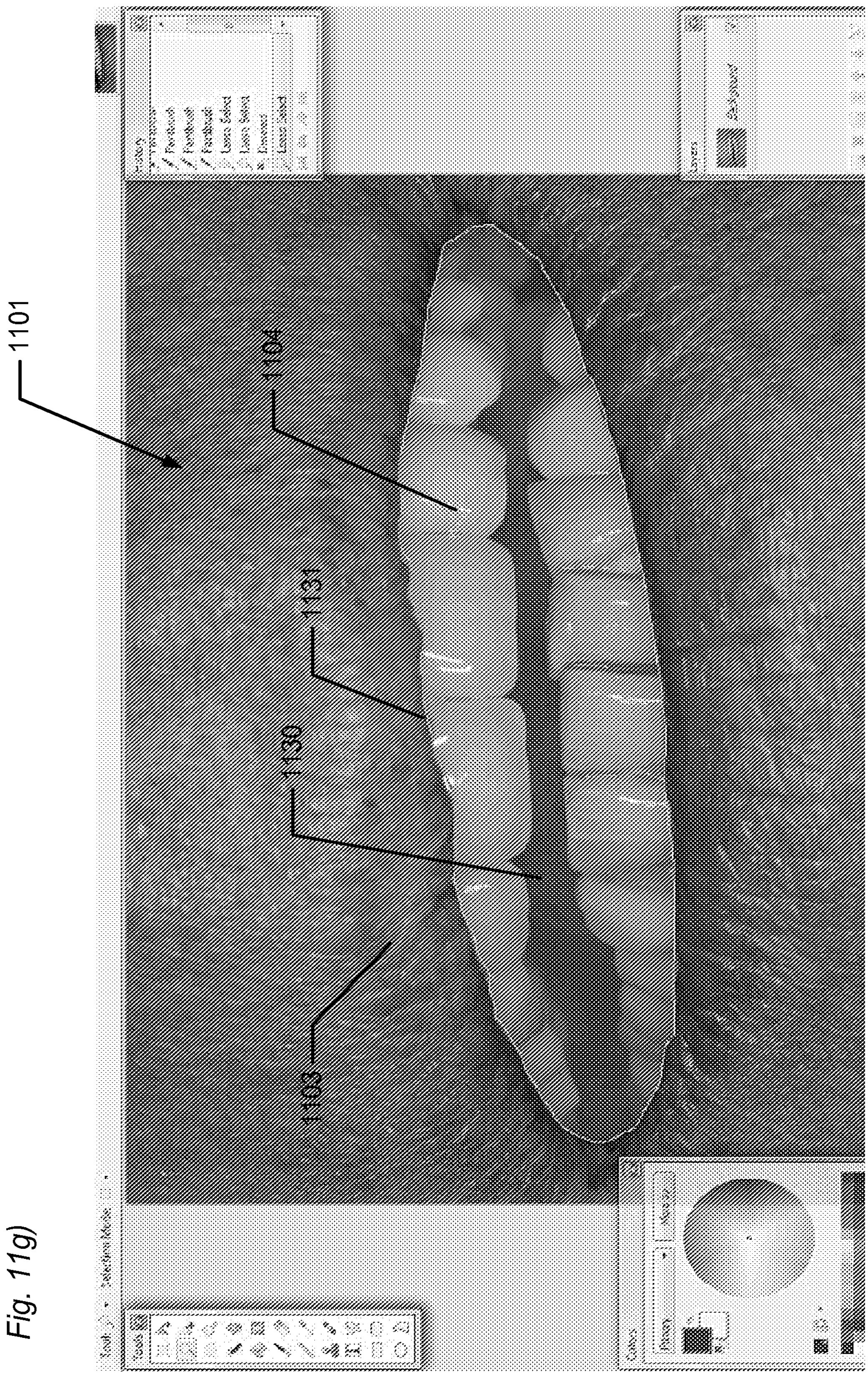


Fig. 11g)

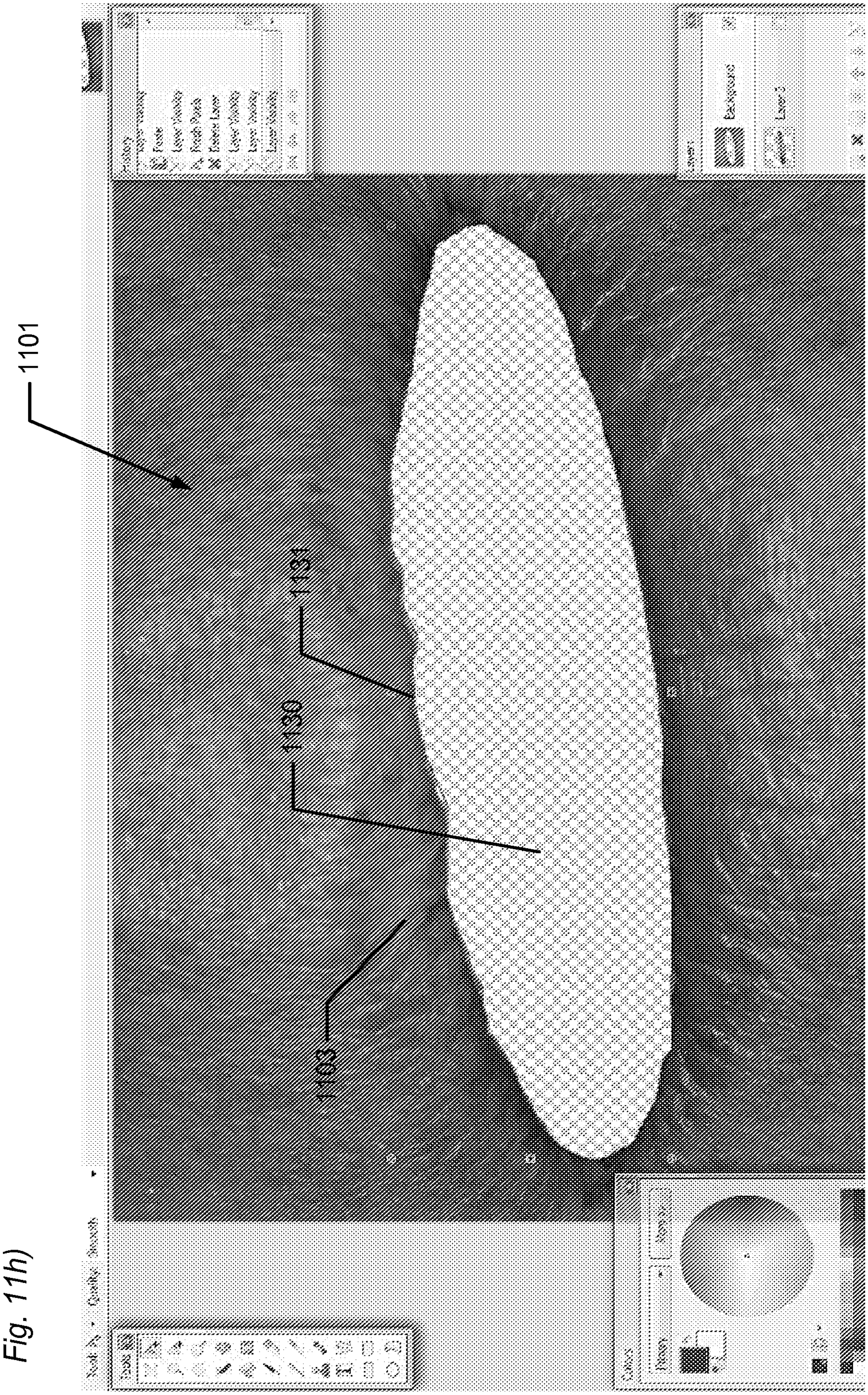


Fig. 11h)

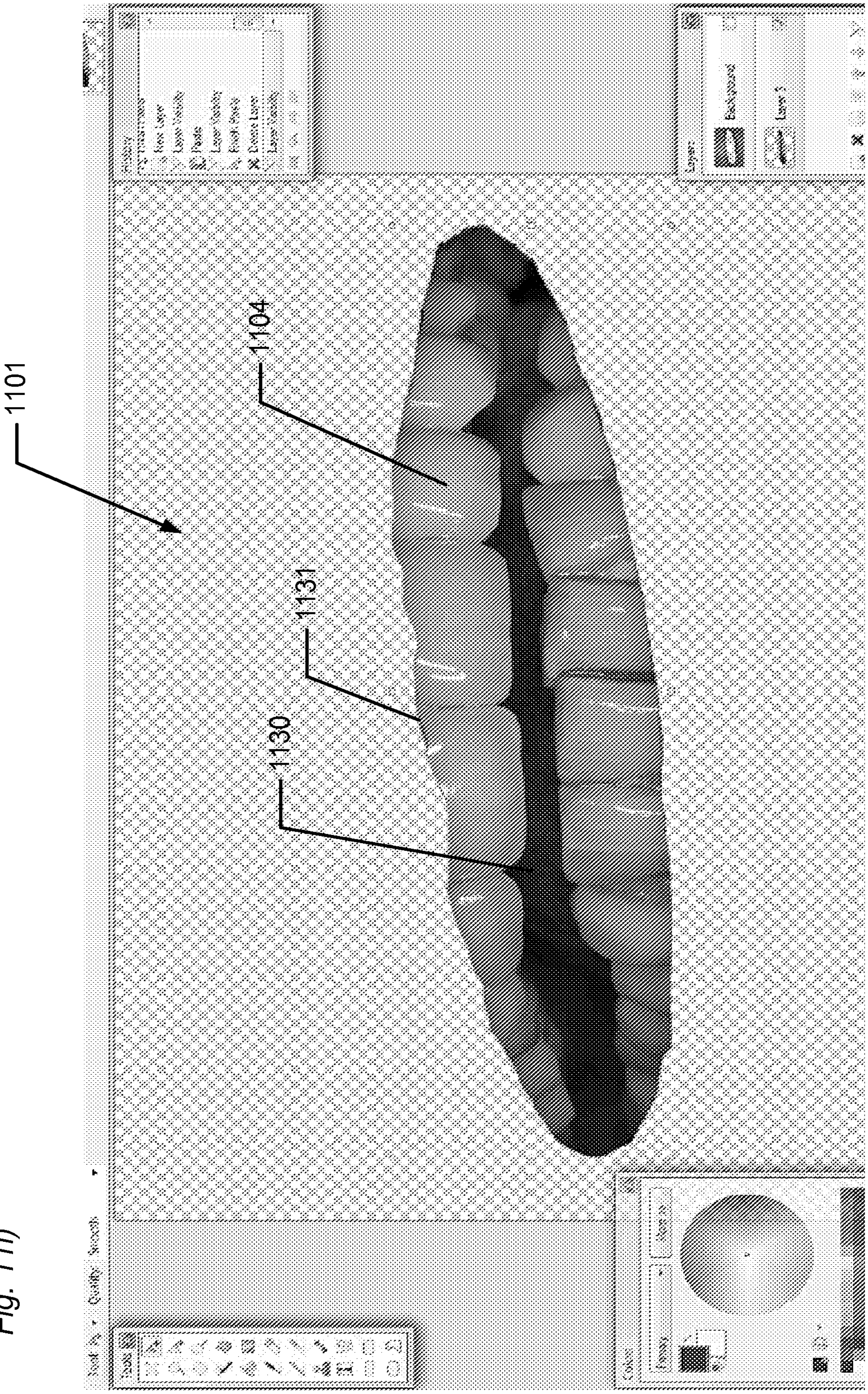


Fig. 11i)

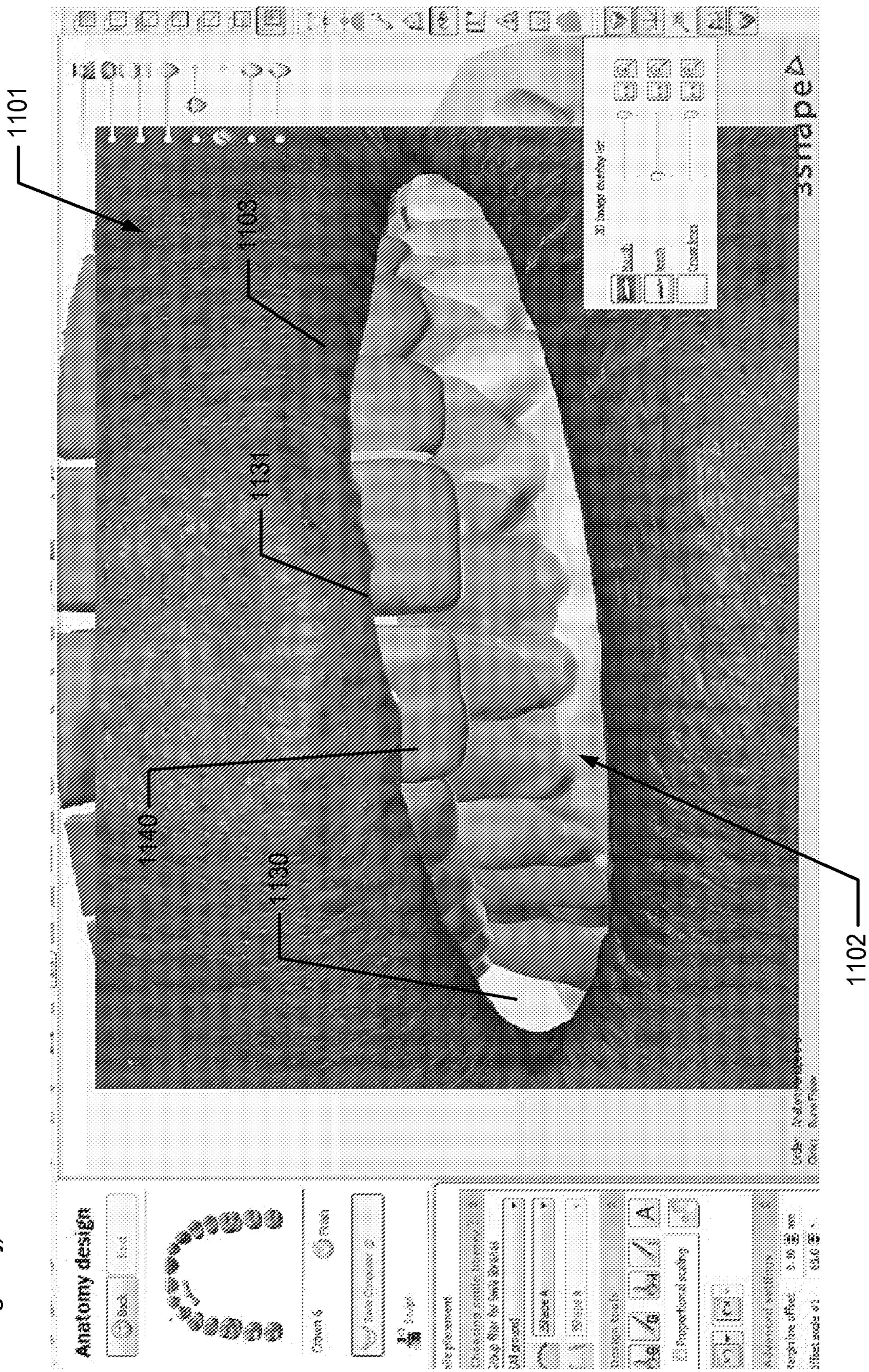


Fig. 11j)

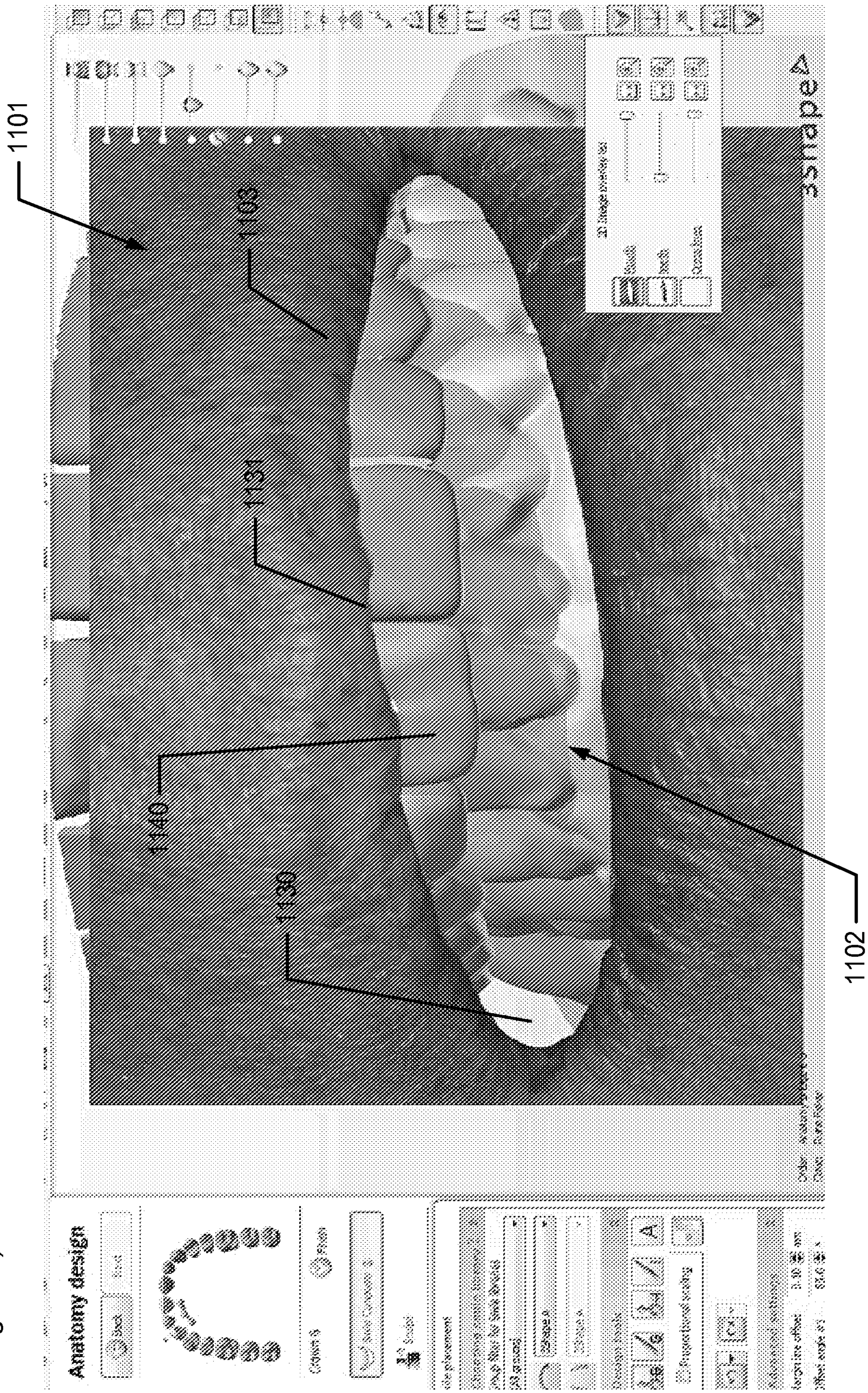


Fig. 11k)

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
13/807,443	Nikolaj DEICHMANN	0079124-000062

21839
BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

INTERNATIONAL APPLICATION NO.	
PCT/DK2011/050246	
I.A. FILING DATE	PRIORITY DATE
06/29/2011	06/29/2010

CONFIRMATION NO. 1045
371 FORMALITIES LETTER

OC000000058634989

Date Mailed: 01/15/2013

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as a Designated Office (37 CFR 1.494):

- Indication of Small Entity Status
- Priority Document
- Copy of the International Application filed on 12/28/2012
- Copy of the International Search Report filed on 12/28/2012
- Preliminary Amendments filed on 12/28/2012
- Information Disclosure Statements filed on 12/28/2012
- U.S. Basic National Fees filed on 12/28/2012
- Priority Documents filed on 12/28/2012

The applicant needs to satisfy supplemental fees problems indicated below.

The following items **MUST** be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:

- Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date.
- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.492(h) of $65 for a small entity in compliance with 37 CFR 1.27, must be submitted with the missing items identified in this letter.

SUMMARY OF FEES DUE:

Total additional fees required for this application is $**65** for a Small Entity:

- $**65** Surcharge.

ALL OF THE ITEMS SET FORTH ABOVE MUST BE SUBMITTED WITHIN TWO (2) MONTHS FROM THE DATE OF THIS NOTICE OR BY 32 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

FORM PCT/DO/EO/905 (371 Formalities Notice)

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

JUELETHIA A PALMER

Telephone: (571) 272-9050

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number
13/807,443

APPLICATION AS FILED - PART I

FOR	NUMBER FILED (Column 1)	NUMBER EXTRA (Column 2)	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	195		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	250		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	29 minus 20 =	* 9	x 31 =	279	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*	x 125 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	849		TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

COMBINED DECLARATION AND POWER OF ATTORNEY FOR UTILITY OR DESIGN PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

2D IMAGE ARRANGEMENT

the application of which **(check only one item below)**:

☐ is attached hereto.

☐ was filed as United States Patent application Number __________ on __________________ and was amended on __________________ (if applicable).

☒ was filed as PCT International application Number PCT/DK2011/050246 on 29 June 2011 and was amended on __________________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified application, including the claims, and drawings (if any), as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §§ 119 (a)-(d), 172 or 365(a) of any foreign application(s) for patent or inventor's certificate or of any international (PCT) application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international (PCT) application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §§119(a)-(d), 172 or 365(a):				
COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (MM/DD/YYYY)	PRIORITY CLAIMED UNDER 35 U.S.C. §§119, 172 OR 365(a)	
			Yes	No
DK	PA 2010 00568	06/29/2010	X	
DK	PA 2011 00191	03/18/2011	X	

I hereby appoint the attorneys and agents associated with the following PTO Customer Number of Buchanan Ingersoll & Rooney PC to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and transact all business in connection with international applications directed to said invention:

Customer Number **2 1 8 3 9**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

FULL NAME OF SOLE OR FIRST INVENTOR	Nikolaj DEICHMANN
Signature	
Date	18/2-2013
Residence (City, State, Country)	Copenhagen Ø, Denmark
Citizenship	Denmark
Mailing Address	Järnolofs Väg 10
City, State, ZIP, Country	SE-21851 Klagshamn, Sweden
FULL NAME SECOND INVENTOR, IF ANY	Tais CLAUSEN
Signature	
Date	18/2-2013
Residence (City, State, Country)	Klagshamn, Sweden
Citizenship	Denmark
Mailing Address	Signe Löfdahls Väg 12
City, State, ZIP, Country	SE-21851 Klagshamn, Sweden
FULL NAME THIRD INVENTOR, IF ANY	Rune FISKER
Signature	
Date	18/2-2013
Residence (City, State, Country)	Virum, Denmark
Citizenship	Denmark
Mailing Address	Kaplevej 87
City, State, ZIP, Country	DK-2830 Virum, Denmark

FULL NAME FOURTH INVENTOR, IF ANY	Henrik ÖJELUND
Signature	Henrik Öjelund
Date	18/2-2013
Residence (City, State, Country)	Lyngby, Denmark
Citizenship	Sweden
Mailing Address	Kulsvierparken 55
City, State, ZIP, Country	DK-2800 Lyngby, Denmark

Electronic Patent Application Fee Transmittal

Application Number:	13807443
Filing Date:	
Title of Invention:	2D IMAGE ARRANGEMENT
First Named Inventor/Applicant Name:	Nikolaj DEICHMANN
Filer:	William C. Rowland/Robin Copeland
Attorney Docket Number:	0079124-000062

Filed as Small Entity

U.S. National Stage under 35 USC 371 Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Oath/Decl > 30 Mo. from Priority Date	2617	1	65	65
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**65**

Electronic Acknowledgement Receipt

EFS ID:	15092879
Application Number:	13807443
International Application Number:	
Confirmation Number:	1045
Title of Invention:	2D IMAGE ARRANGEMENT
First Named Inventor/Applicant Name:	Nikolaj DEICHMANN
Customer Number:	21839
Filer:	William C. Rowland/Robin Copeland
Filer Authorized By:	William C. Rowland
Attorney Docket Number:	0079124-000062
Receipt Date:	01-MAR-2013
Filing Date:	
Time Stamp:	13:52:51
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$65
RAM confirmation Number	143
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	Missing_Requirements_Transmittal_Letter.pdf	193559 5f7890ac35d3ef0bced42c4871b83ddf25876279	no	3
Warnings:					
Information:					
2	Oath or Declaration filed	Declaration.pdf	157761 3c70e1ab7aa74dca90f2a77baeea5256b3d099be	no	3
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30314 d88433b8594a68c1a8de0299ade178e67a7a9778	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	381634	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NO. 0079124-000062 U.S. APPLICATION NO. (If known) 13/807,443
INTERNATIONAL APPLICATION NO. PCT/DK2011/050246	INTERNATIONAL FILING DATE 29 June 2011 (29.06.2011)	PRIORITY DATE CLAIMED 29 June 2010 (29.06.2010)
TITLE OF INVENTION 2D IMAGE ARRANGEMENT		
APPLICANT(S) FOR DO/EO/US DEICHMANN, Nikolaj; CLAUSEN, Tais; FISKER, Rune; and ÖJELUND, Henrik		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). NOTE: The express request under 35 U.S.C. 371(f) will not be effective unless the requirements under 35 U.S.C. 371(c)(1), (2), and (4) for payment of the basic national fee, copy of the International Application and English translation thereof (if required), and the oath or declaration of the inventor(s) have been received.

2. ☐ A copy of the International Application (35 U.S.C. 371(c)(2)) is attached hereto (not required if the International Application was previously communicated by the International Bureau or was filed in the United States Receiving Office (RO/US)).

3. An English language translation of the International Application (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).

4. An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4))
   a. ☒ is attached.
   b. ☐ was previously filed in the international phase under PCT Rule 4.17(iv).

Items 5 to 8 below concern amendments made in the international phase.

PCT Article 19 and 34 amendments

5. ☐ Amendments to the claims under PCT Article 19 are attached (not required if communicated by the International Bureau) (35 U.S.C. 371(c)(3)).

6. ☐ English translation of the PCT Article 19 amendment is attached (35 U.S.C. 371(c)(3)).

7. ☐ English translation of annexes (Article 19 and/or 34 amendments only) of the International Preliminary Examination Report is attached (35 U.S.C. 371(c)(5)).

Cancellation of amendments made in the international phase

8a. ☐ Do not enter the amendment made in the international phase under PCT Article 19.

8b. ☐ Do not enter the amendment made in the international phase under PCT Article 34.

NOTE: A proper amendment made in English under Article 19 or 34 will be entered in the U.S. national phase application absent a clear instruction from applicant not to enter the amendment(s).

The following items 9 to 17 concern a document(s) or information included.

9. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

10. ☐ A preliminary amendment

11. ☐ An Application Data Sheet under 37 CFR 1.76.

12. ☐ A substitute specification. NOTE: A substitute specification cannot include claims. See 37 CFR 1.125(b).

13. ☐ A power of attorney and/or change of address letter.

14. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.3 and 37 CFR 1.821-1.825.

15. ☐ Assignment papers *(cover sheet and document(s))*. Name of Assignee : **3Shape A/S**.

16. ☐ 37 CFR 3.73(c) Statement *(when there is an Assignee)*.

U.S. APPLICATION NO. (If known)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NO.
13/807,443	PCT/DK2011/050246	0079124-000062

17. ☐ Other items or information:

The following fees have been submitted.	CALCULATIONS	PTO USE ONLY
18. ☐ Basic national fee (37 CFR 1.492(a)) **$390**	**$ 0.00**	
19. ☐ Examination fee (37 CFR 1.492(c)) If the written opinion prepared by ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) .... **$0** All other situations.... .... **$250**	**$ 0.00**	
20. ☐ Search fee (37 CFR 1.492(b)) If the written opinion prepared by ISA/US or the International preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) .... **$0** Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority............ **$120** International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB............ **$500** All other situations............ **$630**	**$ 0.00**	
TOTAL OF 18, 19 and 20 =	**$ 0.00**	
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing in compliance with 37 CFR 1.821(c) or (e) in an electronic medium or computer program listing in an electronic medium) (37 CFR 1.492(j)). Fee for each additional 50 sheets of paper or fraction thereof **$320**		

Total Sheets	Extra sheets	Number of each additional 50 or fraction thereof (round **up** to a whole number)	RATE		
- 100 =	/50 =		x $320	**$ 0.00**	

Surcharge of **$130.00** for furnishing any of the search fee, examination fee, or the oath or declaration after the date of commencement of the national stage (37 CFR 1.492(h)).	**$ 130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	**<<TEXT>> - 20 =**	**<<TEXT>>**	x **$62**	**$ 0.00**	
Independent Claims	**<<TEXT>> - 3 =**	**<<TEXT>>**	**x $250**	**$ 0.00**	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			**+ $460**	**$ 0.00**	

TOTAL OF ABOVE CALCULATIONS =	**$ 130.00**	
☒ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by ½.		
SUBTOTAL =	**$ 65.00**	
Processing fee of **$130.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)). **+**	**$ 0.00**	
TOTAL NATIONAL FEE =	**$ 65.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property **+**	**$ 0.00**	
TOTAL FEES ENCLOSED =	**$ 65.00**	
	Amount to be refunded:	**$**
	Amount to be charged:	**$**

a. ☐ A check in the amount of $_______ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. 02-4800 in the amount of $_______ to cover the above fees.

c. ☒ The Director is hereby authorized to charge additional fees which may be required, or credit any overpayment, to Deposit Account No. 02-4800 as follows:

i. ☒ any required fee

ii. ☐ any required fee except for excess claims fees required under 37 CFR 1.492(d) and (e) and multiple dependent claim fee required under 37 CFR 1.492(f).

d. ☒ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. The PTO-2038 should only be mailed or faxed to the USPTO. However, when paying the basic national fee, the PTO-2038 may NOT be faxed to the USPTO.

ADVISORY: If filing by EFS-Web, do **NOT** attach the PTO-2038 form as a PDF along with your EFS-Web submission. Please be advised that this is **not** recommended and by doing so your **credit card information may be displayed via PAIR.** To protect your information, it is recommended to pay fees online by using the electronic payment method.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

Correspondence Address

☒ The address associated with Customer Number 21839 **OR** ☐ Correspondence address below

Name	**Buchanan Ingersoll & Rooney PC**				
Address	**P.O. Box 1404**				
City	**Alexandria**	State	**VA**	Zip Code	**22313-1404**
Country	**USA**			Telephone	**(703) 836-6620**
Email					

Signature	William C Rowland	Date	**March 1, 2013**
Name (Print/Type)	William C. Rowland	Registration No. (Attorney/Agent)	30888

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/807,443	03/01/2013		914	0079124-000062	29	2

CONFIRMATION NO. 1045

21839
BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

FILING RECEIPT

OC000000061062480

Date Mailed: 05/13/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Nikolaj Deichmann, Copenhagen O, DENMARK;
Tais Clausen, Klagshamn, SWEDEN;
Rune Fisker, Virum, DENMARK;
Henrik Öjelund, Lyngby, DENMARK;

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Nikolaj Deichmann, Copenhagen O, DENMARK;
Tais Clausen, Klagshamn, SWEDEN;
Rune Fisker, Virum, DENMARK;
Henrik Öjelund, Lyngby, DENMARK;

Assignment For Published Patent Application

3Shape A/S, Copenhagen k, DENMARK

Power of Attorney: The patent practitioners associated with Customer Number 21839

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/DK2011/050246 06/29/2011
which claims benefit of 61/359,454 06/29/2010
and claims benefit of 61/454,200 03/18/2011

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)
DENMARK PA201100191 03/18/2011 No Access Code Provided
DENMARK PA201000568 06/29/2010 No Access Code Provided

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

If Required, Foreign Filing License Granted: 05/07/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/807,443**

Projected Publication Date: 08/22/2013

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

2D IMAGE ARRANGEMENT

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

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Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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NOT GRANTED

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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
13/807,443	Nikolaj Deichmann	0079124-000062

21839
BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
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INTERNATIONAL APPLICATION NO.	
PCT/DK2011/050246	
I.A. FILING DATE	PRIORITY DATE
06/29/2011	06/29/2010

CONFIRMATION NO. 1045
371 ACCEPTANCE LETTER

OC000000061062481

Date Mailed: 05/13/2013

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as a Designated / Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is ACCEPTED for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above and the relevant dates are:

03/01/2013	03/01/2013
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1), (c)(2) and (c)(4) REQUIREMENTS	DATE OF COMPLETION OF ALL 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE " FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1), (c)(2) and (c)(4) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** *The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363).* Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

The following items have been received:

- Indication of Small Entity Status
- Copy of the International Application filed on 12/28/2012
- Copy of the International Search Report filed on 12/28/2012
- Preliminary Amendments filed on 12/28/2012
- Information Disclosure Statements filed on 12/28/2012
- Oath or Declaration filed on 03/01/2013
- U.S. Basic National Fees filed on 12/28/2012
- Priority Documents filed on 12/28/2012

FORM PCT/DO/EO/903 (371 Acceptance Notice)

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

JUELETHIA A PALMER

Telephone: (571) 272-9050

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/807,443

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	140		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	240		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	360		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	29 minus 20 =	* 9	x 40 =	360	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*	x 210 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1100		TOTAL	

APPLICATION AS AMENDED - PART II

AMENDMENT A		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2123
	Examiner Name	Unassigned
	Attorney Docket Number	0079124-000062

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	6068482		2000-05-30	SNOW	
	2	6261248	B1	2001-07-17	TAKAISHI et al.	

If you wish to add additional U.S. Patent citation information please click the Add button. Add

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Examiner Initial*	Cite No	Publication Number	Kind Code1	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20030163291	A1	2003-08-28	JORDAN et al.	

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Examiner Initial*	Cite No	Foreign Document Number3	Country Code2 i	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T5
	1	1 124 487	EP	B1	2007-05-23	CADENT LTD.		☐
	2	2008/128700	WO	A1	2008-10-30	MATERIALISE DENTAL N.V.		☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2123
	Examiner Name	Unassigned
	Attorney Docket Number	0079124-000062

	3	2010/008435	WO	A1	2010-01-21	DENTSPLY INTERNATIONAL INC.		☐

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	Search Report issued by the Danish Patent and Trademark Office on January 28, 2011, in the corresponding Danish Patent Application No. PA 2010 00568. (4 pages)	☐
	2	Notification of Transmittal of the International Search Report (Forms PCT/ISA/220 and PCT/ISA/210) and the Written Opinion of the International Searching Authority (Form PCT/ISA/237) dated July 9, 2011, issued in corresponding International Application No. PCT/DK2011/050246. (11 pages)	☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2123
	Examiner Name	Unassigned
	Attorney Docket Number	0079124-000062

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/WCRowland/	Date (YYYY-MM-DD)	2013-06-03
Name/Print	William C. Rowland	Registration Number	32,814

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 124 487 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.05.2007 Bulletin 2007/21

(21) Application number: **99952782.3**

(22) Date of filing: **01.11.1999**

(51) Int Cl.:
A61B 6/00 (2006.01) *A61B 6/14* (2006.01)

(86) International application number:
PCT/IL1999/000577

(87) International publication number:
WO 2000/025677 (11.05.2000 Gazette 2000/19)

(54) **DENTAL IMAGE PROCESSING METHOD AND SYSTEM**

VERFAHREN UND VORRICHTUNG ZUR VERARBEITUNG VON DENTALBILDERN

PROCEDE ET SYSTEME DE TRAITEMENT D'IMAGE DENTAIRE

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **01.11.1998 IL 12683898**

(43) Date of publication of application:
22.08.2001 Bulletin 2001/34

(73) Proprietor: **Cadent Ltd.**
60372 Or Yehuda (IL)

(72) Inventors:
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  Ganei Tikva 55900 (IL)
- **TAUB, Eldad**
  71908 Reut (IL)

(74) Representative: **Joly, Jean-Jacques et al**
Cabinet Beau de Loménie
158, rue de l'Université
75340 Paris Cédex 07 (FR)

(56) References cited:
EP-A- 0 488 987
EP-A- 0 741 994
US-A- 5 151 856
US-A- 5 278 756

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

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ages according to the data representative of said basic landmarks.

[0012] In accordance with one embodiment of the invention, the imaging method and system is used to obtain orthodontic-relevant information, namely information to be used by an orthodont within the framework of an orthodontic treatment or for the design of such a treatment. This embodiment involves a registration of at least two images, one being a three-dimensional virtual image of a teeth model and the other being a two-dimensional image, e.g. a cephalometric image. Occasionally, other images may also be brought into registration consisting, for example of one or more of a lateral videographic image, a frontal videographic image and a frontal cephalometric image.

[0013] In accordance with another embodiment of the invention, the method and system are used for proper design of a dental implant or of a crown. For proper placement of an implant, the bone has to be carefully studied beforehand and examined whether it can receive the dental implant. In addition, the exact position and orientation of the dental implant has to be properly pre-designed. Typically, for a proper design of an implant, a three-dimensional virtual image of a teeth model is brought into registration with both a lateral cephalometric image and at times also with a frontal cephalometric image. This will allow to properly predict the manner of receipt of the implant within the bones of the jaw.

[0014] In the following, the invention will be described with particular reference to imaging for the purpose of design of the orthodontic treatment. It will however be appreciated, that the invention applies, *mutatis mutandis* also to its application for the purpose of proper design of tooth implants.

[0015] The first image is preferably an x-ray image, typically a cephalometric image obtained by radiographic cephalometric technique. The x-ray image is preferably a lateral image although at times the image may be from another orientation, e.g. a frontal image. In a cephalometric image, some facial profile aspects may at times be seen. However, typically, before an orthodontic treatment also a third, side elevational view of the face is taken from the same direction in which the radiographic cephalometric image was obtained. In accordance with an embodiment of the invention, such a third image, comprising at least a profile of facial aspects, is also obtained and used in the imaging technique of the invention. The side elevational image may be obtained, for example, by video cephalometry.

[0016] The term "*virtual three-dimensional teeth image*" refers to an image, represented within the computer environment which consists primarily of the teeth of one or both jaws. For example, a virtual three-dimensional teeth image may be represented in a manner resembling an image of a plaster model. A virtual three-dimensional image may be obtained by a variety of techniques, e.g. those described in the references mentioned above. Particularly, the three-dimensional virtual image may be obtained by the method described in WO 97/03622, which is an example of the manner of obtaining a three-dimensional virtual image for use in the method and system of the invention. It should be understood that the invention is not limited to a specific type of image obtained by one imaging technique or another. For example, the two-dimensional image may be obtained by a variety of different imaging techniques including magnetic resonance imaging (MRI), computerized tomography (CT) various radio-imaging techniques, etc. Similarly, the three-dimensional teeth image may be obtained by any one of a number of imaging techniques available including those disclosed in the aforementioned references as well as others such as those making use of a scanning probe, various photographic techniques, techniques in which teeth are scanned by a probing light beam, etc.

[0017] The term "*image*" as used herein should not be understood only as referring to the image as acquired in the imaging technique but rather may be also a result of initial image processing, e.g. an image processing intended to define boundaries of various objects in the image. Thus, the term "*image*" encompasses also a representation, prepared on the basis of an acquired image, of boundaries of objects, e.g. teeth, bones, a profile of facial aspects, etc.

[0018] Often, the imaging technique and analysis in accordance with the invention will make use of a third image, which may be the elevational image mentioned above, or any other image useful in improving the orthodontic analysis. Thus, by way of example, where said first image is a lateral two- dimensional image, said third image may be one or both of the afore- mentioned lateral elevational image or a frontal x-ray or videographic image.

[0019] The basic landmarks which are used for registering the two sets of images, are typically defined points at either the base or the apex of certain selected teeth e.g. the incisors and the first molars. Such basic landmarks may be selected by the user or may be automatically selected by the system's processor, e.g. based on established norms. After selecting the basic landmarks and marking them in one of the images, then the landmarks may be marked in the other images to allow to register both images. The term "*registering*" should not necessarily be understood as meaning a physical registration of the two images but rather as meaning the mapping of each feature in one image to a corresponding feature in another. The outcome of such registration is that any manipulation made on one image will yield a corresponding manipulation in the other image. For example, if one image is manipulated by displacing one tooth, this should result in a corresponding displacement of the same tooth in the other image.

[0020] At times it may be desired to view both images on a screen superimposed one on the other. As two or more images have to be superimposed may be presented initially at a different scale, an initial step which is

Description

FIELD OF THE INVENTION

[0001] The present invention is generally in the field of dentistry and provides an image processing method and system useful as a tool by the dentist or orthodont.

BACKGROUND OF THE INVENTION

[0002] There are a wide variety of imaging techniques used routinely in orthodontics. One important imaging technique is the so-called radiographic cephalometric technique. A radiographic cephalometric image is then used for a cephalometric analysis. Such an analysis is essentially a measurement system designed to describe relationships between the various parts of the skeletal, dental and soft tissue elements of the craniofacial complex. The two cephalometric images typically used are a lateral cephalometric image, which is of prime use in orthodontic and a front cephalometric image which is of somewhat less importance.

[0003] Cephalometric methods enable to define certain norms of a skeletal, dental and soft tissue of the craniofacial complex. A cephalometric measurement of individuals can then be compared with norms for age, sex and population group. A cephalogram is in effect a two-dimensional representation of a three-dimensional craniofacial structure. It is thus difficult in an analysis performed on such an image to distinguish between bi-lateral structures to trace them independently. Additionally, facial aspects are not entirely symmetrical, this may add a further inaccuracy to an analysis of this kind. Other sources of errors in a cephalometric image include different magnification of different aspects depending on the distance from the film and imperfect positioning of the patient in the cephalostat. These all add up to considerable errors in cephalometry.

[0004] An orthodont, prior to beginning the orthodontic treatment typically takes a teeth impression on the basis of which a plaster model may be prepared. There are also known a number of imaging techniques which allow to obtain, within a computer environment, a virtual three-dimensional image of the teeth. Such techniques are described for example in WO 97/03622 and DE-C-414311. A three-dimensional teeth image provides a different information than that obtained by a cephalometric analysis. Particularly, a virtual teeth image allows better appreciation of the three-dimensional structure of the teeth and the relative position of different teeth.

[0005] EP-A-0 488 987 discloses a procedure for displaying movable bodies. Here, images of the body are acquired with a camera precisely located with respect to a magnetic field source (coils). To locate the body with respect to the camera, a magnetic response assembly is attached to the body, and a magnetic stylus is used to mark three measurement points on the body. This enables to display points on the body that cannot be imaged by the camera.

[0006] EP-A-0 741 994 discloses a technique for planning a surgical intervention in the area of the patient's jaw by means of a model. The technique utilizes a position-determining device inserted in a patients oral cavity. This positioning device is formed with marking points to be located in at least one image of the oral cavity.

[0007] US-A-5 151 856 discloses a method of displaying cardiac function which forms a 3-D model of a heart on which is superimposed an arterial diagram obtained from a patient angiogram.

[0008] For the purpose of proper design of orthodontic treatment it would have been high advantageous to have a method and system whereby information which can be acquired from one type of image can be transferred or superpositioned to information available from another type of image.

GENERAL DESCRIPTION OF THE INVENTION

[0009] In accordance with the invention a novel method and system is provided in which information and data available from one type of teeth imaging technique is transferred and used in an image obtained by another kind of teeth imaging technique. This transfer of information provides the dentist or the orthodont with a powerful tool for designing of orthodontic treatment

[0010] In accordance with the invention there is provided an image processing method comprising:

(a) applying at least a first imaging technique and a second imagining technique to acquire a first, two-dimensional image of at least a first portion of teeth and a second, three- dimensional virtual image of at least a second portion of the teeth, respectively, there being at least a partial overlap between said first and second portions; and

(b) defining a set of basic landmarks in either one of the two images, locating said set in the other of the two images and registering said set in the two images.

[0011] By another of its aspects the present invention provides an image processing system, comprising:

(i) a first utility for receipt of first data representative of a first two-dimensional image of at least a first teeth portion;

(ii) a second utility for receipt of second data representative of a second three-dimensional virtual image of teeth of at least a second teeth portion;

(iii) a module for defining basic landmarks in both images and for generating data representative thereof; and

(iv) a processor associated with said first and said second utility and with said module, for receiving said first and said second data and for mapping elements in one of the two images to the other of the two im-necessary to be taken by the system is to either enlarge or reduce the scale of one image until there is an essential complete overlap of the basic landmarks in the two images. It should however be noted that registering of different images may not necessarily imply superpositioning, but rather at times the two registered images may be represented separately, e.g. side-by-side. The important result of the act of registering is that manipulation made on one of the images will effect the other as well.

[0021] In the following, the invention will be described with particular reference to an embodiment in which the first image is a cephalometric image and the second image is a virtual three-dimensional image. This specific reference should not however be construed as meaning that the invention is limited thereto. On the contrary, by applying the general teaching of the invention, information may be transferred between images obtained by other imaging techniques.

[0022] In accordance with one embodiment of the invention, after landmarks have been defined in the three-dimensional virtual images and in the cephalometric image, the correct orientation of the virtual three-dimensional teeth model has to be determined so as to allow it to be brought into conformity with the cephalometric image. This may at times require extensive computational time. It has however been found that the process of registration of the two images can be considerably accelerated by defining the cephalometric image to overlap the mid palatal plane of the virtual three-dimensional teeth image. In other words, the cephalometric image is defined to lie on the mid palatal plane and the cephalographic image is then adjusted until the basic landmarks overlap with the projection of the corresponding basic landmarks of the virtual three-dimensional image onto the mid palatal plane.

[0023] The invention permits also an analysis of the effect of teeth displacement on various aspects of the cranofacial complex. For example, teeth may be displaced on the virtual three-dimensional image of teeth model in a manner they are expected to be shifted during the course of the orthodontic treatment. Thus, for example, by marking various landmarks on a displaced teeth and marking and then displacing the same landmarks in the cephalometric model, it may be possible to check on both images whether the orthodontic treatment achieves a result which matches a certain acceptable norm or how changes should be made to achieve such a norm. If, for example, a desired result as viewed in an amended cephalometric image (namely a cephalometric image after a tooth has been displaced) does not match the desired results, it is possible to go back to the virtual three- dimensional teeth model and proceed with a simulation and then map the results onto the cephalometric image, and so forth.

[0024] By way of example, in order to achieve the same degree of displacement in one image, the shifting of a certain landmark which is associated with a displaced object is then compared to some basic landmarks and the same relation of displacements is then related to the other image.

[0025] One particular example of analysis which can be made by such simulation is to determine the effect of such displacement on soft facial tissue, particularly outer facial tissue. This will allow an estimation of the effect of the orthodontic treatment on the esthetic appearance of the individual.

[0026] A simulation of the treatment and then translation of the results to a cephalometric image allows also to determine whether shifts in various elements such as the jaw, are within permitted physiological or aesthetical limits. An uncontrolled shifting of a tooth or a jaw in an orthodontic treatment may give rise to various physiological and functional problems.

[0027] The invention will now be illustrated below with reference to some specific, non-limiting embodiments, with occasional reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1A shows an example of a radiographic cephalometric image.

Fig. 1B shows a virtual three-dimensional image of teeth, presented in the manner resembling a plaster teeth model.

Fig. 2 shows a super-position of a three-dimensional teeth model and a cephalometric image.

Figs. 3A and **3B** show two examples of super-position of a three-dimensional model and a video cephalometric image.

Fig. 4A shows a cephalometric image with some basic landmarks marked thereon.

Fig. 4B shows a three-dimensional virtual image of the same teeth as those shown in the cephalometric image of Fig. 4A, with the same basic landmarks marked thereon.

Fig. 5 shows a super-position of the two images.

Fig. 6 is a block diagram representation of a system in accordance with the invention.

Figs. 7A and **7B** are flowcharts showing the manner of mapping elements from a three-dimensional virtual teeth model to a cephalometric image. **Fig. 7A** shows the user's interaction modules whereas **Fig. 7B** shows the software functionality underlying the manner of performing of displacement and mapping the displacement from the three-dimensional virtual teeth model to the cephalometric image.

Figs. 8A and **8B** are flowcharts showing the manner of mapping elements from a cepthalometric image to a three-dimensional virtual teeth model. **Fig. 8A** shows the user's interaction modules whereas **Figs. 8B** shows the software functionality underlying the manner of performing of displacement and mapping the displacement from the cephalometric image to the virtual three-dimensional teeth model.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0029] In accordance with the present invention images are acquired including at least one two-dimensional teeth image and at least one three-dimensional teeth image and both are combined for the purpose of improving the orthodont's ability to predict the effect of orthodontic treatment on various parameters. This combination allows the orthodont to considerably increase the depth of his understanding on the outcome of the orthodontic treatment. Hitherto, analysis which was made on a cephalometric images could not have been readily translated to the other tools available to him - this being the three-dimensional teeth model, typically a plaster model. In the reverse, information gained by him from studying a three-dimensional teeth model, could not have been readily translated to a cephalometric image. As is well known to the artisan, each one of the images allows a limited range of analysis which can be made and a true analysis can only be gained from thorough analysis based on the two types of images.

[0030] It is only with the present invention that a proper analysis becomes feasible.

[0031] An image, once acquired and converted to a representation within a computer environment can be manipulated, e.g. by displacing certain elements, such as one or more teeth or even an entire jaw. The cepthalometric image allows to view the interrelation between some elements and may be used, for example, to test the effect of the treatment on some physiological or functional parameters as well as the aesthetic parameters. There is, however, a significant deficiency in that it is impossible to fully translate this information to the three-dimensional real-life environment. The present invention permits a proper analysis of the effect of displacement of elements and or better understanding of how changes will effect the real-life situation.

[0032] Reference is first being made to Figs 1A and 1B, showing respectively, a cephalometric radiograph and a three-dimensional virtual teeth image. The virtual teeth image which is shown in Fig. 1B, is represented in a manner resembling a plaster teeth model. As will no doubt be appreciated by the artisan, this is but an example, and the two-dimensional or the virtual three dimensional teeth image may be represented in a different way.

[0033] Prior to the present invention, each of these different images, was represented separately. The three-dimensional virtual image was represented either as a plaster model or a three-dimensional virtual representation in a computer environement. In accordance with the invention, two different images, one being a two-dimensional image, e.g. a cephalometric radiograph, is combined with a three-dimensional teeth image. A super-position of two such images is represented in exemplary Fig. 2. As can be seen, the cephalometric image is combined with the three-dimensional virtual teeth image such that it lies on the mid palatal plane of the three-dimensional virtual teeth image. The relative position of the two images is fixed such that basic landmarks defined in the two images concur, as will be described further below.

[0034] Another implementation of the invention can be seen in exemplary Figs. 3A and 3B. In these figures, a three-dimensional virtual teeth image is superpositioned with a lateral or profile picture of an individual. The profile pictures in Figs. 3A and 3B are each from a slightly differently orientation and accordingly the virtual three-dimensional teeth model in Fig. 3B is rotated with respect to the orientation of the model in Fig. 3A.

[0035] In order to combine a cephalometric image and a three-dimensional virtual model, basic landmarks have to be defined and marked in both images. These basic landmarks may be entered manually by the user, although alternatively, they may be automatically generated by a computer, based on standard image analysis method, or based on an earlier user input. Generally, such basic landmarks may be arbitrary landmarks or may be orthodontic relevant landmarks which may be used later in a cephalometric analysis, in accordance with one of the acceptable norms therefor. (For review on a cephalometric analysis see Radiographic Cephalometry, From Basics to Videoimaging, Jacobson A., *et al.*, Quintessence Publishing Co., Inc., Chicago, Berlin, 1995).

[0036] A cephalometric radiograph and the three-dimensional teeth model from the same individual, are shown in Figs. 4A and 4B. In these figures, two basic landmarks have been marked - L1 and L2. After these landmarks have been marked, the two images are brought into registration which results in super-positioning as can be seen in Fig. 5 (the same two landmarks L1 and L2 can also be seen here). The registration in the manner shown in Figs. 4A, 4B and 5 is performed using two defined landmarks. Obviously, it is possible at times to use more landmarks for this purpose to increase accuracy of registration.

[0037] In order to reduce computational time, the cephalometric radiograph is combined with the three-dimensional virtual teeth image by placing (in a virtual sense) the cephalometric image on the mid palatal plane. For proper registration, the scale of the two images has to be adjusted and then one image has to be shifted versus the other until the projection of the basic landmarks of the three-dimensional virtual image of teeth model onto its mid palatal plane are in register with the corresponding landmarks in the cephalometric image.

[0038] The cephalometric radiograph and the cephalometric videograph as shown herein, are images as acquired by the utilized imaging technique. It should however be noted that at times it is advantageous to produce initially a representation of the image, e.g. a graphic representation of boundaries of objects of interest within the image. For example, rather than a full cephalographic image, a representation comprising boundaries of some major bones and several teeth, e.g. the first and second molar teeth and the incisors. These aforementioned teeth are usually the important teeth for the cephalometric analysis, as their position is relatively sensitive to displacement of teeth and jaws. Furthermore, the position of these teeth is an important marker for studying or gauging the effect of teeth position on various functional as well as aesthetical facial aspects.

[0039] Producing a graphical representation of some aspects of an image, particularly of a cephalometric image, is very useful for the purpose of a virtual displacement of the teeth in the image so as to study the effect of the treatment on functional or facial aesthetic parameters, as generally known *per se.*

[0040] A system in accordance with the embodiment of the invention can be seen in Fig. 6. It comprises a central computing unit **20** with three input utilities **22, 24** and **26**, which may be integral within module **28**. These utilities may comprise, as known *per se,* a data entry port and the necessary data transfer software. Furthermore, rather than importing of data through a data entry port, the data to these utilities may be imported from a storage media or from an information carrier, e.g. a magnetic or an optical disk. As will no doubt be further understood, module **28** may also comprise a scanner for scanning images, may comprise a camera for direct image acquisition, etc.

[0041] The system still further comprises a module **30**, connected to a user input interface **32** e.g. a keypad, a cursor driver, etc. By means of interface **32** the user may define the landmarks or may induce the system to enter into various operational modes, some of which will be explained below.

[0042] Module **30** and utility **28** are connected to a processor **40** for image processing so as to combine the two images as described, for example further below. Processor **40** may be connected to monitor **50** and may be also connected to other display means, e.g. a printer.

[0043] A flowchart of an embodiment of the manner of linking between a three-dimensional virtual teeth model and a cephalometric image can be seen in Figs. 7A and 7B. Fig. 7A is a flowchart of the user interaction steps whereas Fig. 7B is a software functionality flowchart on the manner of combining the two images. At a first step **100**, the system receives an input of data representative of a three-dimensional virtual teeth model. Then at **110**, basic landmarks are marked on discernable objects in the three-dimensional virtual teeth model as represented in image **111**. Such basic landmarks may, for example, be points on crowns and roots of upper and lower first molars (landmarks **1-4** of image **111**) as well as on crowns and roots of upper and lower centrals (landmarks **5-8** in image **111**). Landsmarks **1** and **4** as well as landmarks **5** and **8** mark the approximate position of the roots of the teeth. The real root position cannot be seen in such a model but the orthodont, based on his experience, can relatively accurately mark their roots' position.

[0044] At a next step **120**, a cephalometric image of the same patient is input and on this image, the same key points are then marked (see **131**). Then, the two images may be matched, which may be by way of superposition as shown above, which can be represented on a screen, or by any other way of mapping of each location in one image to that of the other image.

[0045] At a next step **140** teeth and jaws in the three-dimensional model may be displaced on the three-dimensional model to receive a desired result. Then, as represented in the flowchart of Fig. 7B, the software at next steps **150** and **160** moves skeletal elements and teeth, respectively, according to movement performed by the user on the three-dimensional virtual teeth model. Then, at **170**, a cephalometric analysis can be made on the amended (after displacement) cepthalometric image to see whether desired proportional measurements have been reached in such teeth displacement or whether any medication should be made.

[0046] The reverse sequence of operation, namely the mapping of each point from a cephalometric image to a three-dimensional virtual teeth model is seen in Figs. 8A and 8B. In Figs. 8A and Fig. 8B, each of steps **200-270** corresponds, *mutatis mutandis* to the steps **100-170** in Figs. 7A and 7B. This eventually results in mapping of each point in a cephalometric image to the corresponding location of the three-dimensional virtual teeth model to allow to translate any displacement performed on the former image to that in the latter.

Claims

1. An image processing method comprising :

    (a) defining a set of basic landmarks (110) in one of two images consisting of a first two-dimensional image of at least a first portion of a patient's teeth and a second three-dimensional virtual image of at least a second portion of the teeth, there being at least a partial overlap between first and second portions, said set of basic landmarks being in an overlapping region of the two images;
    (b) locating the set of basic landmarks in the other of the two images (130); and
    (c) combining said two images together by registering said basic landmark with each of the two images retaining its respective two-dimensional or three-dimensional characteristics (140).

2. A method according to Claim 1, wherein said first image is a longitudinal cross-sectional image.

3. A method according to Claim 2, wherein said first image is a radiographic x-ray image.

4. A method according to Claim 3, wherein said first image is a cephalometric image.

5. A method according to any one of Claims 1-4, wherein step (a) comprises applying a third imaging technique to acquire a third image comprising at least a profile of facial aspects.

6. A method according to any of Claims 1-4, wherein said three-dimensional image comprises substantially all teeth of at least one jaw, and the two-dimensional image is positioned on the mid palatal plane of the three-dimensional image.

7. A method according to Claim 1, comprising the following step :

(d) displacing at least one tooth in at least one of the images in a manner resembling the manner in which said at least one tooth can be shifted in real-life orthodontic treatment; and
(e) by applying a set of rules which define manner in which each element in one image maps to a corresponding element in the other image, displacing said at least one tooth in said other image.

8. A method according to Claim 7, wherein said set of rules comprise defining in said one image at least one object-associated landmark of said at least one tooth, locating said object-associated landmark, and displacing said object-associated landmark in said other image, in proportion to its movement in said one image.

9. A method according to Claim 8, wherein said basic landmarks are fixed, the displacement of the at least one object-associated landmark in said one image is defined according to said basic landmarks and said at least one object-associated landmark is then displaced in the same relative displacement in respect of the basic landmarks in said other image.

10. A method according to any one of Claims 7-9, wherein said one image is a virtual three-dimensional image of a teeth model and said other image is a lateral image.

11. A method according to Claim 10, wherein said lateral image is a cephalometric image.

12. A method according to Claim 11, comprising the following step :

(f) by applying a set of rules defining displacement of soft facial tissue caused by displacement of said at least one tooth, predicting effect of the displacement of said at least one tooth in said virtual three-dimensional image on soft facial tissue image in said lateral image.

13. A method according to Claim 12, wherein the displacement of said soft tissue is predicted using a third image of at least a profile of facial aspects.

14. An image processing system comprising :

(i) first and second utilities (22, 24) for receipt of, respectively, first data representative of a first two-dimensional cross-sectional image of at least a first teeth portion, and second data representative of a second, three-dimensional virtual image of teeth model of at least a second teeth portion, an overlapping region existing between said first and second portions;
(ii) a module for defining basic landmarks (30) in at least one of the first and second teeth portions as selected locations within the overlapping region, and for generating data representative thereof; and
(iii) a processor (40) associated with said first and said second utility and with said module (22, 24, 30), and operable for

- analyzing first and said second data,
- mapping elements in one of the two images to the other of the two images according to the data representative of said basic landmarks, and
- combining the two images together by registering said basic landmarks in the two images, such that each of the two images retains its respective two-dimensional or three-dimensional characteristics.

15. A system according to Claim 14, wherein said first image is a cephalometric image.

16. A system according to Claim 15, comprising a third utility for receipt of third data representative of a third image comprising at least a profile of facial aspects.

17. A system according to Claims 14-16, wherein the first, second and third utilities are integrated together as one utility.

18. A system according to any one of Claims 14-17, wherein said second utility comprises a data transferring module for transferring data representative of the second, virtual three-dimensional image to the processor.

19. A system according to any one of Claim 14-18, comprising a module defining a set of rules for displacing at least one virtual tooth representation in one of the images.

20. A system according to Claim 19, wherein said set of rules define a displacement representing the manner of shifting of the at least one tooth in a real-life orthodontic treatment.

21. A system according to Claim 19, wherein said processor translates the displacement of said at least one virtual tooth representation in one of the images to displacement of a corresponding tooth in the other image.

22. A system according to Claim 21, wherein said one of the images is a virtual three-dimensional image of teeth model, and the other image is a cephalometric image.

23. A system according to Claim 22, comprising a module defining a set of rules for predicting the effect of displacement of teeth in the cephalometric image of soft facial tissue.

Patentansprüche

1. Bildverarbeitungsverfahren umfassend:

   (a) Definieren eines Satzes von Basismarkierungen (110) in einem von zwei ein erstes, zweidimensionales Bild wenigstens eines ersten Teils der Zähne eines Patienten und ein zweites, dreidimensionales Bild wenigstens eines zweiten Teils der Zähne umfassenden zwei Bildern, wobei es wenigstens eine partielle Überlappung zwischen dem ersten und dem zweiten Teil gibt, wobei der Satz von Basismarkierungen sich in einer überlappenden Region der beiden Bilder befindet,
   (b) Lokalisieren des Satzes von Basismarkierungen in dem anderen der beiden Bilder (130) und
   (c) Kombinieren der beiden Bilder miteinander durch Registrieren der Basismarkierungen, wobei jedes der beiden Bilder seine jeweiligen zweidimensionalen oder dreidimensionalen Eigenschaften (140) behält.

2. Verfahren nach Anspruch 1, wobei das erste Bild ein longitudinales Querschnittsbild ist.

3. Verfahren nach Anspruch 2, wobei das erste Bild ein radiographisches Röntgenbild ist.

4. Verfahren nach Anspruch 3, wobei das erste Bild ein kephalometrisches Bild ist.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei Schritt (a) das Anwenden einer dritten Bildtechnik umfaßt, um ein drittes Bild zu erhalten, das wenigstens ein Profil von Gesichtsansichten umfaßt.

6. Verfahren nach einem der Ansprüche 1 bis 4, wobei das dreidimensionale Bild im wesentlichen alle Zähne wenigstens eines Kiefers umfaßt und wobei das zweidimensionale Bild in der Mitte der palatinalen Ebene des dreidimensionalen Bildes positioniert ist.

7. Verfahren nach Anspruch 1, umfassend die folgenden Schritte:

   (d) Verschieben wenigstens eines Zahnes in wenigstens einem der Bilder in einer Art, die der Art ähnelt, in welcher der wenigstens eine Zahn bei tatsächlicher realer kieferorthopädischer Behandlung verschoben werden kann, und
   (e) Verschieben des wenigstens einen Zahnes in dem anderen Bild durch Anwenden eines Satzes von Regeln, welche eine Art definieren, in der jedes Element in einem Bild ein entsprechendes Element in dem anderen Bild abbildet.

8. Verfahren nach Anspruch 7, wobei der Satz von Regeln das Definieren wenigstens einer objektbezogenen Markierung des wenigstens einen Zahns in dem einen Bild, das Lokalisieren der objektbezogenen Markierung und das Verschieben der objektbezogenen Markierung in dem anderen Bild proportional zu ihrer Bewegung in dem einen Bild umfaßt

9. Verfahren nach Anspruch 8, wobei die Basismarkierungen fixiert sind, die Verschiebung der wenigstens einen objektbezogenen Markierung in dem einen Bild gemäß den Basismarkierungen definiert wird und wobei die objektbezogene Markierung dann mit derselben relativen Verschiebung in Bezug auf die Basismarkierungen in dem anderen Bild verschoben wird.

10. Verfahren nach einem der Ansprüche 7 bis 9, wobei das eine Bild ein virtuelles dreidimensionales Bild eines Modells der Zähne und das andere Bild ein seitliches Bild ist.

11. Verfahren nach Anspruch 10, wobei das seitliche Bild ein kephalometrisches Bild ist.

12. Verfahren nach Anspruch 11, umfassend den folgenden Schritt:

   (f) Voraussagen des Effektes der Verschiebung des wenigstens einen Zahns in dem virtuellen dreidimensionalen Bild auf das Erscheinungsbild des weichen Gesichtsgewebes in dem lateralen Bild durch Anwenden eines Satzes von Regeln, die die durch die Verschiebung des wenigstens einen Zahns verursachte Verschiebung von weichem Gesichtsgewebe definieren.

13. Verfahren nach Anspruch 12, wobei die Verschie-

bung des weichen Gewebes unter Verwendung eines dritten Bildes wenigstens eines Profils von Gestchtsansichten vorausgesagt wird.

14. Bildverarbeitungssystem umfassend:

(i) erste und zweite Einrichtungen (22, 24) zum Empfang von ersten Daten, die ein erstes zweidimensionales Querschnittsbild wenigstens eines ersten Zahnabschnittes repräsentieren, bzw. von zweiten Daten, die ein zweites, dreidimensionales virtuelles Bild eines Zahnmodells wenigstens eines zweiten Zahnabschnittes repräsentieren, wobei eine Überlappungsregion zwischen dem ersten und dem zweiten Abschnitt existiert,
(ii) einem Modul zum Definieren von Basismarkierungen (30) in wenigstens einem der ersten und zweiten Abschnitt der Zähne als ausgewählte Orte innerhalb der Überlappungsregion und zum Generieren von dafür repräsentativen Daten und
(iii) einem mit der ersten und der zweiten Einrichtung und dem Modul (22, 24, 30) verbundenen Prozessor (40), der betrieben werden kann zum

- Analysieren erster und zweiter Daten,
- Abbilden von Elementen in einem der beiden Bilder auf das andere der beiden Bilder entsprechend den für die Basismarkierungen repräsentativen Daten,
- Kombinieren der beiden Bilder miteinander durch Registrieren der Basismarken in beiden Bildern, so daß jedes der beiden Bilder seine entsprechenden zweidimensionalen bzw. dreidimensionalen Eigenschaften behält,

15. System nach Anspruch 14, wobei das erste Bild ein kephalometrisches Bild ist.

16. System nach Anspruch 15, umfassend eine dritte Einrichtung zum Empfangen von dritten Daten, die ein drittes Bild repräsentieren, welches wenigstens ein Profil von Gesichtsansichten umfaßt.

17. System nach einem der Ansprüche 14 bis 16, wobei die erste, zweite und dritte Einrichtung zusammen als eine Einrichtung integriert sind.

18. System nach einem der Ansprüche 14 bis 17, wobei die zweite Einrichtung ein Datentransfermodul zum Übertragen von Daten, die das zweite, virtuelle dreidimensionale Bild repräsentieren, auf den Prozessor umfaßt.

19. System nach einem der Ansprüche 14 bis 18, umfassend ein Modul, das wenigstens einen Satz von Regeln zum Verschieben wenigstens einer virtuellen Zahnrepräsentation in einem der Bilder definiert.

20. System nach Anspruch 19, wobei der Satz von Regeln eine Verschiebung definiert, die die Art der Verschiebung des wenigstens einen Zahnes bei realer kieferorthopädischer Behandlung entspricht.

21. System nach Anspruch 19, wobei der Prozessor die Verschiebung der wenigstens einen virtuellen Zahnrepräsentation in einem der Bilder in eine Verschiebung eines entsprechenden Zahns in dem anderen Bild umsetzt.

22. System nach Anspruch 21, wobei das eine der Bilder ein virtuelles dreidimensionales Bild eines Modells der Zähne und das andere Bild ein kephalometrisches Bild ist.

23. System nach Anspruch 22, umfassend ein Modul, das einen Satz von Regeln zum Vorhersagen des Effekts der Verschiebung von Zähnen in dem kephalometrischen Bild von weichem Gesichtsgewebe definiert.

Revendications

1. Procédé de traitement d'image comprenant:

(a) la définition d'un ensemble de repères basiques (110) dans l'une de deux images composées d'une première image en deux dimensions d'au moins une première partie des dents d'un patient et d'une seconde image virtuelle en trois dimensions d'au moins une seconde partie des dents, avec au moins un chevauchement partiel entre la première et la seconde parties, ledit ensemble de points de repère basiques étant dans une région de chevauchement des deux images ;
(b) la localisation de l'ensemble de points de repère basiques dans l'autre des deux images (130) ; et
(c) la combinaison desdites deux images ensemble en enregistrant ledit point de repère basique avec chacune des deux images conservant ses caractéristiques en deux dimensions ou en trois dimensions respectivement (140).

2. Procédé selon la revendication 1, dans lequel ladite première image est une image longitudinale en coupe.

3. Procédé selon la revendication 2, dans lequel ladite première image est une image radiographique à rayons X.

4. Procédé selon la revendication 3, dans lequel ladite première image est une image céphalométrique.

5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel l'étape (a) comprend l'application d'une troisième technique d'imagerie afin d'acquérir une troisième image comprenant au moins un profil d'aspects faciaux.

6. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel ladite image en trois dimensions comprend sensiblement toutes les dents d'au moins une mâchoire, et l'image en deux dimensions est positionnée sur le plan palatin intermédiaire de l'image en trois dimensions.

7. Procédé selon la revendication 1, comprenant l'étape suivante :

(d) le déplacement d' au moins une dent dans au moins l'une des images d'une manière ressemblant à la manière selon laquelle ladite dent au moins peut être décalée lors d'un traitement orthodontique réel ; et
(e) en appliquant un ensemble de règles qui définissent la manière dont chaque élément d'une image est mappé par rapport à un élément correspondant de l'autre image, le déplacement de ladite dent au moins dans ladite autre image.

8. Procédé selon la revendication 7, dans lequel ledit ensemble de règles comprend la définition, dans ladite image, d'au moins un point de repère associé à un objet de ladite dent au moins, la localisation dudit point de repère associé à un objet, et le déplacement dudit point de repère associé à un objet dans ladite autre image, proportionnellement à son mouvement dans ladite image.

9. Procédé selon la revendication 8, dans lequel lesdits points de repère basiques sont fixes, le déplacement de point de repère associé à un objet au moins dans ladite image est défini selon lesdits points de repère basiques et ledit point de repère associé à un objet au moins est ensuite déplacé selon le même déplacement relatif par rapport aux points de repère basiques dans ladite autre image.

10. Procédé selon l'une quelconque des revendications 7 à 9, dans lequel ladite image est une image virtuelle en trois dimensions d'un modèle de dent et ladite autre image est une image latérale.

11. Procédé selon la revendication 10, dans lequel ladite image latérale est une image céphalométrique.

12. Procédé selon la revendication 11, comprenant l'étape suivante :

(f) en appliquant un ensemble de règles définissant un déplacement d'un tissu facial souple provoqué par un déplacement de ladite dent au moins, la prédiction d'un effet du déplacement de ladite dent au moins dans ladite image virtuelle en trois dimensions sur l'image d'un tissu facial souple dans ladite image latérale.

13. Procédé selon la revendication 12, dans lequel le déplacement dudit tissu souple est prédit en utilisant une troisième image d'au moins un profil d'aspects faciaux.

14. Système de traitement d'image comprenant :

(i) un premier et un second dispositifs (22, 24) destinés à la réception, respectivement, de premières données représentatives d'une première image en coupe en deux dimensions d'au moins une première partie des dents, et de secondes données représentatives d'une seconde image virtuelle en trois dimensions d'un modèle de dent d'au moins une seconde partie des dents, une région de chevauchement existant entre lesdites première et seconde parties ;
(ii) un module destiné à définir des points de repère basiques (30) dans au moins l'une de la première et de la seconde parties des dents comme étant des emplacements sélectionnés dans la région de chevauchement, et à générer des données représentatives de ceux-ci ; et
(iii) un processeur (40) associé auxdits premier et second dispositifs et audit module (22, 24, 30), et capable

- d'analyser lesdites premières et secondes données,
- de mapper des éléments dans l'une des deux images par rapport à l'autre des deux images selon les données représentatives desdits points de repère basiques, et
- de combiner les deux images ensemble en enregistrant lesdits points de repère basiques dans les deux images, de telle sorte que chacune des deux images conserve ses caractéristiques en deux dimensions ou en trois dimensions respectives.

15. Système selon la revendication 14, dans lequel ladite première image est une image céphalométrique.

16. Système selon la revendication 15, comprenant un troisième dispositif destiné à la réception de troisièmes données représentatives d'une troisième image comprenant au moins un profil d'aspects faciaux.

17. Système selon les revendications 14 à 16, dans lequel le premier, le second et le troisième dispositifs

sont intégrés ensemble comme un seul dispositif.

18. Système selon l'une quelconque des revendications 14 à 17, dans lequel ledit second dispositif comprend un module de transfert de données destiné à transférer des données représentatives de la seconde image virtuelle en trois dimensions au processeur.

19. Système selon l'une quelconque des revendications 14 à 18, comprenant un module définissant un ensemble de règles afin de déplacer au moins une représentation de dent virtuelle dans l'une des images.

20. Système selon la revendication 19, dans lequel ledit ensemble de règles définit un déplacement représentant la manière de décaler la dent au moins lors d'un traitement orthodontique réel.

21. Système selon la revendication 19, dans lequel ledit processeur traduit le déplacement de ladite représentation de dent virtuelle au moins dans l'une des images en déplacement d'une dent correspondante dans l'autre image.

22. Système selon la revendication 21, dans lequel ladite des images est une image virtuelle en trois dimensions d'un modèle de dents, et l'autre image est une image céphalométrique.

23. Système selon la revendication 22, comprenant un module définissant un ensemble de règles afin de prédire l'effet du déplacement d'une dent dans l'image céphalométrique d'un tissu facial souple.

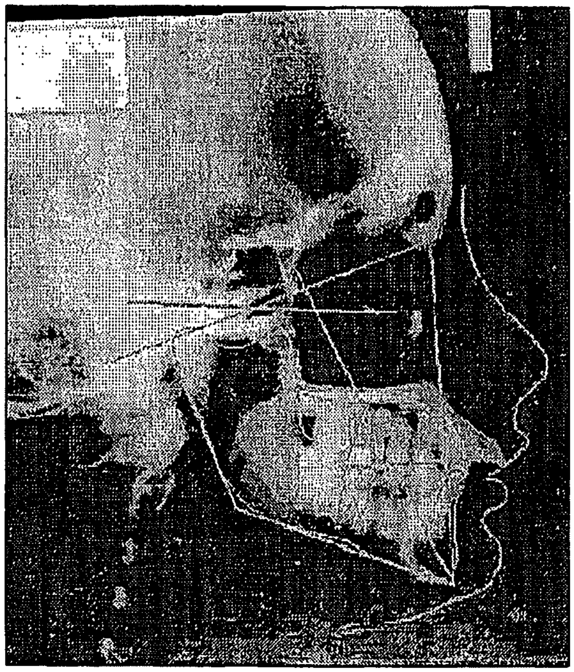


FIG.1A
PRIOR ART

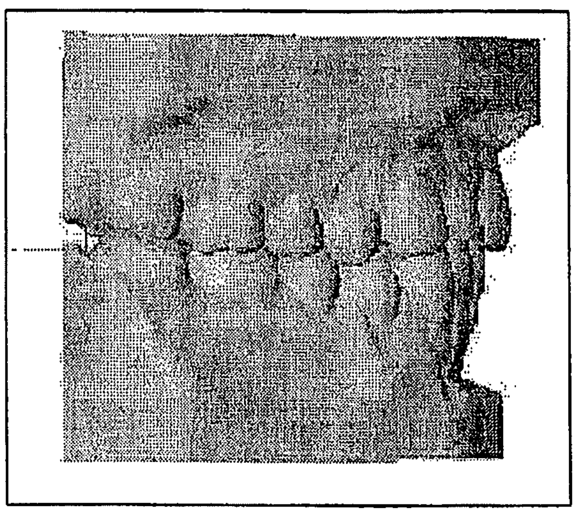


FIG.1B
PRIOR ART

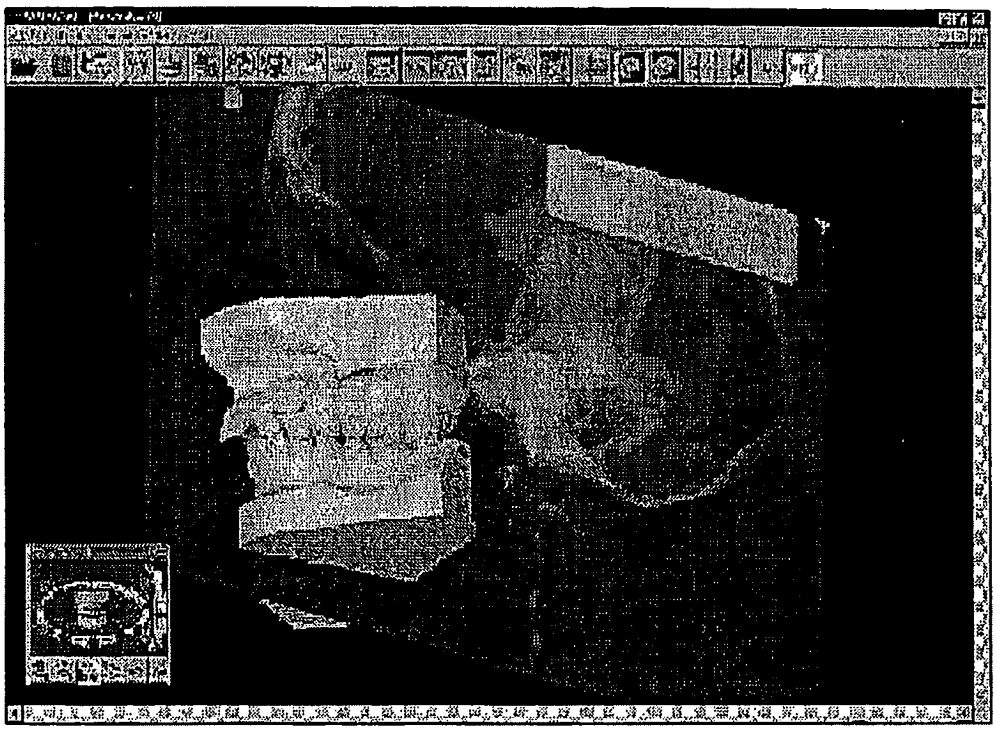


FIG.2

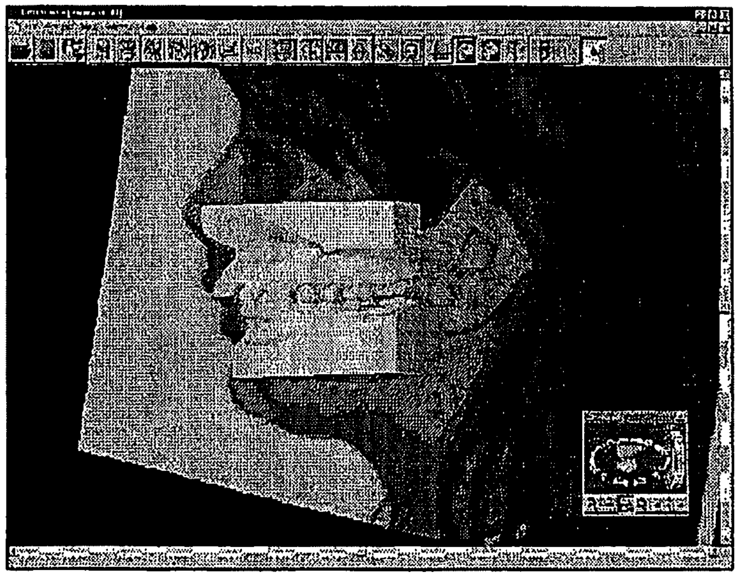


FIG.3A

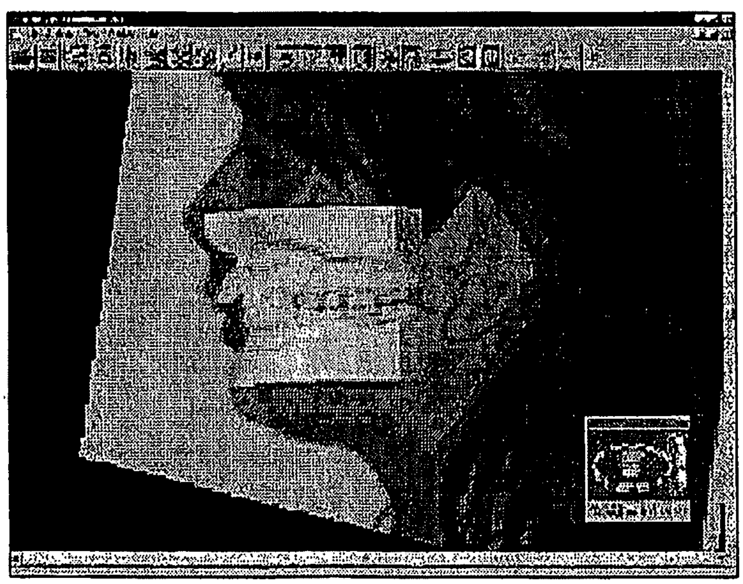


FIG.3B

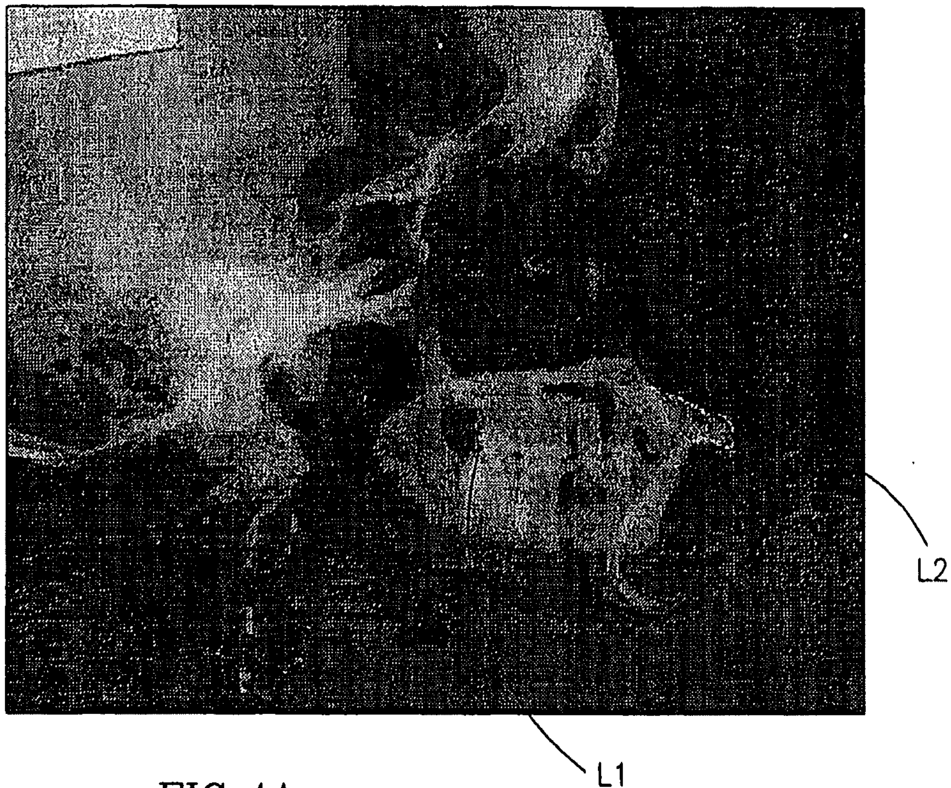


FIG.4A

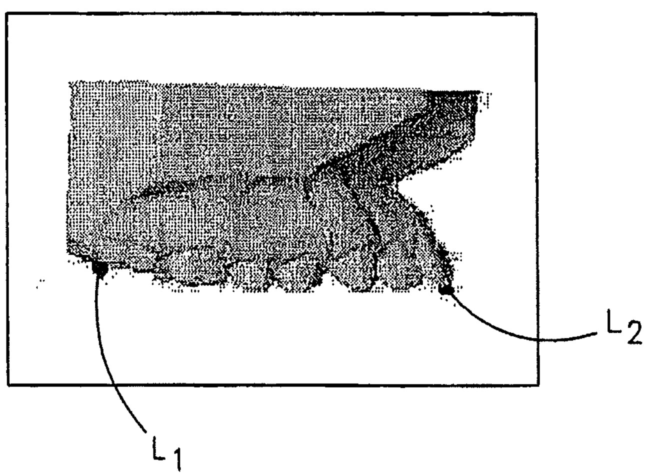


FIG.4B

FIG.5

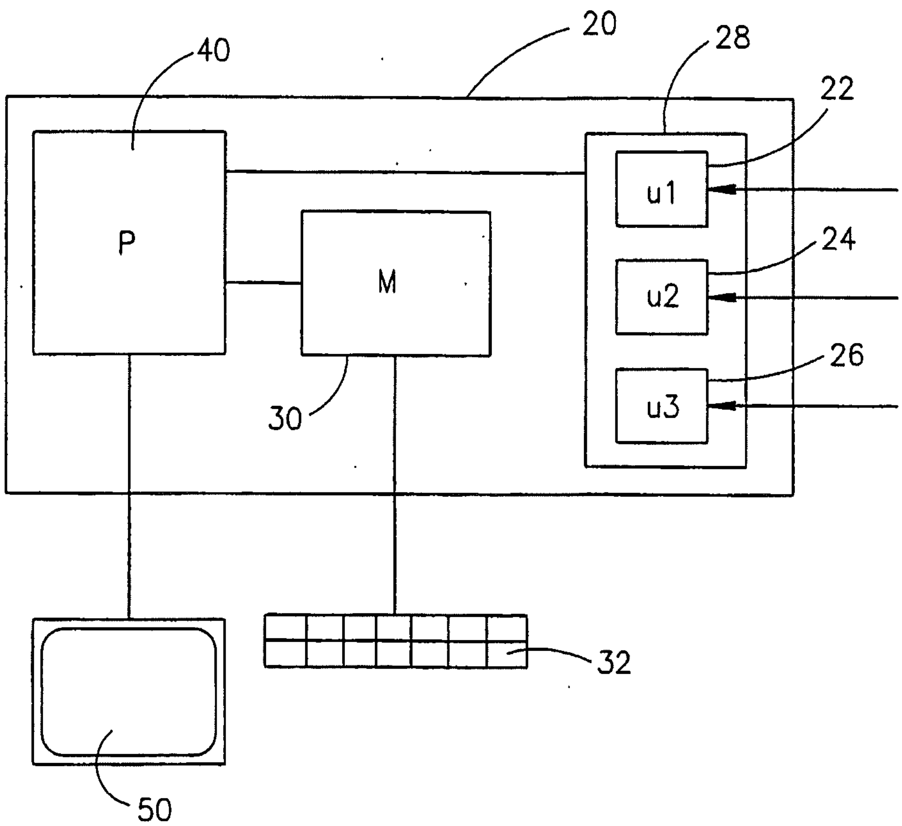
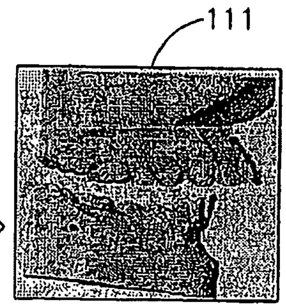


FIG.6

100 INPUT A 3D VIRTUAL MODE

110 MARK BASIC LANDMARKS



120 INPUT A CEPHALOMETRIC X-RAY OF THE SAME PATIENT

130 MARK THE SAME BASIC LANDMARKS

140 MOVE TEETH AND JAWS ON 3D VIRTUAL MODEL TO RECEIVE DESIRED RESULTS

FIG.7A

150 ON CEPHALOMETRIC X-RAY MOVE SKELETAL ELEMENTS ACCORDING TO MOVEMENTS THE USER PERFORMED ON 3D MODEL

160 ON CEPHALOMETRIC X-RAY MOVE TEETH ACCORDING TO MOVEMENTS THE USER PERFORMED ON 3D MODEL

170 ON CEPHALOMETRIC X-RAY UPDATE THE RESULTS OF DESIRED PROPORTIONAL MEASUREMENTS

FIG.7B

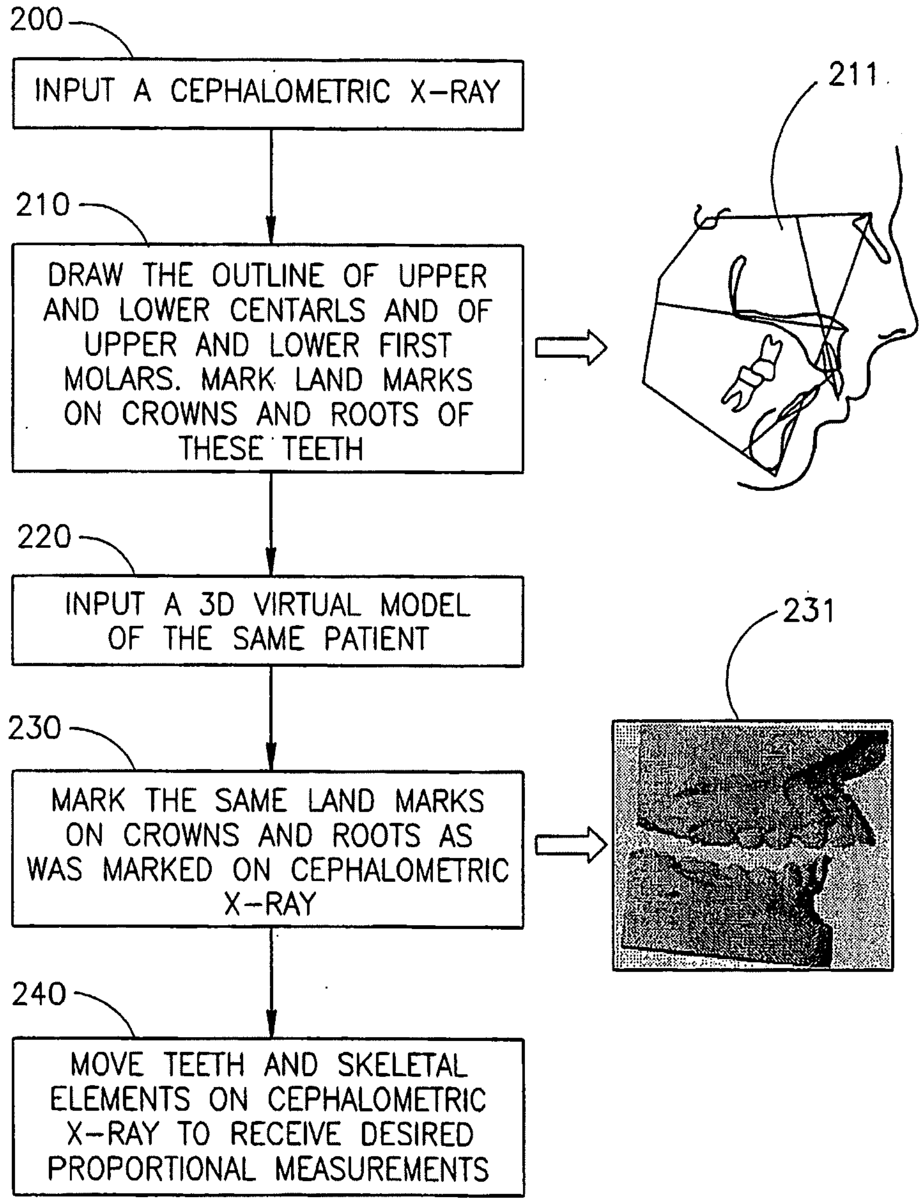

200
INPUT A CEPHALOMETRIC X-RAY
210
DRAW THE OUTLINE OF UPPER AND LOWER CENTARLS AND OF UPPER AND LOWER FIRST MOLARS. MARK LAND MARKS ON CROWNS AND ROOTS OF THESE TEETH
211
220
INPUT A 3D VIRTUAL MODEL OF THE SAME PATIENT
230
MARK THE SAME LAND MARKS ON CROWNS AND ROOTS AS WAS MARKED ON CEPHALOMETRIC X-RAY
231
240
MOVE TEETH AND SKELETAL ELEMENTS ON CEPHALOMETRIC X-RAY TO RECEIVE DESIRED PROPORTIONAL MEASUREMENTS

FIG.8A

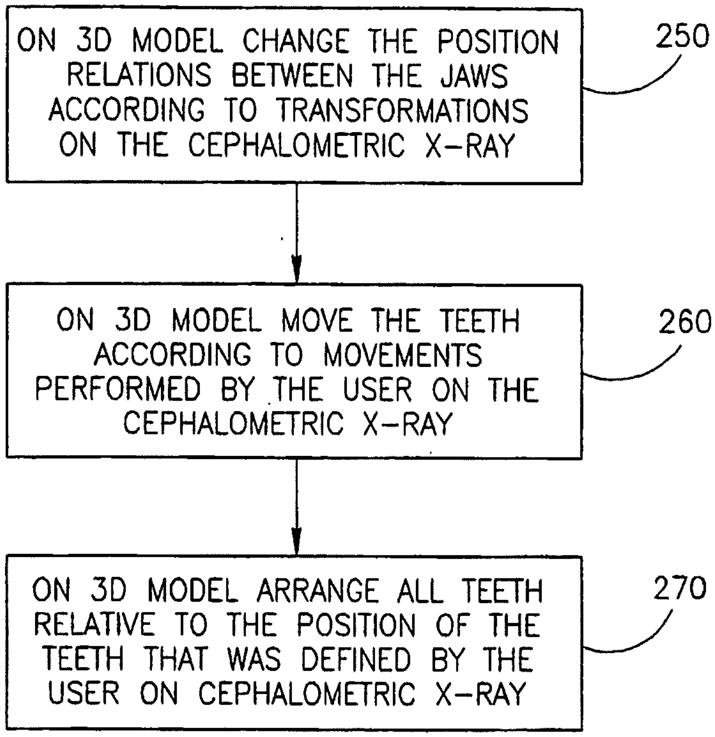

ON 3D MODEL CHANGE THE POSITION RELATIONS BETWEEN THE JAWS ACCORDING TO TRANSFORMATIONS ON THE CEPHALOMETRIC X-RAY
250
ON 3D MODEL MOVE THE TEETH ACCORDING TO MOVEMENTS PERFORMED BY THE USER ON THE CEPHALOMETRIC X-RAY
260
ON 3D MODEL ARRANGE ALL TEETH RELATIVE TO THE POSITION OF THE TEETH THAT WAS DEFINED BY THE USER ON CEPHALOMETRIC X-RAY
270

FIG.8B

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(54) Title: COMPUTER-ASSISTED CREATION OF A CUSTOM TOOTH SET-UP USING FACIAL ANALYSIS

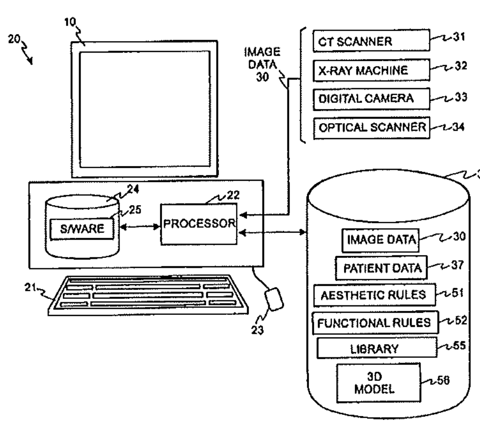

Fig. 1

(57) Abstract: A method for automatic, or semi-automatic, planning of dental treatment for a patient comprises: (a) obtaining data about an area which is to be treated and data about a face of a patient; (b) performing a computer-assisted analysis of the data to determine properties of at least the face of the patient; (c) creating a modified tooth set-up using a set of stored rules which make use of the determined facial properties. A three-dimensional representation simulates the appearance of the modified tooth set-up and the patient's face surrounding the treatment area. The method also determines properties of existing teeth and creates a modified tooth set-up which is also based on the existing teeth of the patient. The method can be implemented as software running on a workstation.

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COMPUTER-ASSISTED CREATION OF A CUSTOM TOOTH SET-UP USING FACIAL ANALYSIS

FIELD OF THE INVENTION

This invention relates generally to the field of computer technology used for the planning of dental treatments and to computer software tools for planning an optimised tooth (and soft tissue) set-up for a patient as well as to systems and methods planning an optimised tooth (and soft tissue) set-up for a patient.

BACKGROUND TO THE INVENTION

For dental or orthodontic treatment one or more imaging modalities such as orthopantograms (dental X-ray), computerized tomography (CT) scans or digital photographs are commonly used to analyze, diagnose and document a patient's condition. Recently, digital patient information has also found its way into the planning stage of treatment. Several software solutions exist for simulating dental implant placement in medical (CT) images (SimPlant™, Materialise Belgium), orthodontic treatment can be simulated using digitized information of the patient's dentition (OrthoCAD, Cadent, U.S.; Invisalign, Align Technologies, U.S.) and maxillofacial reconstructions can be planned in a virtual environment (SimPlant CMF, Materialise, Belgium). While these solutions provide powerful tools to the clinician to try out different alternatives at a functional level, the implications of these alternatives at an aesthetical level are generally far from being clear or in some cases disregarded altogether when choosing the clinical approach.

WO2004/098378 and WO2004/098379 describe a workstation for creating a virtual three-dimensional model of a patient using several imaging sources, such as a CT scan, an X-ray and photographs. Software tools allow a trained user to manipulate the model to simulate changes in the position of teeth, such as through orthodontic treatment. The tools described in these documents can be used to plan treatment, and can present a simulation of the outcome of the treatment to a patient. However, as these tools give the user a considerable degree of freedom in the treatment planning, with many decisions to be made by the user, they still require an experienced user to plan the treatment.

Accordingly, the present invention seeks to provide an improved way of planning dental treatments for a patient.

SUMMARY OF THE INVENTION

An object of the present invention is to provide computer based methods and systems for the planning of dental treatments and computer software tools for planning an optimised tooth (and soft tissue) set-up for a patient.

A first aspect of the present invention provides a method for automatic, or semi-automatic, planning of dental treatment for a patient comprising:

(a) obtaining data about an area which is to be treated and data about a face of a patient;

(b) performing a computer-assisted analysis of the data to determine properties of at least the face of the patient; and,

(c) creating a modified tooth set-up using a set of stored rules which make use of the determined facial properties.

For the purpose of this application the term 'dental treatment' includes, but is not limited to, prosthetic reconstructions on natural teeth (crown and bridgework, veneers), loose prostheses, prosthetic reconstructions supported by implants, corrections of the soft tissue (i.e. the gums of the patient, mucosa and gingival) and orthodontic treatments, i.e. treatments to correct the position of teeth.

The invention recognises that dental treatment needs to be planned in the context of a patient's face, to provide a result which is aesthetically pleasing as well as being clinically correct. The invention also provides a tool for achieving this, by performing a computer-assisted analysis of facial characteristics, and the use of stored rules to create an optimum tooth and soft tissue set-up. This greatly simplifies the process of creating the modified tooth and soft tissue set-up.

Preferably, the method further comprises generating a three-dimensional representation which simulates the appearance of at least the treatment area with the modified tooth set-up. The three-dimensional representation preferably also simulates the appearance of the patient's face surrounding the treatment area. This allows a patient to view, in advance of the treatment, the post-treatment effects of the modified tooth and soft tissue set-up. Preferably, the three-dimensional representation is as life-like as possible by the use of colour and texture on prosthetic teeth used in the modified set-up. The effect of modified tooth set-up on surrounding facial features (e.g. lips) can also be shown using the three-dimensional representation. This will allow a patient to assess the aesthetical outcome of dental treatment either subsequent to or, more ideally, prior to the selection of the type of clinical treatment. For example, a patient may be offered the choice of a treatment with dental implants, a treatment using crown and bridgework and a treatment using a loose prosthesis and each of these treatment options can be visualised. Such an approach is highly advantageous for the patient, who in an early stage is more involved in the decision making process and is better informed about the aesthetical implications of the different alternatives (e.g. grinding down of teeth vs. implant placement to allow anchoring of a bridge; stripping of the teeth vs. tooth extraction to solve crowding along the dental arch etc.).

The functionality of this invention can be implemented in software, hardware or a combination of these. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed processor. Accordingly, another aspect of the invention provides software comprising instructions (code) which, when executed by a computer or processor, implements the method. The software may be tangibly embodied on an electronic memory device, hard disk, optical disk or any other machine-readable storage medium or it may be downloaded to the computer or processor via a network connection.

A further aspect of the invention provides apparatus for performing the method.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 schematically shows a workstation for implementing the present invention;

Figure 2 shows a flow chart of a method according to an embodiment of the present invention;

Figure 3 shows one way of registering a 3D photograph and digitised plaster casts using a face bow;

Figure 4 shows an example of an aesthetical rule in which the width of maxillary incisors should be equal to the width of the nose base;

Figure 5 shows an example of an aesthetical rule in which the distance between eyebrow and nose base should be equal to distance between nose base and top of chin during occlusion;

Figure 6 shows an example of an aesthetical rule in which the occlusal plane or the line connecting the cusps of the maxillar canines should be parallel to the interpupillary line;

Figure7 shows buccal corridors during smiling;

Figure 8 shows an example of a class 1 molar relationship;

Figures 9A-9C show an example of modifying the functional properties of a prosthetic tooth;

Figure 10 shows the reconstruction of missing teeth by means of library teeth;

Figure 11 shows the application of texture to library teeth to give a life-like representation of reconstructed teeth;

Figure 12 shows an alternative view of reconstructed teeth.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. Where the term "comprising" is used in the present description and claims, it does not exclude other elements or steps. Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Figure 1 schematically shows a system for implementing an embodiment of the present invention. The system can take the form of a computer workstation 20, such as a general purpose PC, which has a processor 22 and memory/storage 24 and a display 10. Software 25 to implement the invention is stored in memory 24 and executed by the processor 22. A user can interact with the workstation using a keyboard 21, mouse 23 or another input device such as a graphics tablet or an electronic stylus. Workstation 20 receives inputs from a variety of imaging sources, such as a computerized tomography (CT) scanner 31, a dental X-ray machine 32, a digital camera 33 and an optical scanner 34. Each of the imaging sources 31-34 can be manipulated by a user to acquire the image data, and then send this data to the workstation. Alternatively, one or more of the imaging sources 31-34 can be under the control of the workstation 20, with the workstation 20 automatically controlling operation of those imaging sources to acquire the image data. As an example, the workstation 20 can control the digital camera 33 to acquire a picture from each of three predetermined views with respect to the patient. The acquired image data 30 from each imaging source can be stored in the raw form in which it is acquired, or can be processed to convert it into a form in which it can be more readily combined with image data from other sources. This data (in raw or processed format) can be stored 35 within the workstation 20, or externally of the workstation, such as on an external storage device or server which is networked to the workstation 20. Other data 37 about a patient, such as their medical history, can also be stored 35.

The image data 30 that has been acquired from the imaging sources 31-34 is used to generate a virtual, three-dimensional model 56 which is a life-like representation of at least the area of the human body to be treated. Typically, this area will be the patient's jaw, teeth (if any are remaining) and soft tissue surrounding these parts, such as the gums, lips and skin on the outer surface of the face. The extent of the 3D model can be restricted just to the area to be treated and the soft tissue immediately surrounding this area or it can extend to the entire face and head of the user.

Figure 2 shows a flow chart which outlines the main steps of a method of planning treatment in accordance with an embodiment of the invention. Each of the steps will be described in detail.

Acquiring image data (steps 60, 61, Figure 2)

According to one embodiment of the present invention, the 3D model is created by making 3D measurements of the area to be treated and by converting the measurement data into a digital solid or surface model (for instance, in standard triangulated language [.stl] format). Images from digital 2D or 3D photographs, or from scanned printed photographs, of the same area are then mapped onto this model.
A 3D photograph is taken by an optical device that allows capturing the 3D geometry/shape of the object as well as its texture (and optionally colour). In general the device comprises a laser scanner to measure the 3D geometry/shape and a camera

for imaging the texture. Both the 3D geometry description and the texture are then combined in one 3D image. A 3D photograph can be taken by a fixed camera or by a moving camera. In the latter case a 3D photograph showing all sides (front, left, back, and right side) of the object is created.

The 3D measurement can be performed directly or indirectly on the area to be treated. A direct measurement can take the form of a CT-scan of the patient, or an optical scan of the head of a patient. A CT-scan gives detail about both soft tissue and bone in a 3D co-ordinate system, by providing a stack of 2D images. Based on these 2D images, a 3D model of the bone or face can be reconstructed. An optical scan of the patient's head can give information about the outer shape and surface features of the face and head. In addition, a small optical scanner can be used to scan the intra-oral region.

An indirect measurement can take the form of an optical scan of a physical replica of the area to be treated, such as a plaster cast manufactured from an impression which has been taken of the area to be treated. Measuring techniques can include, but are not limited to, non-contact scanning using: laser, white light or the like; tactile scanning using a measurement probe; and volumetric scanning such as CT, MRI, µCT, etc. The term 'CT' as used here refers to medical CT scanners where the object remains fixed and the source and detector turn around the object, and results in images with pixel size of about 0.25 mm or more. The term 'µCT' refers to non-medical CT scanners where typically the object turns and the source and detector are fixed, and results in images with a typical pixel size 10 to 20 times smaller than that achieved with a CT scan. µCT generally results in more accurate images and can also accurately visualize much smaller details.

Converting the measurement data into a digital model will, depending on the applied measurement technique, involve a series of commonly known data processing techniques such as image segmentation and point cloud meshing. Data derived from different imaging sources (e.g. CT, optical scan...) needs to be combined into a single model. Initially, a separate model is constructed from each image data source (e.g. a model for CT scan data, a model for optical scan data) and the set of individual models is then combined into a single model. One of several known techniques may be used to combine the models:

- the 3D models can be registered onto each other by manually translating and/or rotating one of the 3D models with respect to the other. The models are displayed on display 10 of the workstation 20 and an operator manipulates the models.

- the 3D models are registered onto each other by indicating corresponding points on both 3D models and applying an N-points registration algorithm. Afterwards an automatic optimization of the registration is possible using a registration optimisation program such as a least-squares registration algorithm.
- the 3D models are registered onto each other using a fully automatic registration algorithm based on feature recognition. For example, the registration may be done by a cloud-of-points technique or it may be done by automatically identifying common features in the images.

Such techniques are described, for example, in: P.J. Besl and N.D. McKay, "A method for registration of 3-d shapes", IEEE Trans. Pat. Anal. And Mach. Intel 14(2), pp 239-256, Feb 1992; R. San-Jose, A. Brun and C.-F. Westin, "Robust generalized total least squares iterative closest point registration", in C. Barillot, D.R. Haynor, and P.Hellier (Eds.): MICCAI 2004, LNCS 3216, pp. 234-241, 2004; A. Gruen and D. Akca, "Least squares 3D surface and curve matching", ISPRS Journal of Photogrammetry and Remote Sensing 59(3), pp 151-174, May 2005.

Photographs (2D or 3D) can be scaled to a required dimension using one of several techniques:

- a calibration piece, i.e. a piece with exactly known geometric dimensions, can be added in the field of view of the camera while taking photographic images of the patient. This allows exact scaling of the photographs afterwards.
- measurements can be performed on photographs and 3D models by using anatomical reference distances (e.g. interpupillary distance...) to determine the scale factor for the photographs.
- The scaling can be done automatically by automatically detecting reference points or features in the images and scaling these to match each other.

For mapping of the 2D or 3D photographs onto the digital model one of several techniques may be used when photographs and digital models contain identical surfaces (e.g. teeth visible in photograph, facial skin...):

- Manual registration: The photograph is aligned with the digitized treatment area. The photograph can be scaled and translated. The 3D representation of the treatment area can be rotated. The user rotates the representation to adapt its orientation to match the angle under which the photograph was made. The size of the photograph is adjusted and the image is translated until it is aligned with the view on the 3D representation. The steps are repeated to tune the registration.

- Semi-automatic registration: The user rotates the representation to adapt its orientation to match the angle under which the photograph was taken. Photograph and 3D representation are shown side-by-side. Reference points are indicated on both to mark corresponding features. A final mapping is performed either by: a least-squares algorithm/n-point registration/ICP (Iterative Closest Point) registration, which will find the optimal transformation necessary to align both sets of points; or by an exact matching at the location of the reference points and minimal deformations in between, using an RBF (radial base functions) optimization approach.
- Automatic registration: Registration applying feature recognition.

In a case where no identical surfaces are available (e.g. mapping of 2D or 3D photograph of edentulous patient onto digitized 3D models of the maxillar and mandibular plaster casts) the above-mentioned registration techniques cannot be used. In these cases a preferential approach makes use of face bow measurements to map the different data sets. Referring to Figure 3, a face bow is a mechanical device used in dentistry to record the positional relations of the maxillary arch to the temporomandibular joints, and to orient dental casts in this same relationship to the opening axis of the mechanical articulator. A face bow consists of two metal parts attached together. The first part 3, called the bite fork, is shaped like a horseshoe and is inserted in the mouth of the patient and clamped between upper and lower jaw. The second part comprises two curved elements 1, 9. The ends 8 of the first curved element 1 are positioned in the ear channels of the patient. The second curved element 9 forms a nasal guide that is put in contact with the nose of the patient. The bite fork 3 is fixed to the second curved element 9. The current position of all parts of the face bow is maintained and then used to transfer the plaster cast into the corresponding mechanical articulator. This implies that the face bow used for transfer of the occlusion from the patient's mouth to the mechanical articulator is now virtually created and positioned onto the 3D photograph of the patient (Figure 3). The bite registration 3 is also digitized and used to register the digital 3D models of the patient's jaws in the same coordinate system as the 3D photograph. In case of 2D photographs, a virtual face bow cannot be used and a preferential method in this case is using the default values (as used in a mechanical articulator) to position the 3D models of the patient's jaws in correct relation to the intercondylar axis, which can be defined onto the 2D photograph of the patient's face.

As an alternative to the above described method, a three-dimensional model of the area to be treated can be built directly from a 2D video sequence, such as by matching objects and features appearing in images which have been acquired from different viewpoints. Since the video data inherently holds information that can be related to more than mere spatial coordinates of the captured points, but also to color, texture, etc. the calculated reconstruction can be made to reflect each of these qualities, thereby achieving a life-like model.

The composite 3D model created at step 61 should preferably include the face of the patient to allow facial analysis to be based on the model. The 3D model used to plan a modified tooth set-up does not have to be life-like, but this information is useful to visualize to the user and patient the effects of the treatment and can be rendered in the final stage 66 of the method when a virtual representation of the tooth set-up following treatment is displayed to a user and a patient.

Facial analysis (steps 62, 63, Figure 2)

According to one embodiment of the invention the 3D model of the patient, which has been created in one of the ways described above, is analysed to determine information about the aesthetical appearance of the face and/or of the area to be treated. This analysis can be fully automatic, or semi-automatic. In a semi-automatic analysis, the computer program prompts the user to indicate certain anatomical points and/or lines on the face of the patient, which are needed for the facial analysis. The user marks these points on the graphical representation of the face by using an input tool such as a mouse 23, keyboard 21, graphics tablet, electronic stylus etc. The program then performs facial analysis based on measurements between these marked points and automatically creates or modifies the tooth set-up as described below. The following table, and Figures 4-6, show some example anatomical points which the program can prompt a user to mark. Even in the semi-automatic embodiment, the program can be arranged to automatically determine some of the facial features without any user prompting and input such as, for example, the overall shape of a patient's face (rule A) and the interpupillary line (rule D).

A set of general aesthetical rules use the results of the facial analysis to create an aesthetically optimal dental configuration or tooth set-up, based on the particular characteristics of the patient's face. The following table gives a non-exhaustive list of fourteen possible facial analyses and corresponding rules:

	Aesthetical analysis	**Aesthetical rule**
A	Determine the shape of the patient's face and, if available, the patient's teeth. Three main facial shapes exist: (i) rectangular or square shaped. A rectangular or square shaped face has substantially the same width at the forehead and just below the cheekbones; (ii) tapered. A tapered face is wide at the forehead and narrows to a small delicate chin; (iii) oval. An oval face is slightly wider at the cheekbones than at the forehead or jaw-line. Teeth are classified in three different shapes: tapered, ovoid, and square-shaped. If a patient has any remaining teeth, the shape of the teeth can be determined based on the digitized information of the patient's remaining dentition.	The optimal tooth shape is selected according to the following rules: (1) In partially edentulous cases (i.e. the patient has some teeth remaining) the tooth shape is determined based on the shape of the remaining natural teeth and/or the shape of the patient's face. (2) In edentulous cases the tooth shape is chosen based solely on the analysis of the shape of the patient's face. A rectangular or square shaped face corresponds with square-shaped teeth. A tapered face corresponds with tapered-shaped teeth. An oval face corresponds with ovoid-shaped teeth.

	Aesthetical analysis	Aesthetical rule
B	Determine the width of the nose base (see 4, Figure 4).	Design or reshape the four maxillar incisors so that their total width (5, Figure 4) is approximately equal to the width of the nose base (Gerber).
C	Determine the distance between eyebrow and nose base (see Figure 5).	Position the occlusal plane relative to the patient's face so that the distance between the nose base and the top of the chin during occlusion is equal to said distance between eyebrow and nose base.
D	Determine the interpupillary line, i.e. the line connecting the centre of the eyes (6, Figure 6).	Reconstruct or correct the teeth so that the occlusal plane or the line connecting the cusps of the maxillar canines (7, Figure 6) is parallel to said interpupillary line.
E	Determine the symmetry line of the face, i.e. the line from the centre of the forehead along the subnasal point to the centre point of the chin.	Angulate or reorient the frontal maxillar incisors so that their facial axis is parallel to said symmetry line and position the central incisors so that their contact point lies on said symmetry line.
F	Determine the nasio-labial angle, i.e. the angle between the columella of the nose and the anterior surface of the upper lip measured in a sagittal (lateral) view of the patient's face.	Reconstruct or correct the maxillar incisors so that the nasio-labial angle is approximately 90°. Therefore a soft tissue simulation is needed to predict the tooth position for the upper lip position, more particular with a nasio-labial angle of 90°.

	Aesthetical analysis	Aesthetical rule
G	Determine in a sagittal (lateral) view of the patient's face the distance of the upper and lower lip to the line through the tip of the nose and the chin.	Reconstruct or correct the teeth so that the distance of upper lip to said line is 4 mm and the distance of lower lip to said line is 2 mm.
H	Determine the position of the upper lip while smiling.	Position or correct the frontal maxillar teeth so that only one quarter of their height is covered by the upper lip while smiling. For some patients the smile-line, i.e. the borderline of the upper lip during normal smiling, is much higher than ideally, and the upper gum is exposed. In these cases a gingival correction is needed to allow implant placement in the frontal maxilla. Without gingival correction pink porcelain will be needed in the prosthetic reconstruction and this is not compatible with the necessary interdental spaces for cleaning purposes of the implants.
I	Determine the curve formed by the lower lip while smiling	Position or correct the frontal maxillar teeth so that their incisal edge is parallel to said curve and just touching the lower lip or showing a slight gap.

	Aesthetical analysis	Aesthetical rule
J	Determine the buccal corridor, i.e. the small space visible between the angles of the mouth and the teeth, during smiling (12, Figure 7).	Determine or adapt the maxillar dental arch shape as well as the orientation of maxillar premolars and molars to obtain a normal size of said buccal corridor. A too wide dental arch will result in no buccal corridor while a too small dental arch will result in a buccal corridor that is too prominent.
K	Determine the width to height ratio of the maxillar central incisors.	Adapt the maxillar central incisors if needed to approximate the ideal value of 80% for the width to height ratio.
L	Determine the proportion of maxillar central incisor width to lateral incisor width to canine width.	Adapt maxillar incisors and canines if needed to obtain the ideal width proportion of 1.6, 1, and 0.6 respectively.
M	Determine the position of the upper lip during talking.	Adapt the position or size of the maxillar incisors to obtain a visibility of approximately 1.5 mm of said teeth during talking.
N	Determine the overjet of the teeth in a sagittal (lateral) view.	Incline or adapt the inclination of the frontal teeth to obtain an overjet value used in common practice, i.e. 2 mm.

The analyses listed above fall into the broad categories of: aesthetic characteristics of the patient's face, including measurements between facial features (A-G); aesthetic characteristics of the face which may be determined by the underlying jaw and teeth (H, I, J, M) and aesthetic characteristics of the patient's teeth (K, L, N). The analysis of aesthetic features can be performed on the virtual model 56 of the patient, or on some of the image data 30 of the patient, such as photographs of the patient's face and teeth.

<u>Functional analysis (steps 64, 65, Figure 2)</u>

In addition to making an analysis of the aesthetic properties of the patient, the analysis can be extended to include a computer-assisted analysis of more 'functional' characteristics of a patient. Functional information resulting from this analysis can be used in a set of functional rules which can adapt the dental configuration derived at step 63, Figure 2. Alternatively, the dental configuration may be directly based on a combined set of aesthetic and functional rules which make use of both the aesthetic and functional information.

The following table gives a non-exhaustive list of functional analyses and corresponding rules:

Functional analysis	**Functional rule**
Determine class (I, II, or III) of molar relationship. (i) Class I malocclusion refers to a malocclusion in which the buccal groove of the mandibular first permanent molar occludes with the mesiobuccal cusp of the maxillary first permanent molar. (ii) Class II malocclusion refers to a malocclusion in which the buccal groove of the mandibular first permanent molar occludes posterior (distal) to the mesiobuccal cusp of the maxillary first permanent molar. (iii) Class III malocclusion refers to a malocclusion in which the buccal groove of the mandibular first permanent molar occludes anterior (mesial) to the mesiobuccal cusp of the maxillary first permanent molar.	Ideally, a class I molar relationship (Figure 8) should be created. But, if a patient has, for instance, class II/III molar relationships at the left side, then the right side can be reconstructed mimicking the class II/III molar relationships.

Functional analysis	Functional rule
Determine crown angulation of remaining teeth.	Mimic crown angulation of remaining teeth in prosthetic reconstruction. If no remaining teeth, use average values for the angulation of the crowns.
Determine crown inclination of remaining teeth	Mimic crown inclination of remaining teeth in prosthetic reconstruction. If no remaining teeth, use average values for the inclination of the crowns.
Determine dental arch for upper and lower jaw based on remaining teeth or for edentulous cases based on average curves and the jaw information (Staub...).	Align crowns tangent to determined dental arch.
Determine midline of dental arches (upper and lower).	Adapt dental arches until these midlines match.
Determine contact between neighboring teeth.	Mimic contact of remaining teeth. If edentulous position crowns in tight contact to neighbors.
Determine contact points during movement of the jaws.	Adapt occlusal surfaces of the crowns to obtain an ideal articulation.
Determine overjet.	Adapt tooth position or reconstruct crown to obtain optimal value of 2 mm.
Determine overbite.	Adapt tooth position or reconstruct crown to obtain optimal value of 2 mm.

Functional analysis is not limited to optimal tooth contacts but can in a broader sense include phonetics and biomechanics (e.g. optimal tooth loading).

The computer-assisted functional analysis can include identification of ideal tooth contact points and can be performed by means of digitized information of static and dynamic check bites of the individual patient or by means of a virtual articulator. An articulator is a mechanical instrument which is used to examine the static and dynamic contact relationships between the occlusal surfaces of both dental arches. It represents the human temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached in order to simulate some or all mandibular movements. Different settings regarding the jaw morphology and mandibular movement can be adjusted on an articulator. Those values are set using patient-specific data or average values known in literature. A virtual articulator establishes the static and dynamic contact relationships in a virtual environment. It simulates forward, backward, left lateral, right lateral, opening and closing mandibular movements as constrained by the geometric restrictions imposed by settings using patient-specific data or average values known in literature. Moreover, a virtual articulator calculates and visualizes the resulting occlusal contacts. Alternatively jaw movement and occlusal contacts can be recorded and provided as a 3D path relative to known landmarks on the patient.

Figures 9A-9C illustrate one example of how the functional characteristics of a set-up are determined and modified. Figure 9A shows a proposed tooth set-up resulting from facial analysis and application of the aesthetic rules. This has resulted in a prosthetic tooth 16 being inserted into a modified set-up. Initially the tooth 16 has a default shape and surface features, such as the default properties of an element in the library 55 of elements. In Figure 9B the occlusal surface of the new tooth 16 is analysed with respect to antagonists (e.g. the teeth shown directly above tooth 16). As a result of the analysis, the outer surface of the tooth 16 is modified to present a better occlusal surface. Figure 9C shows the result of the optimization.

Each of the functional and aesthetical rules can be assigned a weighting factor to more, or less, profoundly influence their impact on the final dentition. Each weighting factor can have a value based on past experience. Alternatively, each weighting factor can be adjusted by the team treating the patient, in accordance with their expertise on a case-by-case basis. The following is a practical example of how the weighting factors can be used. Suppose a tooth set-up must be created for a patient missing the four maxillar incisors and both canines. Aesthetical rule L predicts the ideal proportion for the widths of the missing teeth. Aesthetical rule B predicts the total width of the four maxillar incisors based on the width of the nose base of the patient. If the patient has a very small nose then rule L should be determining for the final width of the teeth, so rule L must have a higher weighting factor than rule B. This will result in a normal proportional width of the missing teeth in between the remaining maxillary first premolars. If, in this case, rule L would have been given a much lower weighting factor than rule B, then very small maxillar incisors would be created in combination with very thick canines to be able to fill the gap in between the remaining maxillary first premolars. So the ideal proportion would not be respected and would result in a less aesthetical outcome.

The process of generating an optimal tooth (and soft tissue) set-up can be achieved in different ways:

- a tooth (and soft tissue) set-up can be optimized with respect to all, or only some, aesthetical rules in an iterative process;
- a tooth (and soft tissue) set-up can be determined as the weighted average of all, or some, aesthetical rules with weighting factors representing, for example, the importance of the aesthetical rules to achieving an optimal set-up;
- a tooth (and soft tissue) set-up can be determined using a first sub-set of rules and then optimized using a second sub-set of the rules.

Where a patient has a partial set of teeth, the invention can generate an optimal dental configuration which virtually models replacement teeth in the places where the patient is currently missing teeth. The replacement teeth are selected in accordance with the aesthetic and functional rules. Figure 10 shows an example where a group of six prosthetic teeth 14 have been inserted into a model of a patient's jaw.

Additionally, it may be desirable to reposition some of the patient's existing teeth. This can also be modelled, and the results of the repositioning can be displayed to the patient. A library 55 stores individual teeth (of varying type, shape and size) and complete or partial set-ups, for use with patients who are fully or partially edentulous. Each of the library set-ups can be adapted in accordance with the aesthetic (and functional) rules, or the software may select the best of the library set-ups based on the aesthetic (and functional) rules. The digital library 55 of elements can have a default set of predefined properties such as colour, texture etc. to give them a life-like appearance. Alternatively, such information may be mapped onto a 'plain' element to obtain a desired life-like appearance. A selection of options can, for example, be presented to a user in the form of a menu offering a palette of colours and textures. Figure 11 shows the model of Figure 10 following the application of colour and texture to library elements 14 and Figure 12 shows another life-like representation of a treatment area with prosthetic teeth to which colour and texture have been applied.

The virtual modeling may be performed by user interaction in the digital environment. Software 25 executed by the workstation creates a graphical user interface on display 10 which allows a user to make select, introduce, position, reposition or modify individual teeth or groups of teeth in an automatic or semi-automatic manner. The software can include routines which automatically position teeth along a predefined arch, or routines for automatically positioning teeth in function of occlusion relative to the antagonist dentition. Alternatives for orthodontic cases are tooth extraction, widening of the jaw and stripping (i.e. reducing the width) of teeth. The occlusal surface of already positioned teeth may also be modified using the software tools.

Virtual representation of treatment area, post-treatment (step 66, Figure 2)

The final step of the method displays a virtual representation of the treatment area, displaying the effect of the optimal tooth (and soft tissue) set-up. It is likely that there will be a range of possible treatment options. As an example, for dental restorations alternative treatment options can include different tooth morphologies, sizes and colours. Each of the treatment options can be presented to a user and a patient and the patient will be able to view the aesthetic results of the treatment. In a particular embodiment, the virtual representation can be modified to simulate different facial expressions, such as smiling. Step 66 can use the same 3D model as was created at step 61, Figure 2, and updated to include the treatment work determined at step 65, Figure 2. The modified tooth set-up determined at step 65 can be used to update a life-like representation of the area to be treated. The update consists of spatially matching the life-like representation of the treatment area and the modified tooth set-up and visualizing them simultaneously on a display 10. Spatially matching refers to registering both entities. For instance when only a 2D photograph of the patient is available then the optimal tooth set-up should be positioned, oriented, and scaled relative to the 2D photograph and then embedded within the photograph to visualize the result. Alternatively, elements (for example, teeth) may be removed from the 3D life-like representation of the treatment area and replaced by corresponding counterparts in the generated set-up. Updating the life-like representation implies calculating the effect of the generated optimal tooth (and soft tissue) set-up on the position, inclination and/or deformation of the entire or local regions of the treatment area. The treatment area is modified accordingly. One example pertains to the way in which the lips are supported by the teeth. Modifying the inclination of the teeth will also change the position of the lips.

In a further embodiment of invention the computer assisted facial analysis can result in quantitative and qualitative (textual) guidelines, which are subsequently used by a dental technician to create the optimal tooth set-up manually. Afterwards, the created tooth set-up (wax-up) can be scanned and converted to a 3D model so a composite 3D image representation can be created to show the effect of the new set-up on the patient's face.

Illustrative examples

Example 1

A 3D photograph, or a set of 2D photographs, are taken of the face (while smiling) of a patient needing orthodontic treatment. Also, impressions of the patient's dentition are taken in alginate or silicon material. Using these impressions, plaster models of the intra-oral anatomy of the patient are manufactured. The plaster models are subsequently digitized using an optical scanner in order to yield a virtual 3D model that represents the dentition of the patient prior to treatment. In software, the virtual 3D model of the patient's dentition is registered onto the 3D photograph of the patient's face to create a life-like representation. The plaster casts contain the information of the gums and the 3D photograph contains the surface information of the patient's face. Computer-assisted facial and functional analyses are performed and the results of these analyses are used in a set of rules to establish an optimum dentition for the patient. Adapting position, inclination, and angulation of the patient's natural teeth in accordance to the rules creates the optimal tooth set-up. If necessary, natural teeth presently sited in the patient's jaw can be extracted virtually to obtain an optimized diagnostic tooth set-up. Finally the optimal tooth set-up is visualized together with the patient's 3D photograph.

Example 2

A 2D photograph, a CT scan and impressions are taken of a partially edentulous patient needing a prosthetic reconstruction. A virtual, life-like, representation of the patient is created by mapping the 2D photograph onto the 3D soft tissue model of the patient's face generated from the CT images and registering the 3D models of the patient's dentition generated from μCT images of the impressions with the CT images of the patient's face. Replacement teeth are selected for the sites where the patient is currently missing teeth. The replacement teeth are selected by performing the facial/aesthetic analysis and following the aesthetical and functional rules, so as to match the shape of the remaining dentition of the patient. The software can select the replacement teeth automatically from a library of teeth, and place these in the virtual model of the patient's mouth, or the software can suggest a selection of suitable teeth on the basis of the aesthetical information and the rules. A user can then use their judgement to select the best replacement teeth from those suggested by the software, and place these within the virtual model of the jaw. Then, the occlusal surfaces of these library teeth are functionally optimized based on the functional rules and the results of the computer-assisted functional analysis.

Example 3

A 3D photograph and impressions are taken of a fully edentulous patient. Scanning these impressions via μCT and performing image processing (segmentation, 3D model creation, surface inversion etc.) yields a digital representation of the intra-oral anatomy of the patient. Positioning the virtual 3D models of the patient's edentulous jaws relative to the 3D photograph using face bow measurements creates the virtual, life-like, representation. Then, an initial tooth set-up is created from library teeth by using statistical information (e.g. Staub pentagram, average shape of dental arch) as well as rules established by the computer assisted facial analysis. A computer-assisted functional analysis is performed for this initial diagnostic set-up taking into account patient specific parameters for setting the virtual articulator. The occlusal surfaces of these library teeth are optimized functionally to obtain optimal occlusion and articulation. The optimization process is iterated until the best compromise is found between functional and aesthetical considerations.

The invention is not limited to the embodiments described herein, which may be modified or varied without departing from the scope of the invention.

CLAIMS

1. A method for automatic, or semi-automatic, planning of dental treatment for a patient comprising:

(a) obtaining data about an area which is to be treated and data about a face of a patient;

(b) performing a computer-assisted analysis of the data to determine properties of at least the face of the patient;

(c) creating a modified tooth set-up using a set of stored rules which make use of the determined facial properties.

2. A method according to claim 1 further comprising generating a three-dimensional representation which simulates the appearance of at least the treatment area with the modified tooth set-up.

3. A method according to claim 2 wherein the step of generating a three-dimensional representation also simulates the appearance of the patient's face surrounding the treatment area.

4. A method according to any one of the preceding claims wherein the step (b) of performing a computer-assisted analysis of the data also determines properties of existing teeth and step (c) creates a modified tooth set-up using a set of rules which make use of the determined facial properties and the existing teeth of the patient.

5. A method according to any one of the preceding claims wherein step (c) comprises generating a three-dimensional model of the area to be treated from the obtained data and creating a modified tooth set-up on the model.

6. A method according to any one of the preceding claims wherein the step of performing a computer-assisted analysis of the data comprises prompting a user to indicate the position of anatomical points on a two-dimensional or three-dimensional representation of the face of the patient and automatically determining facial properties based on inputs received from a user.

7. A method according to any one of the preceding claims wherein the analysis at step (b) comprises determining a shape of the patient's face and step (c) comprises selecting a shape of prosthetic teeth on the basis of the determined shape.

8. A method according to any one of the preceding claims wherein the analysis at step (b) comprises determining distance between features of the patient's face or an alignment of features of the patient's face and step (c) comprises modifying the tooth set-up based on the determined distance or alignment.

9. A method according to claim 8 wherein the analysis at step (b) comprises determining the interpupillary line and step (c) comprises reconstructing teeth, or correcting the position of the teeth, so that the occlusal plane or the line connecting the cusps of the maxillar canines is parallel to the determined interpupillary line.

10. A method according to any one of the preceding claims wherein the analysis at step (b) comprises determining the position of the patient's lip and step (c) comprises modifying the tooth set-up based on the determined position.

11. A method according to claim 10 wherein the facial analysis at step (b) comprises determining the position of the upper lip while smiling and step (c) comprises positioning the frontal maxillar teeth so that only one quarter of their height is covered by the upper lip while smiling.

12. A method according to any one of the preceding claims further comprising determining functional data of the area to be treated or the modified set-up and step (c) uses the functional data.

13. A method according to claim 12 wherein the functional data concerns the occlusion or articulation of the area to be treated or the modified tooth set-up.

14. A method according to claim 13 wherein the step of determining functional data comprises determining optimum tooth contact points and step (c) comprises

modifying the tooth set-up to optimise the tooth contact points.

15. A method according to claim 14 wherein the data obtained at step (a) is used to generate a three-dimensional model of the patient and the determination of tooth contact points uses the model.

16. A method according to any one of the preceding claims wherein the data obtained at step (a) is used to generate a three-dimensional model of the patient and the facial analysis of step (b) uses the model.

17. A method according to any one of the preceding claims wherein the set of rules used in step (c) are weighted.

18. A method according to claim 17 wherein the set of rules used in step (c) are weighted according to their relative importance for optimizing the tooth set-up.

19. A method according to any one of the preceding claims wherein the data about a face of a patient comprises one or more of: a 2D photograph; a 3D photograph; an optical scan of the external surface of at least part of the patient's head.

20. A method according to any one of the preceding claims wherein the data about an area to be treated comprises data acquired using a plurality of different imaging techniques.

21. A method according to claim 20 wherein the imaging techniques comprise: a 2D photograph; a 3D photograph; an intra-oral optical scan; an X-ray; a computed tomography scan.

22. A method according to claim 20 or 21 wherein step (c) comprises correlating the data acquired using different imaging techniques to generate a three-dimensional model of the patient's jaw and existing teeth.

23. A method according to any one of the preceding claims wherein step (c) further

comprises allowing a user to manipulate the modified tooth set-up via a graphical user interface.

24. A method according to claim 23 wherein step (c) further comprises accessing a library of elements and using the library to create the modified tooth set-up.

25. A computer program product comprising code which, when executed by a processor, performs the method according to any one of the preceding claims.

26. Apparatus for automatic, or semi-automatic, planning of dental treatment for a patient, the apparatus comprising:

an input for receiving data about an area which is to be treated and data about a face of a patient; and

a processor which is arranged to:

perform a computer-assisted analysis of the data to determine properties of at least the face of the patient;

create a modified tooth set-up using a set of stored rules which make use of the determined facial properties.

27. Apparatus according to claim 26 wherein the processor is further arranged to generate a three-dimensional representation which simulates the appearance of at least the treatment area with the modified tooth set-up.

28. Apparatus according to claim 27 wherein the processor is further arranged to generate a three-dimensional representation which also simulates the appearance of the patient's face surrounding the treatment area.

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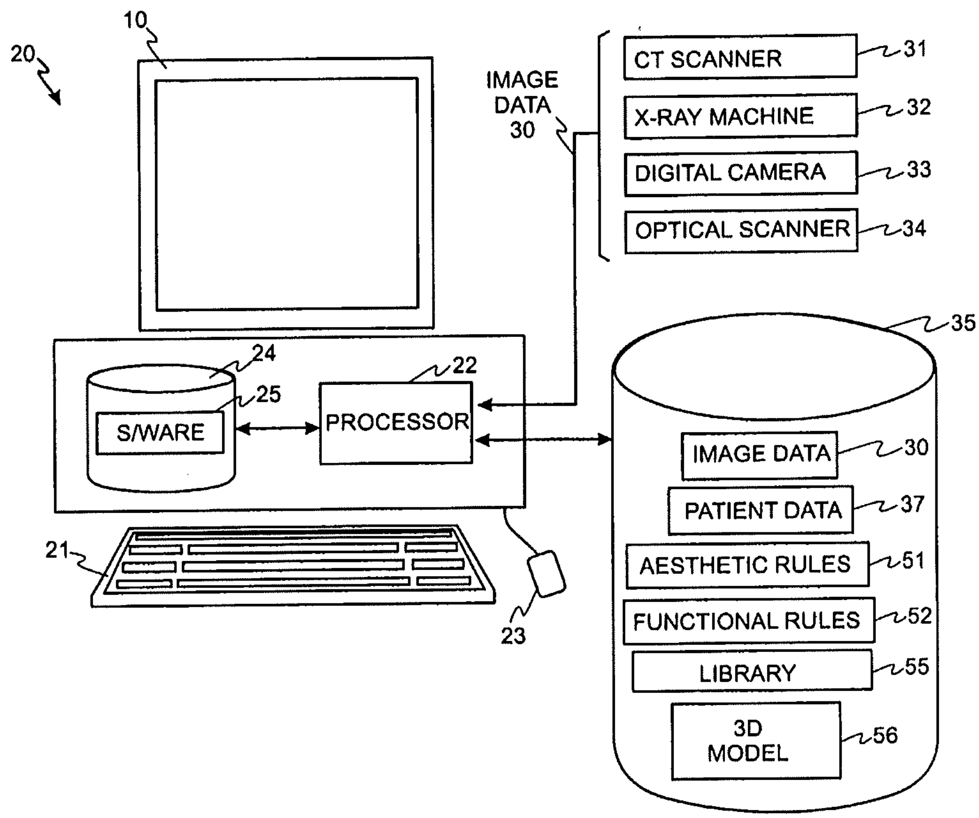
10
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IMAGE
DATA
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X-RAY MACHINE
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OPTICAL SCANNER
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PROCESSOR
IMAGE DATA
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PATIENT DATA
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AESTHETIC RULES
51
FUNCTIONAL RULES
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LIBRARY
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3D
MODEL
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Fig. 1

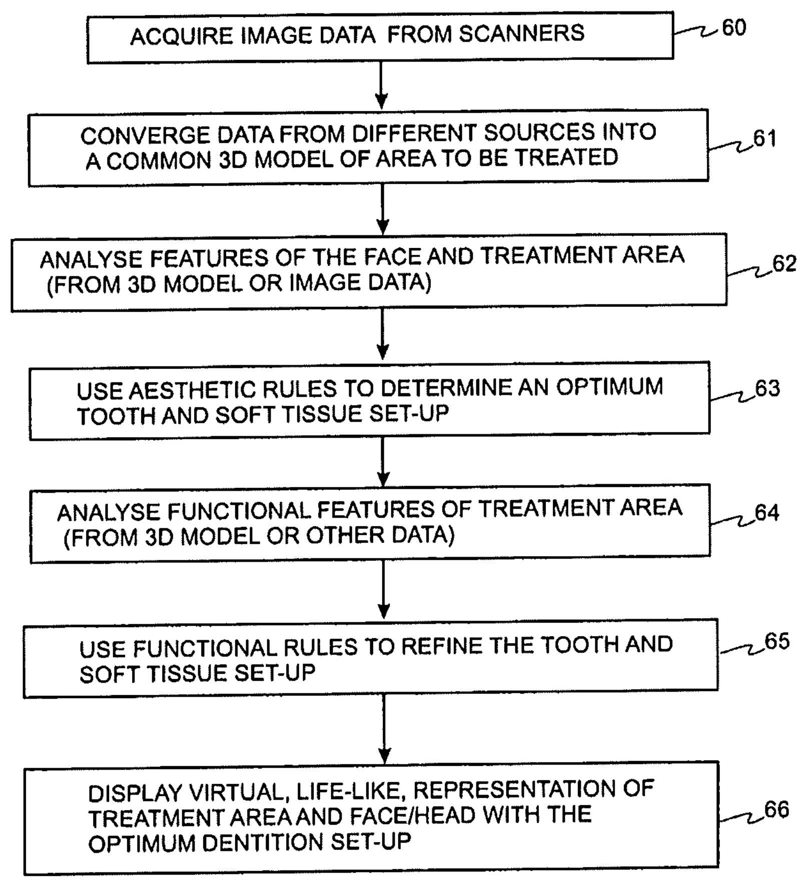
ACQUIRE IMAGE DATA FROM SCANNERS
60
CONVERGE DATA FROM DIFFERENT SOURCES INTO A COMMON 3D MODEL OF AREA TO BE TREATED
61
ANALYSE FEATURES OF THE FACE AND TREATMENT AREA (FROM 3D MODEL OR IMAGE DATA)
62
USE AESTHETIC RULES TO DETERMINE AN OPTIMUM TOOTH AND SOFT TISSUE SET-UP
63
ANALYSE FUNCTIONAL FEATURES OF TREATMENT AREA (FROM 3D MODEL OR OTHER DATA)
64
USE FUNCTIONAL RULES TO REFINE THE TOOTH AND SOFT TISSUE SET-UP
65
DISPLAY VIRTUAL, LIFE-LIKE, REPRESENTATION OF TREATMENT AREA AND FACE/HEAD WITH THE OPTIMUM DENTITION SET-UP
66

Fig. 2

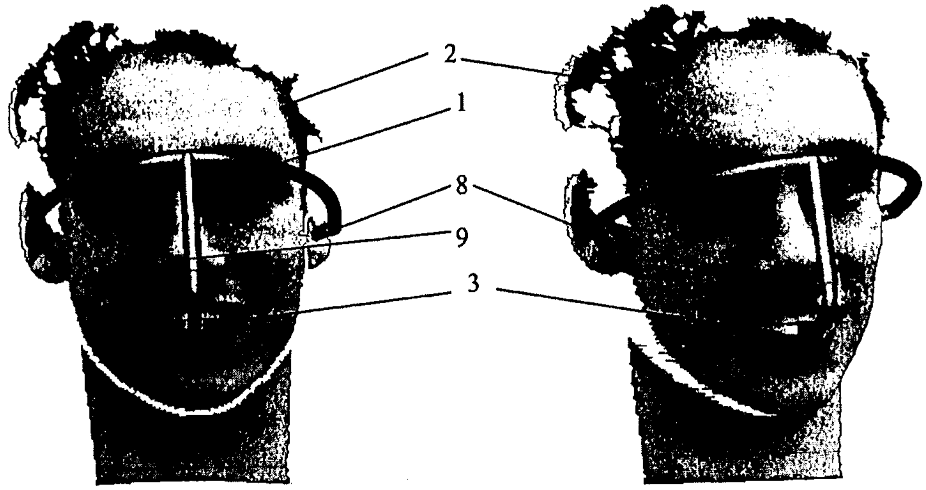

Fig. 3

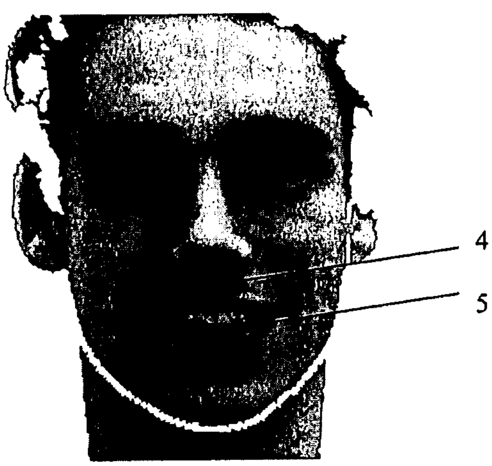

Fig. 4

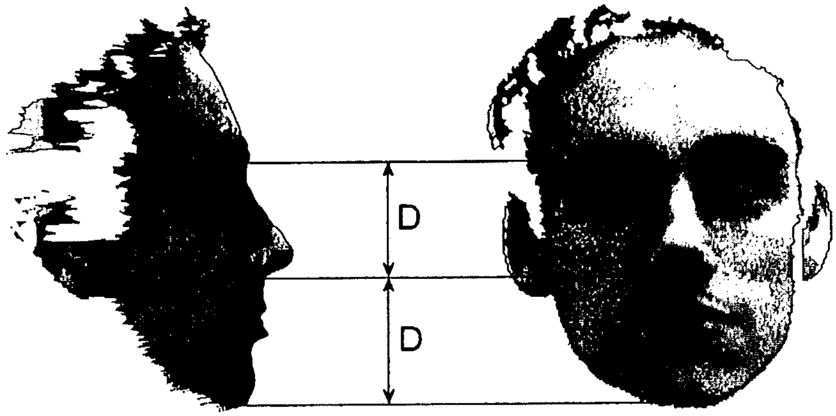

Fig. 5

Fig. 6

Fig. 7

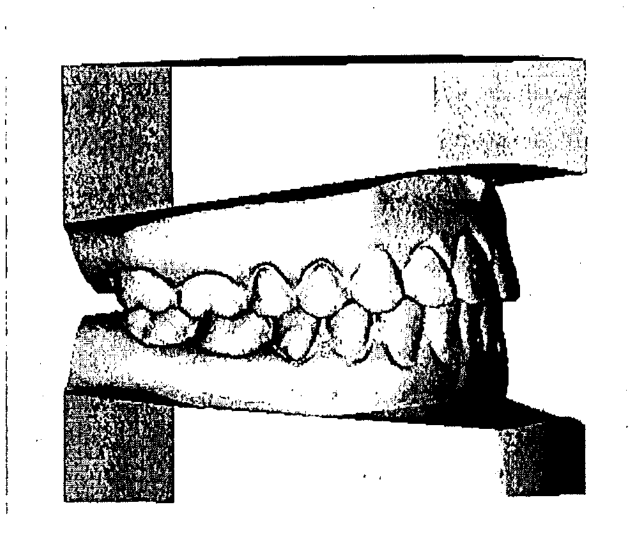

Fig. 8

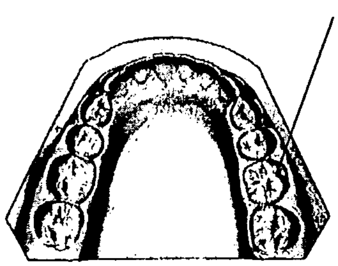

Fig. 9A

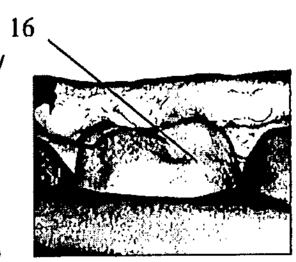

Fig. 9B

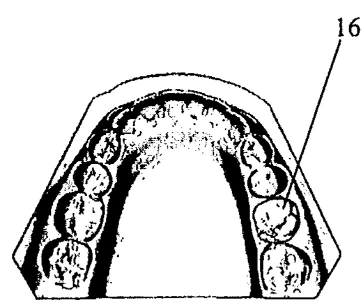

Fig. 9C

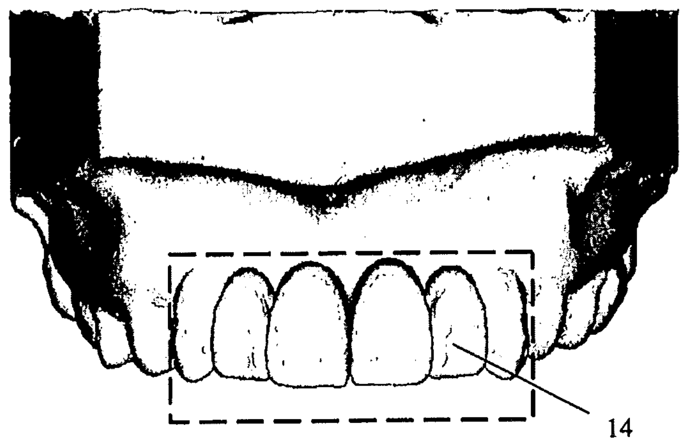

Fig. 10

Fig. 11

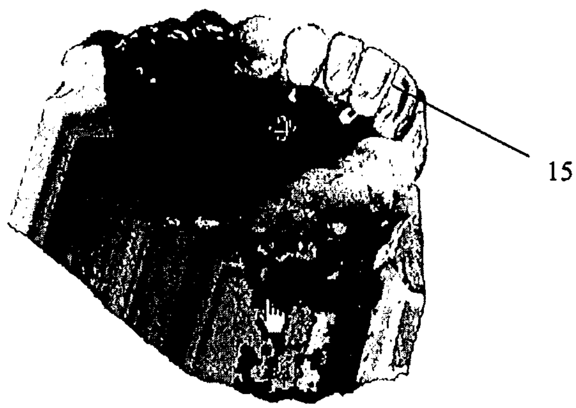

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/003072

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61C13/00 A61C19/00 A61B5/00 A61B19/00 G06T7/00
G06T7/60 G06T17/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61C A61B G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/000063 A (MEDICIM NV) 5 January 2006 (2006-01-05)	1-8, 12-23, 25-28
Y	paragraph [0002] - paragraph [0004] paragraph [0012] - paragraph [0014] paragraph [0016] paragraph [0021] - paragraph [0022] paragraph [0039] paragraph [0042] paragraph [0054] - paragraph [0055] paragraph [0058] claims 1,5,11-14,16; figures 7,11-15 ----- -/--	9-11,24

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2008	11/08/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Raybould, Bruce

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/003072

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/098378 A (ORAMETRIX INC) 18 November 2004 (2004-11-18) cited in the application page 22, line 23 - page 23, line 4 page 29, line 25 - line 29 page 35, line 14 - page 36, line 12 page 36, line 28 - line 30	9-11,24

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/003072

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 2006000063	A	05-01-2006	BR	PI0511379	A	04-12-2007
			CN	1998022	A	11-07-2007
			EP	1759353	A1	07-03-2007
			JP	2008503280	T	07-02-2008
			US	2007197902	A1	23-08-2007
WO 2004098378	A	18-11-2004	EP	1624823	A2	15-02-2006

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(74) **Agents: BIEBER, James, B.** et al.; Dentsply International Inc., 570, West College Avenue, P.o. Box 872, York, PA 17405-0872 (US).

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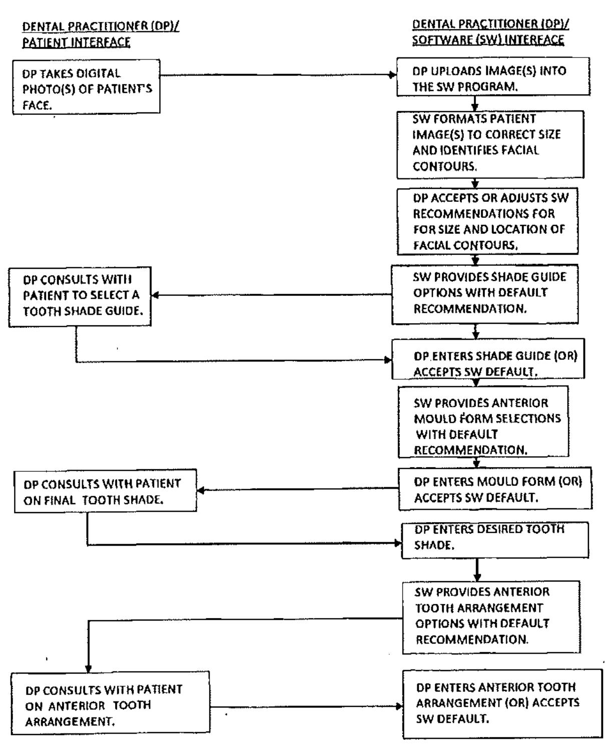
[Continued on next page]

(54) **Title:** METHODS FOR DESIGNING A CUSTOMIZED DENTAL PROSTHESIS USING DIGITAL IMAGES OF A PATIENT

FIGURE 1



(57) **Abstract**: Methods and systems for producing customized dental restoration and prosthesis, particularly denture prescriptions using a computer software program are provided. In this system, digital photographs of the patient to be fitted with the denture are taken, and the photographs are transferred to the software program. Based on these photographs, the program makes certain calculations. The program then prompts the dental professional to select the desired materials and structure for the denture. Based on this input, the program automatically produces a prescription for the denture. The digital prescription is sent to a dental laboratory for making the denture.

WO 2010/008435 A1

SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

METHODS FOR DESIGNING A CUSTOMIZED DENTAL PROSTHESIS USING DIGITAL IMAGES OF A PATIENT

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The invention relates generally to methods for designing customized dental restorations and prostheses and particularly dentures. The methods involve taking digital photographs of the patient to be fitted with the restoration or prosthesis and transferring the photographs to a computer software program. The software program uses the photographs to make certain calculations that are translated into their corresponding anterior maxillary tooth mould forms. The program prompts the dental professional to select the desired materials and structure for the denture, such as denture tooth shade, tooth arrangement, patient ridge condition, occlusal scheme, and denture base. This information is used to generate a customized prescription for the denture. The resulting prescription is sent to a dental laboratory that manufactures the denture.

Brief Description of the Related Art

[0002] Dental professionals use different dental prostheses or appliances to treat patients with lost teeth or tooth structure. By the terms, "prosthesis," "restoration" "and "appliance" as used herein, it is meant a dental product that replaces or restores lost tooth structure, teeth, or oral tissue including, but not limited to, fillings, inlays, onlays, veneers, crowns, bridges, full dentures, removable partial dentures, relines of full and partial dentures, nightguards, occlusal splints, and the like._ Common dental prostheses for full or partially edentulous patients include, for example, full dentures and partial dentures. The dentures are used to restore or replace the lost teeth. In general, removable partial dentures are used to replace some, but not all, of the patient's natural teeth. The partial denture includes a base having a partial set of embedded artificial teeth which rests in the edentulous space and is coupled to abutment teeth by clasps or other connectors. Full dentures, on the other hand, are used to replace all of the patient's natural teeth. A full denture includes a base having a full set of embedded artificial teeth which fits over either the upper gum tissue or lower gum tissue. Partial dentures are designed to preserve any remaining teeth along with hard and soft oral tissue. The dentures must be functional. Furthermore, the denture should enhance the dental and facial aesthetics of the patient. The denture teeth should appear natural. However, it is often difficult to make form-fitting and comfortable dentures. The process is time-consuming requiring the patient to make several dental office visits. In many instance, the dentist must reshape and adjust the denture several times before the patient is satisfied.

[0003] Today, a variety of methods are used to make dentures. In one traditional method, a dentist first takes impressions of a patient's dental anatomy. A paste-like material, such as an alginate, is placed in a standard or custom-made impression tray. The dentist inserts the tray in the mouth of a patient and he/she bites down into the tray. Separate impression trays for the upper and lower dental arches are used. The dentist allows the impression material to harden and then removes the trays from the patient's mouth. The hardened impressions are finally sent to a dental laboratory. There, a dental technician prepares models of the upper/lower dental arches by pouring dental stone into the hardened impressions. After a release coating is applied to the dental models, they are placed in a conditioning oven and warmed. A polymerizable resin used to form the baseplate is molded over the warm models. Then, the resin-coated models are placed in a light-curing unit and irradiated with light to harden the baseplate resin. After the light-curing cycle has been completed, the models are removed from the unit and allowed to cool. The hardened baseplates are removed from the respective models. It is customary for the technician to mount wax occlusal rims over the baseplates. The resulting wax rim baseplates are returned to the dentist so they can be evaluated for fit and comfort in the patient's mouth. Then, the completed occlusal registration is articulated.

[0004] Next, artificial teeth are built on the processed baseplate and wax rims using a "lost wax" process. In this method, wax is applied to the baseplate and a set of artificial teeth is positioned in the wax. The processed baseplate, with completed tooth arrangement, is placed in a flask containing an investing material. Then, the flask is heated to eliminate the wax. Upon melting, the wax flows out of the flask. Removing the wax from inside of the flask leaves an interior cavity having the shape of the denture. In a next step, a polymerizable acrylic composition is "packed into" into the interior cavity of the flask. The acrylic composition is heated so that it bonds to the teeth and baseplate. When this acrylic composition cures and hardens, it will hold the artificial teeth in position.

[0005] Designing and fabricating dentures is a complex process. Many time-consuming steps must be followed to prepare a denture having good aesthetics and mechanical properties. Artificial teeth having the proper color, shade, translucency, length, width, and geometry must be selected and incorporated into the baseplate. The process involves numerous dental professionals including dentists, dental assistants, and laboratory technicians and their work must be carefully coordinated to produce an aesthetically-pleasing and functional denture.

[0006] In recent years, computer-based systems using digital images have been developed so that certain dental prostheses can be made more efficiently in a time-saving manner. For example, Lehmann, US Patent 6,786,726 discloses a computer network system for making prostheses such as caps, crowns, bridges, fillings, and the like. In this method, the dental practitioner takes a digital image of the patient's tooth (resulting in a real image). A reference tooth shade (resulting in a reference image) image is also taken. The real and reference images are correlated to find a composite match number having an associated shade. The images are forwarded via computer network to a dental laboratory giving a dental technician access to the images. This allows both the dentist and technician to have simultaneous access to the images - they are able to evaluate the patient's case and develop a treatment plan together using the interactive network.

[0007] Jelonek, US Patent 7,035,702 discloses a method for making dental restorations involving the steps of determining the geometrical and aesthetic constraints of the restoration. These constraints are inputted into a computer to mathematically select a recipe for producing the dental restoration. A database of materials and procedures for preparing the dental restoration is compiled. Then, a recipe for making the restoration is produced from the database based on inputted data.

[0008] Taub, US Patent 7,33,874 discloses methods for designing and producing dental prostheses using a communication network between a dental clinic and dental laboratory. The system also includes a dental service center which is a separate entity from the dental laboratory. The service center generates a virtual 3D model of the patient's dentition from data obtained by scanning the teeth directly or by scanning a physical model of the teeth. The manufacturing of the prosthesis is shared between the service center and dental lab. The clinic sends instructions to the dental laboratory and service center. In one example, the data needed to produce the virtual 3D model is transmitted from the dental clinic or laboratory to the dental service center. A prescription specifying the teeth that are to be moved in the dental treatment as well as the final position of the teeth is sent to the service center. Then, the service center uses software to make a virtual 3D model, which is used to determine the dental appliance needed. Finally, this information is sent to the dental lab which makes the appliance.

[0009] The above-described systems may provide some advantages, but they are not used for designing and making dentures for edentulous patients, which present particular problems. As described above, in a conventional denture-making process, the dentist must manually measure the facial and oral dimensions of the patient, and selects artificial tooth colors, shades, and dimensions using manual tools such as tooth indicators, shade guides, and mould guides. Based on this information, the dentist sends a prescription for the denture to a dental laboratory. There are many variables to this process and the resulting prescription for the denture depends upon the techniques, skills, and experience level of the dental professionals. Some prescriptions will provide detailed information about the requested denture including patient's dental anatomy, baseplate materials, tooth dimensions and shapes, tooth color and shades, and the like. Other prescriptions will simply request the denture be made as the laboratory sees fit and will only provide information on the tooth shade.

[0010]The methods and system of the present invention provides the dental professional with a new chair-side method for writing denture prescriptions. The dentist can use the system to generate detailed digital prescriptions including information on facial dimensions of the patient, tooth length, width and geometry, requested composition of the artificial teeth, edentulous ridge condition and occlusal registration of the patient, denture base materials, and color and shade of the artificial teeth. The resulting prescription can be sent by e-mail, paper mail, or facsimile to a dental laboratory that will manufacture the denture. This system is easy-to-use, consistent, and time-saving for the dentist.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]The novel features that are characteristic of the present invention are set forth in the appended claims. However, the preferred embodiments of the invention, together with further objects and attendant advantages, are best understood by reference to the following detailed description in connection with the accompanying drawings in which:

[0012]**FIG. 1** is a block functional diagram showing the general steps of preparing a denture in accordance with one embodiment of this invention;

[0013]**FIG. 2** is a schematic diagram showing a digital imaging system that can be used to prepare a denture in accordance with one embodiment of this invention;

[0014]**FIG. 3** is a perspective frontal view of a patient ready to be photographed with the digital imaging system of this invention;

[0015]**FIG. 4A** is a perspective view of a mouth shield for placing in the mouth of a patient to be photographed with the digital imaging system of this invention;

[0016]**FIG. 4B** is a perspective view of a reference sticker for placing on the forehead of a patient to photographed with the digital imaging system of this invention;

[0017]**FIG. 5** is a perspective view of a digital image of a patient showing facial contours marked with reference lines;

[0018]**FIG. 6** is a computer screen shot showing different dental shade guides that can be used in accordance with this invention;

[0019]**FIG. 7** is a computer screen shot showing different tooth mould forms that can be used in accordance with this invention;

[0020]**FIG. 8** is a computer screen shot showing different edentulous ridge conditions of a patient to be fitted with a denture that can be used in accordance with this invention;

[0021]**FIG. 9** is a computer screen shot showing different occlusal schemes for a patient to be fitted with a denture that can be used in accordance with this invention;

[0022]**FIG. 10** is a computer screen shot showing different denture base materials and baseplate colors for a patient to be fitted with a denture that can be used in accordance with this invention; and

[0023]**FIG. 11** is a schematic diagram showing the general steps of designing and making a denture in accordance with one embodiment of this invention.

DETAILED DESCRIPTION OF THE INVENTION

[0024] The present invention provides different methods for designing customized dental restorations and prostheses, particularly dentures, using digital images. Although the methods described herein primarily refer to dentures, it should be understood that other dental restorations and prostheses can be designed in accordance with the invention. Referring to **FIG. 1**, the functional steps for designing and preparing a denture in accordance with one version of the invention are generally shown. Particularly, in Step 1, the dental practitioner takes at least one digital photograph of a patient's face and transfers the photograph to a computer software program.

[0025]Referring to **FIG. 2**, a digital imaging system, which can be used in the system and method, is generally indicated at (10). Ordinary digital cameras (12) can be used to take color digital photographs of a patient (14). Preferably, only one color digital photograph of the patient's face is taken, the photograph being a frontal view (16). Additional color digital photographs, however, can be taken if needed. For example, a profile or side view photograph of the patient could be taken. The digital photographs are loaded in a software program which is loaded in a computer (20) that includes a user interface system such as keyboard and/or mouse (22). The software can be packaged in any conventional way, for example, as a compact disc (CD). The software provides the user with interface tools such as graphic icons, images, text, windows, menus, and other screen displays so he/she can navigate their way through the program and complete the steps required to generate a denture prescription.

[0026]Prior to taking the digital photographs, a grey screen reference sticker" (24) is placed on the forehead of the patient and a grey screen mouth shield" (26) is positioned inside the mouth of the patient. The sticker (24) and mouth shield (26) are used so that a grey screening and color balancing procedure can be performed as described further below. In **FIG. 3**, a frontal view of a patient (14) wearing reference sticker (24) and mouth shield (26) is shown. Referring to **FIG. 4A**, the mouth shield (26) has a ribbon-like structure with notched portions (27a, 27b). The mouth shield (26) is made from a thin, soft, and flexible material. The mouth shield should have good dimensional stability and be sufficiently rigid so that it retains its position once it is placed inside of the mouth Suitable materials for making the mouth shield (26) include, but are not limited, to urethane foam and flexible wax-based sheets. The mouth shield (26) is designed to fit most patients and has a length in the range of about 70 to about 90 mm; width of about 25 to about 50 mm; and thickness of about 0.25 to about 3 mm. The mouth shield (26) is placed in the mouth of the patient (14) and folded over at notched portions (27a, 27b) so that it is tightly secured between the gums and lips. To adjust the fit of the mouth shield (26) for a given patient, scissors can be used to trim excess portions. As shown in **FIG. 3**, the mouth shield (26) resembles an athletic mouth guard when positioned in the mouth of the patient (14). As shown in **FIG. 4B**, the removable reference sticker (24) is a paper or film material having an adhesive coated on its backside. The square-shaped sticker (24) generally measures about 1 cm x about 1 cm. The sticker (24) can be placed on the forehead of the patient and removed after the photographs have been taken.

[0027]The color grey preferably is used for the reference sticker (24) and mouth shield (26), because it contrasts sharply with other skin colors and the patient would not normally be wearing any other grey object on his/her face when taking the photographs. In "grey screening," the system checks to see which pixels in the input image (digital color photograph) are not grey and labels those pixels as "target" pixels. The software then blends the "input image" (patient's facial image, which is a collection of all target pixels) into a "destination image" that will appear on the computer monitor screen (21). The pixels in the grey areas are not labeled as target pixels and thus will not be blended in with the rest of the pixels constituting the facial features.

[0028]This technique of blending two images together after a color has been removed from one of the images can be referred to as chroma keying. This results in the input image (facial image) having "color voids" or "color removal points" (where pixels are missing) upon being blended into the destination image. Particularly, voids will appear in the area of the forehead (where the grey screen sticker has been placed) and area of the mouth (where the grey screen mouth shield has been inserted).

[0029]The software program first looks to the forehead area. Because the software knows the relative dimensions of the grey sticker (24), it can use this information to make key measurements of the forehead and other facial contours. In addition, the software fills in the voided mouth area with selected tooth shades and tooth forms per the methods discussed further below. That is, the practitioner can select a particular denture structure with artificial teeth and "drop" this picture into the open mouth area of the digital image. The resulting destination image with selected denture is shown to the patient. Thus, the patient can see the results of selecting a specific denture before the treatment plan is finalized. The patient can see how a particular denture structure will affect their overall appearance. The system is beneficial to the practitioner and patient, because it can simulate different treatment plans using different sets of artificial teeth.

[0030]Upon receiving the digital image, the software automatically engages in color balancing to adjust the color of the captured digital image and generate a color balanced reproduction. Color balancing techniques are known in the digital imaging industry. Color balancing is needed, because colors in the captured digital image can shift resulting in an off-color image of the subject. Color shifting can be due to a variety of reasons, for example, shadows, lighting, and backdrops used when the digital image was taken. In the method of this invention, the colors of the facial image of the patient can become distorted; thus, color balancing of the image is needed. Once the digital image has been properly color balanced, a selected artificial tooth set can be "dropped' into the image and a denture prèscription can be generated as described in more detail below. In the color balanced digital image, the color of the selected "dropped in" tooth set is perceived correctly. That is, the color, shade, hue, brilliance, intensity, RGB values, and other characteristics of the tooth set and facial digital image match-up properly. This benefits the dental practitioner, because he/she is better able to select the most appropriate tooth shade with input from the patient. The practitioner and patient can better visualize which tooth shade is the most natural looking.

[0031]It is recognized that other imaging techniques can be used in accordance with this invention. For example, a "green-screening" system can be used, wherein the reference sticker (24) and mouth shield (26) are green colored. However, a "green-screening" system is less preferred, because there can be problems with color balancing and the captured digital image may be off-color.

[0032]In addition to the color balancing step, the software automatically formats the digital image to the correct size, and the formatted, color-balanced image appears on the monitor screen (21) so that the practitioner can view it easily. The software program then identifies the key facial contours, for example, chin, temple, vertical midline, and horizontal plane across the pupils. It is important that vertical and horizontal reference planes of the patient's face be considered so that an aesthetically-pleasing denture with artificial teeth having proper occlusion can be made. The program identifies the vertical midline and horizontal plane across the pupils as shown in **FIG. 5**. The dental practitioner can use the reference lines automatically provided by the program if they are acceptable. Alternatively, the practitioner can override the recommendations made by the program and mark key facial landmarks that they believe are more accurate. The program then provides a recommended face shape that the practitioner again has the ability to accept or override with his/her own selection. In some instances, the program can include a "default" face shape. For example, the face shape, "square tapering" could be used as the default and this shape would be automatically entered if the user did not enter otherwise. Once the facial contours and face shape have been entered and accepted by the practitioner, the software automatically determines the width and length of the central incisor artificial teeth that will be used in the denture. The practitioner also has the ability to accept or decline these measurements and enter his/her own measurements. After all of the requested information has been entered and accepted, the program will provide the recommended maxillary anterior denture tooth mould forms to be used for making the artificial teeth as discussed further below.

[0033]Referring back to the block diagram in **FIG. 1**, the dental practitioner next enters the color shade guide that will be used for determining the color and shade of the artificial teeth to be used in the finished denture. Standard dental shade guides are known in the dental industry and these guides can be used in the system of this invention. For example, Portrait™ IPN™, Trubyte Bioform™ IPN™, or Bioblend™ IPN™, shade guides available from Dentsply International (York, PA) can be used. Other suitable shade guides include Vita Classical™ and Vita 3-D™ shade guides available from Vita Zahnfabrik H. Rauter GmbH & Co. KG (Germany). The software can provide the practitioner with at least two, and more preferably three shade guide options, to select there from. For example, the software can be programmed so that the text and/or graphic icons of the shade guides: Portrait IPN, Bioform IPN, and Bioblend IPN appear on the computer monitor screen. For example, referring to **FIG. 6**, a screen shot shows three possible shade guide select options. The user can enter the desired shade guide by "clicking" on the mouse and selecting a shade guide from this predetermined set. In some instances, the program can further include a default shade guide. So, if the user does nothing, the default shade guide is automatically selected. In **FIG. 6**, the first shade guide option (Portrait IPN) is designated as the default selection for illustration purposes.

[0034]In accordance with this invention, the dental practitioner uses a tangible, hand-held shade guide (not shown) to select the most appropriate tooth color and shade. As noted above, shade guides are well known in the dental industry. The shade guides include removable colored tabs. The colored tabs come in a variety of shades resembling the appearance of natural teeth. Each shade provides a unique enamel translucency, color blending, and contrasting colors between neck and body of the artificial tooth. To determine the appropriate tooth shade for a given patient, the practitioner removes one of the tabs and holds it up in the mouth of the patient. Together, the practitioner and patient decide upon the appropriate tooth shade. In making this decision, the practitioner and patient address such questions as: Which tooth shade is the most natural looking? Which tooth shade will complement the patient's natural features? And, which tooth shade will enhance cosmetic appearance? The selected tooth shade from the given tooth shade guide is then entered. The software program may provide a drop-down menu on the monitor screen (21) listing each of the predetermined tooth shades for a given shade guide. The practitioner can enter the desired shade by simply scrolling down the menu and clicking on the shade guide in this predetermined set. For example, the Portrait IPN dental shade guide includes 27 translucent shades ranging from shades designated as "P1 to P81." If the practitioner and patient decide that "P2" tooth shade is the best match, the practitioner can enter this shade into the program. In turn, the program can generate an image simulating a denture with the selected tooth shade. Thus, the patient can see the effect of selecting a specific tooth shade and how this shade will impact their appearance. The program also can provide side-by-side comparisons of a denture made with a first tooth shade against a denture made with a second and different tooth shade. These images should be used for comparison references only. In considering which tooth shade would provide the best aesthetics for a given patient, the practitioner should use an actual hand-held tooth shade guide as described above.

[0035]Next, the program recommends a denture tooth mould form that will be used for making the denture. The mould form is chosen based on facial contours, tooth measurements, patients ridge condition, and tooth shades entered according to the steps described above. Moulds for making teeth are well known and include the Bioform® mould system; and Biostabil®, Monoline®, Anatoline®, and Euroline® posterior mould forms, available from Dentsply. As indicated, the moulds are available in anterior and posterior forms. The anterior moulds are used for producing the anterior teeth (central incisors, lateral incisors, and canines), while the posterior moulds are used for producing the posterior teeth (premolars and molars). For example, if the Portrait IPN tooth shade guide (as discussed above) is used, there are 62 anterior mould and 27 posterior occlusal mould forms available based on the Bioform mould system (tapered at angles of 0, 10, 20, 22, 33, and 40 degrees) that can be used. On the other hand, if the Bioblend IPN tooth shade guide (as discussed above) is used, there are 58 upper and lower anterior mould form options and 4 posterior occlusal mould forms available. The appropriate artificial tooth mould form for making the denture can be recommended from these sets and displayed on the computer screen allowing the practitioner to select there from.

[0036]In one preferred embodiment, in the anterior region, at least two, and more preferably, three tooth mould form options are provided by the software program. The user can enter the desired anterior mould form based on these predetermined select options. Referring to **FIG. 7**, a screen shot of the monitor shows three possible anterior mould form options. The user can simply click on the mouse, thereby selecting an anterior mould form from this predetermined set. In some instances, the program can further include a default anterior mould form. For example, in **FIG. 7**, the first mould form is designated as the default selection. Alternatively, if the practitioner wishes, he/she can decide to over-ride the given options and enter a different tooth mould form. In addition, the practitioner, in consultation with the patient, enters the appropriate anterior tooth arrangement that will provide the desired aesthetics and function in the finished denture. In one preferred embodiment, the program can provide three anterior tooth arrangements as options, and the practitioner can select any one of these arrangements.

[0037]Following the functional steps illustrated in **FIG. 1**, the practitioner next evaluates the edentulous ridge condition of the patient and enters this information. The edentulous ridge refers to the remaining portion of the alveolar ridge and soft tissue after the teeth have been removed. The practitioner evaluates and generally characterizes the ridge condition as being either poor, average, or good. The program can provide these three options for selection as shown in the computer screen shot of **FIG. 8**. The practitioner enters the ridge condition that most closely resembles the patient's actual condition. Based on the edentulous ridge condition, suitable posterior denture tooth mould form options are provided as shown in **FIG. 8**. The practitioner can select the desired mould form from the set displayed on the computer screen. For example, if the patient has an average ridge condition, then the posterior mould form options: Biostabil® (tapered at 22°); (tapered at 20°) and Anatoline® (tapered at 10°), are displayed, and the practitioner selects one of these mould forms.

[0038]In addition, the practitioner enters the desired occlusal scheme for the patient. Several occlusal scheme select options can be provided by the software as shown in the computer screen shot of **FIG. 9**. For example, the occlusal schemes can be classified as: a) bilateral balanced, b) lingualized, or c) linear, and the practitioner can select from one of these options. In **FIG. 9**, the bilateral balanced option is designated as the default occlusal scheme for illustration purposes. If the practitioner wishes, he/she can accept this default option.

[0039]The material that will be used to make the denture is also entered. The practitioner can work with the patient in making this decision or accept the default selections made by the program. A set of predetermined denture base materials preferably is loaded in the software program and appear as select options on the computer screen as shown in **FIG. 10.** For example, denture bases made from such materials as Lucitone 199® acrylic resin or Eclipse® baseplate resin which is a wax-like polymerizable material, both available from Dentsply can be added as predetermined selections. In this example, the user can enter the desired denture base material by clicking on the mouse and selecting either Lucitone 199® acrylic resin or Eclipse® baseplate resin. The desired color of the baseplate also needs to be entered. The baseplate color can be entered by selecting a color from a wide variety of select color options provided by the program. As also shown in **FIG. 10**, several color options intended to resemble healthy gum tissue can be provided including light pink; light reddish pink; and dark pink. Alternatively, the baseplate can be clear and transparent. Eclipse® baseplates are available in a clear version. Desired denture base materials and colors can be selected from the automatically programmed sets. In preferred cases, the program includes default select denture base materials and colors. For example, in **FIG. 10,** Lucitone 199® acrylic resin in its original color is designated as the default selection.

[0040]It should be understood that the functional steps shown in the block diagram of **FIG. 1** are for illustrative purposes only and are not meant to be restrictive. In other versions, it is contemplated that some of the steps could be eliminated to expedite the method for generating the customized prescription. Also, it is anticipated that the sequence of steps could be changed in some instances depending upon the needs of the practitioner and patient. As shown in **FIG. 1**, the output of the system, based on the input of data and other information as described above, is a digital prescription for making a denture for the given patient. The customized digital prescription includes detailed information on facial dimensions of the patient, tooth length, width and geometry, requested composition of the artificial teeth, edentulous ridge condition and occlusal scheme, denture base materials, and color and shade of the artificial teeth. In addition, the digital prescription is HIPAA-compliant. One example of such a digital prescription is shown below.

[0041]<u>**Example of Digital Prescription**</u>

Facial Classification: Square tapering
Tooth Length: 9.60
Width of the anterior teeth: 8.60
Denture tooth composition: Premium IPN
Ridge condition: Average
Occlusal scheme: Bilateral balanced
Denture base material: Lucitone 199® acrylic resin
Denture base color: Original
Shade guide: Portrait™
Anterior shade: P2
Posterior shade: P2

Maxillary

Anterior Teeth: Shade P2, Mould 22G Posterior Teeth: Shade P2, Mould 31M

Mandibular

Anterior Teeth: Shade P2, Mould P Posterior Teeth: Shade P2, Mould 31M

[0042]The resulting customized digital prescription can be sent by e-mail, facsimile, paper mail, or other means to a dental laboratory that will manufacture the denture. In addition, a copy of the digital prescription can be provided to the patient for his/her records. The dental laboratory can use conventional techniques to fabricate the denture as prescribed. In **FIG. 11**, a schematic diagram showing the basic steps of generating a customized digital prescription and transmitting the prescription to a dental laboratory in accordance with this invention are shown.

[0043]The methods and systems of this invention provide the dental practitioner with a new tool for designing and making dentures. As described above, the dentist can use the system to generate customized digital prescriptions. In addition, the system can be used as a tutorial for patients and staff in the dental office. For practitioners, the system offers many benefits including a quick and accurate means for prescribing dentures and recording the prescriptions. The system helps the practitioner by providing a step-by-step guide to designing a customized denture for a given patient. The practitioner is led step-by-step through the procedure.

[0044]Particularly, the system provides reference points across the facial digital image(s) of the patient so that the dentist can more accurately identify facial contours. Based on this information, the system automatically provides facial and tooth measurements and provides suggestions for tooth shade and denture base shade. Furthermore, the system prompts the practitioner by asking key questions such as: What is the edentulous ridge condition of patient? What is the occlusal scheme? What is the desired tooth arrangement? This helps the practitioner design a close fitting and comfortable denture. The resulting denture helps enhance the appearance of the patient and is fully functional. The system also helps facilitate two-way communication between the practitioner and patient. Rather than the practitioner deciding on the make and style of the denture and dictating this to the patient one-way, the patient is invited to participate in the process. The patient is asked for input on the desired tooth shade and denture base shade along with other decision points. Thus, the system is more interactive – the practitioner and patient are more engaged in the process. Each person feels that he/she has more input and control over the design and fabrication of the denture.

[0045]Persons skilled in the art will appreciate that various modifications can be made to the illustrated embodiments and description herein without departing from the spirit and scope of the present invention. It is intended that all such modifications within the spirit and scope of the present invention be covered by the appended claims.

What is claimed is:

Method for generating the prescription by entering information into the software program.

1. A method for producing customized denture prescriptions, comprising the steps of:

a) taking at least one digital photograph of a patient's face and transferring the photograph to a computer software program, wherein the program identifies and measures facial contours of the patient;

b) entering desired materials and structure for making the denture, in consultation with the patient, including a desired tooth shade guide and tooth shade, the tooth shade being selected from the entered tooth shade guide, using the software program so that the program automatically produces a prescription for the denture based on the entered materials and structure; and

c) transmitting the prescription to a dental laboratory for making the denture.

2. The method of claim 1, wherein one photograph of the patient's face is taken, the photograph being a frontal view.

3. The method of claim 1, wherein the tooth shade guide includes removable shade tabs.

4. The method of claim 1, wherein the facial contours of the patient are used to determine the length, width, and shape of artificial teeth used in the denture.

5. The method of claim 1, wherein entering the desired materials of the denture includes entering tooth mould forms for the artificial teeth used in the denture.

5a. The method of claim 5, wherein anterior tooth mould forms are entered.

5b. The method of claim 5, wherein posterior tooth mould forms are entered.

6. The method of claim 1, wherein entering the desired structure of the denture includes entering an edentulous ridge structure.

6a. The method of claim 6, wherein the entered edentulous ridge structure is based on the dental health of the patient.

7. The method of claim 1, wherein entering the desired structure of the denture includes entering an occlusal scheme of the patient.

7a. The method of claim 7, wherein the entered occlusal scheme is based on the dental health of the patient.

8. The method of claim 1, wherein entering the desired materials for making the denture includes entering a denture baseplate material.

8a. The method of claim 8, wherein the denture baseplate material has a color and shade matching the color and shade of the gum tissue of the patient.

8b. The method of claim 8, wherein the denture baseplate material is substantially transparent.

8c. The method of claim 8, wherein the denture baseplate material is made from an acrylic polymer.

8d. The method of claim 8, wherein the denture baseplate material is made from a wax-like polymerizable material.

9. The method of claim 1, wherein the prescription is transmitted to the dental laboratory via e-mail, paper mail, or facsimile.

9a. The method of claim 9, wherein the prescription is also provided to the patient.

Methods for generating the prescription by entering information into the software program using predetermined options provided by the program.

10. A method for producing customized denture prescriptions, comprising the steps of:

a) taking at least one digital photograph of a patient's face and transferring the photograph to a computer software program, wherein the program identifies and measures facial contours of the patient;

b) selecting desired materials and structure for making the denture, in consultation with the patient, including a desired tooth shade guide and tooth shade, the tooth shade being chosen from the selected tooth shade guide, from a set of predetermined materials and structures provided by the software program so that the program automatically produces a prescription for the denture based on the selected materials and structure; and

c) transmitting the prescription to a dental laboratory for making the denture.

11. The method of claim 10, wherein the set of predetermined structures and materials includes at least two options for selecting the dental shade guide.

11a. The method of claim 11, wherein one shade guide option is set as a default option.

12. The method of claim 10, wherein the set of predetermined structures and materials includes at least two options for selecting a tooth mould form for artificial teeth used in the denture.

12a. The method of claim 12, wherein the tooth mould form options are for anterior teeth.

12b. The method of claim 12, wherein the tooth mould form options are for posterior teeth.

12c. The method of claim 12, wherein one mould form option is set as a default option.

13. The method of claim 10, wherein the set of predetermined structures and materials includes at least two options for selecting an edentulous ridge structure of the patient.

14. The method of claim 10, wherein the set of predetermined structures and materials includes at least two options for selecting an occlusal scheme of the patient.

14a. The method of claim 14, wherein one occlusal scheme option is set as a default option.

15. The method of claim 10, wherein the set of predetermined structures and materials includes at least two options for selecting a denture base material and at least two options for selecting denture base color.

15a. The method of claim 15, wherein one denture base material option is set as a default option and one denture base color is set as a default option.

16. The method of claim 10, wherein the prescription is transmitted to the dental laboratory via e-mail, paper mail, or facsimile.

16a. The method of claim 16, wherein the prescription is also provided to the patient.

FIGURE 1

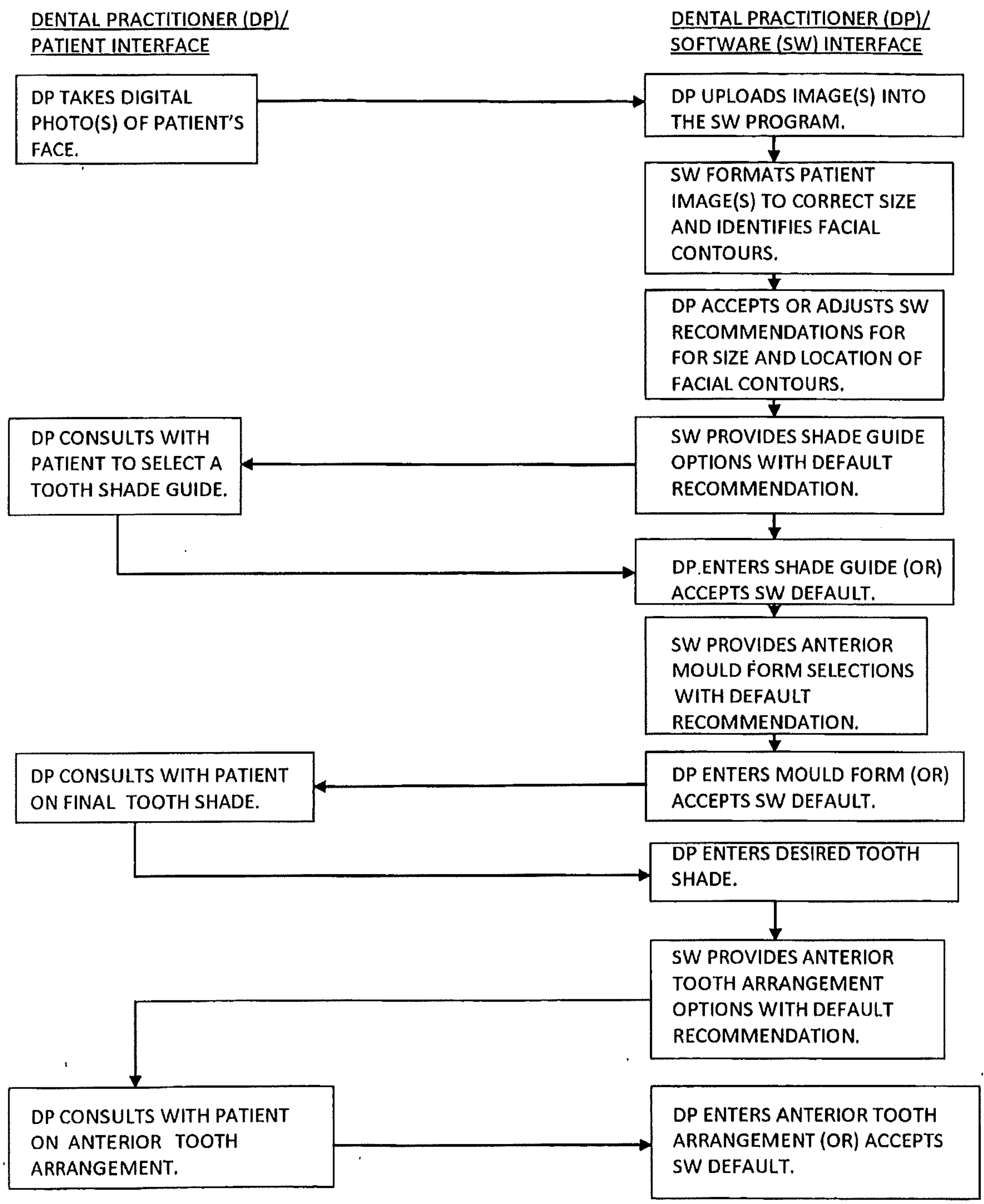

DENTAL PRACTITIONER (DP)/ PATIENT INTERFACE
DENTAL PRACTITIONER (DP)/ SOFTWARE (SW) INTERFACE
DP TAKES DIGITAL PHOTO(S) OF PATIENT'S FACE.
DP UPLOADS IMAGE(S) INTO THE SW PROGRAM.
SW FORMATS PATIENT IMAGE(S) TO CORRECT SIZE AND IDENTIFIES FACIAL CONTOURS.
DP ACCEPTS OR ADJUSTS SW RECOMMENDATIONS FOR FOR SIZE AND LOCATION OF FACIAL CONTOURS.
SW PROVIDES SHADE GUIDE OPTIONS WITH DEFAULT RECOMMENDATION.
DP CONSULTS WITH PATIENT TO SELECT A TOOTH SHADE GUIDE.
DP.ENTERS SHADE GUIDE (OR) ACCEPTS SW DEFAULT.
SW PROVIDES ANTERIOR MOULD FORM SELECTIONS WITH DEFAULT RECOMMENDATION.
DP ENTERS MOULD FORM (OR) ACCEPTS SW DEFAULT.
DP CONSULTS WITH PATIENT ON FINAL TOOTH SHADE.
DP ENTERS DESIRED TOOTH SHADE.
SW PROVIDES ANTERIOR TOOTH ARRANGEMENT OPTIONS WITH DEFAULT RECOMMENDATION.
DP CONSULTS WITH PATIENT ON ANTERIOR TOOTH ARRANGEMENT.
DP ENTERS ANTERIOR TOOTH ARRANGEMENT (OR) ACCEPTS SW DEFAULT.

FIGURE 1 (CONT)

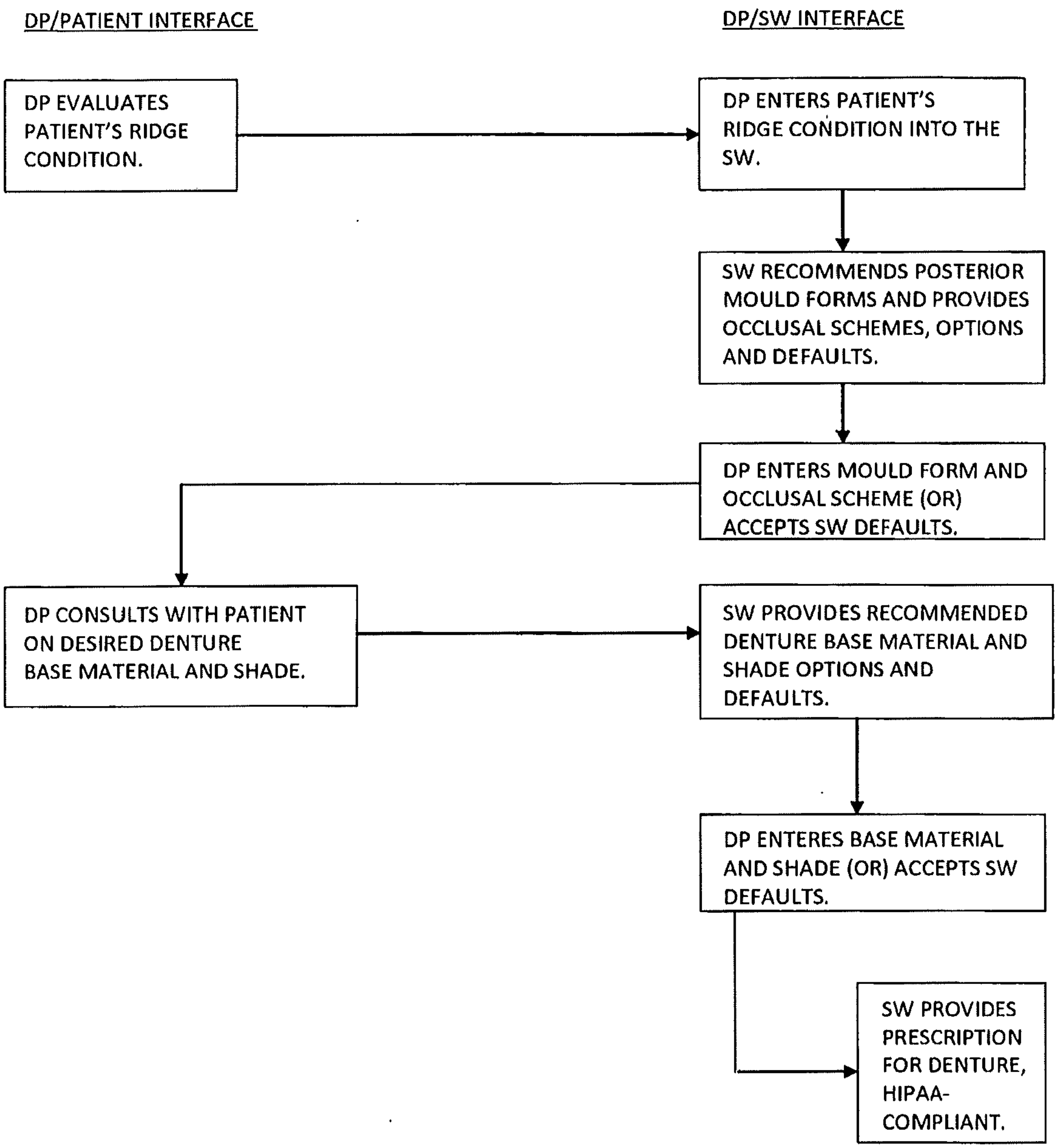


FIGURE 2

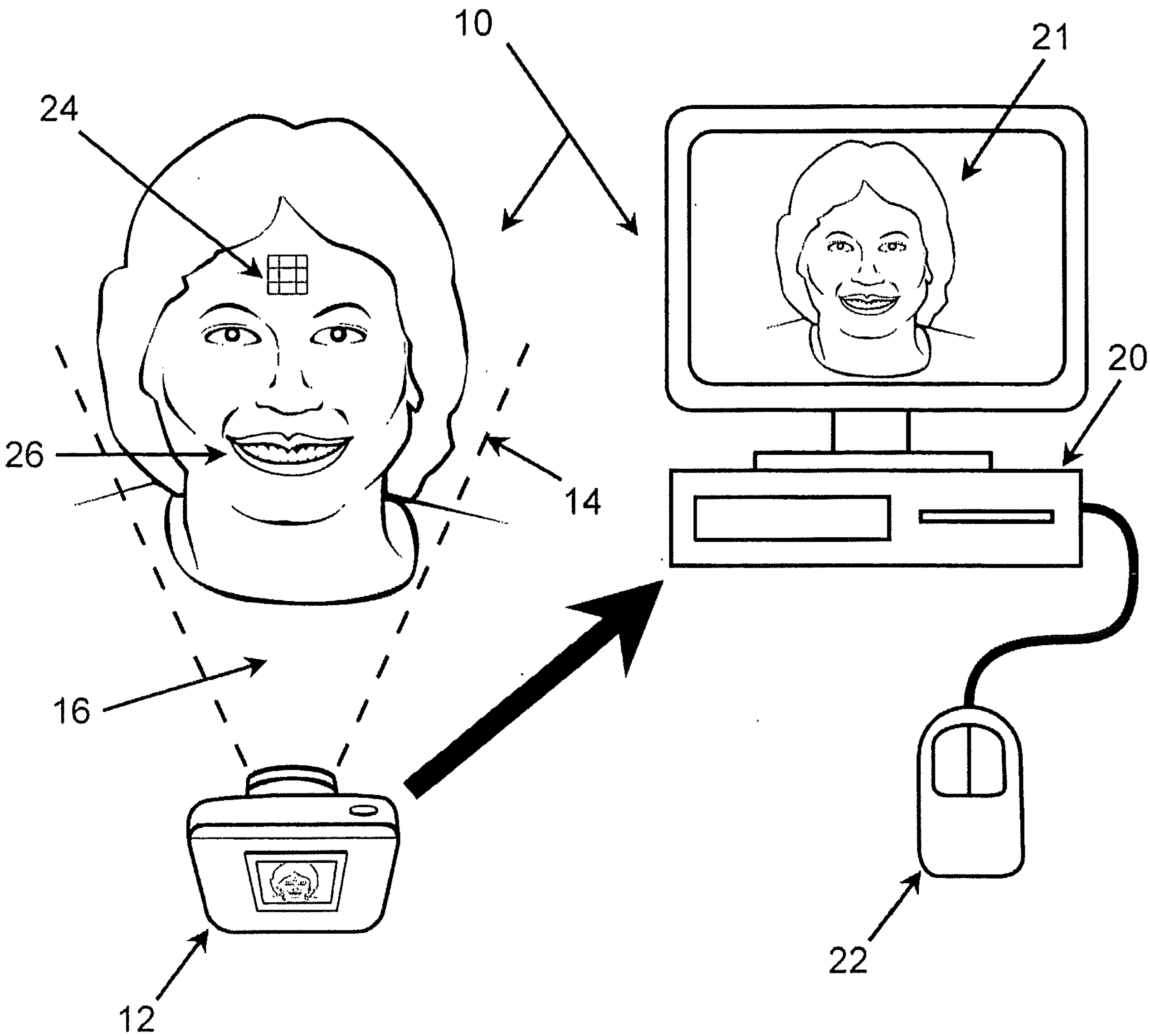


FIGURE 3

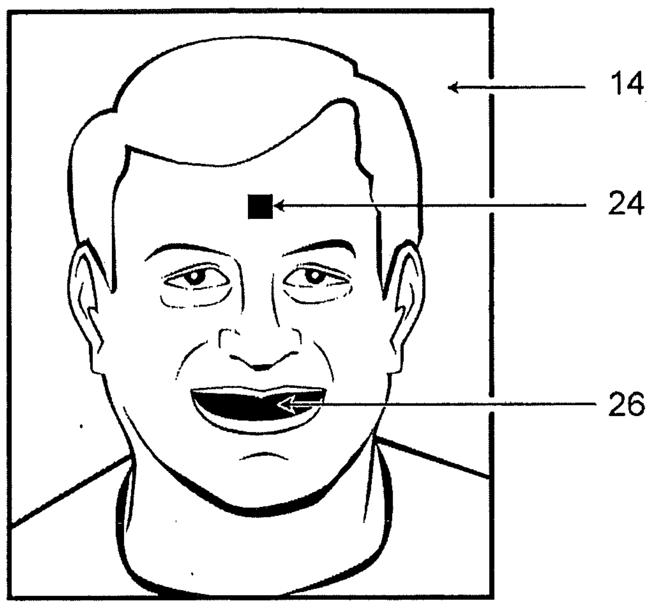


FIGURE 4A

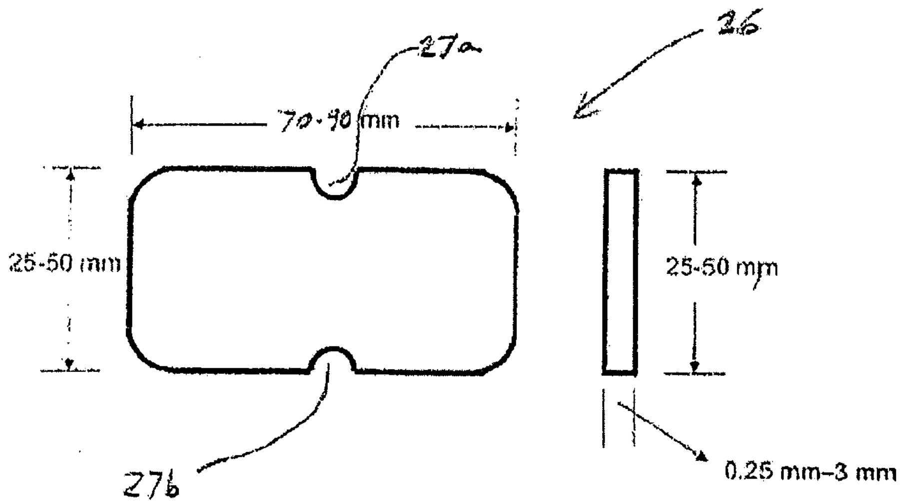


FIGURE 4B

FIG. 4B

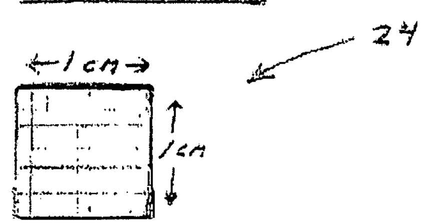


FIGURE 5

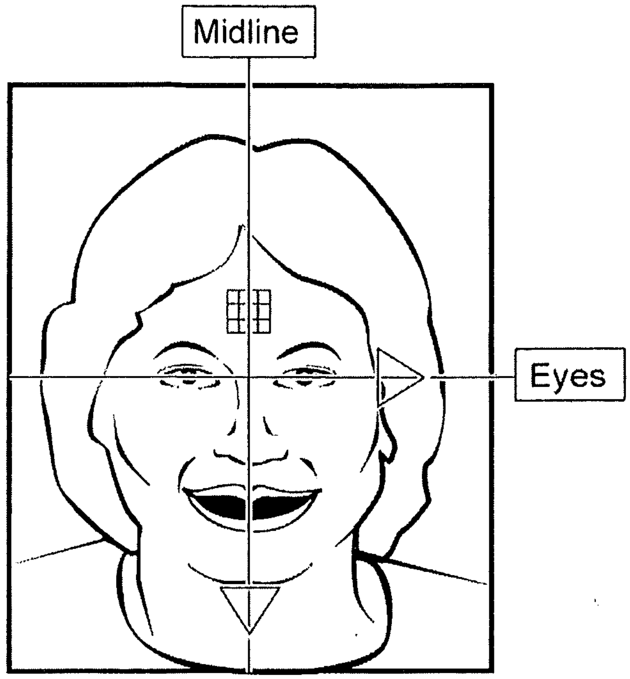
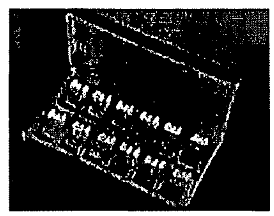


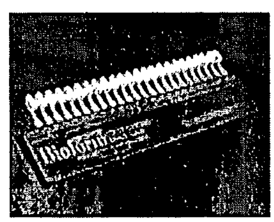
FIGURE 6

DENTAL SHADE GUIDES

○ TRUBYTE PORTRAIT IPN



● TRUBYTE BIOBLEND IPN



● TRUBYTE BIOFORM IPN

FIGURE 7

ANTERIOR MOULD FORMS

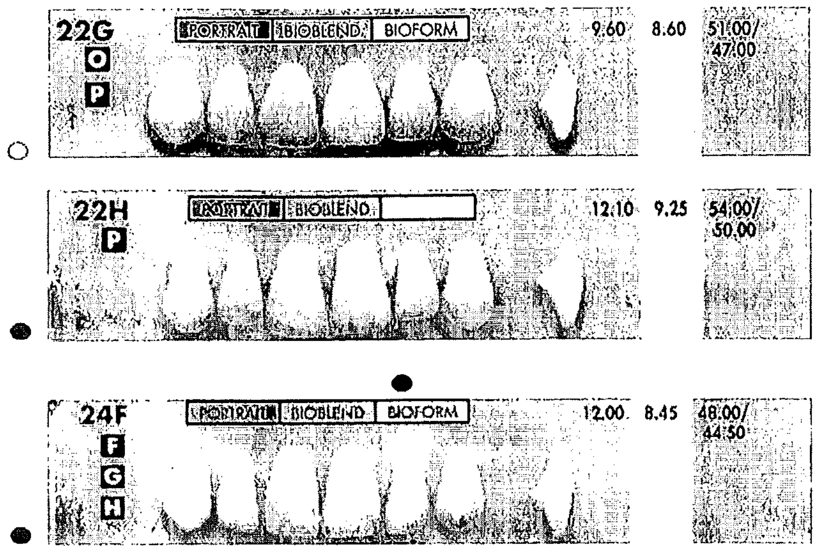
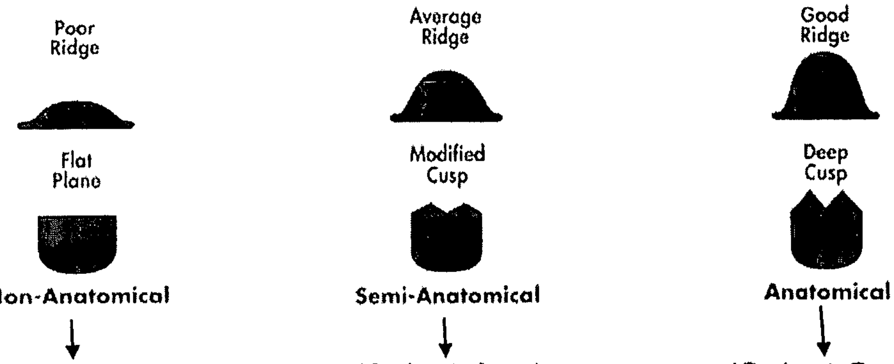


FIGURE 8

EDENTULOUS RIDGE CONDITION



(Select One)	(Select One)	(Select One)
Non-Anatomical	Semi-Anatomical	Anatomical
○ Portrait IPN 0^{0}Posteriors	○ 22^{0} Biostabil	○ 40^{0} Euroline
○ 0^{0} Monoline	○ 20^{0}	○ 33^{0}
	○ 10^{0} Anatoline	○ 30^{0} PT

FIGURE 9

OCCLUSAL SCHEMES

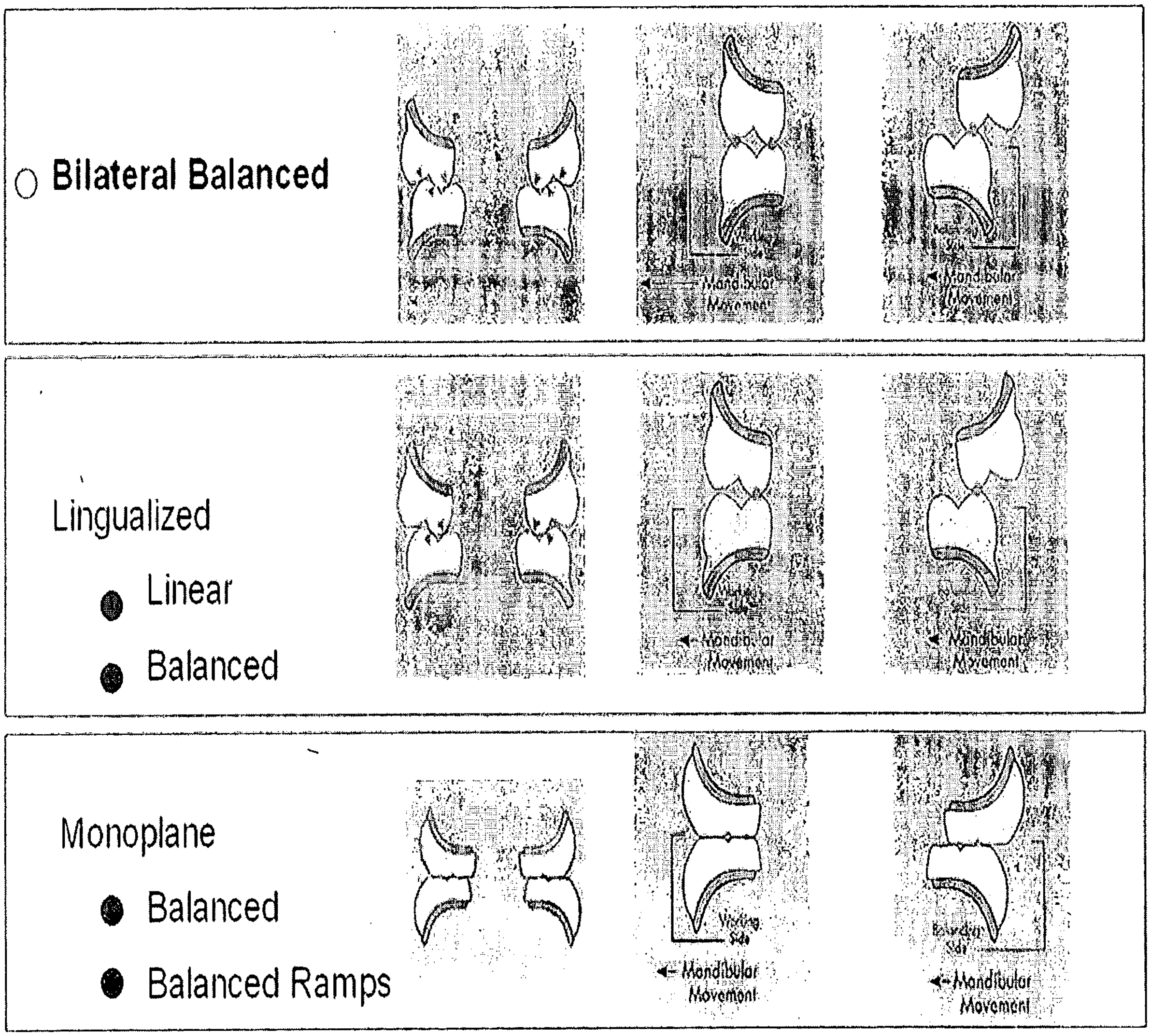
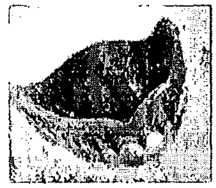


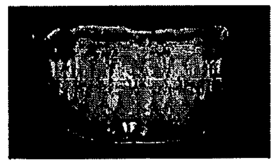
FIGURE 10

DENTURE BASEPLATE MATERIAL

○ LUCITONE 199



● ECLIPSE CLEAR BASE PLATE AND LUCITONE 199



● ECLIPSE

DENTURE BASEPLATE SHADE

BasePlate

○ ORIGINAL

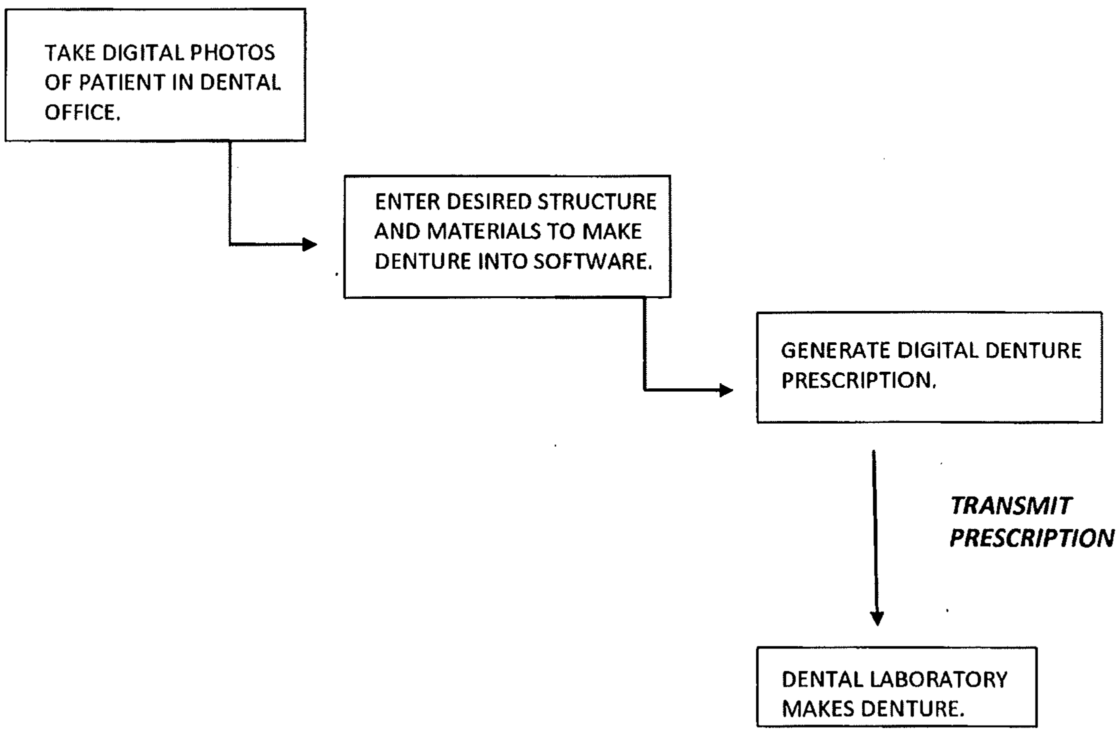
● LIGHT PINK

● LIGHT REDDISH PINK

● DARK PINK

● CLEAR

FIGURE 11


TAKE DIGITAL PHOTOS OF PATIENT IN DENTAL OFFICE.
ENTER DESIRED STRUCTURE AND MATERIALS TO MAKE DENTURE INTO SOFTWARE.
GENERATE DIGITAL DENTURE PRESCRIPTION.
TRANSMIT PRESCRIPTION
DENTAL LABORATORY MAKES DENTURE.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/003351

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61C13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61C G01J A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 707 928 A (OLYMPUS CORP [JP]) 4 October 2006 (2006-10-04) paragraphs [0158], [0159], [0172], [0208], [0377] - [0382]	1-16
A	US 6 261 248 B1 (TAKAISHI YOSHITOMO [JP] ET AL) 17 July 2001 (2001-07-17) column 3, line 43 - column 4, line 42	1-16
A	US 2003/197855 A1 (JUNG WAYNE D [US] ET AL) 23 October 2003 (2003-10-23) paragraphs [0159], [0160], [0190] - [0192], [0214] figure 26	1-16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 October 2009	21/10/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fortune, Bruce

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2009/003351

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1707928	A	04-10-2006	CN	1910431	A	07-02-2007
			WO	2005071372	A1	04-08-2005
			JP	4088313	B2	21-05-2008
			US	2008284902	A1	20-11-2008
			US	2008292295	A1	27-11-2008
			US	2008259336	A1	23-10-2008
			US	2006251408	A1	09-11-2006
US 6261248	B1	17-07-2001	CA	2302725	A1	29-09-2000
			JP	3040997	B2	15-05-2000
			JP	2000342607	A	12-12-2000
US 2003197855	A1	23-10-2003	US	2006050264	A1	09-03-2006

Form PCT/ISA/210 (patent family annex) (April 2005)

PATENT- OG VAREMÆRKESTYRELSEN

Patent- og
Varemærkestyrelsen

Helgeshøj Allé 81
2630 Taastrup

Tlf. : 43 50 80 00
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CVR-nr. : 17 03 94 15

Økonomi- og
Erhvervsministeriet

Partner
nordic patent institute

3Shape A/S
Holmens Kanal 7, 4
1060 København K
Danmark

MODTAGET 31 JAN. 2011

MODTAGET 01 FEB. 2011

28. januar 2011

Vores reference	PA 2010 00568
Din reference	P2010011 - 2D image arrangement
Ansøger/patenthaver	3Shape A/S
CVR-/P-nummer	25553489
Din frist	28. juli 2011

Reply to your patent application of 29/06/2010.

1st technical examination of your patent application

1. Conclusion

We are of the opinion that you will not be able to obtain a patent for your invention. When you filed your application, part of your invention was already known, and the new part of the invention does not differ significantly over the prior art, as stipulated in Section 2(1) of the Danish Patent Act. Below, please find an explanation of our conclusion.

2. Our evaluation of your invention

The relevant prior art is described in the following documents:

(D1) EP 1124487 B1 (CADENT LTD) 23.05.2007, sec [0009], [0010], [0020], [0032], [0034], [0036], fig 1A, 1B, 3A, 3B, 4A, 4B.

(D2) US 6068482 A (SNOW) 30.05.2000, col 1, line 38-44, col 2, line 59-67 to col 3, line 2, col 3, line 28-65, all figures.

(D3) US 2003/0163291 A1 (JORDAN et al) 28.08.2003, sec [0080]-[0087], fig. 4A.

(D4) US 6261248 B1 (TAKAISHI et al) 17.07.2001, col 2, line 10-20, fig 1 and 3.

(D5) WO 2010/008435 A1 (DENTSPLY INTERNATIONAL INC.) 21.01.2010, sec [0029]

D1 describes a computer-implemented method of visualizing, designing and modelling a set of teeth for a patient (see section [0009], [0010]):
- providing one or more 2D digital images;
- providing a 3D virtual model of at least part of the patient's oral cavity (see section [0010], [0032], fig 1A, 1B, 4A, 4B);
- arranging at least one of the one or more 2D digital images relative to the 3D virtual model in a 3D space such that the at least one 2D digital image and the 3D virtual model are aligned when viewed

from a viewpoint, whereby the 3D virtual model and the at least one 2D digital image are both visualized in the 3D space (see section [0034], [0036] fig 2, 3A, 3B, 5);
-the one or more 2D image comprises a patient-specific image;
-the 2D image can be a picture showing the patient's lips (fig 3A, 3B);
-the 2D image and the 3D image can be scaled to fit each other (sec [0020])

D2 and D3 describe a technique similar to D1. D4 and D5 describe a computer implemented method where a 2D image of a set of teeth is placed behind the lips of a patient on a 2D photograph, in order to get an aesthetic impression.

The subject matter of claims 1 and 2 is described in D1-D3. These claims are, therefore, not patentable.

The subject matter of claims 3-6 differs from D1 in that a generic image, a template, a photograph showing lips and teeth seen from the front, and a photograph where a part of the teeth has been cut out, respectively, are chosen as 2D images. The problem addressed by the invention is to obtain different possibilities or targets in the modelling process.

We consider that the person skilled in the art, computer aided modelling of teeth, would be inspired by his specialist knowledge to use different 2D images in order to enable a suitable guide for the modelling process, and thereby suggest the solution mentioned in claims 3-6 of your application. We cannot see that your invention presents a surprising effect. Therefore, the subject matter of claims 3-6 does not differ significantly from the prior art. Thus you will not be able to obtain a patent for this invention.

model?

The subject matter of claims 7 and 8 differs from D1 in that the 3D image, i.e. the teeth, is visible behind the lips. The addressed problem is to obtain a virtual impression of the final result, i.e. the patient with his new set of teeth. It is, however, common knowledge within the field that a 2D 3D/image model of a set of teeth can be superposed on the teeth of a photograph of a patent's face, or that the teeth can be dropped into the open mouth area of a digital image (see for example D4 and D5).

We consider that the skilled person would be inspired by his specialist knowledge to suggest the invention according to claims 7-8. The invention according to claims 7-8 lacks an inventive step and is therefore not patentable.

The subject matter of claim 9 differs from D1 in that the images are scaled to fit. However, it is common knowledge within the field that the 3D and 2D images can be scaled to fit each other (see for example D1 to D3). We consider that a skilled person within the field would be inspired by his specialist knowledge to suggest the invention according to claim 9. The invention according to claim 9 is not patentable due to lack of an inventive step.

The subject matter of claim 10 differs from D1 in that the modelling process is performed automatically. However, it is common knowledge to automate processes in order to reduce the overall process time. The invention according to claim 10 does not differ significantly from D1 and is not patentable.

3. What happens next

We welcome any comments you may have to our letter. We must receive them within the time limit mentioned at the top of this letter. You can send us comments and/or new documents by post, e-mail or via IP Client. If you do not reply within the time limit, your application will be temporarily shelved, i.e. we will discontinue examination of the application.

If you exceed the time limit, it will still be possible for you to reply within an extended time limit of 4 months.

An extension of time limit requires that you pay a resumption fee of DKK 700 to resume the examination of your application. The fee must be paid when you send us your reply.

If you exceed the extended time limit, your application will be finally shelved.

4. Search report
For your information, we have enclosed a search report. The report shows the documents retrieved in our search.

We have enclosed a copy of the documents.

Yours sincerely

Lennart Bitsch
MSc, PhD, Senior Examiner

Encl.:
Search report
Copies: 5 documents

DANISH PATENT AND TRADEMARK OFFICE

SEARCH REPORT	Application No. PA 2010 00568

A. CLASSIFICATION OF SUBJECT MATTER
A61C 7/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: A61C; ECLA: A61C; ICO: A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, TXTE

C. CLAIMS SEARCHED 1-10

D. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1124487 B1 (CADENT LTD) 23.05.2007, sec [0009], [0010], [0020], [0032], [0034], [0036], fig 1A, 1B, 3A, 3B, 4A, 4B.	1-10
X	US 6068482 A (SNOW) 30.05.2000, col 1, line 38-44, col 2, line 59-67 to col 3, line 2, col 3, line 28-65, all figures.	1-10
X	US 2003/0163291 A1 (JORDAN et al) 28.08.2003, sec [0080]-[0087], fig. 4A.	1-10
A	US 6261248 B1 (TAKAISHI et al) 17.07.2001, col 2, line 10-20, fig 1 and 3.	1-10
A	WO 2010/008435 A1 (DENTSPLY INTERNATIONAL INC.) 21.01.2010, ec [0 029]	1-10

☐ Further documents are listed in the continuation of Box D.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance.

"D" document cited in the application.

"E" earlier application or patent but published on or after the filing date.

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified).

"O" document referring to an oral disclosure, use, exhibition or other means.

"P" document published prior to the filling date but later than the priority date claimed.

"T" document not in conflict with the application but cited to understand the principle or theory underlying the invention.

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone.

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family.

Danish Patent and Trademark Office Helgeshøj Allé 81 2630 Taastrup Denmark Tlf.: +45 4350 8000 Fax: +45 4350 8001	Date of completion of the search report 27.01.2011 Authorized officer Lennart Bitsch

October 09

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: HØIBERG A/S St. Kongensgade 59A DK-1264 Copenhagen K Denmark	**PCT** NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION (PCT Rule 44.1)
	Date of mailing (*day/month/year*) 07/09/2011
Applicant's or agent's file reference P2638PC00	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/DK2011/050246	International filing date (*day/month/year*) 29/06/2011
Applicant 3Shape A/S, et al	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
   1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the ISA/ Nordic Patent Institute Helgeshøj Allé 81, 2630 Taastrup, Denmark	Authorized officer Inge Estvan
Facsimile No.	Telephone No.

Form PCT/ISA/220 (July 2010)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P2638PC00	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/DK2011/050246	International filing date (day/month/year) 29/06/2011	(Earliest) Priority Date (day/month/year) 29/06/2010
Applicant 3SHAPE A/S		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed.
      ☐ a translation of the international application into ______________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (see Box No. II).
3. ☐ **Unity of invention is lacking** (see Box No. III).
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract**,
   ☐ the text is approved as submitted by the applicant.
   ☒ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 11 k
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK2011/050246

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

2d image arrangement

Abstract

Disclosed is a method of designing a dental restoration (1140) for a patient, wherein the method comprises:

-providing one or more 2D images (1101), where at least one 2D image (1101) comprises at least one facial feature (1103);
-providing a 3D virtual model (1102) of at least part of the patient's oral cavity;
-arranging at least one of the one or more 2D images (1101) relative to the 3D virtual model (1102) in a virtual 3D space such that the 2D image (1101) and the 3D virtual model (1102) are aligned when viewed from a viewpoint, whereby the 3D virtual model (1102) and the 2D image (1101) are both visualized in the 3D space; and
-modeling a restoration (1140) on the 3D virtual model (1102), where the restoration is designed to fit the facial feature (1103) of the at least one 2D image (1101).

figure 11k

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK2011/050246

A. CLASSIFICATION OF SUBJECT MATTER
A61C 7/00 (2006.01), A61C 13/00 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: A61C; ECLA: A61C; ICO: K61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, TXTE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/128700 A1 (MATERIALISE DENTAL N V [BE]) 30.10.2008, p. 2 line 15 to p. 3 line 19, p. 4 line 31 to p. 7 line 13, p. 7 line 19 to p. 8 line 16, p. 9 line 8-20, p. 15 line 4 to p. 16 line 12, p. 17 line 21-31, p. 18 line 14 to p. 19 line 10, all figures.	1-16, 22, 24-36, 38-95, 97, 99-109
Y		96, 98
X	EP 1124487 B1 (CADENT LTD) 23.05.2007, sec [0009], [0010], [0013]-[0016], [0019]-[0023], [0029], [0032]-[0037], [0043], all figures.	1-3, 5, 7-25, 28-36, 38-61, 67-95, 97-109
Y	WO 2010/008435 A1 (DENTSPLY INTERNATIONAL INC.) 21.01.2010, sec [0010], [0027], [0029], [0032]	96, 98

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02/09/2011	07/09/2011

Name and mailing address of the ISA/
Nordic Patent Institute,
Helgeshøj Allé 81, 2530 Taastrup, Denmark
Facsimile No. +45 43 50 80 08

Authorized officer
Kristian Grønland Woller
Telephone No. +45 43 50 81 38

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK2011/050246

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6068482 A (SNOW) 30.05.2000, col 1, line 38-44, col 2, line 59-67 to col 3, line 2, col 3, line 28-65, col. 5, line 26-36, all figures.	
A	US 2003/0163291 A1 (JORDAN et al) 28.08.2003, sec [0080]-[0087], fig. 4A.	
A	US 6261248 B1 (TAKAISHI et al) 17.07.2001, col 2, line 10-20, fig 1 and 3.	

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/DK2011/050246

Patent document Cited in search report	Publication date	Patent family member(s)	Publication date
WO2008128700 A1 20081030		US2010145898 A1 20100610 JP2010524529 A 20100722 WO2008128700 A1 20081030 EP2134290 A1 20091223	
EP1124487 B1 20070523		US2003169913 A1 20030911 JP2002528215 A 20020903 WO0025677 A1 20000511 DE69936145T T2 20080124 AU6486699 A 20000522 AT362732T T 20070615 IL126838 A 20030410	
US6068482 A 20000530		NONE	
US20030163291 A1 20030828		WO03073382 A1 20030904 JP2005518263 A 20050623 EP1483743 A1 20041208 AU2002360711 A1 20030909 AT434236T T 20090715 US2003163291 A1 20030828	
US6261248 B1 20010717		US6261248 B1 20010717 CA2302725 A1 20000929 JP3040997B1 B1 20000515	
WO2010008435 A1 20100121		JP2011521767 A 20110728 EP2282697 A1 20110216 WO2010008435 A1 20100121 US2010076581 A1 20100325 CA2725818 A1 20100121	

Form PCT/ISA/210 (patent family annex) (July 2009)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
HØIBERG A/S
St. Kongensgade 59A
DK-1264 Copenhagen K
Denmark

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing (*day/month/year*) 07/09/2011	
Applicant's or agent's file reference P2638PC00	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/DK2011/050246	29/06/2011	29/06/2010

International Patent Classification (IPC) or both national classification and IPC
A61C 7/00 (2006.01), A61C 13/00 (2006.01)

Applicant
3SHAPE A/S

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [x] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/	Date of completion of this opinion	Authorized officer
Nordic Patent Institute, Helgeshøj Allé 81, 2630 Taastrup Denmark Facsimile No. +45 43 50 80 08	02/09/2011	Kristian Grønland Woller Telephone No. +45 43 50 81 38

Form PCT/ISA/237 (cover sheet) (July 2011)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	International application No. PCT/DK2011/050246

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [X] the international application in the language in which it was filed.
   - [ ] a translation of the international application into ______________ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:

   a. (means)
   - [ ] on paper
   - [ ] in electronic form

   b. (time)
   - [ ] in the international application as filed
   - [ ] together with the international application in electronic form
   - [ ] subsequently to this Authority for the purposes of search

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	International application No. PCT/DK2011/050246

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	22, 37, 60, 69, 92-93, 96-106	YES
	Claims	1-21, 23-36, 38-59, 61-68, 70-91, 94-95,107-109	NO
Inventive step (IS)	Claims	37	YES
	Claims	1-36, 38-109	NO
Industrial applicability (IA)	Claims	1-109	YES
	Claims		NO

2. Citations and explanations:

D1: WO 2008/128700 A1 (MATERIALISE DENTAL N V) 30.10.2008, p. 2 line 15 to p. 3 line 19, p. 4 line 31 to p. 7 line 13, p. 7 line 19 to p. 8 line 16, p. 9 line 8-20, p. 15 line 4 to p. 16 line 12, p. 17 line 21-31, p. 18 line 14 to p. 19 line 10, all figures.

D2: EP 1124487 B1 (CADENT LTD) 23.05.2007, sec [0009], [0010], [0013]-[0016], [0019]-[0023], [0029], [0032]-[0037], [0043], all figures.

D3: WO 2010/008435 A1 (DENTSPLY INTERNATIONAL INC.) 21.01.2010, sec [0010], [0027], [0029], [0032]

NOVELTY:
D1 describes a computer implemented method for the planning of dental treatment for a patient consisting of:

- obtaining data about the area to be treated and the face of the patient from one or more 2D images
- creating a modified tooth setup using the above determined facial properties
- simulating the modified tooth setup and the patient's face surrounding the treatment area by creating a virtual 3D model of the modified tooth setup
- arranging the virtual 3D model and at least one of the 2D images to be viewed together in the same virtual 3D space

D2 describes a computer implemented method of designing a dental implant, crown or orthodontic treatment comprising:

- providing one or more 2D images of the patient's face
- providing a 3D virtual model of at least part of the patient's oral cavity
- arranging the 2D image and the 3D virtual model so that both the 2D image and the 3D virtual model are visualized in the same 3D virtual space
- modelling a restoration on the 3D model, where the restoration is designed to fit the facial feature of the 2D image.

Therefore the subject-matter of claims 1-21, 23-36, 38-59, 61-68, 70-91, 94-95, and 107-109 is not novel, cf Article 33(2) PCT.

Continued in supplemental box.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/DK2011/050246

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The claim set is unclear, due to the fact that most claims refer back to any of the preceding claims. This results in some claims referring back to claims that deal with completely separate technical issues, or refer back to contradictory claims. For example, claim 13 describes a 3D virtual model comprising no prepared teeth, yet refers to claim 12 which describes a 3D virtual model comprising at least one prepared tooth.

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Box No. V

2. Citations and explanations:
INVENTIVE STEP:

Claims 22, 60, 69, 92-93, 97 and 99-106 only describe technical details which are common technical knowledge for a person skilled in the art, and the subject matter of claims 22, 60, 69, 92-93, 97 and 99-106 therefore does not involve an inventive step, cf Article 33(3) PCT, when seen in relation to any of the preceding claims.

The subject matter of claim 37 differs from the subject matter in D1, in that it performs the alignment between the 3D model and one or more of the 2D images for one or more perspective views by means of interpolation and/or extrapolation of other perspective views. The problem to be solved is to provide an intermediate perspective view utilizing the information already supplied. The person skilled in the art would not be inspired by prior art to provide this solution to the technical problem.

Therefore the subject matter of claim 37 involves an inventive step, cf. Article 33(3) PCT.

The subject matter of claims 96 and 98 differs from D1 in various technical details. These details are described in the prior art, see for example D3 fig. 5. The person skilled in the art would be inspired to combine these two documents to arrive at the same technical solutions, and the subject matter of claims 96 and 98 therefore does not involve an inventive step, cf Article 33(3) PCT, when seen in relation to any of claims 1-36.

INDUSTRIAL APPLICABILITY:
The subject matter of claims 1-109 is industrially applicable, cf Article 33(4) PCT.

Electronic Acknowledgement Receipt

EFS ID:	15933070
Application Number:	13807443
International Application Number:	
Confirmation Number:	1045
Title of Invention:	2D IMAGE ARRANGEMENT
First Named Inventor/Applicant Name:	Nikolaj Deichmann
Customer Number:	21839
Filer:	William C. Rowland/Roberto Negron
Filer Authorized By:	William C. Rowland
Attorney Docket Number:	0079124-000062
Receipt Date:	03-JUN-2013
Filing Date:	01-MAR-2013
Time Stamp:	15:53:32
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	PTO_SB08.PDF	612759 ccd333d5b7b547a127a1ae35a61b45a6154edbdb	no	4

Warnings:

Information:

2	Foreign Reference	Foreign1.pdf	1570367 5c9bca9366281419e39e6d89c419f5698fb0f6fb	no	20
Warnings:					
Information:					
3	Foreign Reference	Foreign2.pdf	1517008 6a4d926e4d95d0984f631aa9c4d15dc0da782b78	no	35
Warnings:					
Information:					
4	Foreign Reference	Foreign3.pdf	1353560 118ff0ff71188ab07926c3307bbe725045560d7c	no	35
Warnings:					
Information:					
5	Non Patent Literature	NPL1.pdf	219779 486ef2b1bdf0e20ceb073b545b6e274d1da128a2	no	4
Warnings:					
Information:					
6	Non Patent Literature	NPL2.pdf	477805 8b5d448518f202223d9281d082395554d3da6008	no	11
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			Total Files Size (in bytes):	5751278	

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/807,443	03/01/2013	Nikolaj Deichmann	0079124-000062

CONFIRMATION NO. 1045

PUBLICATION NOTICE

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21839
BUCHANAN, INGERSOLL & ROONEY PC
POST OFFICE BOX 1404
ALEXANDRIA, VA 22313-1404

Title:2D IMAGE ARRANGEMENT

Publication No.US-2013-0218530-A1
Publication Date:08/22/2013

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The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

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Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**		
	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2128
	Examiner Name	JONES, HUGH M
	Attorney Docket Number	0079124-000062

U.S.PATENTS Remove

Examiner Initial*	Cite No	Patent Number	Kind Code1	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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Examiner Initial*	Cite No	Publication Number	Kind Code1	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20100049351	A1	2010-02-25	Monkmeyer	(Corresponds to JP 2010-503437)

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Examiner Initial*	Cite No	Foreign Document Number3	Country Code2 i	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T5
	1	2002-528215	JP	A	2002-09-03	Cadent Ltd	(with English abstract)	☐
	2	2010-503437	JP	A	2010-02-04	Dental Consulting Moenkmeyer S		☐
	3	2010-524529	JP	A	2010-07-22	Materialise Dental NV	(Corresponds to US 2010/0145898 and WO 2008/128700 cited on December 28, 2012)	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99)**	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2128
	Examiner Name	JONES, HUGH M
	Attorney Docket Number	0079124-000062

	4	00/25677	WO	A1	2000-05-11	Cadent Ltd	(Corresponds to JP 2002-528215)	☐

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Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	An English Translation of the Office Action (Notice of Reasons for Rejection) issued on May 19, 2015, by the Japanese Patent Office in corresponding Japanese Patent Application No. 2013-517019. (2 pages)	☒

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13807443
	Filing Date	2013-03-01
	First Named Inventor	Nikolaj DEICHMANN et al.
	Art Unit	2128
	Examiner Name	JONES, HUGH M
	Attorney Docket Number	0079124-000062

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/WCRowland/	Date (YYYY-MM-DD)	2015-06-30
Name/Print	William C. Rowland	Registration Number	30,888

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1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Espacenet

Bibliographic data: JP2002528215 (A) — 2002-09-03

DENTAL IMAGE PROCESSING METHOD AND SYSTEM

Inventor(s):

Applicant(s):

Classification: - international: ***A61B5/107; A61B6/00; A61B6/14; G06T1/00; G06T3/00;*** (IPC1-7): A61B5/107; A61B6/00; A61B6/14; G06T1/00; G06T3/00
- cooperative: **A61B6/14; A61B6/501; A61C9/0046;** Y10S128/922

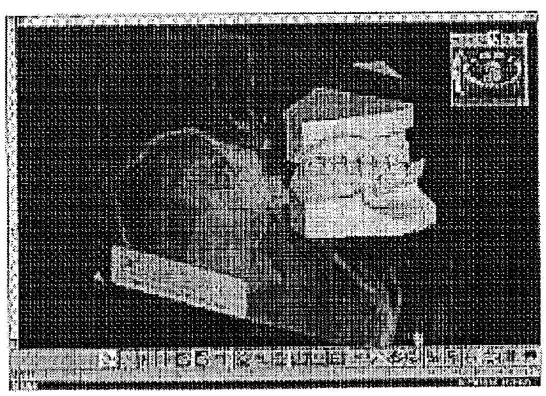
Application number: JP20000579128 19991101

Priority number (s): IL19980126838 19981101 ; WO1999IL00577 19991101

Also published as: WO0025677 (A1) IL126838 (A) DE69936145 (T2) AT362732 (T) EP1124487 (A1) more

Abstract not available for JP2002528215 (A)
Abstract of corresponding document: WO0025677 (A1)

An image processing method for use in dentistry or orthodontic is provided. Two images of teeth, one being a two-dimensional image and one a three-dimensional image are combined in a manner to allow the use of information obtained from one to the other. In order to combine the two images a set of basic landmarks is defined in one, identified in the other and then the two images are registered.



(19)日本国特許庁（ＪＰ）　(12) 公表特許公報(Ａ)　(11)特許出願公表番号
特表2002－528215
(P2002－528215A)
(43)公表日　平成14年9月3日(2002.9.3)

(51)Int.Cl.7		識別記号	ＦＩ			テーマコート゛(参考)
Ａ６１Ｂ	6/14		Ａ６１Ｂ	6/14		４Ｃ０３８
	5/107		Ｇ０６Ｔ	1/00	２９０Ａ	４Ｃ０９３
	6/00			3/00	４００Ｊ	５Ｂ０５７
Ｇ０６Ｔ	1/00	２９０	Ａ６１Ｂ	5/10	３００Ｚ	
	3/00	４００		6/00	３５０Ａ	

審査請求　有　予備審査請求　有　(全 37 頁)

(21)出願番号　特願2000－579128(P2000－579128)
(86) (22)出願日　平成11年11月1日(1999.11.1)
(85)翻訳文提出日　平成13年4月24日(2001.4.24)
(86)国際出願番号　ＰＣＴ／ＩＬ９９／００５７７
(87)国際公開番号　ＷＯ００／２５６７７
(87)国際公開日　平成12年5月11日(2000.5.11)
(31)優先権主張番号　１２６８３８
(32)優先日　平成10年11月1日(1998.11.1)
(33)優先権主張国　イスラエル（ＩＬ）

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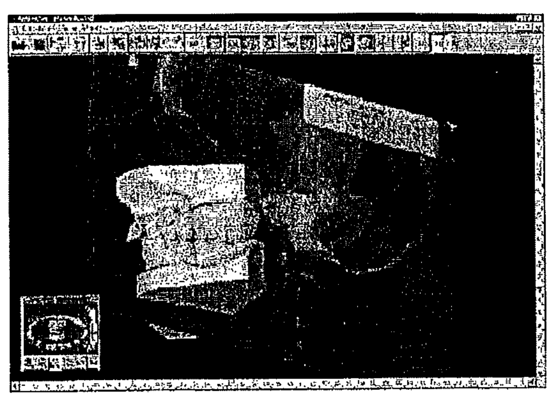
最終頁に続く

(54)【発明の名称】　歯の画像の処理方法とシステム

(57)【要約】
歯科医術もしくは歯科矯正（学）で使用するための画像処理方法が提供される。歯の２つの画像、１つは二次元画像で１つは三次元画像、が組合されて、一方から他方へ向けて得られた情報の使用ができるようにするような方法で組合される。２つの画像を組合せるために、一組の基本ランドマークが一方の中で定義され、他方の中で識別同定されて、二つの画像が位置合せされる。



【特許請求の範囲】

【請求項１】

（ａ）少くとも第１の作像技術と第２の作像技術とを適用して歯の少くとも第１の部分の第１の二次元画像と歯の少くとも第２の部分の第２の三次元仮想画像とをそれぞれ取得し、該第１と第２の部分間には少くとも部分的な重畳があるようにすること、及び、

（ｂ）該２つの画像のいずれか一方に基本ランドマークの組を定義し、該２つの画像の他方内に該組を置いて該組を２つの画像内で位置決めすることとを備えた画像処理方法。

【請求項２】

前記第１の画像はたて方向断面画像である請求項１記載の方法。

【請求項３】

前記第１の作像技術はＸ線撮影法Ｘ線技術である請求項２記載の方法。

【請求項４】

前記第１の画像は頭部測定法画像である請求項３記載の方法。

【請求項５】

前記段階（ａ）は第３の作像技術を適用して少くとも顔面外観のプロフィルを備えている第３の画像を取得することを備えた請求項１ないし４のいずれか１項記載の方法。

【請求項６】

前記三次元画像は、実質的に少くとも１つのあごのすべての歯を含み、また前記二次元画像は、該三次元画像の中央口蓋面上に置かれている請求項１ないし４のいずれか１項記載の方法。

【請求項７】

（ｃ）少くとも１つの歯を前記画像の少くとも一方で変位して、その変位の仕方は前記少くとも１つの歯が実生活の歯科矯正措置でシフトできる仕方と類似しているようにすること、及び、

（ｄ）一方の画像内の各要素が他方の画像内の対応する要素にマップされる規則の組を適用することにより、前記他方の画像内の前記少くとも１つの歯を変位

することとの段階を備えた請求項１記載の方法。

【請求項８】

前記規則の組は、前記一方の画像内で前記少くとも１つの歯の少くとも１つの目的と関係したランドマークを定義すること、前記目的と関係したランドマークを位置決めすること、及び前記目的と関係したランドマークを前記他方の画像内で前記一方の画像内のその動きに比例して変位することを備えている請求項７記載の方法。

【請求項９】

前記基本ランドマークは固定され、前記一方の画像内の前記少くとも１つの目的と関係したランドマークの変位が前記基本ランドマークに従って定義され、また、前記の少くとも１つの目的と関係したランドマークは前記他方の画像内の基本ランドマークに関して同じ相対的変位で移動される請求項８記載の方法。

【請求項１０】

前記一方の画像は歯のモデルの仮想三次元画像であり、また前記他方の画像は横方向画像である請求項７ないし９のいずれか１項記載の方法。

【請求項１１】

前記横方向画像は頭部測定法画像である請求項１０記載の方法。

【請求項１２】

（ｅ）前記少くとも１つの歯の変位によって生ずる軟かい顔面組織の転置を定義する規則の組を適用することにより、前記横方向画像内の軟かい顔面組織画像上で前記仮想三次元画像内で前記少くとも１つの歯の転置の効果を予測する段階を備えた請求項１１記載の方法。

【請求項１３】

前記軟かな組織の変位は、少くとも顔面外観のプロフィルの第３の画像を用いて予測される請求項１２記載の方法。

【請求項１４】

（ｉ）少くとも第１の歯の部分の第１の二次元断面画像を表わす第１のデータを受領するための第１のユーティリティと、

（ii）少くとも第２の歯の部分の歯のモデルの第２の三次元仮想画像を表わす

第２のデータを受領するための第２のユーティリティと、

(iii)両画像内の基本ランドマークを定義し、かつそれを表わすデータを生成するためのモジュールと、

(iv) 前記第１と第２のユーティリティおよび前記モジュールと関係しているプロセッサであって、前記第１と第２のデータを受領し、かつ、２つの画像の一方内の要素と該２つの画像の他方に前記基本ランドマークを表わすデータによりマッピングするプロセッサとを備えた画像処理システム。

【請求項１５】

前記第１の画像は頭部測定法画像である請求項１４記載のシステム。

【請求項１６】

少くとも顔面外観のプロフィルを含む第３の画像を表わす第３のデータを受領するための第３のユーティリティを備えた請求項１５記載のシステム。

【請求項１７】

前記第１、第２、および第３のユーテイリティが統合されている請求項１３ないし１６のいずれか１項記載のシステム。

【請求項１８】

前記第２のユーティリティは、前記第２の、仮想三次元画像を表わすデータを前記プロセッサに転送するためのデータ転送モジュールを備えている請求項１３ないし１７のいずれか１項記載のシステム。

【請求項１９】

画像の１つの中で少くとも１つの仮想の歯の表現を変位するための規則の組を定義するモジュールを備えている請求項１３ないし１８のいずれか１項記載のシステム。

【請求項２０】

前記規則の組は実生活の歯科矯正措置で少くとも１つの歯のシフトの仕方を表わしている変位を定義する請求項１９記載のシステム。

【請求項２１】

前記プロセッサは前記画像の一方における前記少くとも１つの仮想の歯の表現の変位を他方の画像における対応する歯の転置に変換する請求項１９記載のシス

テム。

【請求項２２】

前記画像の一方は歯のモデルの仮想三次元画像であり、また前記他方の画像は頭部測定法画像である請求項２１記載のシステム。

【請求項２３】

軟かな顔面組織の頭部測定法画像内の歯の変位の効果を予測するための規則の組を定義するモジュールを備えた請求項２２記載のシステム。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】

この発明は一般に歯科医学の分野に係り、歯科医もしくは矯正歯科医によるツール（道具）として有用な画像処理方法とシステムを提供するものである。

【0002】

【従来の技術】

矯正歯科学の分野で日常業務、ルーチンとして使用されている作像技術（イメージング技術）は広範な多様性のものがある。１つの重要な作像技術はいわゆるＸ線撮影法（radiographic）の頭部測定法（cephalometric）技術である。Ｘ線撮影法の頭部測定法画像がそこで頭部測定法解析用に使用される。このような解析は骨格の、歯の、及び軟かい組織（soft tissue）の要素でクラニオフェーシャルコンプレックス（頭蓋及び顔面の複合体）についてのものの間の関係を記述するために設計されている。２つの頭部測定法画像で一般に使用されているものは横方向の（ラテラル）頭部測定法画像であり、これは主として矯正歯科学で使用され、また正面の頭部測定法画像であり、これは幾分か重要性に乏しい。

【0003】

頭部測定方法は頭蓋及び顔面複合体の骨格、歯、及び軟かい組織のある種のノルム（標準）を定義することができる。そこで、頭部測定法による個人の測定は、年齢、性別及び個体群（population group）についてのノルムと比較できる。頭部測定法の結果であるセファログラムは実際には三次元の頭蓋及び顔面の構造についての二次元表現である。したがって、このような画像について実行された解析では、バイラテラルな（両側のある）構造間を区別してそれらを独立にトレース（追跡）することはむづかしい。加えて、顔の外観（フェーシャルアスペクト）は完全には対称性がなく、これがこの種の解析に別な不正確さを加えることになる。頭部測定法画像における誤差の別な発生源はフィルムからの距離と、頭部測定法装置（セファロスタット）内での患者の不完全な位置どりとに依存して、異なる外観（アスペクト）を違った拡大倍率とすることを含んでいる。これらのすべてが頭部測定法でかなりの誤差を累積する。

【０００４】

矯正歯科医は、矯正歯科措置を始める前に、一般に歯型をとるが、これには石膏モデル（模型）が作られて基礎とされる。また多数の作像技術が知られていて、これが計算機環境内で歯の仮想三次元画像を得られるようにしている。このような技術は例えばWO 97/03622とDE-C-414311に記述されている。三次元の歯の画像は頭部測定法解析により得られるものとは異なる情報を与える。とくに、仮想の歯の画像は歯と、異なる相対的位置とについての三次元構造についてより評価ができるようにしている。

【０００５】

【発明が解決しようとする課題】

矯正措置の適切な設計の目的にあたり、方法とシステムとして１つの形式の画像から取得できる情報が他の形式の画像から得ることができる情報に転送されたり重畳（スーパーポジション）することができるようにするものをもつことは極めて好都合である。

【０００６】

【課題を解決するための手段】

この発明によると、新しい方法とシステムとが用意されていて、そこでは歯の作像技術の一形式から得られた情報とデータとが他の種類の歯の作像技術により得られた画像内に転送されて使用される。この情報の転送は歯科医もしくは矯正歯科医に対して、矯正措置を設計するための有力なツールを提供する。

【０００７】

この発明によると、画像処理方法が提供されていて、その構成は、

（ａ）少くとも第１の作像技術と第２の作像技術とを適用して歯の少くとも第１の部分の第１の二次元画像と歯の少くとも第２の部分の第２の三次元仮想画像とをそれぞれ取得し、該第１と第２の部分間には少くとも部分的な重畳があるようにすること、及び、

（ｂ）該２つの画像のいずれか一方に基本ランドマークの組を定義し、該２つの画像の他方内に該組を置いて該組を２つの画像内で位置決めすることとを備えている。

【0008】

この発明を別の観点からとらえると、画像処理システムであって、

（ｉ）少くとも第１の歯の部分の第１の二次元断面画像を表わす第１のデータを受領するための第１のユーティリティと、

（ii）少くとも第２の歯の部分の歯のモデルの第２の三次元仮想画像を表わす第２のデータを受領するための第２のユーティリティと、

（iii)両画像内の基本ランドマークを定義し、かつそれを表わすデータを生成するためのモジュールと、

（iv）前記第１と第２のユーティリティおよび前記モジュールと関係しているプロセッサであって、前記第１と第２のデータを受領し、かつ、２つの画像の一方内の要素と該２つの画像の他方に前記基本ランドマークを表わすデータによりマッピングするプロセッサとを備えているものが提供されている。

【0009】

【発明の実施の形態】

この発明の一実施形態によると、この作像方法とシステムとは、矯正歯科（学）関連情報、すなわち矯正措置の枠組内で矯正歯科医によって使用されることになる情報を得るか、このような措置の設計のために使用される。この実施形態は少くとも２つの画像の位置合せを含んでいて、一方は歯のモデル（模型）の三次元仮想像であり、また他方は二次元画像であり、例えば頭部測定法画像である。ときには、他の画像も位置合せに持ち込まれ、例えばいくつかの横方向の（側部の）ビデオグラヒック画像、正面からのビデオグラヒック画像及び正面からの頭部測定法画像で構成されている。

【0010】

この発明の別な実施形態によると、この方法とシステムは歯の埋め込み（デンタルインプラント）もしくは歯冠（クラウン）の適切な設計に使用される。インプラントを適切な位置でするためには、前もって注意深く骨頂を学習し、歯のインプラントを受入れられるかどうかを調べなければならない。歯のインプラントの正確な位置と配向とは適切に前もって設計されなければならない。一般に、インプラントの適切な設計については、歯のモデルの三次元仮想画像が両方の横方

向頭部測定法画像と位置合せがされ、ときには、また正面の頭部測定法画像とも位置合せがされる。これがあごの骨格内部にインプラントを受入れるやり方を適切に予測する。

【0011】

向後は、この発明が歯科矯正措置の設計目的についての作像を特に参照して記述することになる。しかし、この発明は必要な変更を加えて歯のインプラントの適切な設計の目的への応用に対しても適用されることは理解できよう。

【0012】

第一の画像はX線画像が好ましく、一般にはX線撮影法技術によって得られた頭部測定法画像がよい。このX線画像は横方向画像がよいが、場合によっては、この画像は例えば正面画像といった他の配向からのものでもよい。頭部測定法画像では、ある顔の輪郭(プロフィル)の外観も時たま見られることになる。しかし一般には、歯科矯正措置前は、第3の顔の側部の立面ビューがX線撮影頭部測定法画像が撮られたのと同じ方向からとるようにもされる。この発明の実施形態によると、このような第3の画像で顔の外観の少くとも1つの輪郭を含んでいるものが得られて、この発明の作像技術で使用される。この側部立面像は例えばビデオ頭部測定法によって得ることができる。

【0013】

“仮想三次元の歯の画像(virtual three-dimensional teeth image)”という用語は、計算機環境内部で表わされた画像を言い、これは一方もしくは両方のあご(上下顎骨と歯を含む)の歯で主として構成されている。例えば、仮想三次元の歯の画像は石膏モデル(模型)の画像と似たやり方で表わすことができる。仮想三次元画像は各種の技術によって得られ、例えば、上記の参考文献に記述されたところである。とくに、三次元仮想画像はWO 97/03622に記述されている方法によって得られ、この文献はここで、この発明の方法とシステムとで使用するための三次元仮想画像を得る方法の例として参考に組入れる。この発明は1つの作像技術もしくは他の作像技術によって得られる特定形式の画像に限定されるものでないことは理解されなければならない。例えば、二次元画像は各種の異なる作像技術によって得ることができるのであって、これらの技術には磁気共鳴作像

（ＮＭＩ）、コンピュータトモグラフィ（ＣＴ）、各種の放射線作像技術等が含まれる。同じように、三次元の歯の画像は利用可能とされる多数の作像技術のいずれか１つによって得ることができて、その中には前記の参考文献に開示されているものとともに、走査形プローブ、各種の写真技術を使うもの、またプローブ用光ビームによって歯が走査される技術等が含まれている。

【００１４】

ここで使用される“画像（image）”という用語は作像技術で取得されるような画像だけを言うものと解してはならず、むしろ初期画像処理、例えば画像内の各種オブジェクトの境界を定義することを意図した画像処理の結果もこれにあたるとしてよい。したがって、用語“画像”は、例えば、歯、骨、顔の外観のプロフィル等のような、オブジェクトの境界についての、取得した画像を基にして作った、表現を取り込んでいる。

【００１５】

しばしばこの発明による作像技術と解析とが第３の画像を使用することがあり、この画像が上述した立面画像であったり、歯科矯正解析を改善するのに有用な他の何らかの画像であったりする。したがって、例としては、前記第１の画像が横方向の（側部）二次元画像であり、前記第３の画像が上述の横方向立面画像または正面のＸ線もしくはビデオグラヒック画像の一方もしくは両方であってよい。

【００１６】

基本ランドマーク（標認点）で画像の２組を位置合せ（レジスタ）するために使用されるものは、一般にある種の選ばれた歯のベースか頂点のいずれかの点として定義される。例えば門歯（incisor）か臼歯（molar）が選ばれる。このような基本ランドマークはユーザによって選ばれてよいし、システムのプロセッサによって、例えば設定されたノルム（規準）に基づいて、自動的に選ばれてよい。基本ランドマークを選んで、画像の１つの中でランドマークにマークを付けた後に、このランドマークは他の画像の中でマークが付けられて、両方の画像が位置合せができるようになる。用語“位置合せ（registering）”は２つの画像の物理的な位置合わせを必ずしも意味しておらず、むしろその意味は１つの画像中の

各特徴の別なものの中での対応する特徴へのマッピング(写像)である。このような位置合せの結果は、一方の画像についてした何らかの操作が他方の画像内での対応する操作を生ずることになる。例えば、もし一方の画像が1つの歯を変位(displace、位置を変える転置の意)によって操作されるとすると、他の画像の中での同じ歯に対応する転置(変位)を生じさせることになる。

【0017】

時には、一方が他方に重畳されたスクリーン上での両画像を眺めたいと希望されることがある。重畳されなければならない2以上の画像は最初は異なるスケール(目盛寸法)で呈示されてよいので、このシステムによってとられることが必要とされる初期段階は、一方の画像のスケールを拡大か縮小して、2つの画像内の基本ランドマークの本質的な完全な重なりがあるまでそれを行なうことである。しかしながら、異なる画像の位置合せは必ずしも重畳を意味しなくてよく、むしろ時には、2つの位置合わせされた画像が別個に、例えば横並みに呈示されてもよい。位置合せ(レジスタリング)の動作の重要な結果は、画像の一方の上での操作が他方についてもまた影響を与えていることである。

【0018】

以下では、この発明はとくにある実施形態について記述されて行くが、この実施形態では第1の画像が頭部測定法画像であり、また第2の画像が仮想三次元画像である。この特定の参照事項はこの発明がこれに限定されるという意味に解されてはならない。逆に、この発明の一般的な教示を適用することによって、情報が他の作像技術によって得られた画像間で転換されるのである。

【0019】

この発明の一実施形態によると、ランドマークが三次元仮想画像と頭部測定法画像との中で定義された後に、仮想三次元歯のモデルの正しい配向が決定されて、それにより頭部測定法画像とそれが一致関係(conformity)をもつことができるようにしなければならない。このことは時にはかなり莫大な計算時間を必要とする。しかしながら2つの画像の位置合せのプロセスはかなり加速できることが見付かっていて、それには頭部測定法画像が仮想三次元歯の画像の中間口蓋面(mid palatal plane)と重なるように定義することが行なわれ、それによって加

速がされる。換言すると、頭部測定法画像は中間口蓋面上に置かれるように定義され、また頭部測定法画像はそこで調節されて、基本ランドマークが仮想三次元画像の対応する基本ランドマークの中間口蓋面上への投影と一緒に重なるまで調節がされる。

【0020】

この発明は頭蓋及び顔面の複合体の各種の外観上での歯の転置の効果の解析も可能とする。例えば、歯は歯のモデルの仮想三次元画像上で変位されてよく、そのやり方は矯正措置を行なう際にシフトされると期待されるところによる。したがって、例えば、変位された歯について各種のランドマークをマーク付けし、また頭部測定法モデル内で同じランドマークをマーク付けしたりまたそれから転置したりすることによって、両方の画像をチェックして、矯正措置がある受入れ可能なノルムに整合する結果を達成するかどうか、あるいはこのようなノルムを達成するにはどんな変更をすべきかを見る。例えばもし修正を加えた頭部測定法画像(いわゆる歯の転置後の頭部測定法画像である)で眺めたところの所望の結果が所望の結果と整合していないとすると、仮想三次元歯のモデルに戻って、シミュレーションを進行し、それから頭部測定法画像上に結果をマップする等のことをすることは可能である。

【0021】

例を挙げると、1つの画像の中で同じ程度の変位を達成するためには、転置されるオブジェクトと関係しているあるランドマークをシフトすることが次にある基本ランドマークと比較され、転置と同じ関係が他の画像と関係付けられる。

【0022】

このようなシミュレーションによって行うことができる解析の1つの特定例は、軟かな顔の組織、とくに外側の顔の組織上でのこのような転置の効果を判断することである。これは個人のエステティック(美的)外観についての矯正措置の効果の推定を可能にする。

【0023】

この措置のシミュレーションと、それに続く頭部測定法画像への結果の変換はまたあごのような各種の要素内でのシフトが生理学的なあるいは美的な許される

限界の中にあるかどうかを判断することができるようにする。矯正措置での歯とかあごについての制御できないシフトは各種の生理学的及び機能上の問題を生じさせかねない。

【0024】

この発明はある特定の、限定することとしない実施例について、ときに添付の図面を参照しながら、記述される。

【0025】

実施例

この発明によると、画像が取得され、そこには少くとも1つの二次元の歯の画像と、少くとも1つの三次元の歯の画像とが含まれていて、両方が組合され、その目的は各種のパラメータについて矯正措置の効果を予測する矯正歯科医の能力を改良することとされる。この組合せは矯正歯科医にとって矯正措置の結果についてその者の理解の深さをかなり大きくすることができるようにする。これまでは、頭部測定法画像上で行なわれる解析はすぐに矯正歯科医にとって利用可能な他のツールに変換することができなかった。これは三次元の歯のモデルであって、一般には石膏モデルであった。逆に言うと、矯正歯科医によって三次元の歯のモデルを研究することから得られた情報は頭部測定法画像にすぐには変換できなかった。腕ききの職人には良く知られているように、画像の各々は限定された範囲の解析を許し、解析ができても、真の解析は画像の2つの形式に基づいた完全な解析からのみ得ることができる。

【0026】

適切な解析が現実に可能とされるのはこの発明によってのみとされる。

【0027】

画像は、一旦取得されて計算機環境内部での呈示に変換されると、操作処置ができるようになり、例えば何本かの歯とあご全体といったある要素を変位することによりそれができる。頭部測定法画像は若干の要素間での相互関係を眺められるようにし、例えばある生理学的もしくは機能的パラメータと並んでエステティックパラメータについて措置の効果を試験するために使用できる。しかしながら著しい欠点が存在していて、それはこの情報が三次元の実生活環境には完全に変

換することが不可能ということである。この発明は要素の変位の効果の適切な解析を許し、あるいはどのように変化が実生活状態に効果を与えているかについて一層の理解ができるようにする。

【0028】

先ず、図1Aと1Bとを参照するが、この図はそれぞれ頭部測定法X線撮影と、三次元仮想の歯の画像を示している。仮想の歯の画像で図1Bに示してあるものは、石膏の歯のモデル（模型）と似せて表わされている。腕のある職人によって疑いもなく評価されることとなるように、これは単に例であって、二次元もしくは仮想三次元歯の画像は別なやり方で表わされてもよい。

【0029】

この発明の前には、こういった異なる画像の各々が別個に呈示されていた。三次元仮想画像は石膏モデルとしてか、あるいは計算機環境内で三次元仮想表現として表わされていた。この発明によると、２つの異なる画像は、一方が例えば頭部測定法X線撮影写真である二次元画像であり、それが三次元歯の画像と組合わされている。２つのこのような画像の重畳が例として図２に示されている。見て分るように頭部測定法画像は三次元の仮想の歯の画像と組合されて、それが三次元の仮想の歯の画像の中間口蓋面上に置かれている。２つの画像の相対的な位置は固定されて、２つの画像中で定義された基本ランドマークが一致するようにされている。このことは後に詳述する。

【0030】

この発明の別な実施構成は例にあげた図３Aと３Bとで見ることができる。これらの図では、三次元の仮想の歯の画像が個人の横方向もしくはプロフィル（輪郭）映像と重畳されている。図３Aと３Bとのプロフィル映像はそれぞれが僅かずつ異なる配向からのものであり、したがって図３Bにおける仮想三次元の歯のモデルは図３Aにおけるモデルの配向に対して回転している。

【0031】

頭部測定法画像と三次元仮想モデルを組合せるためには、基本ランドマークが両方の画像内で定義されてマーク付けがされねばならない。これら基本ランドマークはユーザによって手操作で入力されてよいが、代って計算機によって自動的

に生成されてよく、それには標準的な画像解析方法に基づくか、先にしたユーザの入力に基づくかによる生成がされる。一般に、このような基本ランドマークは任意のランドマークであるか、矯正歯科学関連ランドマークかであってよく、ランドマークは後に頭部測定法解析で使用できてそのために受け入れることができるノルムの１つに従って解析に使用される。（頭部測定法解析についてはRediographic Cephalometry, From Basics to Video imaging, Jocobson A.et al., Quintessence Publishing Co., Inc., Chicago, Berlin, 1995を見よ）。

【００３２】

頭部測定法Ｘ線撮影写真と三次元はのモデルとで同一個人からのものが図４Ａと４Ｂとに示されている。これらの図では二つの基本ランドマークがマークされていて、Ｌ１とＬ２となっている。こういったランドマークがマークされた後に、２つの画像が位置合せされて、その結果図５で見ることができるように重畳がされる（同じ２つのランドマークＬ１とＬ２とがここでも見える）。図４Ａ，４Ｂ及び５で示したやり方での位置合せは２つの定義したランドマークを用いて実行される。明らかに、時にはもっと多くのランドマークをこの目的のために使用して位置合せの精度を増すことが可能である。

【００３３】

計算時間を短縮するために、（仮想的感覚で）頭部測定法画像を中間石膏面上におくことによって、Ｘ線撮影写真が三次元仮想の歯の画像と組合されている。適切な位置合せのために２つの画像のスケールは調節されなければならず、その後に一方の画像が他方に対してシフトされて、歯のモデルの三次元仮想画像の基本ランドマークの中間石膏面への投影が頭部測定法画像内の対応するランドマークと位置合せされるまでシフトされる。

【００３４】

ここで示した頭部測定法Ｘ線撮影写真と頭部測定法ビデオグラフは利用した作像技術によって取得された画像である。しかしながら、時には最初に画像の表現、例えば、画像内部で関心のあるオブジェクトの境界のグラヒカルな表現を作るのが好都合である。例えば、完全な頭部測定法画像ではなくて、ある主たる骨格といくつかの歯、例えば第１と第２の臼歯と門歯の境界を含んでいる表現である

。こういった上記の歯は頭部測定法解析のためには通常は重要な歯であり、その理由はその位置が比較的歯とあごの変位に感じ易いからである。さらに、これらの歯の位置は各種の機能上のまたエステティックな顔の外観に対する歯の位置がもつ効果を研究しあるいは測定するための重要なマーカーである。

【００３５】

ある画像の、とくに頭部測定法画像の、若干の外観についてのグラヒカル表現を作ることはその画像内での歯の仮想変位の目的にとって非常に有用であり、それによって、一般に本質的に知られているように機能的もしくは顔のエステティックパラメータについての措置の効果を研究するようにする。

【００３６】

この発明の実施例によるシステムは図６で見ることができる。これは３つの入力ユーティリティ２２，２４，２６をもつ中央計算機処理ユニット２０を備えていて、これがモジュール２８の内部で一体化されている。これらのユーテイリティは、一般に本質的に知られているように、データエントリィポートと必要とされるデータ転送ソフトウェアを備えることができる。さらに、データエントリィポートを介してデータをとり込むものではなく、こういったユーテイリティへのデータは記憶媒体もしくは情報キャリヤ例えば磁気または光ディスクから取り入れることができる。無論さらに理解されるように、モジュール２８は画像を走査するスキャナを備えることもよいし、直接画像取得用カメラを備えてよい。

【００３７】

このシステムはまたさらにモジュール３０を備えていて、これがユーザ入力インターフェース３２である、例えばキーパッド、カーソルドライバ等に接続されている。インターフェース３２によって、ユーザはランドマークを定義できるし、あるいは各種の動作モードにシステムが入るように誘導でき、このモードのいくつかは以下に説明される。

【００３８】

モジュール３０とユーテイリティ２８とは画像処理のためにプロセッサ４０に接続されて、例えば以下に記述されるように２つの画像を組合せるようにする。プロセッサ４０はモニタ５０に接続することができて、また他の表示手段、例え

ばプリンタに接続されてよい。

【0039】

三次元仮想の歯のモデルと頭部測定法画像との間のリンキングの仕方の実施例についての流れ図が図7Aと7Bとに示されている。図7Aはユーザ対話(相互作用)段階についての流れ図であり、また図7Bは2つの画像を組合せるやり方についてのソフトウェア機能性流れ図である。第1の段階100では、このシステムは三次元仮想の歯のモデルを表わすデータの入力を受領する。次に段階110では、基本ランドマークが画像111内に表わされているように三次元仮想の歯のモデル内で認識可能なオブジェクト上でマーク(が付)される。このような基本ランドマークは、例えば歯冠と上下の第1の臼歯の歯根上の点(画像111のランドマーク1～4)であり、上下のセントラル(中心部)の歯冠上と歯根(画像111のランドマーク5～8)も同様である。ランドマーク1と4、またランドマーク5と8は歯根のおおよその位置をマークしている。実際の歯根の位置はこのようなモデルでは見ることができないが、矯正歯科医は経験に基づいて比較的正確にそれらの歯根位置をマークできる。

【0040】

次の段階120では、同一患者の頭部測定法画像がこの画像上に入力されて、同じキーポイントがそこでマークされる(131を見よ)。次に、2つの画像が整合をとられて、上述したように重畳によって整合され、スクリーン上にそれが表わされるか、一方の画像内の各位置が他方の画像上に各位置に写像される他の方法によって整合される。

【0041】

次の段階140では三次元モデル内の歯とあごとは三次元モデル上で転置(変位)されて所望の結果を受ける。そこで図7Bに示したように、ソフトウェアは次の段階150,160で骨格要素と歯とをそれぞれ動かすことを、ユーザが三次元仮想の歯のモデル上で実行した動きに従って、行なう。次に段階170では、頭部測定法解析が修正された(変位後の)頭部測定法画像上で行なうことができて、所望の比例測定がこのような歯の変位(転置)で到達できたかどうか、あるいは何らかの薬物療法がされねばならないかどうかを見ることになる。

【0042】

操作の逆のシーケンス、すなわち頭部測定法画像からの各点を三次元仮想モデルに向けてするマッピング（写像）は図８Ａと８Ｂとで見ることができる。図８Ａと８Ｂとでは、各段階２００〜２７０は図７Ａと７Ｂの段階１００〜１７０に準じた対応がとれている。これが最終的には頭部測定法画像内の各点を三次元仮想の歯のモデルの対応する位置へマッピングして前の画像上で実行された変位を後のものへと変換できるようにしている。

【図面の簡単な説明】

【図１】

（Ａ）はＸ線撮影頭部測定法画像を示し、（Ｂ）は歯の仮想三次元画像を、石膏の歯のモデルに似せたやり方で表わした図。

【図２】

三次元歯のモデルと頭部測定法画像の重畳を示す図。

【図３】

（Ａ）と（Ｂ）とは三次元モデルとビデオ頭部測定法画像の重畳の二例を示す図。

【図４】

（Ａ）は頭部測定法画像を示し、その上に若干の基本ランドマークがマークされており、（Ｂ）は（Ａ）の頭部測定法画像に示したのと同じ歯の三次元仮想画像を示し、その上に同じ基本ランドマークがマークされている図。

【図５】

二つの画像の重畳を示す図。

【図６】

この発明によるシステムのブロック図。

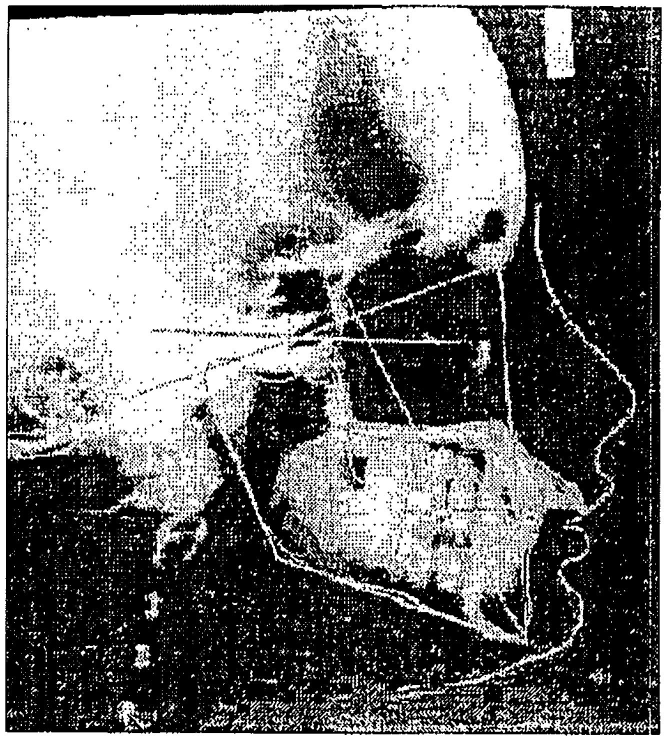
【図７】

（Ａ）と（Ｂ）とは頭部測定法画像へ三次元仮想の歯のモデルからの要素のマッピングのやり方を示す流れ図であり、（Ａ）はユーザの対話モジュールを示し、（Ｂ）は頭部測定法画像へ三次元仮想の歯のモデルからの変位の実行と変位のマッピングのやり方の下にあるソフトウェア機能を示す図。

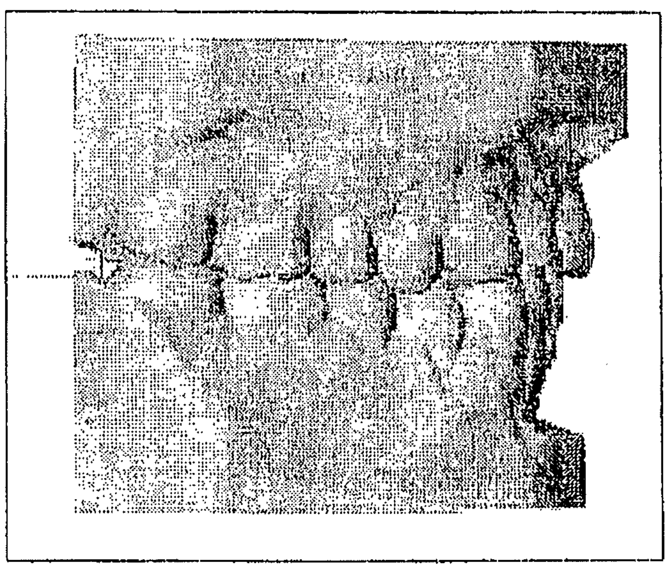
【図８】

（Ａ）と（Ｂ）とは三次元仮想の歯のモデルへの頭部測定法画像からの要素のマッピングのやり方を示す流れ図であって、（Ａ）はユーザの対話モジュールを示し、（Ｂ）は仮想の三次元歯のモデルへの頭部測定法画像からの変位の実行と変位のマッピングとのやり方の下にあるソフトウェア機能性を示す図。

【図1】

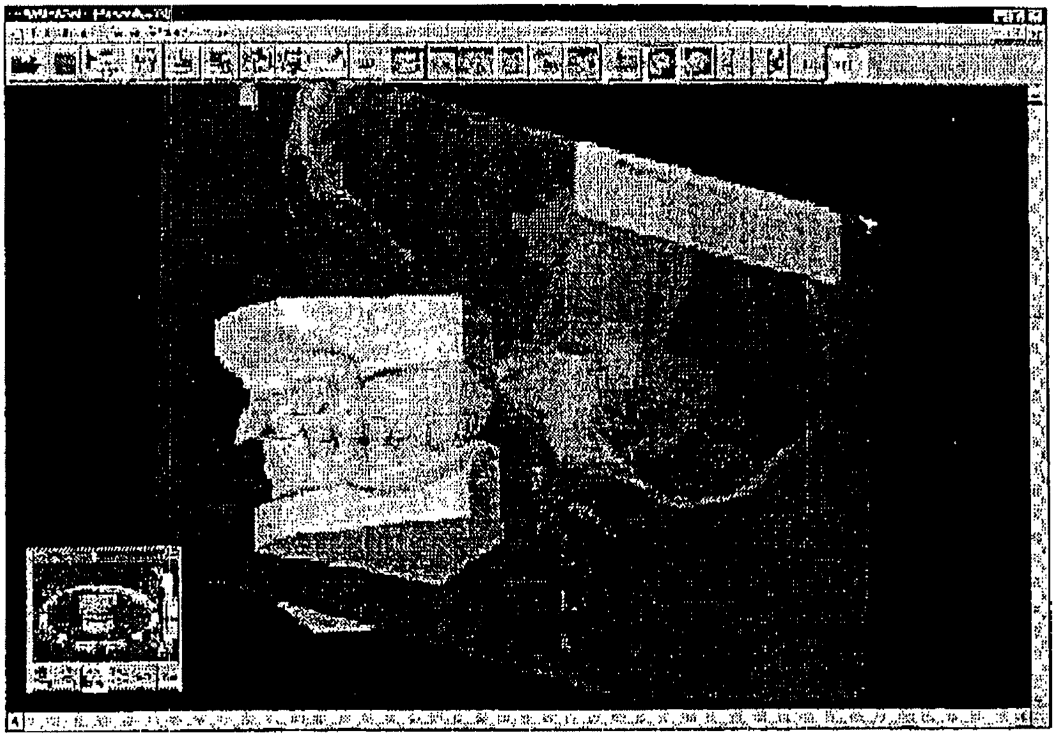


(A)
先行技術



(B)
先行技術

【図２】

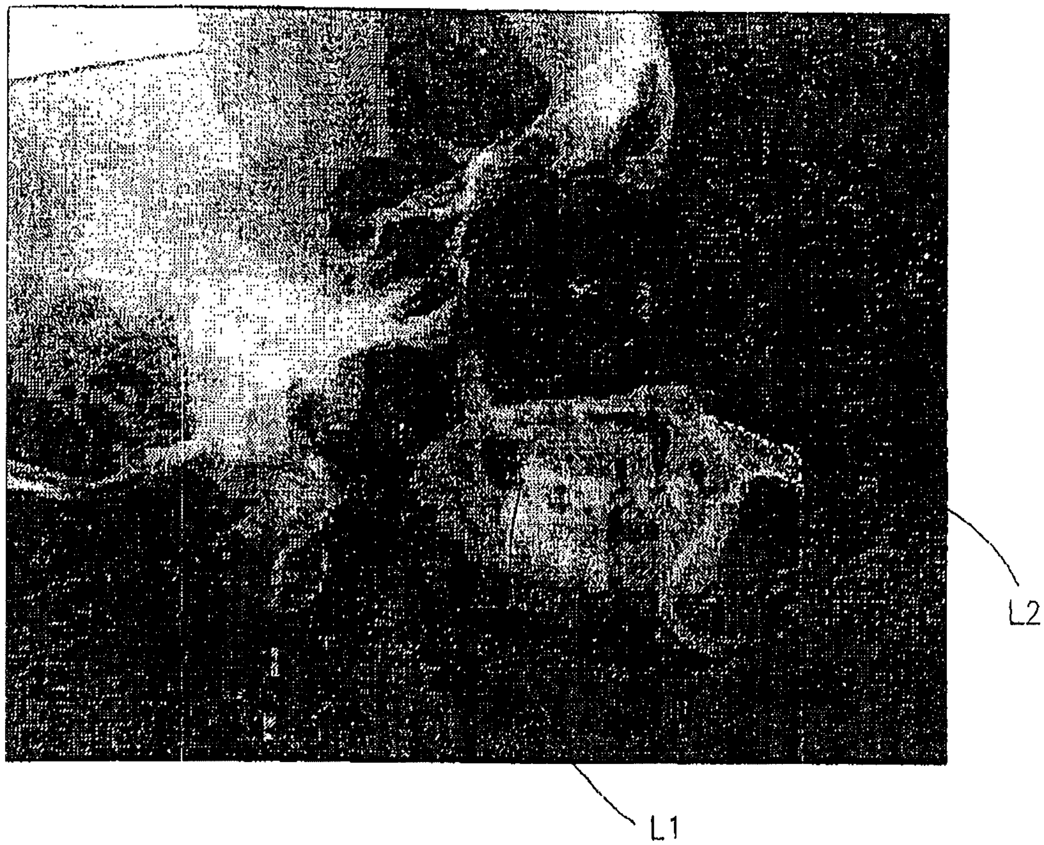


【図3】

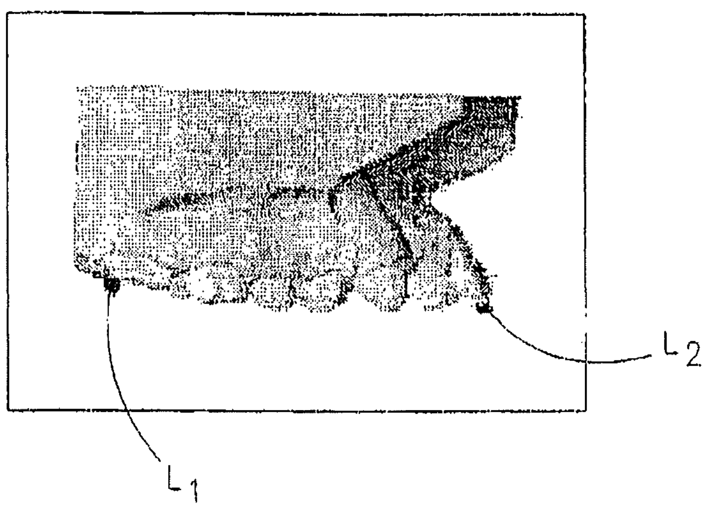
(A)

(B)

【図4】



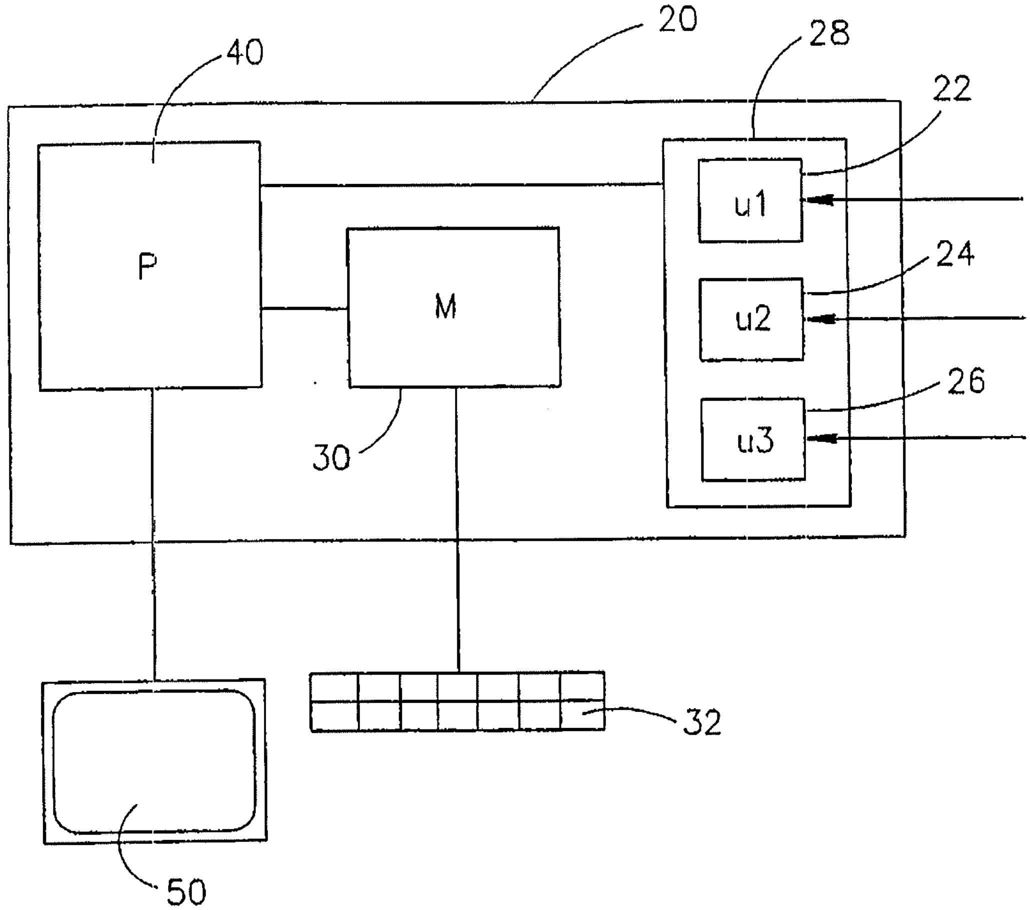
(A)



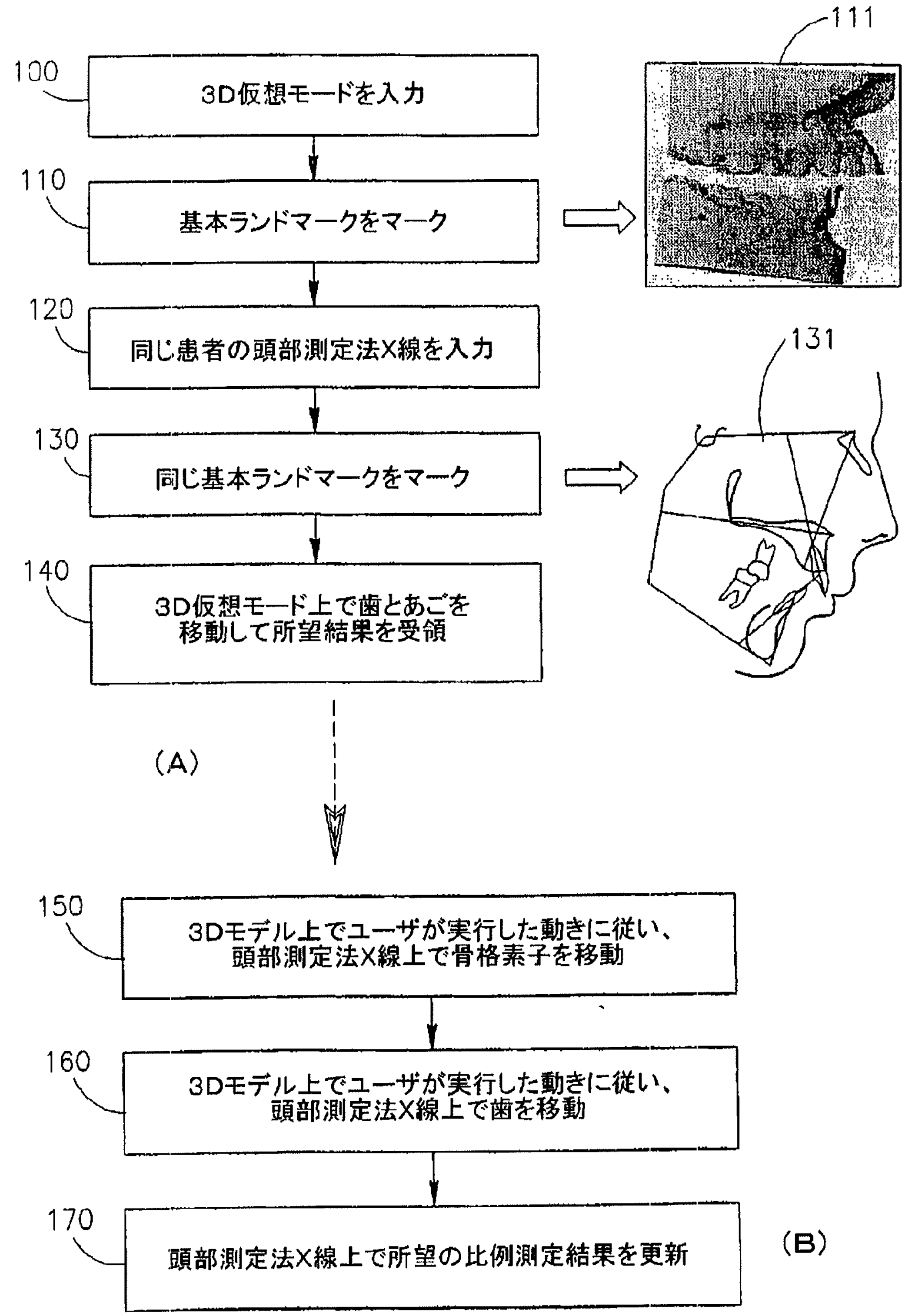
(B)

【図5】

【図6】



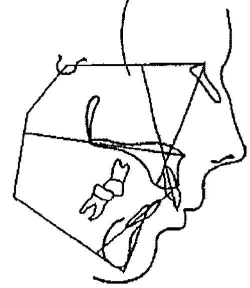
【図7】


111
100
3D仮想モードを入力
110
基本ランドマークをマーク
120
同じ患者の頭部測定法X線を入力
131
130
同じ基本ランドマークをマーク
140
3D仮想モード上で歯とあごを
移動して所望結果を受領
(A)
150
3Dモデル上でユーザが実行した動きに従い、
頭部測定法X線上で骨格素子を移動
160
3Dモデル上でユーザが実行した動きに従い、
頭部測定法X線上で歯を移動
170
頭部測定法X線上で所望の比例測定結果を更新
(B)

【図８】

200
頭部測定法X線を入力

210
上下の中心部と上下の第一臼歯（モラー）の外形を描画。これらの歯の歯冠と歯根のランドマークをマーク

211


220
同じ患者の3D仮想モデルを入力

230
頭部測定法X線上でマークされたように歯冠と歯根上に同じランドマークをマーク

231


240
所望の比例測定を受領するために頭部測定法X線上で歯と骨格素子を移動

(A)

250
頭部測定法X線上の変換に従いあごの間の位置関係を3Dモデル上で変更

260
頭部測定法X線上でユーザにより実行された移動に従い3Dモデル上で歯を移動

270
頭部測定法X線上でユーザにより定義された歯の位置に関し、3Dモデル上ですべての歯を配列

(B)

【手続補正書】特許協力条約第３４条補正の翻訳文提出書
【提出日】平成１３年１月２９日（２００１．１．２９）
【手続補正１】
【補正対象書類名】明細書
【補正対象項目名】０００４
【補正方法】変更
【補正内容】

【０００４】

矯正歯科医は、矯正歯科措置を始める前に、一般に歯型をとるが、これには石膏モデル（模型）が作られて基礎とされる。また多数の作像技術が知られていて、これが計算機環境内で歯の仮想三次元画像を得られるようにしている。このような技術は例えばWO 97/03622とDE-C-414311に記述されている。三次元の歯の画像は頭部測定法解析により得られるものとは異なる情報を与える。とくに、仮想の歯の画像は歯と、異なる相対的位置とについての三次元構造についてより評価ができるようにしている。

EP-A-0 488 987は動いている物体（身体）を表示するためのプロセスを開示している。ここでは身体の画像がカメラにより取得され、カメラは磁場源（コイル）に対して正確に位置決めされている。カメラに対して身体を正確に位置付けるために、磁気応答アッセンブリィが身体に取付けられ、磁気的なスタイラスが使用されて、身体上の３つの測定点をマーク付けするのにあてる。これがカメラによっては作像はされない身体上の点の表示を可能としている。

EP-A-0 741 994はモデルによって患者のあごの領域内での外科的介入を計画するための技術を開示している。この技術は患者の口腔（oral cavity）内に挿入された位置判断用装置を利用する。この位置決め装置は口腔の少くとも１つの画像内に置かれることになるマーキング点と一緒に形成されている。

【手続補正書】特許協力条約第34条補正の翻訳文提出書

【提出日】平成13年2月19日(2001.2.19)

【手続補正1】

【補正対象書類名】明細書

【補正対象項目名】特許請求の範囲

【補正方法】変更

【補正内容】

【特許請求の範囲】

【請求項1】 (a)患者の歯の少くとも第1の部分についての第1の二次元画像と、該歯の少くとも第2の部分ついての第2の三次元仮想画像とで成る2つの画像の一方内に基本ランドマークの組を定義し、第1と第2の部分間には少くとも部分的な重畳があり、該基本ランドマークは該2つの画像の重畳領域内にあるようにすることと、

(b)該2つの画像の他方内に基本ランドマークの組を置くことと、

(c)それぞれの二次元もしくは三次元特性を保持している該2つの画像を、該基本ランドマークが2つの画像のそれぞれで位置合せをすることにより、組合せることとを備えた画像処理方法。

【請求項2】 前記第1の画像はたて方向断面画像である請求項1記載の方法。

【請求項3】 前記第1の画像はX線撮影法X線画像である請求項2記載の方法。

【請求項4】 前記第1の画像は頭部測定法画像である請求項3記載の方法。

【請求項5】 前記段階(a)は第3の作像技術を適用して少くとも顔面外観のプロフィルを備えている第3の画像を取得することを備えた請求項1ないし4のいずれか1項記載の方法。

【請求項6】 前記三次元画像は、実質的に少くとも1つのあごのすべての歯を含み、また前記二次元画像は、該三次元画像の中央口蓋面上に置かれている請求項1ないし4のいずれか1項記載の方法。

【請求項７】　（ｄ）少くとも１つの歯を前記画像の少くとも一方で変位して、その変位の仕方は前記少くとも１つの歯が実生活の歯科矯正措置でシフトできる仕方と類似しているようにすること、及び、

（ｅ）一方の画像内の各要素が他方の画像内の対応する要素にマップされる規則の組を適用することにより、前記他方の画像内の前記少くとも１つの歯を変位することとの段階を備えた請求項１記載の方法。

【請求項８】　前記規則の組は、前記一方の画像内で前記少くとも１つの歯の少くとも１つの目的と関係したランドマークを定義すること、前記目的と関係したランドマークを位置決めすること、及び前記目的と関係したランドマークを前記他方の画像内で前記一方の画像内のその動きに比例して変位することを備えている請求項７記載の方法。

【請求項９】　前記基本ランドマークは固定され、前記一方の画像内の前記少くとも１つの目的と関係したランドマークの変位が前記基本ランドマークに従って定義され、また、前記の少くとも１つの目的と関係したランドマークは前記他方の画像内の基本ランドマークに関して同じ相対的変位で移動される請求項８記載の方法。

【請求項１０】　前記一方の画像は歯のモデルの仮想三次元画像であり、また前記他方の画像は横方向画像である請求項７ないし９のいずれか１項記載の方法。

【請求項１１】　前記横方向画像は頭部測定法画像である請求項１０記載の方法。

【請求項１２】　（ｆ）前記少くとも１つの歯の変位によって生ずる軟かい顔面組織の転置を定義する規則の組を適用することにより、前記横方向画像内の軟かい顔面組織画像上で前記仮想三次元画像内で前記少くとも１つの歯の転置の効果を予測する段階を備えた請求項１１記載の方法。

【請求項１３】　前記軟かな組織の変位は、少くとも顔面外観のプロフィルの第３の画像を用いて予測される請求項１２記載の方法。

【請求項１４】　（ｉ）少くとも第１の歯の部分についての第１の二次元断面像を表わす第１のデータと少くとも第２の歯の部分についての歯のモデルの第

２の三次元仮想画像を表わす第２のデータとをそれぞれ受領するための第１と第２のユーティリティと、ただしここで該第１と第２の部分との間には重畳範囲が存在するものとしており、

（ii）該重畳範囲内部で選ばれた位置として２つの画像の少くとも一方内で基本ランドマークを定義し、かつ、それを表わすデータを生成するモジュールと、

（iii)該第１と第２のユーティリティと関係し、また該モジュールと関係しているプロセッサであって、

第１と第２のデータを解析し、

該２つの画像の一方内の要素を２つの画像の他方に、該基本ランドマークを表わすデータにより、マッピングし、かつ、

該２つの画像内の該基本ランドマークを位置合わせすることにより２つの画像を組合せて、２つの画像の各々がそれぞれ二次元もしくは三次元特性を維持するように、

動作するプロセッサとを備えた画像処理システム。

【請求項１５】　前記第１の画像は頭部測定法画像である請求項１４記載のシステム。

【請求項１６】　少くとも顔面外観のプロフィルを含む第３の画像を表わす第３のデータを受領するための第３のユーティリティを備えた請求項１５記載のシステム。

【請求項１７】　前記第１、第２、および第３のユーテイリティが統合されている請求項１６記載のシステム。

【請求項１８】　前記第２のユーティリティは、前記第２の、仮想三次元画像を表わすデータを前記プロセッサに転送するためのデータ転送モジュールを備えている請求項１３ないし１７のいずれか１項記載のシステム。

【請求項１９】　画像の１つの中で少くとも１つの仮想の歯の表現を変位するための規則の組を定義するモジュールを備えている請求項１３ないし１８のいずれか１項記載のシステム。

【請求項２０】　前記規則の組は実生活の歯科矯正措置で少くとも１つの歯のシフトの仕方を表わしている変位を定義する請求項１９記載のシステム。

【請求項２１】　前記プロセッサは前記画像の一方における前記少なくとも１つの仮想の歯の表現の変位を他方の画像における対応する歯の転置に変換する請求項１９記載のシステム。

【請求項２２】　前記画像の一方は歯のモデルの仮想三次元画像であり、また前記他方の画像は頭部測定法画像である請求項２１記載のシステム。

【請求項２３】　軟かな顔面組織の頭部測定法画像内の歯の変位の効果を予測するための規則の組を定義するモジュールを備えた請求項２２記載のシステム。

【手続補正書】

【提出日】平成13年7月27日(2001.7.27)

【手続補正1】

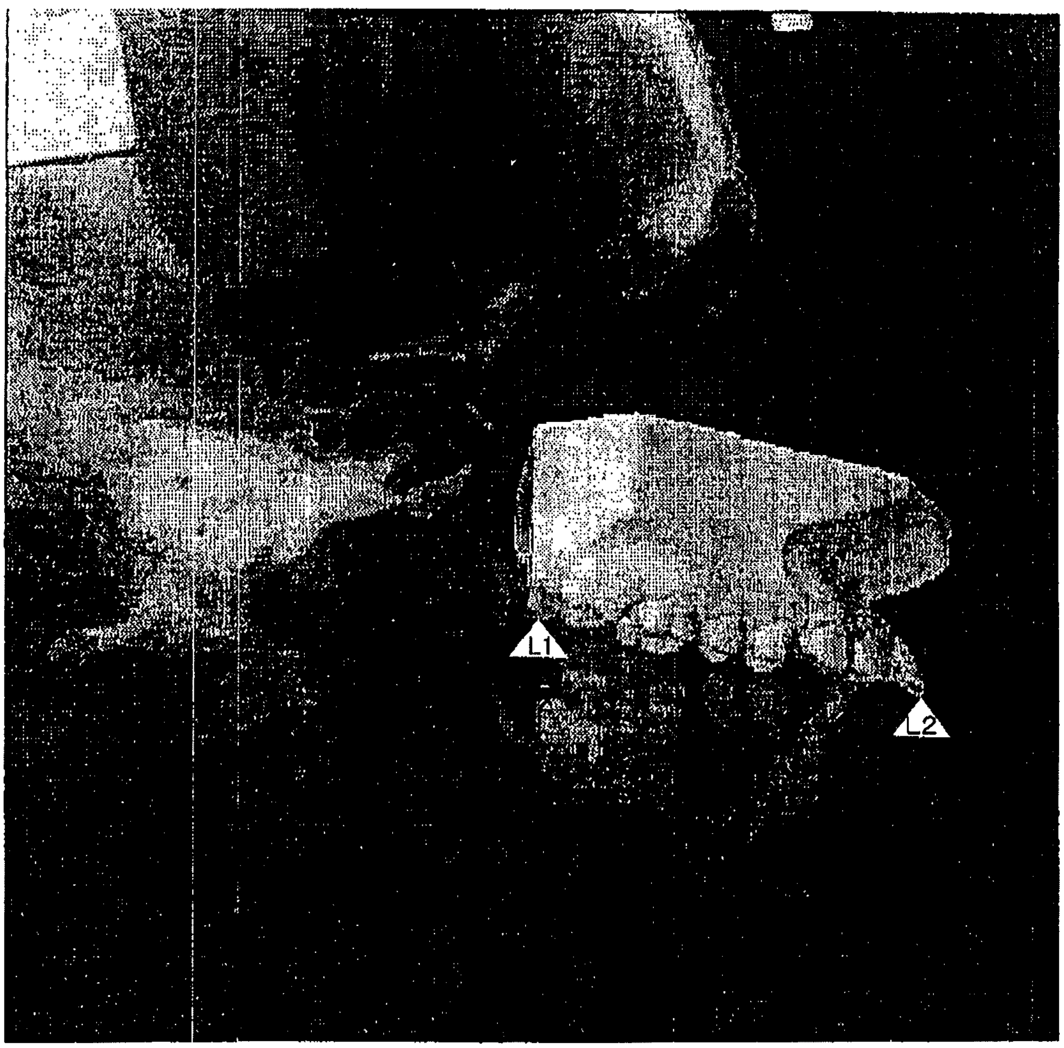
【補正対象書類名】図面

【補正対象項目名】図5

【補正方法】変更

【補正内容】

【図5】



【国際調査報告】

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 99/00577

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B6/00 A61B6/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 488 987 A (TRUPPE MICHAEL) 3 June 1992 (1992-06-03)	1-3,14, 17
A	page 2, line 2 - line 28 page 4, line 23 - line 47 ---	6,18
A	EP 0 741 994 A (TRUPPE MICHAEL) 13 November 1996 (1996-11-13) column 5, line 42 - line 59 column 7, line 15 - line 59 ---	1-3,6,7, 14,17-19
A	US 5 151 856 A (HALMANN MENACHEM ET AL) 29 September 1992 (1992-09-29) column 4, line 23 - line 61 column 9, line 30 - line 53 ---	1,14

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 February 2000	17 02 2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Knüpling, M

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INTERNATIONAL SEARCH REPORT

Intel. .onal Application No
PCT/IL 99/00577

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte. . .onal Application No
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			WO	9008505	A	09-08-1990

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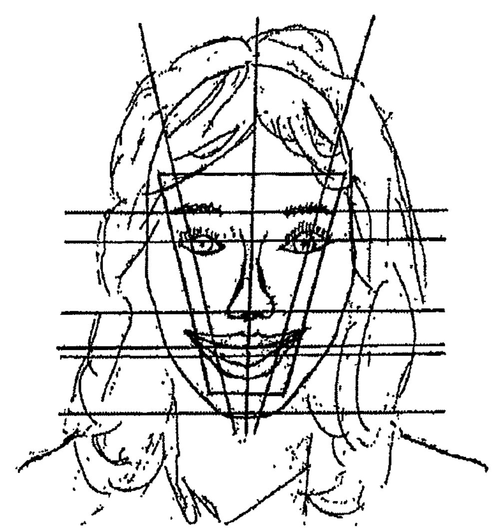
最終頁に続く

(54)【発明の名称】義歯の作製方法および作製システム

(57)【要約】
本発明は、以下のステップを有する義歯の作製方法に関する。置換すべき歯とその周辺のデータを検出するステップ；あらかじめ作製された義歯部分のデータを備えるデータバンクを作成するステップ；置換すべき歯およびその周辺の記録されたデータに基づき、機能的理由および/または美的理由および/または安定性の理由から不適切である義歯部分を除外するステップ；使用すべき義歯部分を選択するステップ；患者の歯に通常の配置規則にしたがい組み込まれた義歯部分の周辺を、画像ソフトウエアを使用して仮想的に表示するステップ；該当する歯を仕上げし、場合によりインプラントを挿入した後で、患者の口腔内の実際状況のデータを検出するステップ；選択された義歯部分と、仕上げ後の実際状況のデータとの整合性を検査するステップ；選択された義歯部分を、仕上げ後の実際状況のデータにしたがい変更するステップ。



【特許請求の範囲】
【請求項1】
以下のステップを有する義歯の作製方法：
・置換すべき歯とその周辺のデータを検出するステップ；
・あらかじめ作製された義歯部分のデータを備えるデータバンクを作成するステップ；
・置換すべき歯およびその周辺の記録されたデータに基づき、機能的理由および／または美的理由および／または安定性の理由から不適切である義歯部分を除外するステップ；
・使用すべき義歯部分を選択するステップ；
・患者の歯に通常の配置規則にしたがい組み込まれた義歯部分の周辺を、画像ソフトウエアを使用して仮想的に表示するステップ；
・該当する歯を仕上げし、場合によりインプラントを挿入した後で、患者の口腔内の実際状況のデータを検出するステップ；
・選択された義歯部分と、仕上げ後の実際状況のデータとの整合性を検査するステップ；
・選択された義歯部分を提供するステップ；
・選択された義歯部分を、仕上げ後の実際状況のデータにしたがい変更するステップ。
【請求項2】
請求項１記載の方法であって、
選択された義歯部分の周辺および／または該義歯部分の配置を仮想的に表示し、変更する方法。
【請求項3】
請求項１または２記載の方法であって、
選択された義歯部分は、CAD法で変更される方法。
【請求項4】
請求項１から３までのいずれか一項記載の方法であって、
選択された義歯部分と、仕上げ後の実際状況のデータとの整合性が存在しない場合、整合性が達成されるように変更が提案される方法。
【請求項5】
以下の手段を有する義歯の作製システム：
・置換すべき歯とその周辺のデータを検出する手段；
・あらかじめ作製された義歯部分のデータを備えるデータバンク；
・置換すべき歯またはその周辺のデータに基づき、機能的理由および／または美的理由および／または安定性の理由から不適切である義歯部分を前記データバンクから除外する手段；
・義歯部分を、前記データバンクに残った義歯部分から選択する手段；
・患者の歯に通常の配置規則にしたがい組み込まれた、選択された義歯部分とその周辺を仮想的に表示する手段；
・該当する歯を仕上げし、場合によりインプラントを挿入した後で、患者の口腔内の実際状況またはモデルに基づく実際状況のデータを検出する手段；
・選択された義歯部分と、仕上げ後の実際状況のデータとの整合性を検査する手段；
・選択された義歯部分を、仕上げ後の実際状況のデータにしたがい変更する手段。
【請求項6】
請求項５記載のシステムであって、
周辺を仮想的に表示された、選択された義歯部分を変更する付加的手段を有するシステム。
【請求項7】
請求項５または６記載のシステムであって、
仮想的に表示された、選択された義歯部分の配置を変更する付加的手段を有するシステム。
【請求項8】

請求項５から７までのいずれか一項記載のシステムであって、
【発明の詳細な説明】部分を変更する手段はCADシステムであるシステム。
【技術分野】
【0001】
本発明は、義歯の作製方法および作製システムに関する。
【背景技術】
【0002】
クラウン、ブリッジ、部分義歯、または総義歯である義歯は、外部エンベロープと、通常はフレームを含む周辺部分からなる。外部エンベロープは美的要求を満たさなければならず、また外部エンベロープは歯に応じた機能通りの発声を可能にする。周辺部分は、義歯が患者の口腔内に恒久的にまたは取り出し可能に、しっかりと係留されるように構成しなければならない。
【0003】
従来の義歯は個別のハンドメードである。プランニングおよび作製は、準備された歯から出発して外部エンベロープへと行われる。外部エンベロープは、フレームを備える周辺部分が作製されて初めて完成される。
【0004】
義歯を提供すべき患者は次のようなフェーズを経験する。まず既往歴が記録され、それに所見記録が続く。続いて診断と治療法選択が行われる。その後に、衛生フェーズとプレプロセテックな前処理をともなう本来の治療が開始される。これらの前処理が終了すると、固有のクラウンまたはブリッジのプラニングと作製により、部分義歯または総義歯を提供するプロセテック作業を開始することができる。
【0005】
クラウン義歯およびブリッジ義歯を実現する際には、患者での仕上げの前であって、成形およびモデル作製の後にギプスモデルで見本仕上げを行うのが現在までは通常のことである。どのような形態で暫定体の作製をプラニングしているかに応じて、義歯の表面加工の前にアルジネート成形体、またはシリコーン成形体、深絞り加工されたフォイル、またはシャーレ暫定体を完成しなければならない。さらに仕上げの前にカラー選択を実行しておくことが推奨される。
【0006】
仕上げの際には複数のポイント、例えば歯髄の保護、歯周炎の保護を考慮しなければならない。そして材料科学的要因、構造的要因、および美的要因を考慮して保持形態および抵抗形態を達成する。
【0007】
研磨された歯根の表面加工および清浄に続いて、最終的成形が行われる。続いてラボでモデルが作製される。固定義歯と取り出し可能義歯を組み合わせる際には、例えば以下の方法が適用される。
【0008】
まず仕上げモデルと内部クラウンが作製される。クリニックでは内部クラウン（一次クラウン）の試装着と、固定成形が行われる。次のステップでラボでは構造モデルとレジスタステンシルが作製される。その後、顔つきアーチの転移、顎関係の決定、およびモデルモンタージュが再びクリニックで行われる。ラボではこれに基づいて、歯配置がワックスで行われ、この歯配置がクリニックで試装着される。続いてラボでは外側クラウン（二次クラウン）と接続フレーム（三次構造体）が作製される。フレームの造形と加工は第一に美的観点から行われる。したがってフレームはできるだけ精巧であり、かつ同時に長寿命であるよう構成される。フレームの満足のいく寸法は実際には確実に制御できない。
【0009】
金属フレームにセラミック物体を据え付ける場合には、それらの熱膨張係数を相互に整合しなければならない。この据付けは、セラミック粉体を滅菌水と混合し、このようにして得られたスラリーをブラシにより処置すべき面に塗布することにより行われる。セラミ

ック物体は部分毎に順次積層される。構築された型は個別の歯科技工士の熟練度に依存するものであるが、この型は続いてセラミック炉内で相応の温度で焼成される。結果物は、とりわけ複数の歯を含む構造体の場合、同じように再現可能ではない。

【0010】

次に接続フレームは、最終的な歯配置とともにクリニックのワックスで再度試装着される。

【0011】

同じセッションで、美的処理も行うことができる。義歯の機能的かつ美的なエンベロープは最終加工ステップで得られ、プラニング時に前もって予測することはできない。または非常に制限的な予測しかできない。続いて表面が機械的に研磨される。最後に義歯は公知の方法にしたがい組み込まれる。

【0012】

現在まで使用されているこの方法の欠点は、義歯が内側から外側に構築され、したがって外側の美的エンベロープが最終ステップで初めて設定されることである。患者、歯科医師、および歯科技工士は、完成した義歯がどのように見えるかイメージすることができないか、または非常に曖昧にしかイメージできない。なぜなら、結果が歯科技工士の職人的熟練度に大きく依存しているからである。とりわけ患者は、安定性および機能性に反するエステティックの問題を考慮する際に、根拠となる決定を下すことができない。さらに公知の方法は、順次実行すべき多数の個別のステップからなり、患者は長期間、暫定体で生活しなければならず、多数回の試装着を行わなければならない。

【図面の簡単な説明】

【0041】

【図1】美的分析において、置換すべき歯の周辺の種々の側面を静的および動的に考慮する様子を示す概略図である。

【図2】顎関節相関決定とモデルの作製後、ならびに顎関節相関どおりにモデルが、例えば咬合器に配向された後にどのように見えるかを示す概略図である。

【図3】暫定的サプライ品を作製するためにシステムにより提案された外形が相応する物理的配置から取り出され、CNNマシンに取り付けられた様子を示す概略図である。

【図4】暫定的サプライ品を作製するためにシステムにより提案された外形が相応する物理的配置から取り出され、CNNマシンに取り付けられた様子を示す概略図である。

【図5】図５ａは既製の橋脚歯を示し、図５ｂは個別化された橋脚歯を備える下顎モデルを、舌から見て右側方から左側方への断面で示す。図５ｃから５ｆは、下顎のサプライ品のために作製された義歯部分を示す概略図である。

【図6】上顎に義歯を設ける様子を示す概略図である。

【図7】個別部分をモデルに嵌め込んだ後での完全な義歯を、右側方、正面、および左側方で示す概略図である。

【図8】組み立てられた義歯を示す概略図である。

【図9】本発明の択一的実施例を示す概略図である。

【図1a】

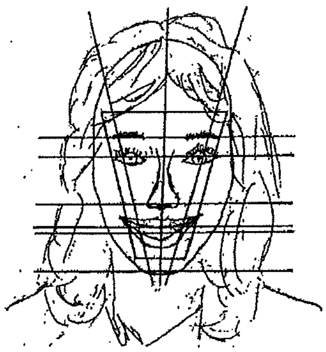
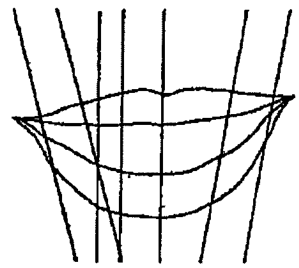


Abb. 1a

【図1b】



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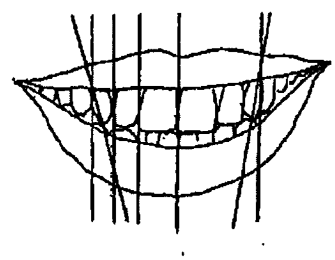
【図1c】



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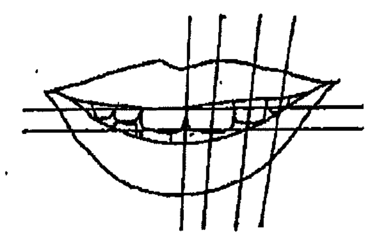
【図1d】



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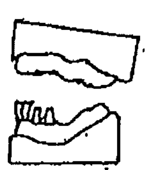
【図2a】



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【図2b】

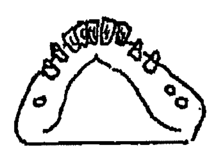
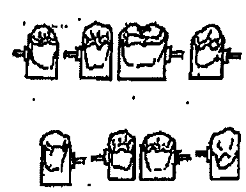


Abb. 2b

【図3a】



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【図3b】

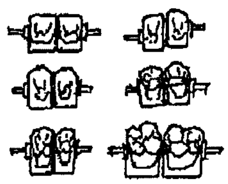


Abb. 3b

【図4b】

Abb. 4b

【図4a】

Abb. 4a

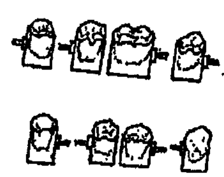
【図5a】

Abb. 5a

【図5b】

Abb. 5b

【図5e】



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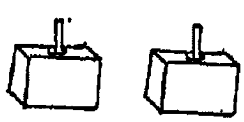
【図5c】



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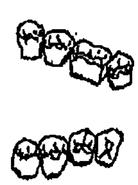
【図5f】



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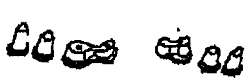
【図5d】



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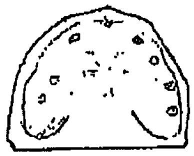
【図6a】



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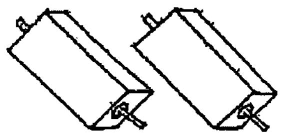
【図6b】



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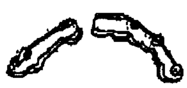
【図6c】



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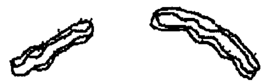
【図6d】

Abb. 6d

【図6e】



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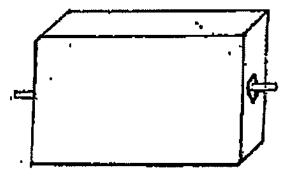
【図6f】



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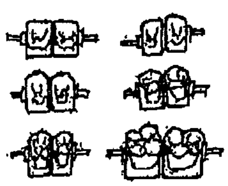
【図6g】

Abb. 6g

【図6h】



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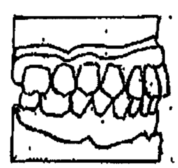
【図6i】

Abb. 6i

【図7a】



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【図7b】

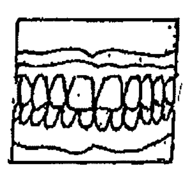


Abb. 7b

【図7c】

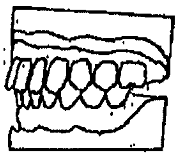


Abb. 7c

【図8a】

Abb. 8a

【図8b】

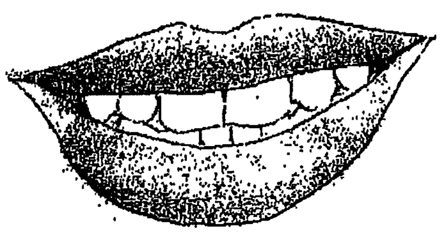
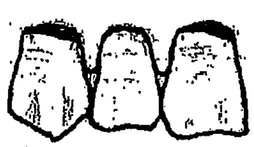


Abb. 8b

【図9a】



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【図9b】

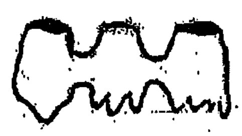

Abb. 9b

【図9c】

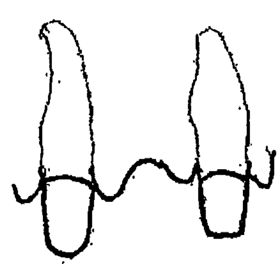

Abb. 9c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/008031

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61C13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2005 034803 A1 (GEHRMANN WOLFGANG [DE]) 16 March 2006 (2006-03-16) paragraph [0001] paragraph [0012] - paragraph [0015] paragraph [0020] paragraph [0026] paragraph [0030] - paragraph [0031] -----	1-8
A	US 2005/089822 A1 (GENG Z J [US]) 28 April 2005 (2005-04-28) the whole document -----	1-8
A	US 4 742 464 A (DURET FRANCOIS [FR] ET AL) 3 May 1988 (1988-05-03) the whole document -----	1-8

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Date of the actual completion of the international search	Date of mailing of the international search report
8 Januar 2008	16/01/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kerner, Bodo

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/008031

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102005034803 A1	16-03-2006	NONE	
US 2005089822 A1	28-04-2005	NONE	
US 4742464 A	03-05-1988	NONE	

Form PCT/ISA/210 (patent family annex) (April 2005)

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP2007/008031

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
INV. A61C13/00

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B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
A61C

Recherchierte, aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

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C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	DE 10 2005 034803 A1 (GEHRMANN WOLFGANG [DE]) 16. März 2006 (2006-03-16) Absatz [0001] Absatz [0012] - Absatz [0015] Absatz [0020] Absatz [0026] Absatz [0030] - Absatz [0031]	1-8
A	US 2005/089822 A1 (GENG Z J [US]) 28. April 2005 (2005-04-28) das ganze Dokument	1-8
A	US 4 742 464 A (DURET FRANCOIS [FR] ET AL) 3. Mai 1988 (1988-05-03) das ganze Dokument	1-8

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Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
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Name und Postanschrift der Internationalen Recherchenbehörde	Bevollmächtigter Bediensteter
Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kerner, Bodo

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INTERNATIONALER RECHERCHENBERICHT

Angaben zu Veröffentlichungen, die zur selben Patentfamilie gehören

Internationales Aktenzeichen
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Im Recherchenbericht angeführtes Patentdokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
DE 102005034803 A1	16-03-2006	KEINE	
US 2005089822 A1	28-04-2005	KEINE	
US 4742464 A	03-05-1988	KEINE	

Formblatt PCT/ISA/210 (Anhang Patentfamilie) (April 2005)

(81)指定国　AP(BW,GH,GM,KE,LS,MW,MZ,NA,SD,SL,SZ,TZ,UG,ZM,ZW),EA(AM,AZ,BY,KG,KZ,MD,RU,TJ,TM),EP(AT,BE,BG,CH,CY,CZ,DE,DK,EE,ES,FI,FR,GB,GR,HU,IE,IS,IT,LT,LU,LV,MC,MT,NL,PL,PT,RO,SE,SI,SK,TR),OA(BF,BJ,CF,CG,CI,CM,GA,GN,GQ,GW,ML,MR,NE,SN,TD,TG),AE,AG,AL,AM,AT,AU,AZ,BA,BB,BG,BH,BR,BW,BY,BZ,CA,CH,CN,CO,CR,CU,CZ,DE,DK,DM,DO,DZ,EC,EE,EG,ES,FI,GB,GD,GE,GH,GM,GT,HN,HR,HU,ID,IL,IN,IS,JP,KE,KG,KM,KN,KP,KR,KZ,LA,LC,LK,LR,LS,LT,LU,LY,MA,MD,ME,MG,MK,MN,MW,MX,MY,MZ,NA,NG,NI,NO,NZ,OM,PG,PH,PL,PT,RO,RS,RU,SC,SD,SE,SG,SK,SL,SM,SV,SY,TJ,TM,TN,TR,TT,TZ,UA,UG,US,UZ,VC,VN,ZA,ZM,ZW

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スペイン国　カラ　ドール　エス　フォルティ　４４

(19)日本国特許庁(JP)　(12)**公 表 特 許 公 報(A)**　(11)特許出願公表番号
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(43)公表日　**平成22年7月22日(2010.7.22)**

(51)Int.Cl.		F I			テーマコード（参考）
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(54)【発明の名称】顔面解析を用いた特注歯セットアップのコンピュータ支援作成

(57)【要約】
患者の歯科治療の自動的または半自動的計画のための方法は、（ａ）治療すべき部位についてのデータと患者の顔面についてのデータとを得るステップと、（ｂ）少なくとも患者の顔面の特性を決定するために、当該データのコンピュータ支援顔面解析を行うステップと、（ｃ）決定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するステップと、を含む。三次元表示は、修正された歯セットアップおよび治療部位を取囲む患者の顔面の外観をシミュレートする。また当該方法は、現存する歯の特性を判定し、患者の現存する歯にも基づく修正された歯セットアップを作成する。当該方法は、ワークステーション上で作動するソフトウエアとして実現することができる。

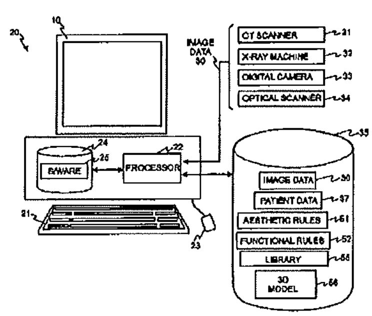

Fig. 1

【特許請求の範囲】

【請求項１】

患者の歯科治療の自動的または半自動的計画のための方法であって、

（ａ）治療すべき部位についてのデータと患者の顔面についてのデータとを得るステップと、

（ｂ）少なくとも患者の顔面の特性を判定するために、当該データのコンピュータ支援顔面解析を行うステップと、

（ｃ）判定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するステップと、を含む、方法。

【請求項２】

少なくとも修正された歯セットアップを有する治療部位の外観をシミュレートする三次元表示を生成するステップをさらに含む、請求項１に記載の方法。

【請求項３】

三次元表示を生成するステップはさらに、治療部位を取囲む患者の顔面の外観もシミュレートする、請求項２に記載の方法。

【請求項４】

データのコンピュータ支援顔面解析を行うステップ（ｂ）は、現存する歯の特性も判定し、ステップ（ｃ）は、所定の顔面特性と現存する歯とを利用する規則のセットを使用して、修正された歯セットアップを作成する、先行する請求項のうちいずれか１項に記載の方法。

【請求項５】

ステップ（ｃ）は、得られたデータから治療すべき部位の三次元モデルを生成し、修正された歯セットアップを当該モデル上に作成することを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項６】

データのコンピュータ支援顔面解析を行うステップは、解剖学的な点の位置を患者の顔面の二次元または三次元表示において指定するようユーザに促すことと、ユーザから受取った入力に基づいて顔面特性を自動的に判定することとを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項７】

ステップ（ｂ）における解析は患者の顔面の形状を判定することを含み、ステップ（ｃ）は、所定の形状に基づいて補綴歯の形状を選択することを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項８】

ステップ（ｂ）における解析は、患者の顔面の特徴同士の距離または患者の顔面の特徴の配列の判定を含み、ステップ（ｃ）は、判定された距離または配列に基づいて歯セットアップを修正することを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項９】

ステップ（ｂ）における解析は瞳孔間線を判定することを含み、ステップ（ｃ）は、上顎犬歯の咬頭同士を結ぶ咬合面もしくは線が、判定された瞳孔間線と平行になるように、歯を再建するまたは歯の位置を補正することを含む、請求項８に記載の方法。

【請求項１０】

ステップ（ｂ）における解析は、患者の唇の位置を判定することを含み、ステップ（ｃ）は、判定された位置に基づいて歯セットアップを修正することを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項１１】

ステップ（ｂ）における顔面解析は、微笑時の上唇の位置を判定することを含み、ステップ（ｃ）は、微笑時に正面上顎歯の高さの４分の１のみが上唇によって覆われるように正面上顎歯を位置決めすることを含む、請求項１０に記載の方法。

【請求項１２】

治療すべき部位または修正されたセットアップの機能的データを判定するステップをさらに含み、ステップ（ｃ）は当該機能的データを使用する、先行する請求項のうちいずれか１項に記載の方法。

【請求項１３】

機能データは、治療すべき部位の咬合もしくは咬交、または修正された歯セットアップに関連する、請求項１２に記載の方法。

【請求項１４】

機能データを判定するステップは、最適な歯接点を判定することを含み、ステップ（ｃ）は、歯セットアップを修正して歯接点を最適化することを含む、請求項１３に記載の方法。

【請求項１５】

ステップ（ａ）において得られたデータは、患者の三次元モデルを生成するのに使用され、歯接点の判定は当該モデルを使用する、請求項１４に記載の方法。

【請求項１６】

ステップ（ａ）において得られたデータは、患者の三次元モデルを生成するのに使用され、ステップ（ｂ）の顔面解析は当該モデルを使用する、先行する請求項のうちいずれか１項に記載の方法。

【請求項１７】

ステップ（ｃ）において使用される規則のセットは重み付けされる、先行する請求項のうちいずれか１項に記載の方法。

【請求項１８】

ステップ（ｃ）において使用される規則のセットは、歯セットアップを最適化するためにそれらの相対的な重要性に従って重み付けされる、請求項１７に記載の方法。

【請求項１９】

患者の顔面についてのデータは、患者の頭部の少なくとも一部の外面の二次元写真、三次元写真、光学スキャンのうち１つ以上を含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項２０】

治療すべき部位についてのデータは、複数の異なる撮像技術を使用して取得されたデータを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項２１】

撮像技術は、二次元写真、三次元写真、口腔内光学スキャン、Ｘ線、コンピュータ断層撮影を含む、請求項２０に記載の方法。

【請求項２２】

ステップ（ｃ）は、異なる撮像技術を使用して取得されたデータを相関させて、患者の顎および現存する歯の三次元モデルを生成することを含む、請求項２０または２１に記載の方法。

【請求項２３】

ステップ（ｃ）はさらに、修正された歯セットアップをグラフィカルユーザインターフェースによってユーザに操作させることを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項２４】

ステップ（ｃ）はさらに、要素のライブラリにアクセスし、ライブラリを使用して修正された歯セットアップを作成する、請求項２３に記載の方法。

【請求項２５】

プロセッサによって実行されると、先行する請求項のうちいずれか１項に記載の方法を行うコードを備えるコンピュータプログラム製品。

【請求項２６】

患者の歯科治療の自動的または半自動的計画のための装置であって、前記装置は、

治療すべき部位についてのデータと患者の顔面についてのデータとを受取るための入力

と、

プロセッサとを備え、前記プロセッサは、

当該データのコンピュータ支援顔面解析を行って、少なくとも患者の顔面の特性を判定し、

判定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するように設けられる、装置。

【請求項２７】

プロセッサはさらに、少なくとも修正された歯セットアップを有する治療部位の外観をシミュレートする三次元表示を生成するように設けられる、請求項２６に記載の装置。

【請求項２８】

プロセッサはさらに、治療部位を取囲む患者の顔面の外観もシミュレートするように設けられる、請求項２７に記載の装置。

【発明の詳細な説明】

【技術分野】

【０００１】

発明の分野

本発明は概して、歯科治療の計画に使用されるコンピュータ技術の分野と、患者に最適化された歯（および軟組織）セットアップを計画するためのコンピュータソフトウエアツールと、患者に最適化された歯（および軟組織）セットアップを計画するシステムおよび方法とに関する。

【背景技術】

【０００２】

発明の背景

歯科治療または歯列矯正治療について、正写図（orthopantograms）（歯科Ｘ線）、コンピュータ断層撮影法（ＣＴ）スキャン、またはデジタル写真などの１つ以上の撮像様式を一般に使用して、患者の状態を解析し、診断し、かつ文書化する。近年、患者のデジタル情報は、治療の計画段階にも入り込んでいる。医療用（ＣＴ）画像において歯科インプラント配置をシミュレートするためのいくつかのソフトウエア解決法があり（シムプラント（登録商標）、マテリアリーセ、ベルギー国）、デジタル化された患者の歯列についての情報を用いて歯列矯正治療をシミュレートすることができ（ＯｒｔｈｏＣＡＤ（登録商標）、カデント、米国；インビザライン（登録商標）、アラインテクノロジー、米国）、顎顔面再建を仮想環境において計画することができる（シムプラント（登録商標）ＣＭＦ、マテリアリーセ、ベルギー国）。これらの解決法は、臨床医が機能的レベルにおいて異なる代替案を試みるための強力な手段を与えるが、審美的レベルにおけるこれらの代替案の影響は、一般に明白であるとは言い難い、または臨床的手法を選択する際に完全に無視される場合がある。

【０００３】

ＷＯ２００４／０９８３７８およびＷＯ２００４／０９８３７９は、ＣＴスキャン、Ｘ線および写真などのいくつかの撮像源を用いて患者の仮想三次元モデルを作成するためのワークステーションについて記載している。ソフトウエアツールによって、訓練を受けたユーザが当該モデルを操作して、歯列矯正治療などによる歯の位置の変化をシミュレートすることが可能となる。これらの文献に記載されているツールは、治療を計画するのに使用することができ、治療の成果のシミュレーションを患者に提示することができる。しかし、これらのツールは治療計画における大幅な自由度をユーザに与え、ユーザが下すべき決定が多いため、治療を計画するには熟練したユーザが依然として必要である。

【０００４】

したがって、本発明は、患者の歯科治療を計画する改良された方法を提供することを追求する。

【発明の概要】

【０００５】

本発明の目的は、歯科治療を計画するためのコンピュータを用いた方法およびシステムと、患者に最適化された歯（および軟組織）セットアップを計画するためのコンピュータソフトウエアツールとを提供することである。

【０００６】

本発明の第一の局面は、患者の歯科治療の自動的または半自動的計画のための方法を提供する。当該方法は、

（ａ）治療すべき部位についてのデータと患者の顔面についてのデータとを得るステップと、

（ｂ）少なくとも患者の顔面の特性を判定するために、当該データのコンピュータ支援顔面解析を行うステップと、

（ｃ）判定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するステップと、を含む。

【０００７】

本願の目的について、「歯科治療」という用語は、限定はしないが、生来の歯に対する補綴再建（歯冠およびブリッジ、被覆）、脱着可能な補綴、インプラントによって支持された補綴再建、軟組織（すなわち患者の歯肉、粘膜および歯茎）の補正、ならびに歯列矯正治療、すなわち歯の位置を補正するための治療を含む。

【０００８】

本発明は、審美的に満足を与えかつ臨床的に妥当な結果をもたらすためには、患者の顔面に即して歯科治療を計画する必要があると認識している。また本発明は、これを実現するためのツールを、顔面の特色についてコンピュータ支援解析を行うことと、最適な歯および軟組織セットアップを作成するために保存されている規則の使用とによって提供する。これにより、修正された歯および軟組織セットアップを作成するプロセスが大幅に簡略化される。

【０００９】

好ましくは、当該方法はさらに、少なくとも修正された歯セットアップを有する治療部位の外観をシミュレートする三次元表示を生成するステップを含む。三次元表示は、好ましくは、治療部位を取囲む患者の顔面の外観もシミュレートする。これによって、患者は、修正された歯および軟組織セットアップの治療後の効果を治療に先立って確認することができる。好ましくは、三次元表示は、修正されたセットアップにおいて使用される補綴歯に対して色および質感を使用することによって、可能な限り実物様である。周囲の顔面特徴（たとえば唇）に対する、修正された歯および軟組織セットアップの効果も、三次元表示を用いて示すことができる。これによって、臨床的治療の種類を選択した後またはより理想的には選択する前に、患者が歯科治療の審美的成果を評価することが可能となる。たとえば、歯科インプラントによる治療、歯冠およびブリッジを用いた治療、ならびに脱着可能な補綴を用いた治療の選択が患者に提供され得、これらの治療選択肢の各々を視覚化することができる。このような手法は患者にとって非常に有益であり、患者は早い段階で判定プロセスに一層関与し、異なる代替案（たとえば、歯の研磨に対して、ブリッジを固定させるためのインプラント配置；歯の剥離に対して、歯列弓に沿った叢生を解決するための抜歯など）の審美的な影響について、より良く告知される。

【００１０】

本発明の機能性は、ソフトウエア、ハードウエア、またはこれらの組合せにおいて実現することができる。本発明は、いくつかの別個の要素を含むハードウエアと、適切にプログラミングされたプロセッサとによって実現することができる。したがって、発明の別の局面は、コンピュータまたはプロセッサによって実行されると当該方法を実現する指示（コード）を含むソフトウエアを提供する。当該ソフトウエアは、電子メモリデバイス、ハードディスク、光ディスクもしくはいずれかの他の機械で読取り可能な記憶媒体上に触知可能に具体化することができる、またはネットワーク接続によってコンピュータもしくはプロセッサにダウンロードされ得る。

【００１１】

発明のさらなる局面は、当該方法を実行するための装置を提供する。

発明の実施形態を、例示のみを目的として添付の図面を参照して説明する。

【図面の簡単な説明】

【００１２】

【図１】本発明を実現するためのワークステーションの概略図である。

【図２】本発明の一実施形態に係る方法のフローチャートである。

【図３】三次元写真とデジタル化された石膏型とを顔弓を用いて位置合せする一方法を示す図である。

【図４】上顎切歯の幅が鼻底の幅に等しくなるであろう審美的規則の一例を示す図である。

【図５】咬合時に、眉毛と鼻底との距離が鼻底と頤の頂点との距離に等しくなるであろう審美的規則の一例を示す図である。

【図６】上顎犬歯の咬頭を結ぶ咬合面または線が瞳孔間線と平行になるであろう審美的規則の一例を示す図である。

【図７】微笑時のバッカルコリダー（buccal corridor）を示す図である。

【図８】分類１の臼歯関係の一例を示す図である。

【図９Ａ】補綴歯の機能的特性を修正する一例を示す図である。

【図９Ｂ】補綴歯の機能的特性を修正する一例を示す図である。

【図９Ｃ】補綴歯の機能的特性を修正する一例を示す図である。

【図１０】ライブラリ歯による欠損歯の再建を示す図である。

【図１１】ライブラリ歯に質感を適用して、再建される歯の実物様表示を示す図である。

【図１２】再建される歯の代替的な図である。

【発明を実施するための形態】

【００１３】

好ましい実施形態の説明

本発明を特定の実施形態およびある図面を参照して説明するが、発明はそれに限定されず、請求項によってのみ限定される。説明される図面は概略的なものに過ぎず、限定的なものではない。図面において、例示目的のために、一部の要素の寸法が誇張され、一律の縮尺で描かれていない場合がある。「備える」という用語が本説明および請求項において用いられているが、他の要素または工程を排除するものではない。さらに、本説明および請求項における第１、第２、第３等の用語は、同様の要素を区別するために用いられており、連続的なまたは時間的な順序を説明するためのものとは限らない。このように用いられる用語は適切な状況下で交換可能であり、本明細書において説明する発明の実施形態は、本明細書において説明または図示されるものとは異なる順番で動作可能であると理解される。

【００１４】

図１は、本発明の一実施形態を実現するためのシステムを概略的に示す。当該システムは、汎用ＰＣなどのコンピュータワークステーション２０の形態を取り得、ワークステーション２０は、プロセッサ２２、メモリ／記憶装置２４およびディスプレイ１０を有する。本発明を実現するためのソフトウエア２５がメモリ２４に保存されており、プロセッサ２２によって実行される。ユーザは、キーボード２１、マウス２３または他の入力装置、たとえばグラフィックスタブレットもしくは電子ペンを用いてワークステーションと対話することができる。ワークステーション２０は、コンピュータ断層撮影（ＣＴ）スキャナ３１、歯科Ｘ線機械３２、デジタルカメラ３３、および光学スキャナ３４などの多様な撮像源からの入力を受取る。撮像源３１～３４の各々はユーザによって操作され、画像データを取得し、次いで当該データをワークステーションに送ることができる。代替的に、撮像源３１～３４の１つ以上はワークステーション２０の制御下にあり得、ワークステーション２０はこれらの撮像源の動作を自動的に制御して、画像データを取得する。一例として、ワークステーション２０は、デジタルカメラ３０を制御して、患者についての３枚の所定の図の各々から像を取得することができる。各撮像源から取得された画像データ３０

は、取得された状態の未処理フォーマットで保存することができる、または他のソースからの画像データとより簡単に組合せることができるフォーマットに変換されるように処理することができる。当該データ（未処理もしくは処理済みフォーマット）はワークステーション２０内の３５、または外部記憶装置もしくはワークステーション２０にネットワーク接続されたサーバなどのワークステーション外部に保存することができる。患者についての他のデータ３７、たとえば医療履歴も３５に保存することができる。

【００１５】

撮像源３１～３４から取得された画像データ３０は、少なくとも治療すべきヒトの体の部位の実物様表示である仮想三次元モデル５６を生成するのに使用される。典型的に、当該部位は、患者の顎、（残存している場合は）歯、ならびにこれらの部分を取囲む軟組織、たとえば歯肉、唇および顔の外面の皮膚である。三次元モデルの範囲は、治療すべき部位および当該部位を直接取囲む軟組織だけに限定することができる、またはユーザの顔面および頭部全体に拡張することができる。

【００１６】

図２は、発明の一実施形態に係る治療を計画する方法の主要なステップを概説するフローチャートを示す。各ステップを詳細に説明する。

画像データの取得（ステップ６０、６１、図２）

本発明の一実施形態によれば、治療すべき部位について三次元測定を行うことと、測定データを（たとえば、スタンダードトライアンギュレイテッドランゲージ［．ｓｔｌ］フォーマットで）デジタル立体または表面モデルに変換することとによって、三次元モデルが作成される。次いで、同じ部位のデジタル二次元もしくは三次元写真からの画像、または走査された印刷写真からの画像が当該モデル上にマッピングされる。対象物の三次元幾何学的配置／形状とその質感（および任意に色）とを取込むことが可能な光デバイスによって三次元写真が取られる。一般に、当該デバイスは、三次元幾何学的配置／形状を測定するためのレーザスキャナと、質感を撮像するためのカメラとを含む。次いで、三次元幾何学的配置描写および質感が１つの三次元画像に組合される。三次元写真は、固定カメラまたは移動カメラによって取ることができる。後者の場合、対象物のすべての側面（前、左、後および右側）を示す三次元写真が作成される。

【００１７】

三次元測定は、治療すべき部位に対して直接または間接的に行うことができる。直接測定は、患者のＣＴスキャン、または患者の頭部の光学スキャンの形態を取り得る。ＣＴスキャンは、二次元画像の積み重ねを供給することによって、軟組織と骨の両方についての詳細を三次元座標系に示す。これらの二次元画像に基づいて、骨または顔面の三次元モデルを再建することができる。患者の頭部の光学スキャンは、顔面および頭部の外形形状および表面特徴についての情報をもたらすことができる。また、小さい光学スキャナを使用して口腔内領域をスキャンすることができる。

【００１８】

間接的測定は、治療すべき部位の身体複製、たとえば治療すべき部位について取られた印象から製造された石膏型の光学スキャンの形態を取ることができる。測定技術は、限定はしないが、レーザ、白色光等を用いた非接触スキャン、測定プローブを用いた触知スキャン、およびＣＴ、ＭＲＩ、μＣＴ等の容積スキャンを含み得る。本明細書において使用される「ＣＴ」という用語は、対象物が固定されたままで光源および検出器が対象物の周囲を回る医療用ＣＴスキャナを指し、約０．２５ｍｍ以上の画素サイズを有する画像が生じる。「μＣＴ」という用語は、典型的に、対象物が回転し光源および検出器は固定されている非医療用ＣＴスキャナを指し、ＣＴスキャンで実現されるよりも１０～２０倍小さい典型的な画素サイズを有する画像が生じる。μＣＴは、一般に一層正確な画像が生じ、はるかに細かい詳細を正確に視覚化することもできる。

【００１９】

測定データのデジタルモデルへの変換は、適用される測定技術に応じて、一連の一般に知られているデータ処理技術、たとえば画像セグメント化および点群メッシュ（point cl oud meshing）を伴うことになる。異なる撮像源（たとえばＣＴ、光学スキャン…）から導出されたデータは、単一のモデルに組合せる必要がある。まず、各画像データ源から別個のモデルを構築し（たとえば、ＣＴスキャンデータについて１個のモデル、光学スキャンデータについて１個のモデル）、次いで個別のモデルのセットを単一のモデルに組合せる。いくつかの既知の技術のうちの１つを用いてモデルを組合せ得る：

-三次元モデルの一方を他方に対して手作業で並進させ、および／または回転させることによって三次元モデルを互いに位置合せすることができる。当該モデルは、ワークステーション２０のディスプレイ１０上に表示され、オペレータが当該モデルを操作する。

-両方の三次元モデル上の対応する点を示し、かつＮ点位置合せアルゴリズムを適用することによって、三次元モデルを互いに位置合せする。その後、最小二乗位置合せアルゴリズムなどの位置合せ最適化プログラムを用いた位置合せの自動最適化が可能である。

-特徴認識に基づく完全自動位置合せアルゴリズムを用いて、三次元モデルを互いに位置合せする。たとえば、位置合せは、点群(cloud-of-points)技術によって行われ得る、または画像における共通の特徴を自動的に識別することによって行われ得る。

【００２０】

このような技術は、たとえば、P.J.BeslおよびN.D.McKay,「三次元形状の位置合せのための方法（"A method for registration of 3-d shapes"）」、IEEE Trans. Pat. Anal. And March. Intel 14(2), pp239-256, Feb 1992; R.San-Jose, A.BrunおよびC.-F.Westin,「強固な一般化された全最小二乗反復最近点位置合せ（"Robust generalized total least squares iterative closest point registration"）」、in C.Barillot, D.R.HaynorおよびP.Hellier (Eds.): MICCAI 2004, LNCS 3216, pp. 234-241, 2004; A.GruenおよびD.Akca,「最小二乗三次元表面および曲線マッチング（"Least squares 3D surface and curve matching"）」、ISPRS Journal of Photogrammetry and Remote Sensing 59(3), pp 151-174, May 2005に記載されている。

【００２１】

写真（二次元または三次元）は、いくつかの技術のうちの１つを用いて所望の寸法に変倍することができる：

-患者の写真画像を取る間、較正部品、すなわち正確に知られている幾何学的寸法を有する部品をカメラの視野に加えることができる。これにより、後に写真を正確に変倍することが可能となる。

-解剖学的基準距離（たとえば瞳孔間距離…）を使用して写真の変倍係数を判定することによって、写真および三次元モデルに対して測定を行うことができる。

-画像中の基準点または特徴を自動的に検出し、これらを互いに一致するように変倍することによって、変倍を自動的に行うことができる。

【００２２】

二次元または三次元写真をデジタルモデル上にマッピングするために、写真およびデジタルモデルが同一の表面（たとえば写真において視覚可能な歯、顔面の皮膚…）を含む場合は、いくつかの技術のうちの１つを使用し得る：

-手動位置合せ：写真をデジタル化された治療部位と整列させる。当該写真を変倍および並進させることができる。治療部位の三次元表示を回転させることができる。ユーザは、当該表示を回転させて、その配向を写真が取られた角度と一致するように適合させる。写真のサイズが調整され、三次元表示の像と整列するまで画像が並進される。当該ステップは、位置合せを調整するために繰返される。

-半自動位置合せ：ユーザは、当該表示を回転させて、その配向を写真が取られた角度と一致するように適合させる。写真および三次元表示は並べて示される。両方において基準点が指定され、対応する特徴をマークする。最終的なマッピングは、両方の点のセットを整列させるのに必要な最適な変形を求める最小二乗アルゴリズム／ｎ点位置合せ／ＩＣＰ（反復最近点）位置合せと、ＲＢＦ（動径基底関数）最適化手法を用いた基準点の位置およびその間の最小変形での厳密なマッチングとのいずれかによって行われる。

-自動位置合せ：位置合せ適用特徴認識。

【００２３】
同一の表面が利用できない場合（たとえば、無歯の患者の二次元または三次元写真の、上顎および下顎の石膏型のデジタル化された三次元モデルに対するマッピング）、上記の位置合せ技術は使用することができない。これらの場合、優先される手法は、顔弓測定を利用して異なるデータセットをマッピングする。図３を参照し、顔弓は、顎関節に対する上顎弓の位置関係を記録し、この同じ関係で歯型を機械式咬交器の開口軸に配向するために歯科で使用される機械式装置である。顔弓は、互いに取り付けられた２つの金属部分からなる。第１の部分３はバイトフォークと呼ばれ、馬蹄状の形状であり、患者の口に挿入され、上顎と下顎との間に締め付けられる。第２の部分は２つの湾曲要素１，９を含む。第１の湾曲要素１の端部８は、患者の耳道に位置決めされる。第２の湾曲要素９は、患者の鼻と接触する鼻用ガイドを構成する。バイトフォーク３は、第２の湾曲要素９に固定される。顔弓のすべての部分の現在位置が維持され、次いで、対応する機械式咬交器に石膏型を転写するのに使用される。これは、患者の口から機械式咬交器に咬合を転写するのに使用される顔弓が仮想的に作成され、患者の三次元写真上に位置決めされることを意味する（図３）。バイト位置合せ３はデジタル化もされ、患者の顎のデジタル三次元モデルを三次元写真と同じ座標系において位置合せするのに使用される。二次元写真の場合、仮想顔弓は使用することができず、この場合に優先される方法は、（機械式咬交器で使用される）デフォルト値を使用して患者の顎の三次元モデルを正しい関係で顆頭間軸に位置決めすることであり、患者の顔面の二次元写真上に規定することができる。

【００２４】
上記の方法の代替案として、異なる視点から取得された画像に出現する対象物および特徴を一致させることなどによって、治療すべき部位の三次元モデルを二次元映像シーケンスから直接構築することができる。映像データは本来、取込まれた点の単なる空間座標だけでなく、色、質感等にも関連し得る情報を保持しているため、算出された再建はこれらの特質の各々を反映させるように行うことができ、これによって実物様モデルが実現される。

【００２５】
ステップ６１で作成された複合三次元モデルは、顔面解析が当該モデルを基礎とすることができるように患者の顔面を含むことが好ましい。修正された歯セットアップを計画するのに使用される三次元モデルは実物様である必要はないが、当該情報は、治療の効果をユーザおよび患者に対して視覚化するのに有用であり、当該方法の最終段階６６において描画することができ、治療後の歯セットアップの仮想表示がユーザおよび患者に対して示される。

<u>顔面解析（ステップ６２、６３、図２）</u>

発明の一実施形態によれば、上記の方法のうちの１つで作成された患者の三次元モデルは、顔面および／または治療すべき部位の審美的外観についての情報を判定するために解析される。当該解析は、完全自動または半自動であり得る。半自動解析では、コンピュータプログラムは、顔面解析に必要とされるある解剖学的な点および／または線を患者の顔面上に指定するようユーザを促す。ユーザは、マウス２３、キーボード２１、グラフィックスタブレット、電子ペンなどの入力ツールを使用することによって、これらの点を顔面のグラフィック表示上にマークする。当該プログラムは、次いで、これらのマークされた点の間の測定に基づいて顔面解析を行い、下記のように歯セットアップを自動的に作成または修正する。次の表および図４～６は、プログラムがユーザにマークするよう促すことができるいくつかの例示的な解剖学的な点を示す。半自動的な実施形態においても、ユーザへの促しや入力なしに、たとえば患者の顔面の全体形状（規則Ａ）および瞳孔間線（規則Ｄ）などの顔面の特徴のいくつかを自動的に判定するように、当該プログラムを設けることができる。

【００２６】
一般的な審美的規則のセットは、顔面解析の結果を使用し、患者の顔面の特定の特色に基づいて、審美的に最適な歯列配置または歯セットアップを作成する。次の表は、１４の

実行可能な顔面解析および対応する規則の非網羅的なリストを示す。

【０ ０ ２ ７】

【表１】

	審美的解析	審美的規則
A	患者の顔面、および可能であれば患者の歯の形状を判定する。３つの主な顔面形状が存在する： (i)矩形または正方形形状。矩形または正方形形状の顔面は、額と頬骨の真下とにおいてほぼ同じ幅を有する； (ii)先細り。先細りの顔面は額が幅広く、小さく華奢な頤に向かって狭まる； (iii)楕円形。楕円形の顔面は、額または顎の線よりも頬骨の方が若干幅広い。 歯は３つの異なる形状に分類される：先細り、卵形および正方形形状。患者が残存歯を有している場合、患者の残存歯列のデジタル化された情報に基づいて歯の形状を判定することができる。	最適な歯の形状は次の規則にしたがって選択される： （１）部分的に無歯の場合（すなわち患者の何本かの歯が残存している)、残存している生来の歯および／または患者の顔面の形状に基づいて歯の形状が判定される。 （２）無歯の場合、患者の顔面の形状の解析にのみ基づいて歯の形状が選択される。 矩形または正方形形状の顔面は正方形形状の歯に対応する。先細りの顔面は先細り形状の歯に対応する。 楕円形の顔面は卵形形状の歯に対応する。
B	鼻底の幅を判定する（４、図４参照)。	４本の上顎切歯を、それらの全幅（５、図４）が鼻底の幅とほぼ等しくなるように設計するかまたは形状を変える（Gerber)。
C	眉毛と鼻底との距離を判定する（図５参照)。	咬合時の鼻底と頤の頂点との距離が眉毛と鼻底との距離に等しくなるように、咬合面を患者の顔面に対して位置決めする。
D	瞳孔間線、すなわち眼の中心を結ぶ線（６、図６）を判定する。	上顎犬歯の咬頭を結ぶ咬合面または線（７、図６）が前記瞳孔間線と平行になるように、歯を再建または補正する。
E	顔面の対称線、すなわち額の中心から鼻下点に沿って頤の中心点に至る線を判定する。	正面上顎切歯の顔面軸が前記対称線と平行となるように正面上顎切歯を角張らせるかまたは再配向し、中切歯の接点が前記対称線上にあるように中切歯を位置決めする。
F	鼻根点−口唇角度、すなわち患者の顔面の矢状（側面）図において測定された鼻柱と上唇の前面との角度を判定する。	鼻根点-口唇角度がほぼ９０°となるように上顎切歯を再建または補正する。したがって、特に鼻根点−口唇角度が９０°の場合、上唇位置に対する歯の位置を予測するためには軟組織シミュレーションが必要である。

【０ ０ ２ ８】

【表２】

	審美的解析	審美的規則
G	患者の顔面の矢状（側面）図において、上唇および下唇から鼻の先端および頤を通る線までの距離を判定する。	上唇から前記線までの距離が４ｍｍとなり下唇から前記線までの距離が２ｍｍとなるように、歯を再建または補正する。
H	微笑時の上唇の位置を判定する。	微笑時に正面上顎歯の高さの４分の１のみが上唇によって覆われるように、正面上顎歯を位置決めまたは補正する。 一部の患者については、笑線(smile line)すなわち自然な微笑時の上唇の境界線が理想よりもはるかに高く、上側の歯肉が露出される。これらの場合、正面上顎へのインプラント配置が可能となるように歯茎補正が必要とされる。歯茎補正しなければ、補綴再建においてピンクの陶材が必要となり、これはインプラントを洗浄する目的のために必要な歯間空間と両立しない。
I	微笑時に下唇によって形成される曲線を判定する。	正面上顎歯の切歯端が前記曲線と平行となり、かつ下唇にただ触れるだけまたはわずかな間隙を示すように、正面上顎歯を位置決めまたは補正する。
J	微笑時のバッカルコリダー、すなわち口の角度と歯の角度との間に見える狭い空間（１２、図７）を判定する。	自然な大きさの前記バッカルコリダーを得るように、上顎歯列形状と上顎小臼歯および臼歯の配向とを判定または適合化する。歯列弓が大きすぎるとバッカルコリダーがなくなり、歯列弓が小さすぎるとバッカルコリダーが目立ちすぎる。
K	上顎中切歯の高さに対する幅の比を判定する。	必要であれば、高さに対する幅の比について８０％という理想的な値に近付くように上顎中切歯を適合化する。
L	犬歯の幅に対する側切歯の幅に対する上顎中切歯の幅の割合を判定する。	必要であれば、それぞれ１．６、１および０．６という理想的な幅割合を得るように上顎切歯および犬歯を適合化する。
M	会話中の上唇の位置を判定する。	会話時に前記歯について約１．５ｍｍの視認性を得るように、上顎切歯の位置または寸法を適合化する。
N	矢状（側面）図において歯のオーバージェットを判定する。	一般的な慣行で使用されるオーバージェット値すなわち２ｍｍを得るように、正面歯を傾斜させるまたは傾斜を適合化させる。

【００２９】

上に挙げた解析は、次の広範な分類に当てはまる：顔面の特徴の測定を含む患者の顔面の審美的特色（Ａ～Ｇ）；下顎および歯によって判定され得る顔面の審美的特色（Ｈ、Ｉ、Ｊ、Ｍ）；および患者の歯の審美的特色（Ｋ、Ｌ、Ｎ）。審美的特徴の解析は、患者の仮想モデル５６に対して、または患者の画像データ３０の一部、たとえば患者の顔面および歯の写真に対して行うことができる。

機能解析（ステップ６４、６５、図２）

患者の審美的特性の解析を行うのに加え、より「機能的な」患者の特色のコンピュータ支援解析を含むように解析を拡張することができる。この解析に起因する機能的情報は、図２のステップ６３で導出された歯列配置を適合化することができる機能的規則のセットにおいて使用することができる。代替的に、歯列配置は、審美的情報および機能的情報の両方を利用する審美的規則および機能的規則の組合されたセットに直接基づき得る。

【００３０】

次の表は、機能解析および対応する規則の非網羅的なリストを示す。

【００３１】

【表３】

機能解析	機能的規則
臼歯関係の分類（Ｉ、ＩＩまたはＩＩＩ）を判定する。 (i)分類Ｉの不正咬合は、下顎第一永久臼歯の頬側溝が上顎第一永久臼歯の近心頬側咬頭と咬合する不正咬合を指す。 (ii)分類ＩＩの不正咬合は、下顎第一永久臼歯の頬側溝が上顎第一永久臼歯の近心頬側咬頭の後部（遠心）に咬合する不正咬合を指す。 (iii)分類ＩＩＩの不正咬合は、下顎第一永久臼歯の頬側溝が上顎第一永久臼歯の近心頬側咬頭の前部（近心）に咬合する不正咬合を指す。	理想的には、分類Ｉの臼歯関係（図８）が作成されるべきである。しかし、患者がたとえば左側に分類ＩＩ／ＩＩＩの臼歯関係を有している場合は、当該分類ＩＩ／ＩＩＩの臼歯関係を模倣して右側を再建することができる。
残存歯の歯冠角形成を判定する。	補綴再建において、残存歯の歯冠角形成を模倣する。残存歯がない場合、歯冠の角度位置の平均値を使用する。
残存歯の歯冠傾斜を判定する。	補綴再建において、残存歯の歯冠傾斜角を模倣する。残存歯がない場合、歯冠傾斜角の平均値を使用する。
上顎および下顎に関して残存歯に基づいて、または無歯の場合には平均曲線および顎情報に基づいて、歯列弓を判定する(Staub...)。	判定された歯列弓に正接するように歯冠を整列させる。
歯列弓（上側および下側）の中線を判定する。	これらの中線が一致するまで歯列弓を適合化する。
隣接する歯同士の接触を判定する。	残存歯の接触を模倣する。無歯の場合、歯冠を隣接するものに密接させて位置決めする。
顎の運動時の接点を判定する。	理想的な咬交を得るように歯冠の咬合面を適合化する。
オーバージェットを判定する。	最適値２ｍｍを得るように歯の位置を適合化する、または歯冠を再建する。
オーバーバイトを判定する。	最適値２ｍｍを得るように歯の位置を適合化する、または歯冠を再建する。

【００３２】
機能解析は最適な歯の接触に限定されず、広義においては、音声学および生体力学（たとえば最適な歯の負荷）を含み得る。

【００３３】
コンピュータ支援機能解析は、理想的な歯の接点の識別を含み、個々の患者の静的およ

び動的なチェックバイトのデジタル化された情報によって、または仮想咬交器によって行うことができる。咬交器は、両側の歯列弓の咬合面同士の静的および動的な接触関係を検査するのに使用される機械式機器であり、ヒトの顎関節および顎を表わし、下顎の運動の一部またはすべてをシミュレートするために、上顎および下顎の型が取付けられ得る。顎の形態および下顎の運動に関する異なる設定を咬交器において調整することができる。それらの値は、患者固有のデータまたは文献において既知の平均値を用いて設定される。仮想咬交器は、仮想環境において静的および動的な接触関係を定める。患者固有のデータまたは文献において既知の平均値を用いた設定によって課される幾何学的な制限によって制約される下顎の前方運動、後方運動、左側方運動、右側方運動、開口運動、および閉口運動をシミュレートする。さらに、仮想咬交器は、結果として得られる咬合接触を算出し、視覚化する。代替的に、顎の運動および咬合接触は、患者の既知の目印に対する三次元経路として記録および提供することができる。

【００３４】

図９Ａから図９Ｃは、セットアップの機能的特色がどのように判定され修正されるかについての一例を例示する。図９Ａは、顔面解析および審美的規則の適用に起因する歯セットアップ案を示す。これにより、修正されたセットアップに補綴歯１６が挿入されることになった。歯１６は当初、要素のライブラリ５５のある要素のデフォルト特性などのデフォルト形状および表面特徴を有する。図９Ｂにおいて、新たな歯１６の咬合面が対合歯（たとえば歯１６の真上に示される歯）に対して解析される。解析の結果、歯１６の外側面が、より良い咬合面を呈示するように修正される。図９Ｃは、最適化の結果を示す。

【００３５】

機能的規則および審美的規則の各々は、多かれ少なかれ最終的な歯列に深く影響を与えるために重み付け係数を割り当てることができる。各重み付け係数は、過去の経験に基づく値を有することができる。代替的に、各重み付け係数は、患者を治療するチームによって個別に専門知識にしたがって調整することができる。以下は、重み付け係数をどのように使用することができるかについての実用例である。４本の上顎切歯および両方の犬歯が欠損している患者について歯セットアップを作成しなければならないとする。審美的規則Ｌは、欠損歯の幅について理想的な均整を予測する。審美的規則Ｂは、患者の鼻底の幅に基づいて４本の上顎切歯の全幅を予測する。患者の鼻が非常に小さい場合は規則Ｌが歯の最終的な幅について決定すべきであるため、規則Ｌは、規則Ｂよりも高い重み付け係数を有さなければならない。これにより、残存している上顎第一小臼歯同士の間の欠損歯の正常な均整の取れた幅が得られることになる。この場合に、規則Ｌが規則Ｂよりもはるかに低い重み付け係数を与えられているとすると、残存している上顎第一小臼歯同士の間の間隙を埋めることができるように、非常に厚い犬歯と組合せて非常に小さい上顎切歯が作成されることになる。したがって理想的な均整が考慮されず、審美的に劣った成果が生じることになる。

【００３６】

最適な歯（および軟組織）セットアップを生成するプロセスは、異なる様式で達成することができる：

-歯（および軟組織）セットアップは、審美的規則のすべてまたは一部のみについて反復プロセスで最適化することができる；

-歯（および軟組織）セットアップは、審美的規則のすべてまたは一部の重み付け平均として判定することができる。重み付け係数は、たとえば、最適なセットアップを達成するための審美的規則の重要性を表わす；

-歯（および軟組織）セットアップは、第一のサブセットの規則を用いて判定し、次いで第２のサブセットの規則を用いて最適化することができる。

【００３７】

患者が部分的な歯のセットを有している場合、本発明は、患者が現在歯を欠損している場所に移植歯を仮想的にモデリングする最適な歯列配置を生成することができる。移植歯は、審美的規則および機能的規則にしたがって選択される。図１０は、６本の補綴歯１４

のグループが患者の顎のモデルに挿入された例を示す。

【００３８】

また、患者の現存する歯の一部を位置変更することが望ましいこともある。これもモデリングすることができ、位置変更の結果を患者に対して表示することができる。ライブラリ５５は、完全にまたは部分的に無歯の患者に使用するために（さまざまな種類、形状および大きさの）個々の歯と完全なまたは部分的なセットアップとを保存する。ライブラリセットアップの各々は、審美的（および機能的）規則にしたがって適合化することができる、または審美的（および機能的）規則に基づいてライブラリセットアップのうち最良のものを選択し得る。要素のデジタルライブラリ５５は、実物様外観をもたらすために、たとえば色、質感等の規定の特性のデフォルトセットを有することができる。代替的に、このような情報を「無地の」要素上にマッピングして、所望の実物様外観を得てもよい。選択肢の選択は、たとえば、色および質感のパレットを提供するメニューの形態でユーザに提示することができる。図１１は、ライブラリ要素１４に色および質感を適用した後の図１０のモデルを示し、図１２は、色および質感が適用された補綴歯を有する治療部位の別の実物様表示を示す。

【００３９】

仮想モデリングは、デジタル環境においてユーザの対話によって行われ得る。ワークステーションによって実行されるソフトウエア２５は、ディスプレイ１０上にグラフィカルユーザインターフェースを作成し、ユーザが自動的または半自動的に個々の歯もしくは歯のグループを選択、導入、位置決め、位置変更、または修正することが可能となる。当該ソフトウエアは、規定の弓形に沿って自動的に歯を位置決めするルーチン、または対合歯歯列に対する咬合の機能において歯を自動的に位置決めするためのルーチンを含むことができる。歯列矯正の場合の代替案は、抜歯、顎の拡張および歯の剥離（すなわち幅の削減）である。すでに位置決めされた歯の咬合面を、ソフトウエアツールを使用して修正してもよい。

治療部位の仮想表示、治療後（ステップ６６、図２）

当該方法の最終ステップは、治療部位の仮想表示を示し、最適な歯（および軟組織）セットアップの効果を示す。ある範囲の実行可能な治療選択肢が存在する可能性がある。一例として、歯列復元に関して、代替的な治療選択肢は異なる歯の形態、大きさおよび色を含み得る。治療選択肢の各々をユーザおよび患者に対して提示することができ、患者は、治療の審美的な結果を確認することができる。特定の実施形態において、仮想表示を修正して、異なる顔貌、たとえば微笑をシミュレートすることができる。ステップ６６は、図２のステップ６１で作成され、かつ図２のステップ６５で判定された治療作業を含むように更新されたのと同じ三次元モデルを使用することができる。ステップ６５で判定された修正された歯セットアップを使用して、治療すべき部位の実物様表示を更新することができる。更新は、治療部位の実物様表示と修正された歯セットアップとを空間的に一致させること、およびそれらをディスプレイ１０上に同時に視覚化することからなる。空間的に一致させることは、両方の実体を位置合せすることである。たとえば、患者の二次元写真のみが入手可能な場合、結果を視覚化するには、最適な歯セットアップを当該二次元写真に対して位置決めし、配向し、変倍し、次いで写真に埋込まなければならない。代替的に、治療部位の三次元実物様表示から要素（たとえば歯）を取除き、生成されたセットアップにおいて対応する同等物で置換し得る。実物様表示を更新することは、生成された最適な歯（および軟組織）セットアップの、治療部位の全体または局所領域の位置、傾斜および／または変形に対する効果を算出することを意味する。当該治療部位は、相応して修正される。一例は、唇が歯によって支持される様式に関連する。歯の傾斜を修正することは、唇の位置も変化させることになる。

【００４０】

発明のさらなる実施形態において、コンピュータ支援顔面解析は、定量的および定性的な（文字）指針をもたらすことができ、続いて、歯科技工士によって使用され、最適な歯セットアップを手作業で作成する。その後、作成された歯セットアップ（蝋引き(wax-up)

）をスキャンして三次元モデルに変換し、患者の顔面に対する新たなセットアップの効果を示すために複合三次元画像表示を作成することができる。

例示的な例

【実施例１】

【００４１】

歯列矯正治療を必要とする患者の（微笑時の）顔面について、三次元写真、または二次元写真のセットを取る。また、アルギン酸塩またはシリコン材料で患者の歯列の印象を取る。これらの印象を用いて、患者の口腔内解剖学的構造の石膏モデルが作製される。石膏モデルは、その後、治療前に患者の歯列を提示する仮想三次元モデルを得るために、光学スキャナを用いてデジタル化される。ソフトウエアにおいて、患者の歯列の仮想三次元モデルが患者の顔面の三次元写真上に位置合せされ、実物様表示を作成する。石膏型は歯肉の情報を含み、三次元写真は患者の顔面の表面情報を含む。コンピュータ支援顔面機能解析が行われ、これらの解析の結果は規則のセットにおいて使用され、患者の最適な歯列を確定する。患者の生来の歯の位置、傾斜および角形成を当該規則にしたがって適合化することにより、最適な歯セットアップが作成される。必要であれば、患者の顎に現在位置する生来の歯を仮想的に抜き、最適化された診断用の歯セットアップを得ることができる。最後に、患者の三次元写真と合せて、最適な歯セットアップが視覚化される。

【実施例２】

【００４２】

補綴再建を必要とする部分的に無歯の患者について、二次元写真、ＣＴスキャンおよび印象を取る。患者の仮想的な実物様表示は、ＣＴ画像から生成された患者の顔面の三次元軟組織モデル上に二次元写真をマッピングし、かつ歯形のμＣＴ画像から生成された患者の歯列の三次元モデルを患者の顔面のＣＴ画像と位置合せすることによって作成される。患者が現在歯を欠損している箇所について、移植歯が選択される。移植歯は、患者の残存歯列の形状と一致するように、顔面／審美的解析を行い、かつ審美的規則および機能的規則に従うことによって選択される。ソフトウエアは、移植歯を歯のライブラリから自動的に選択し、これらを患者の口の仮想モデルに配置することができる、またはソフトウエアは審美的情報および規則に基づいて適切な歯の選択を提案することができる。ユーザは、ソフトウエアによって提案されたものの中から最良の移植歯を自身の判断で選択し、これらを顎の仮想モデルに配置することができる。次いで、機能的規則およびコンピュータ支援機能解析の結果に基づいて、これらのライブラリ歯の咬合面が機能的に最適化される。

【実施例３】

【００４３】

完全に無歯の患者について、三次元写真および印象を取る。これらの歯形をμＣＴによってスキャンし、画像処理（セグメント化、三次元モデル作成、表面反転等）を行うことによって、患者の口腔内解剖学的構造のデジタル表示が得られる。顔弓測定を用いて患者の無歯の顎の仮想三次元モデルを三次元写真に対して位置決めすることにより、仮想的な実物様表示が作成される。次いで、統計的情報（たとえばStaubペンタグラム、歯列弓の平均的な形状）と、コンピュータ支援顔面解析によって定められた規則とを使用することによって、ライブラリ歯から初期の歯セットアップが作成される。仮想咬交器を設定するための患者固有のパラメータを考慮に入れて、この当初の診断用セットアップについてコンピュータ支援顔面解析が行われる。これらのライブラリ歯の咬合面は、最適な咬合および咬交を得るために機能的に最適化される。最適化プロセスは、機能的事項と審美的事項との間で最良の折衷案が見出されるまで反復される。

【００４４】

本発明は、本明細書において説明した実施形態には限定されず、発明の範囲から逸脱することなく修正または変更され得る。

【図１】

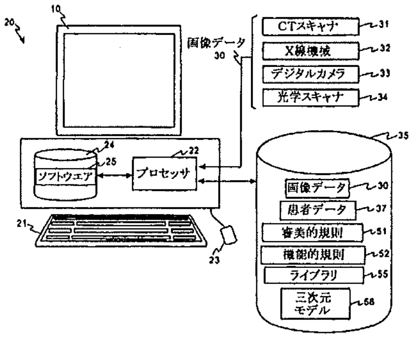

Fig. 1

【図２】

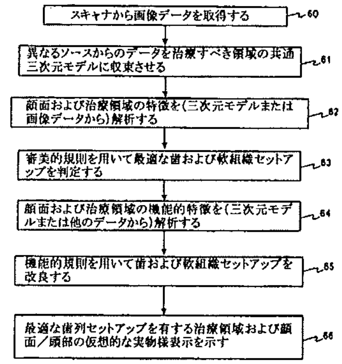

Fig. 2

【図３】

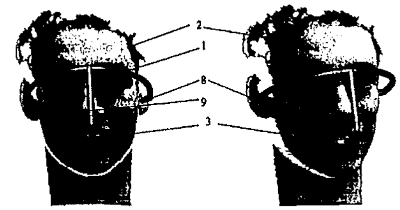

Fig. 3

【図４】

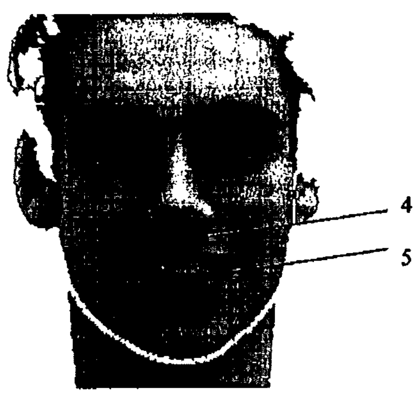

Fig. 4

【図５】

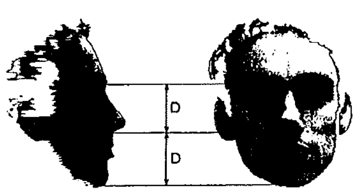

Fig. 5

【図６】

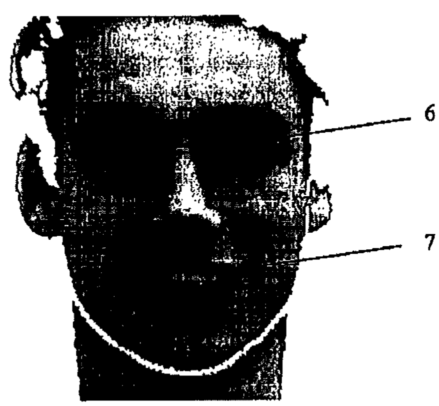

Fig. 6

【図７】

Fig. 7

【図８】

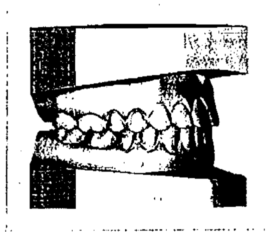

Fig. 8

【図９Ａ】

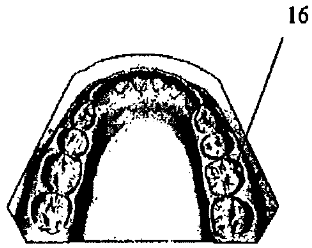

Fig. 9A

【図９Ｂ】

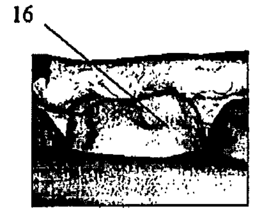

Fig. 9B

【図９Ｃ】

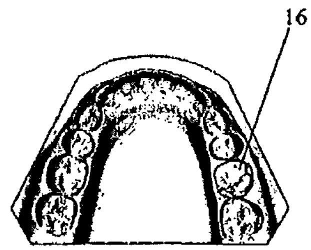

Fig. 9C

【図１０】

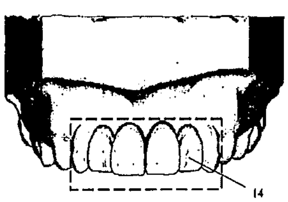

Fig. 10

【図１１】

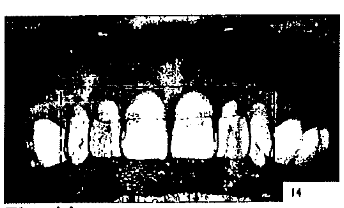

Fig. 11

【図１２】

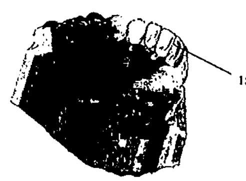

Fig. 12

【手続補正書】
【提出日】平成21年12月22日(2009.12.22)
【手続補正１】
【補正対象書類名】特許請求の範囲
【補正対象項目名】全文
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項１】
患者の歯科治療の自動的または半自動的計画のための方法であって、
（ａ）治療すべき部位についてのデータと患者の顔面についてのデータとを得るステップと、
（ｂ）少なくとも患者の顔面の特性を判定するために、当該データのコンピュータ支援顔面解析を行うステップと、
（ｃ）判定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するステップと、を含み、当該顔面特性は、顔面の特徴の測定を含む患者の顔面の審美的特色、下顎および歯によって判定され得る顔面の審美的特色、ならびに患者の歯の審美的特色から選択される、方法。
【請求項２】
前記規則は：
最適な歯の形状が、
（１）部分的に無歯の場合（すなわち患者の何本かの歯が残存している）、残存している生来の歯および／または患者の顔面の形状に基づいて歯の形状が判定される、または、
（２）無歯の場合、患者の顔面の形状の解析にのみ基づいて歯の形状が選択される、または、矩形もしくは正方形形状の顔面は正方形形状の歯に対応する、または、先細りの顔面は先細り形状の歯に対応する、または、楕円形の顔面は卵形形状の歯に対応する、という規則にしたがって選択される；
４本の上顎切歯を、それらの全幅が鼻底の幅とほぼ等しくなるように設計するかまたは形状を変える；
咬合時の鼻底と頤の頂点との距離が眉毛と鼻底との距離に等しくなるように、咬合面を患者の顔面に対して位置決めする；
上顎犬歯の咬頭を結ぶ咬合面または線が前記瞳孔間線と平行になるように、歯を再建または補正する；
正面上顎切歯の顔面軸が前記対称線と平行となるように正面上顎切歯を角張らせるかまたは再配向し、中切歯の接点が前記対称線上にあるように中切歯を位置決めする；
鼻根点-口唇角度がほぼ９０°となるように上顎切歯を再建または補正し、したがって、特に鼻根点-口唇角度が９０°の場合、上唇位置に対する歯の位置を予測するためには軟組織シミュレーションが必要である；
上唇から前記線までの距離が４ｍｍとなり下唇から前記線までの距離が２ｍｍとなるように、歯を再建または補正する；
一部の患者については、笑線すなわち自然な微笑時の上唇の境界線が理想よりもはるかに高く、上側の歯肉が露出され、これらの場合、正面上顎へのインプラント配置が可能となるように歯茎補正が必要とされ、歯茎補正しなければ、補綴再建においてピンクの陶材が必要となり、これはインプラントを洗浄する目的のために必要な歯間空間と両立しないため、微笑時に正面上顎歯の高さの４分の１のみが上唇によって覆われるように、正面上顎歯を位置決めまたは補正する；
正面上顎歯の切歯端が前記曲線と平行となり、かつ下唇にただ触れるだけまたはわずかな間隙を示すように、正面上顎歯を位置決めまたは補正する；
歯列弓が大きすぎるとバッカルコリダーがなくなり、歯列弓が小さすぎるとバッカルコリダーが目立ちすぎるため、自然な大きさの前記バッカルコリダーを得るように、上顎歯

列形状と上顎小臼歯および臼歯の配向とを判定または適合化する；
必要であれば、高さに対する幅の比について８０％という理想的な値に近付くように上顎中切歯を適合化する；
必要であれば、それぞれ１．６、１および０．６という理想的な幅割合を得るように上顎切歯および犬歯を適合化する；
会話時に前記歯について約１．５ｍｍの視認性を得るように、上顎切歯の位置または寸法を適合化する；
一般的な慣行で使用されるオーバージェット値すなわち２ｍｍを得るように、正面歯を傾斜させるまたは傾斜を適合化させる；
のうちのいずれかである、請求項１に記載の方法。

【請求項３】
少なくとも修正された歯セットアップを有する治療部位の外観をシミュレートする三次元表示を生成するステップをさらに含む、請求項１または２に記載の方法。

【請求項４】
三次元表示を生成するステップはさらに、治療部位を取囲む患者の顔面の外観もシミュレートする、請求項３に記載の方法。

【請求項５】
データのコンピュータ支援顔面解析を行うステップ（ｂ）は、現存する歯の特性も判定し、ステップ（ｃ）は、所定の顔面特性と現存する歯とを利用する規則のセットを使用して、修正された歯セットアップを作成する、または、
ステップ（ｂ）における解析は患者の顔面の形状を判定することを含み、ステップ（ｃ）は、所定の形状に基づいて補綴歯の形状を選択することを含む、または、
ステップ（ｂ）における解析は、患者の顔面の特徴同士の距離または患者の顔面の特徴の配列の判定を含み、ステップ（ｃ）は、判定された距離または配列に基づいて歯セットアップを修正することを含む、または、
ステップ（ｂ）における解析は瞳孔間線を判定することを含み、ステップ（ｃ）は、上顎犬歯の咬頭同士を結ぶ咬合面もしくは線が、判定された瞳孔間線と平行になるように、歯を再建するまたは歯の位置を補正することを含む、または、
ステップ（ｂ）における解析は、患者の唇の位置を判定することを含み、ステップ（ｃ）は、判定された位置に基づいて歯セットアップを修正することを含む、または、
ステップ（ｂ）における顔面解析は、微笑時の上唇の位置を判定することを含み、ステップ（ｃ）は、微笑時に正面上顎歯の高さの４分の１のみが上唇によって覆われるように正面上顎歯を位置決めすることを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項６】
ステップ（ｃ）は、得られたデータから治療すべき部位の三次元モデルを生成し、修正された歯セットアップを当該モデル上に作成することを含む、または、
ステップ（ｃ）において使用される規則のセットは重み付けされる、先行する請求項のうちいずれか１項に記載の方法。

【請求項７】
データのコンピュータ支援顔面解析を行うステップは、解剖学的な点の位置を患者の顔面の二次元または三次元表示において指定するようユーザに促すことと、ユーザから受取った入力に基づいて顔面特性を自動的に判定することとを含む、先行する請求項のうちいずれか１項に記載の方法。

【請求項８】
治療すべき部位または修正されたセットアップの機能的データを判定するステップをさらに含み、ステップ（ｃ）は当該機能的データを使用する、先行する請求項のうちいずれか１項に記載の方法。

【請求項９】
機能データは、治療すべき部位の咬合もしくは咬交、または修正された歯セットアップ

に関連する、請求項８に記載の方法。
【請求項１０】
機能データを判定するステップは、最適な歯接点を判定することを含み、ステップ（ｃ）は、歯セットアップを修正して歯接点を最適化することを含む、請求項９に記載の方法。
【請求項１１】
ステップ（ａ）において得られたデータは、患者の三次元モデルを生成するのに使用され、歯接点の判定は当該モデルを使用する、または、
ステップ（ａ）において得られたデータは、患者の三次元モデルを生成するのに使用され、ステップ（ｂ）の顔面解析は当該モデルを使用する、請求項１０に記載の方法。
【請求項１２】
患者の顔面についてのデータは、患者の頭部の少なくとも一部の外面の二次元写真、三次元写真、光学スキャンのうち１つ以上を含む、先行する請求項のうちいずれか１項に記載の方法。
【請求項１３】
治療すべき部位についてのデータは、複数の異なる撮像技術を使用して取得されたデータを含む、好ましくは、撮像技術は、二次元写真、三次元写真、口腔内光学スキャン、Ｘ線、コンピュータ断層撮影を含む、先行する請求項のうちいずれか１項に記載の方法。
【請求項１４】
ステップ（ｃ）は、異なる撮像技術を使用して取得されたデータを相関させて、患者の顎および現存する歯の三次元モデルを生成することを含む、または、
ステップ（ｃ）はさらに、修正された歯セットアップをグラフィカルユーザインターフェースによってユーザに操作させることを含む、または、
ステップ（ｃ）はさらに、要素のライブラリにアクセスし、ライブラリを使用して修正された歯セットアップを作成する、請求項１３に記載の方法。
【請求項１５】
患者の歯科治療の自動的または半自動的計画のための装置であって、前記装置は、
治療すべき部位についてのデータと患者の顔面についてのデータとを受取るための入力と、
プロセッサとを備え、前記プロセッサは、
当該データのコンピュータ支援顔面解析を行って、少なくとも患者の顔面の特性を判定し、
判定された顔面特性を利用する保存された規則のセットを使用して、修正された歯セットアップを作成するように設けられ、当該顔面特性は、顔面の特徴の測定を含む患者の顔面の審美的特色、下顎および歯によって判定され得る顔面の審美的特色、ならびに患者の歯の審美的特色から選択される、装置。
【請求項１６】
プロセッサはさらに、少なくとも修正された歯セットアップを有する治療部位の外観をシミュレートする三次元表示を生成するように設けられる、請求項１５に記載の装置。
【請求項１７】
プロセッサはさらに、治療部位を取囲む患者の顔面の外観もシミュレートするように設けられる、請求項１６に記載の装置。

【国際調査報告】

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/003072

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61C13/00 A61C19/00 A61B5/00 A61B19/00 G06T7/00
G06T7/60 G06T17/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61C A61B G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/000063 A (MEDICIM NV) 5 January 2006 (2006-01-05)	1-8, 12-23, 25-28
Y	paragraph [0002] - paragraph [0004] paragraph [0012] - paragraph [0014] paragraph [0016] paragraph [0021] - paragraph [0022] paragraph [0039] paragraph [0042] paragraph [0054] - paragraph [0055] paragraph [0058] claims 1,5,11-14,16; figures 7,11-15 ----- -/--	9-11,24

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 August 2008	11/08/2008
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Raybould, Bruce

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/003072

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2004/098378 A (ORAMETRIX INC) 18 November 2004 (2004-11-18) cited in the application page 22, line 23 - page 23, line 4 page 29, line 25 - line 29 page 35, line 14 - page 36, line 12 page 36, line 28 - line 30	9-11,24

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/003072

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006000063 A	05-01-2006	BR PI0511379 A	04-12-2007
		CN 1998022 A	11-07-2007
		EP 1759353 A1	07-03-2007
		JP 2008503280 T	07-02-2008
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WO 2004098378 A	18-11-2004	EP 1624823 A2	15-02-2006

Form PCT/ISA/210 (patent family annex) (April 2005)

フロントページの続き

(51)Int.Cl.		FI		テーマコード（参考）
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(54) Title: DENTAL IMAGE PROCESSING METHOD AND SYSTEM

(57) Abstract

An image processing method for use in dentistry or orthodontic is provided. Two images of teeth, one being a two-dimensional image and one a three-dimensional image are combined in a manner to allow the use of information obtained from one to the other. In order to combine the two images a set of basic landmarks is defined in one, identified in the other and then the two images are registered.

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DENTAL IMAGE PROCESSING METHOD AND SYSTEM

FIELD OF THE INVENTION

The present invention is generally in the field of dentistry and provides an image processing method and system useful as a tool by the dentist or orthodont.

BACKGROUND OF THE INVENTION

There are a wide variety of imaging techniques used routinely in orthrdontics. One important imaging technique is the so-called radiographic cephalometric technique. A radiographic cephalometric image is then used for a cephalometric analysis. Such an analysis is essentially a measurement system designed to describe relationships between the various parts of the skeletal, dental and soft tissue elements of the cranofacial complex. The two cephalometric images typically used are a lateral cephalometric image, which is of prime use in orthodontic and a front cephalometric image which is of somewhat less importance.

Cephalometric methods enable to define certain norms of a skeletal, dental and soft tissue of the cranofacial complex. A cephalometric measurement of individuals can then be compared with norms for age, sex and population group. A cephalogram is in effect a two-dimensional representation of a three-dimensional cranofacial structure. It is thus difficult in an analysis performed on such an image to distinguish between bi-lateral structures to trace them independently. Additionally, facial aspects are not entirely asymmetrical, this may add a further inaccuracy to an analysis of this kind. Other sources of errors in a cephalometric image include different magnification of different aspects depending on the distance from the film and imperfect positioning of the patient in the cephalostat. These all add up to considerable errors in cephalometry.

An orthodont, prior to beginning the orthodontic treatment typically takes a teeth impression on the basis of which a plaster model may be prepared. There are known also a number of imaging techniques which allow to obtain, within a computer environment, a virtual three-dimensional image of the teeth. Such techniques are described for example in WO 97/03622 and DE-C-414311. A three-dimensional teeth image provides a different information than that obtained by a cephalometric analysis. Particularly, a virtual teeth image allows better appreciation of the three-dimensional structure of the teeth and the relative position of different teeth.

For the purpose of proper design of orthodontic treatment it would have been high advantageous to have a method and system whereby information which can be acquired from one type of image can be transferred or superpositioned to information available from another type of image.

GENERAL DESCRIPTION OF THE INVENTION

In accordance with the invention a novel method and system is provided in which information and data available from one type of teeth imaging technique is transferred and used in an image obtained by another kind of teeth imaging technique. This transfer of information provides the dentist or the orthodont with a powerful tool for designing of orthodontic treatment.

In accordance with the invention there is provided an image processing method comprising:

(a) applying at least a first imaging technique and a second imagining technique to acquire a first, two-dimensional image of at least a first portion of teeth and a second, three- dimensional virtual image of at least a second portion of the teeth, respectively, there being at least a partial overlap between said first and second portions; and

(b) defining a set of basic landmarks in either one of the two images, locating said set in the other of the two images and registering said set in the two images.

By another of its aspects the present invention provides an image processing system, comprising:

(i) a first utility for receipt of first data representative of a first two-dimensional image of at least a first teeth portion;

(ii) a second utility for receipt of second data representative of a second three-dimensional virtual image of teeth of at least a second teeth portion;

(iii) a module for defining basic landmarks in both images and for generating data representative thereof; and

(iv) a processor associated with said first and said second utility and with said module, for receiving said first and said second data and for mapping elements in one of the two images to the other of the two images according to the data representative of said basic landmarks.

In accordance with one embodiment of the invention, the imaging method and system is used to obtain orthodontic-relevant information, namely information to be used by an orthodont within the framework of an orthodontic treatment or for the design of such a treatment. This embodiment involves a registration of at least two images, one being a three-dimensional virtual image of a teeth model and the other being a two-dimensional image, e.g. a cephalometric image. Occasionally, other images may also be brought into registration consisting, for example of one or more of a lateral videographic image, a frontal videographic image and a frontal cephalometric image.

In accordance with another embodiment of the invention, the method and system are used for proper design of a dental implant or of a crown. For proper placement of an implant, the bone has to be carefully studied beforehand and examined whether it can receive the dental implant. In addition, the exact position and orientation of the dental implant has to be properly pre-designed. Typically, for a proper design of an implant, a three-dimensional virtual image of a teeth model is brought into registration with both a lateral cephalometric image and at times also with a frontal cephalometric image. This will allow to properly predict the manner of receipt of the implant within the bones of the jaw.

In the following, the invention will be described with particular reference to imaging for the purpose of design of the orthodontic treatment. It will however be appreciated, that the invention applies, *mutatis mutandis* also to its application for the purpose of proper design of tooth implants.

The first image is preferably an x-ray image, typically a cephalometric image obtained by radiographic cephalometric technique. The x-ray image is preferably a lateral image although at times the image may be from another orientation, e.g. a frontal image. In a cephalometric image, some facial profile aspects may at times be seen. However, typically, before an orthodontic treatment also a third, side elevational view of the face is taken from the same direction in which the radiographic cephalometric image was obtained. In accordance with an embodiment of the invention, such a third image, comprising at least a profile of facial aspects, is also obtained and used in the imaging technique of the invention. The side elevational image may be obtained, for example, by video cephalometry.

The term *"virtual three-dimensional teeth image"* refers to an image, represented within the computer environment which consists primarily of the teeth of one or both jaws. For example, a virtual three-dimensional teeth image may be represented in a manner resembling an image of a plaster model. A virtual three-dimensional image may be obtained by a variety of techniques, e.g. those described in the references mentioned above. Particularly, the three-dimensional virtual image may be obtained by the method described in WO 97/03622, which is incorporated herein by reference as an example of the manner of obtaining a three-dimensional virtual image for use in the method and system of the invention. It should be understood that the invention is not limited to a specific type of image obtained by one imaging technique or another. For example, the two-dimensional image may be obtained by a variety of different imaging techniques including magnetic resonance imaging (MRI), computerized tomography (CT) various radio-imaging techniques, etc. Similarly, the three-dimensional teeth image may be obtained by any one of a number of imaging techniques available including those disclosed in the aforementioned references as well as others such as those making use of a scanning probe, various photographic techniques, techniques in which teeth are scanned by a probing light beam, etc.

The term *"image"* as used herein should not be understood only as referring to the image as acquired in the imaging technique but rather may be also a result of initial image processing, e.g. an image processing intended to define boundaries of various objects in the image. Thus, the term *"image"* encompasses also a representation, prepared on the basis of an acquired image, of boundaries of objects, e.g. teeth, bones, a profile of facial aspects, etc.

Often, the imaging technique and analysis in accordance with the invention will make use of a third image, which may be the elevational image mentioned above, or any other image useful in improving the orthodontic analysis. Thus, by way of example, where said first image is a lateral two- dimensional image, said third image may be one or both of the afore- mentioned lateral elevational image or a frontal x-ray or videographic image.

The basic landmarks which are used for registering the two sets of images, are typically defined points at either the base or the apex of certain selected teeth e.g. the incisors and the first molars. Such basic landmarks may be selected by the user or may be automatically selected by the system's processor, e.g. based on established norms. After selecting the basic landmarks and marking them in one of the images, then the landmarks may be marked in the other images to allow to register both images. The term *"registering"* should not necessarily be understood as meaning a physical registration of the two images but rather as meaning the mapping of each feature in one image to a corresponding feature in another. The outcome of such registration is that any manipulation made on one image will yield a corresponding manipulation in the other image. For example, if one image is manipulated by displacing one tooth, this should result in a corresponding displacement of the same tooth in the other image.

At times it may be desired to view both images on a screen superimposed one on the other. As two or more images have to be superimposed may be presented initially at a different scale, an initial step which is necessary to be taken by the system is to either enlarge or reduce the scale of one image until there is an essential complete overlap of the basic landmarks in the two images. It should however be noted that registering of different images may not necessarily imply superpositioning, but rather at times the two registered images may be represented separately, e.g. side-by-side. The important result of the act of registering is that manipulation made on one of the images will effect the other as well.

In the following, the invention will be described with particular reference to an embodiment in which the first image is a cephalometric image and the second image is a virtual three-dimensional image. This specific reference should not however be construed as meaning that the invention is limited thereto. On the contrary, by applying the general teaching of the invention, information may be transferred between images obtained by other imaging techniques.

In accordance with one embodiment of the invention, after landmarks have been defined in the three-dimensional virtual images and in the cephalometric image, the correct orientation of the virtual three-dimensional teeth model has to be determined so as to allow it to be brought into conformity with the cephalometric image. This may at times require extensive computational time. It has however been found that the process of registration of the two images can be considerably accelerated by defining the cephalometric image to overlap the mid palatal plane of the virtual three-dimensional teeth image. In other words, the cephalometric image is defined to lie on the mid palatal plane and the cephalographic image is then adjusted until the basic landmarks overlap with the projection of the corresponding basic landmarks of the virtual three-dimensional image onto the mid palatal plane.

The invention permits also an analysis of the effect of teeth displacement on various aspects of the cranofacial complex. For example, teeth may be displaced on the virtual three-dimensional image of teeth model in a manner they are expected to be shifted during the course of the orthodontic treatment. Thus, for example, by marking various landmarks on a displaced teeth and marking and then displacing the same landmarks in the cephalometric model, it may be possible to check on both images whether the orthodontic treatment achieves a result which matches a certain acceptable norm or how changes should be made to achieve such a norm. If, for example, a desired result as viewed in an amended cephalometric image (namely a cephalometric image after a tooth has been displaced) does not match the desired results, it is possible to go back to the virtual three- dimensional teeth model and proceed with a simulation and then map the results onto the cephalometric image, and so forth.

By way of example, in order to achieve the same degree of displacement in one image, the shifting of a certain landmark which is associated with a displaced object is then compared to some basic landmarks and the same relation of displacements is then related to the other image.

One particular example of analysis which can be made by such simulation is to determine the effect of such displacement on soft facial tissue, particularly outer facial tissue. This will allow an estimation of the effect of the orthodontic treatment on the esthetic appearance of the individual.

A simulation of the treatment and then translation of the results to a cephalometric image allows also to determine whether shifts in various elements such as the jaw, are within permitted physiological or aesthetical limits. An uncontrolled shifting of a tooth or a jaw in an orthodontic treatment may give rise to various physiological and functional problems.

The invention will now be illustrated below with reference to some specific, non-limiting embodiments, with occasional reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A shows an example of a radiographic cephalometric image.

Fig. 1B shows a virtual three-dimensional image of teeth, presented in the manner resembling a plaster teeth model.

Fig. 2 shows a super-position of a three-dimensional teeth model and a cephalometric image.

Figs. 3A and **3B** show two examples of super-position of a three-dimensional model and a video cephalometric image.

Fig. 4A shows a cephalometric image with some basic landmarks marked thereon.

Fig. 4B shows a three-dimensional virtual image of the same teeth as those shown in the cephalometric image of Fig. 4A, with the same basic landmarks marked thereon.

Fig. 5 shows a super-position of the two images.

Fig. 6 is a block diagram representation of a system in accordance with the invention.

Figs. 7A and **7B** are flowcharts showing the manner of mapping elements from a three-dimensional virtual teeth model to a cephalometric image. **Fig. 7A** shows the user's interaction modules whereas **Fig. 7B** shows the software functionality underlying the manner of performing of displacement and mapping the displacement from the three-dimensional virtual teeth model to the cephalometric image.

Figs. 8A and **8B** are flowcharts showing the manner of mapping elements from a cepthalometric image to a three-dimensional virtual teeth model. **Fig. 8A** shows the user's interaction modules whereas **Figs. 8B** shows the software functionality underlying the manner of performing of displacement and mapping the displacement from the cephalometric image to the virtual three-dimensional teeth model.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

In accordance with the present invention images are acquired including at least one two-dimensional teeth image and at least one three-dimensional teeth image and both are combined for the purpose of improving the orthodont's ability to predict the effect of orthodontic treatment on various parameters. This combination allows the orthodont to considerably increase the depth of his understanding on the outcome of the orthodontic treatment. Hitherto, analysis which was made on a cephalometric images could not have been readily translated to the other tools available to him – this being the three-dimensional teeth model, typically a plaster model. In the reverse, information gained by him from studying a three-dimensional teeth model, could not have been readily translated to a cephalometric image. As is well known to the artisan, each one of the images allows a limited range of analysis which can be made and a true analysis can only be gained from thorough analysis based on the two types of images.

It is only with the present invention that a proper analysis becomes feasible.

An image, once acquired and converted to a representation within a computer environment can be manipulated, e.g. by displacing certain elements, such as one or more teeth or even an entire jaw. The cepthalometric image allows to view the interrelation between some elements and may be used, for example, to test the effect of the treatment on some physiological or functional parameters as well as the aesthetic parameters. There is, however, a significant deficiency in that it is impossible to fully translate this information to the three-dimensional real-life environment. The present invention permits a proper analysis of the effect of displacement of elements and or better understanding of how changes will effect the real-life situation.

Reference is first being made to Figs 1A and 1B, showing respectively, a cephalometric radiograph and a three-dimensional virtual teeth image. The virtual teeth image which is shown in Fig. 1B, is represented in a manner resembling a plaster teeth model. As will no doubt be appreciated by the artisan, this is but an example, and the two-dimensional or the virtual three dimensional teeth image may be represented in a different way.

Prior to the present invention, each of these different images, was represented separately. The three-dimensional virtual image was represented either as a plaster model or a three-dimensional virtual representation in a computer environement. In accordance with the invention, two different images, one being a two-dimensional image, e.g. a cephalometric radiograph, is combined with a three-dimensional teeth image. A super-position of two such images is represented in exemplary Fig. 2. As can be seen, the cephalometric image is combined with the three-dimensional virtual teeth image such that it lies on the mid palatal plane of the three-dimensional virtual teeth image. The relative position of the two images is fixed such that basic landmarks defined in the two images concur, as will be described further below.

Another implementation of the invention can be seen in exemplary Figs. 3A and 3B. In these figures, a three-dimensional virtual teeth image is superpositioned with a lateral or profile picture of an individual. The profile pictures in Figs. 3A and 3B are each from a slightly differently orientation and accordingly the virtual three-dimensional teeth model in Fig. 3B is rotated with respect to the orientation of the model in Fig. 3A.

In order to combine a cephalometric image and a three-dimensional virtual model, basic landmarks have to be defined and marked in both images. These basic landmarks may be entered manually by the user, although alternatively, they may be automatically generated by a computer, based on standard image analysis method, or based on an earlier user input. Generally, such basic landmarks may be arbitrary landmarks or may be orthodontic relevant landmarks which may be used later in a cephalometric analysis, in accordance with one of the acceptable norms therefor. (For review on a cephalometric analysis see Radiographic Cephalometry, From Basics to Videoimaging, Jacobson A., *et al.*, Quintessence Publishing Co., Inc., Chicago, Berlin, 1995).

A cephalometric radiograph and the three-dimensional teeth model from the same individual, are shown in Figs. 4A and 4B. In these figures, two basic landmarks have been marked – **L1** and **L2**. After these landmarks have been marked, the two images are brought into registration which results in super-positioning as can be seen in Fig. 5 (the same two landmarks **L1** and **L2** can also be seen here). The registration in the manner shown in Figs. 4A, 4B and 5 is performed using two defined landmarks. Obviously, it is possible at times to use more landmarks for this purpose to increase accuracy of registration.

In order to reduce computational time, the cephalometric radiograph is combined with the three-dimensional virtual teeth image by placing (in a virtual sense) the cephalometric image on the mid palatal plane. For proper registration, the scale of the two images has to be adjusted and then one image has to be shifted versus the other until the projection of the basic landmarks of the three-dimensional virtual image of teeth model onto its mid palatal plane are in register with the corresponding landmarks in the cephalometric image.

The cephalometric radiograph and the cephalometric videograph as shown herein, are images as acquired by the utilized imaging technique. It should however be noted that at times it is advantageous to produce initially a representation of the image, e.g. a graphic representation of boundaries of objects of interest within the image. For example, rather than a full cephalographic image, a representation comprising boundaries of some major bones and several teeth, e.g. the first and second molar teeth and the incisors. These aforementioned teeth are usually the important teeth for the cephalometric analysis, as their position is relatively sensitive to displacement of teeth and jaws. Furthermore, the position of these teeth is an important marker for studying or gauging the effect of teeth position on various functional as well as aesthetical facial aspects.

Producing a graphical representation of some aspects of an image, particularly of a cephalometric image, is very useful for the purpose of a virtual displacement of the teeth in the image so as to study the effect of the treatment on functional or facial aesthetic parameters, as generally known *per se*.

A system in accordance with the embodiment of the invention can be seen in Fig. 6. It comprises a central computing unit **20** with three input utilities **22, 24** and **26**, which may be integral within module **28**. These utilities may comprise, as known *per se*, a data entry port and the necessary data transfer software. Furthermore, rather than importing of data through a data entry port, the data to these utilities may be imported from a storage media or from an information carrier, e.g. a magnetic or an optical disk. As will no doubt be further understood, module **28** may also comprise a scanner for scanning images, may comprise a camera for direct image acquisition, etc.

The system still further comprises a module **30**, connected to a user input interface **32** e.g. a keypad, a cursor driver, etc. By means of interface **32** the user may define the landmarks or may induce the system to enter into various operational modes, some of which will be explained below.

Module **30** and utility **28** are connected to a processor **40** for image processing so as to combine the two images as described, for example further below. Processor **40** may be connected to monitor **50** and may be also connected to other display means, e.g. a printer.

A flowchart of an embodiment of the manner of linking between a three-dimensional virtual teeth model and a cephalometric image can be seen in Figs. 7A and 7B. Fig. 7A is a flowchart of the user interaction steps whereas Fig. 7B is a software functionality flowchart on the manner of combining the two images. At a first step **100**, the system receives an input of data representative of a three-dimensional virtual teeth model. Then at **110**, basic landmarks are marked on discernable objects in the three-dimensional virtual teeth model as represented in image **111**. Such basic landmarks may, for example, be points on crowns and roots of upper and lower first molars (landmarks **1-4** of image **111**) as well as on crowns and roots of upper and lower centrals (landmarks **5-8** in image **111**). Landsmarks **1** and **4** as well as landmarks **5** and **8** mark the approximate position of the roots of the teeth. The real root position cannot be seen in such a model but the orthodont, based on his experience, can relatively accurately mark their roots' position.

At a next step **120**, a cephalometric image of the same patient is input and on this image, the same key points are then marked (see **131**). Then, the two images may be matched, which may be by way of super-position as shown above, which can be represented on a screen, or by any other way of mapping of each location in one image to that of the other image.

At a next step **140** teeth and jaws in the three-dimensional model may be displaced on the three-dimensional model to receive a desired result. Then, as represented in the flowchart of Fig. 7B, the software at next steps **150** and **160** moves skeletal elements and teeth, respectively, according to movement performed by the user on the three-dimensional virtual teeth model. Then, at **170**, a cephalometric analysis can be made on the amended (after displacement) cepthalometric image to see whether desired proportional measurements have been reached in such teeth displacement or whether any medication should be made.

The reverse sequence of operation, namely the mapping of each point from a cephalometric image to a three-dimensional virtual teeth model is seen in Figs. 8A and 8B. In Figs. 8A and Fig. 8B, each of steps **200-270** corresponds, *mutatis mutandis* to the steps **100-170** in Figs. 7A and 7B. This eventually results in mapping of each point in a cephalometric image to the corresponding location of the three-dimensional virtual teeth model to allow to translate any displacement performed on the former image to that in the latter.