7654712

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

October 26, 2017

THIS IS TO CERTIFY THAT ANNEXED IS A TRUE COPY FROM THE RECORDS OF THIS OFFICE OF THE FILE WRAPPER AND CONTENTS OF:

APPLICATION NUMBER: *13/807,443*
FILING DATE: *March 01, 2013*
PATENT NUMBER: *9336336*
ISSUE DATE: *May 10, 2016*

Certified by

Michelle K. Lee

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE
DEPARTMENT OF COMMERCE

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)
INTERNATIONAL APPLICATION NO. PCT/DK2011/050246	INTERNATIONAL FILING DATE 2011 June 29 (2011.06.29)	PRIORITY DATE CLAIMED 2010 June 29 (2010.06.29)
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)*.

17. ☒ Other items or information:
General Authorization for Petitions for Extensions of Time and Payment of Fees
Form PCT/IB/304
Form PCT/ISA/210

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

The following fees have been submitted.	CALCULATIONS	PTO USE ONLY
18. ☒ Basic national fee (37 CFR 1.492(a)) $390	$ 390.00	
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	$ 250.00	
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	$ 500.00	
TOTAL OF 18, 19 and 20 =	$ 1,140.00	
☐ 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	CALCULATIONS	PTO USE ONLY
- 100 =	/ 50 =		x $320	$ 0.00	

	CALCULATIONS	PTO USE ONLY
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)).	$ 0.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	CALCULATIONS	PTO USE ONLY
Total claims	29 - 20 =	9	x $62	$ 558.00	
Independent Claims	2 - 3 =	0	x $250	$ 0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $460	$ 0.00	

	CALCULATIONS	PTO USE ONLY
TOTAL OF ABOVE CALCULATIONS =	$ 1,698.00	
☒ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by ½.	849.00	
SUBTOTAL =	$ 849.00	
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 =	$ 849.00	
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 =	$ 849.00	
	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	**December 28, 2012**
Name (Print/Type)	William C. Rowland	Registration No. (Attorney/Agent)	30888

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	
Nikolaj DEICHMANN et al.	Group Art Unit:
Application No.:	Confirmation No.:
Filed: December 28, 2012	
For: 2D IMAGE ARRANGEMENT	

GENERAL AUTHORIZATION FOR PETITIONS FOR EXTENSIONS OF TIME AND PAYMENT OF FEES

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with 37 C.F.R. § 1.136(a)(3), the U.S. Patent and Trademark Office is hereby provided with a general authorization to treat any concurrent or future reply requiring a petition for an extension of time for its timely submission as containing a request therefor for the appropriate length of time.

The Commissioner is hereby authorized to charge any appropriate fees that may be required by this paper, or any other submissions in this application, and to credit any overpayment, to Deposit Account No. 02-4800.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date: December 28, 2012

By: William C. Rowland
William C. Rowland
Registration No. 30888

Customer Number 21839
703.836.6620

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	) Group Art Unit: Unassigned
Nikolaj DEICHMANN et al.	) Confirmation No.: Unassigned
Application No.: Unassigned	)
Filed: December 28, 2012	)
For: 2D IMAGE ARRANGEMENT	)

PRELIMINARY AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Prior to examination of the above-captioned patent application, kindly amend the application as follows.

AMENDMENTS TO THE ABSTRACT:

Please replace the original Abstract with the following amended Abstract of the Disclosure. This new Abstract of the Disclosure is also set forth on a separate sheet attached to the end of this Preliminary Amendment:

ABSTRACT OF THE DISCLOSURE

Disclosed is a method of designing a dental restoration for a patient, wherein the method ~~comprises:~~ includes [[-]] providing one or more 2D images, where at least one 2D image ~~comprises~~ includes 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.

~~(fig. 11k) should be published)~~

AMENDMENTS TO THE CLAIMS:

The following listing of claims will replace all prior versions and listings of claims in this application.

LISTING OF CLAIMS:

Claims 1-109 (Canceled)

110. (New) 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.

111. (New) The method according to claim 110, wherein facial features are present in an image of the patient and/or in a generic image of a person.

112. (New) The method according to claim 110, 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.

113. (New) The method according to claim 110, wherein the designing of the restoration is performed to automatically fit the facial features of the at least one 2D digital image.

114. (New) The method according to claim 110, wherein the 2D image and the 3D model are aligned based on one or more unprepared teeth.

115. (New) The method according to claim 110, 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.

116. (New) The method according to claim 110, wherein the 2D image and the second 3D virtual model comprising no prepared teeth are aligned.

117. (New) The method according to claim 110, 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.

118. (New) The method according to claim 110, 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.

119. (New) The method according to claim 110, wherein the method comprises cutting out the part of the 2D image which is inside the edge of the lips.

120. (New) The method according to claim 110, wherein the edge of the lips is marked on the 2D image.

121. (New) The method according to claim 110, 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.

122. (New) The method according to claim 110, 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.

123. (New) The method according to claim 110, 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.

124. (New) The method according to claim 110, 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.

125. (New) The method according to claim 110, 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.

126. (New) The method according to claim 110, 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.

127. (New) The method according to claim 110, wherein texture from the 2D image is mapped onto the 3D virtual model and/or the restoration.

128. (New) The method according to claim 110, wherein the method further comprises changing a perspective view of the one or more 2D digital image and/or of the 3D virtual model to obtain the same perspective view.

129. (New) The method according to claim 128, wherein the method comprises determining an angle of one or more of the perspective views.

130. (New) The method according to claim 128, wherein the angle of the 3D model and the 2D image is configured to adapt relative to the perspective view of the 2D image.

131. (New) The method according to claim 128, 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.

132. (New) The method according to claim 110, wherein the one or more 2D digital image is retrieved from a library comprising a number of images of teeth.

133. (New) The method according to claim 110, wherein the one or more 2D digital image is a template for supporting designing the patient's teeth.

134. (New) The method according to claim 110, wherein the one or more 2D digital image shows a facial feature in the form of at least a number of front teeth.

135. (New) The method according to claim 110, wherein the one or more 2D digital image is an X-ray image of the patient's teeth.

136. (New) The method according to claim 110, 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.

137. (New) A nontransitory computer readable medium encoded with a computer program for causing a data processing system to perform the method of claim 110, when said program code is executed on the data processing system.

138. (New) 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.

REMARKS

By way of the foregoing amendments, the Abstract has been amended to make a minor change. Claims 1-109 have been canceled and new claims 110-138 have been added. No new matter has been introduced by these changes.

It is requested that the application be examined on the basis of the Abstract and the claims presented herein. Early and favorable consideration of this application is respectfully requested.

Should any questions arise in connection with this application, it is respectfully requested that the undersigned be contacted at the number indicated below.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date: December 28, 2012

By: /WCRowland/
William C. Rowland
Registration No. 30888

Customer No. 21839
(703) 836-6620

ABSTRACT OF THE DISCLOSURE

Disclosed is a method of designing a dental restoration for a patient, wherein the method includes providing one or more 2D images, where at least one 2D image includes 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.

APPLICATION DATA SHEET

Application Information

Application Number::	
Filing Date::	
Application Type::	Nonprovisional
Subject Matter::	Utility
Suggested Classification::	
Suggested Group Art Unit::	
CD-ROM or CD-R?::	None
Number of CD Disks::	
Number of Copies of CDs::	
Sequence Submission?::	
Computer Readable Form (CRF)?::	No
Number of Copies of CRF::	
Title::	2D IMAGE ARRANGEMENT
Attorney Docket Number::	0079124-000062
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	
Total Drawing Sheets::	27
Small Entity?::	Yes

Latin Name::	
Variety Denomination Name::	
Petition Included?::	No
Petition Type::	
Licensed US Govt. Agency::	
Contract or Grant Numbers::	
Secrecy Order in Parent Appl.?::	No

Applicant Information

Applicant Authority Type::	Inventor
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State or Province of Residence::	
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Postal or Zip Code of Mailing Address::	S-218 51
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Primary Citizenship Country::	Denmark
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State or Province of Residence::	
Country of Residence::	Denmark
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State or Province of Mailing Address::	
Country of Mailing Address::	Denmark
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Primary Citizenship Country::	Sweden
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Given Name::	Henrik
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Phone Number::	(703) 836-6620
Fax Number:	(703) 836-2021

Representative Information

Representative Customer Number::	21839

Domestic Priority Information

Application::	**Continuity Type::**	**Parent Application::**	**Parent Filing Date::**
This Application	National Stage of	PCT/DK2011/050246	06/29/2011
PCT/DK2011/050246	Claiming the benefit under 35 USC 119(e)	61/359,454	06/29/2010
PCT/DK2011/050246	Claiming the benefit under 35 USC 119(e)	61/454,200	03/18/2011

Foreign Priority Information

Country::	Application Number::	Filing Date::	Priority Claimed::
Denmark	PA 2010 00568	06/29/2010	Yes
Denmark	PA 2011 00191	03/18/2011	Yes

Assignee Information

Assignee Name::	3Shape A/S
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State or Province of Mailing Address::	
Country of Mailing Address::	Denmark
Postal or Zip Code of Mailing Address::	DK-1060

Signature	/William C Rowland/	Date	December 28, 2012
Name	William C. Rowland	Registration No.	30888

Attorney Docket No. 0079124-000062

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
	)	
Nikolaj DEICHMANN et al.	)	Group Art Unit:
	)	
Application No.:	)	Confirmation No.:
	)	
Filed: December 28, 2012	)	
	)	
For: 2D IMAGE ARRANGEMENT	)	

FIRST INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with the duty of disclosure as set forth in 37 C.F.R. § 1.56, the accompanying information is being submitted in accordance with 37 C.F.R. §§ 1.97 and 1.98.

To assist the Examiner, the documents are listed on the attached citation form. It is respectfully requested that an Examiner initialed copy of this form be returned to the undersigned.

Respectfully submitted,

BUCHANAN INGERSOLL & ROONEY PC

Date December 28, 2012

By: William C. Rowland
William C. Rowland
Registration No. 30888

Customer Number 21839
703 836 6620

Substitute for form 1449/PTO				***Complete if Known***	
FIRST INFORMATION DISCLOSURE STATEMENT BY APPLICANT				*Application Number*	
				Filing Date	**December 28, 2012**
				First Named Inventor	**Nikolaj DEICHMANN et al.**
				Art Unit	
(Use as many sheets as necessary)				*Examiner Name*	
Sheet	1	of	1	*Attorney Docket Number*	**0079124-000062**

U.S. PATENT DOCUMENTS

Examiner Initials'	Cite No.[1]	Document Number Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-6,068,482 A	05-30-2000	Snow	
		US-2003/0163291 A1	08-28-2003	Jordan et al.	
		US-6,261,248 B1	07-17-2001	Takaishi et al.	
		US-2010/0145898 A1	06-10-2010	Malfliet et al. (corresponds to WO 2008/128700 A1, see below)	
		US-2003/0169913 A1	09-11-2003	Kopelman et al. (corresponds to EP 1 124 487 A1, see below)	
		US-2010/0076581 A1	03-25-2010	Violante et al. (corresponds to WO 2010/008435 A1, see below)	
		US-2006/0127836 A1	06-15-2006	Wen	

FOREIGN PATENT DOCUMENTS

Examiner Initials'	Cite No.[1]	Foreign Patent Document Country Code[3] Number[4] Kind Code [5]*(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		*WO 2008/128700 A1	10-30-2008	Materialise Dental N.V.		
		*EP 1 124 487 A1	08-22-2001	Cadent Ltd		X
		*WO 2010/008435 A1	01-21-2010	Dentsply International Inc.		
		*WO 2010/031404 A1	03-25-2010	3Shape A/S		

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	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, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		*International Search Report (PCT/ISA/210) issued on September 7, 2011, by the Denmark Patent Office as the International Searching Authority for International Application No. PCT/DK2011/050246.	

*Copy Attached

Examiner Signature		Date Considered	

Electronic Patent Application Fee Transmittal

Application Number:	
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:				
Basic National Stage Fee	2631	1	195	195
Natl Stage Search Fee - Report provided	2642	1	250	250
Natl Stage Exam Fee - all other cases	2633	1	125	125
Pages:				
Claims:				
Claims in excess of 20	2615	9	31	279
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
	Total in USD ($)			**849**

Electronic Acknowledgement Receipt

EFS ID:	14576193
Application Number:	13807443
International Application Number:	PCT/DK11/50246
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:	28-DEC-2012
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1		Specification_Claims_Abstract.pdf	2972409 b6f540bc40ec94b78fe3b9fc2967ff9b0fa56f5a	yes	68

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2	Drawings-only black and white line drawings	Drawings.pdf	5645322 d1f95367d11d8993d712878c0d1cda2d1066f4ca	no	27

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3	Documents submitted with 371 Applications	PCTIB304.pdf	83753 f7493bdea45b918fefa3f4a4daf7df887568bfdc	no	1

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4	Non Patent Literature	PCTISA210.pdf	126967 147264c37a122672482b656240165adcbb02d152	no	3

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5	Foreign Reference	EP1124487.pdf	137075 9eb078a7927b9e78a61cbc71ab498bd37f81e46f	no	2

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6	Foreign Reference	WO2008128700.pdf	4470503 90ffc2d52d0f793dfc2e69cbb29716bc85059bd3	no	35

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7	Foreign Reference	WO2010008435.pdf	3683721 5db10b61a1b731de1ea369e41502a68087736819	no	35

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8	Foreign Reference	WO2010031404.pdf	3069043 ce149d073d075692c7a6ca106051a5748b8 8746f	no	29
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9	Transmittal of New Application	PCT1390_Transmittal_Letter.pdf	198707 a0296832e10b0b786812efaa676c5db3bcf ae32d	no	3
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10	Authorization for Extension of Time all replies	General_Authorization.pdf	35219 f9bbf381ffdf2bf89babd13791f3c22682f14 947	no	1
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11	Preliminary Amendment	Preliminary_Amendment.pdf	273396 cd507610d18a5a0162d8df4db5f019e22c9 ee4eb	no	10
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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.

2D image arrangement

Abstract

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.

(fig. 11k) should be published)

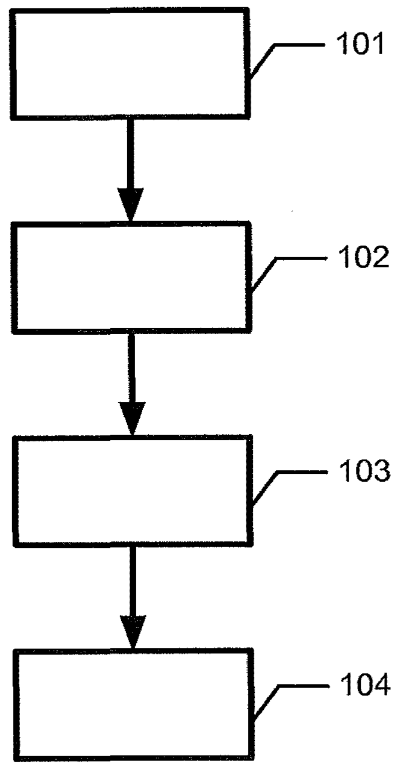


Fig. 1

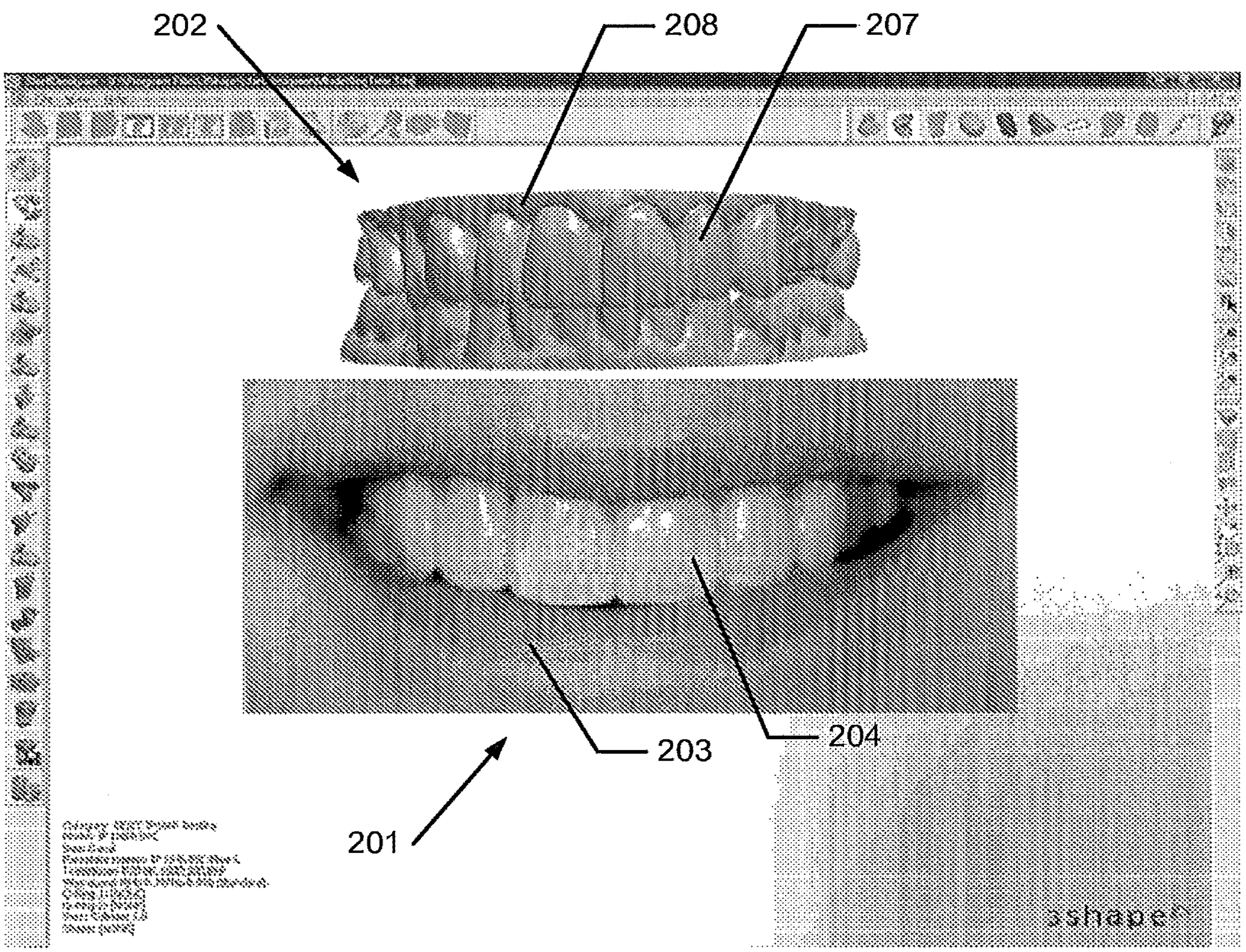


Fig. 2a)

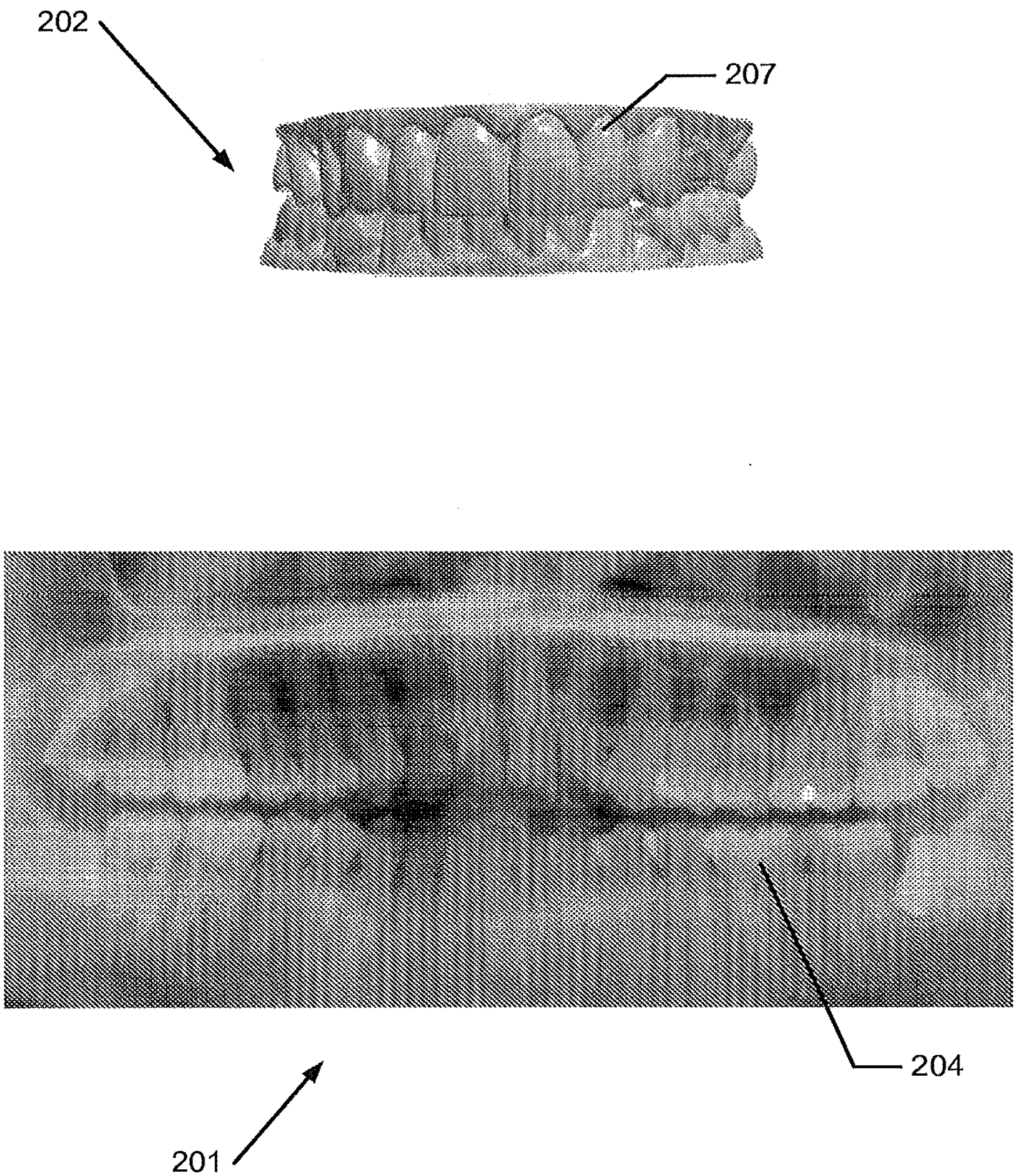


Fig. 2b)

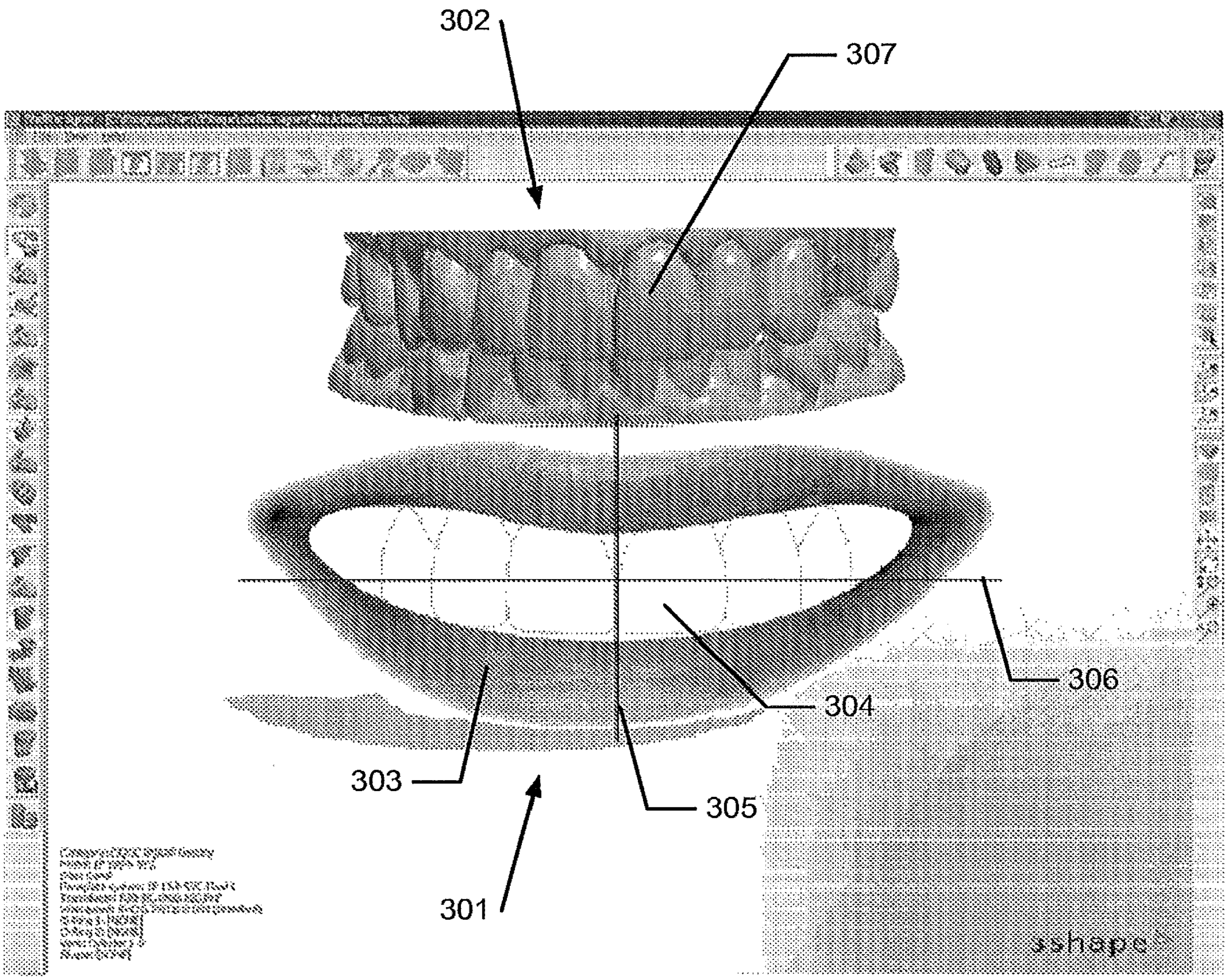


Fig. 3a)

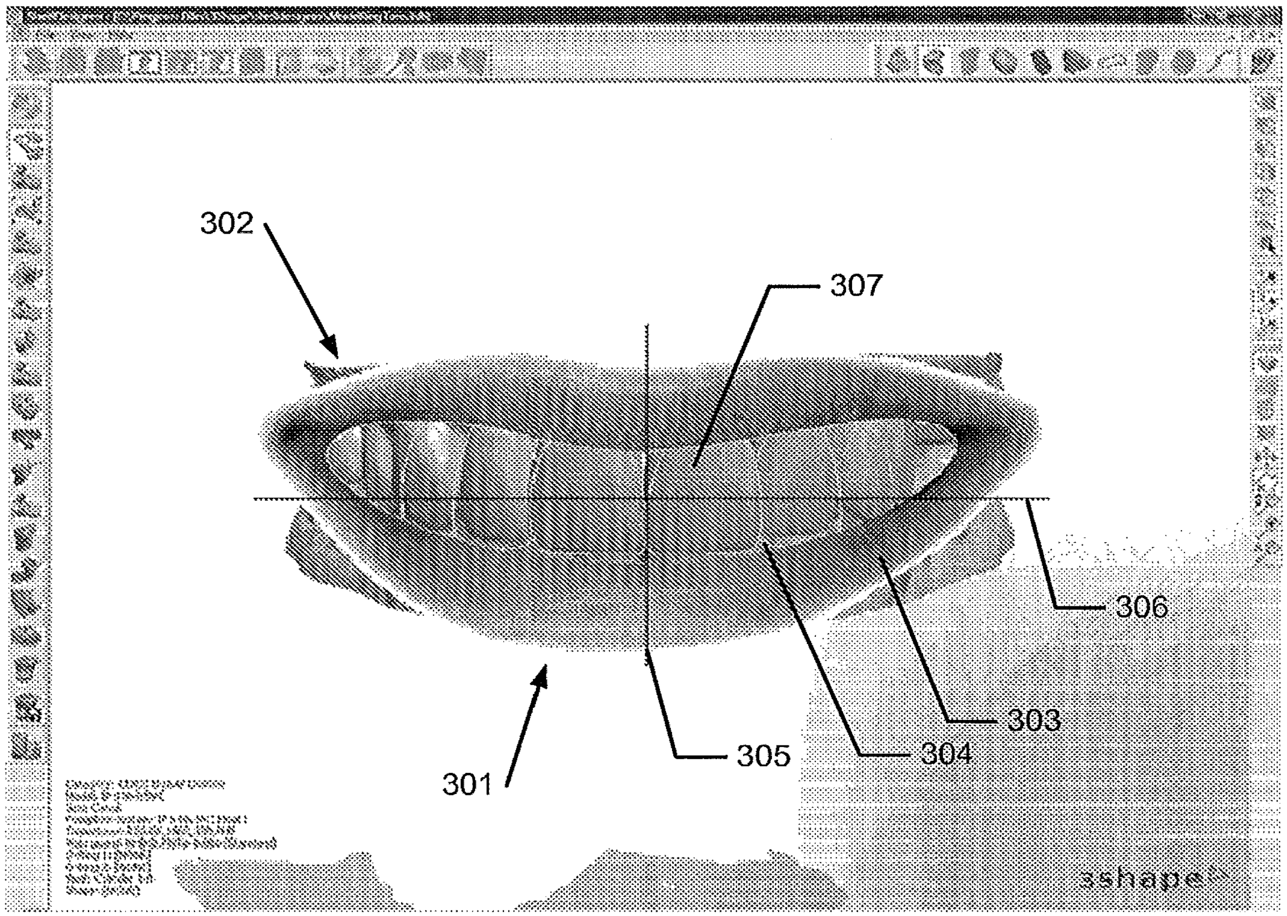


Fig. 3b)

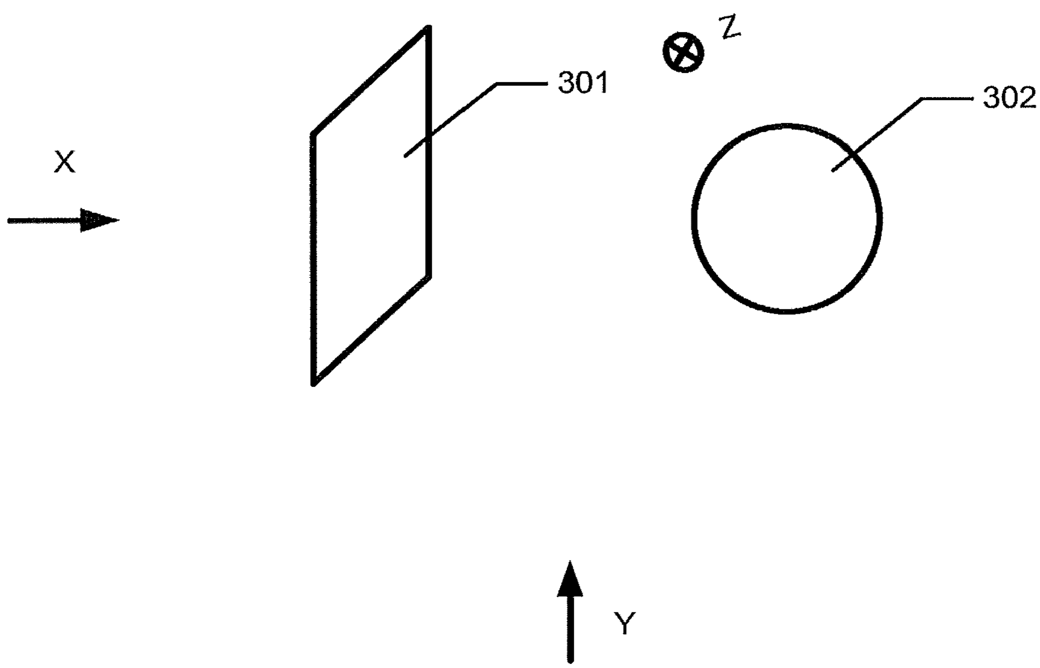


Fig. 3c)

Fig. 4a)

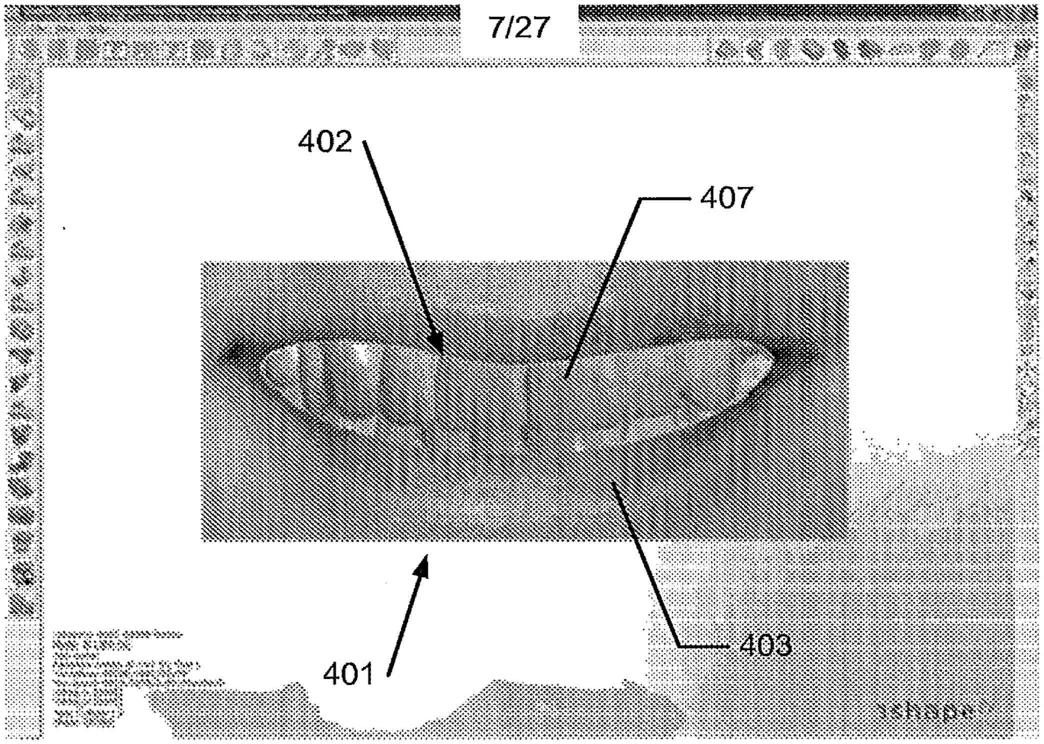
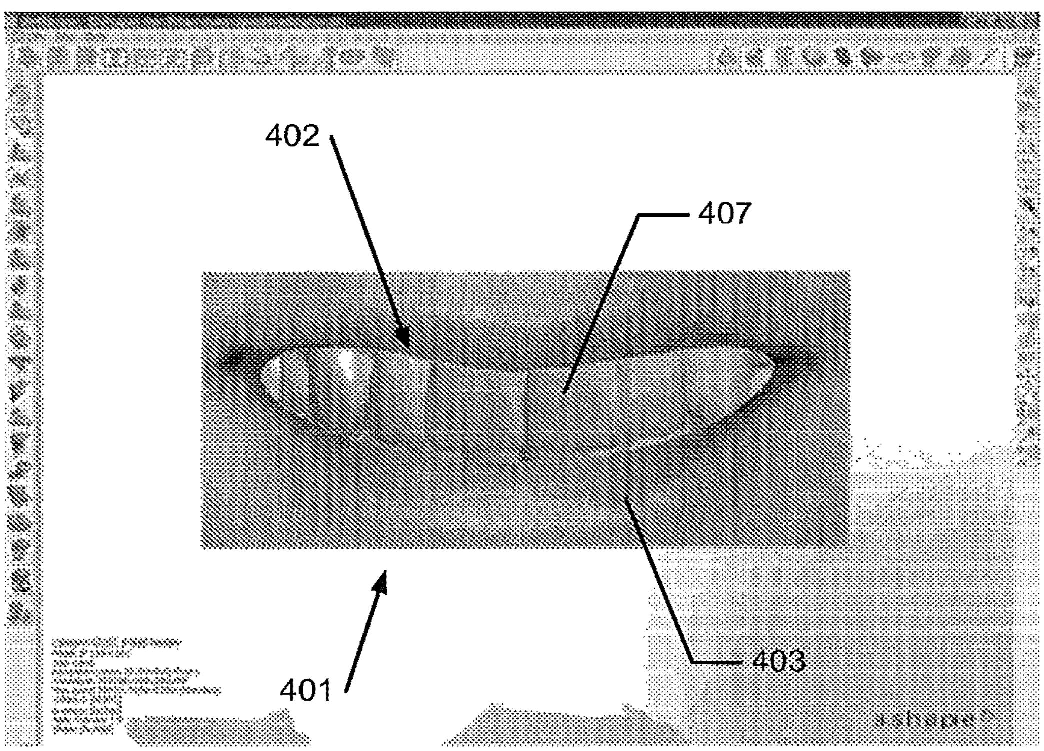


Fig. 4b)



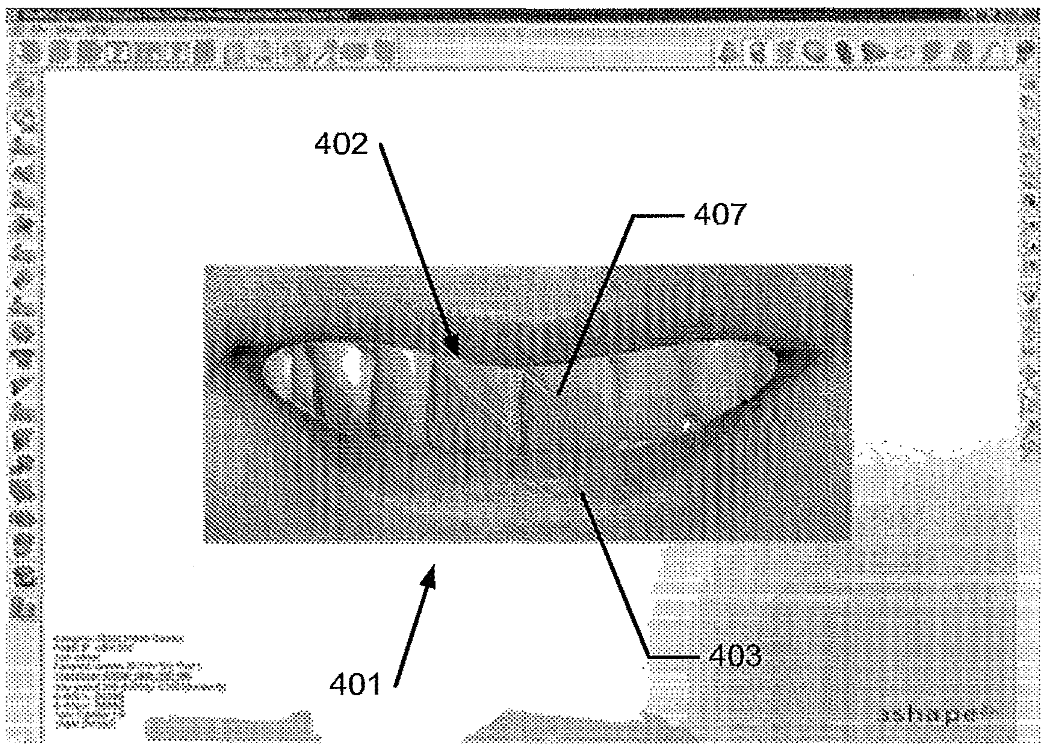


Fig. 4c)

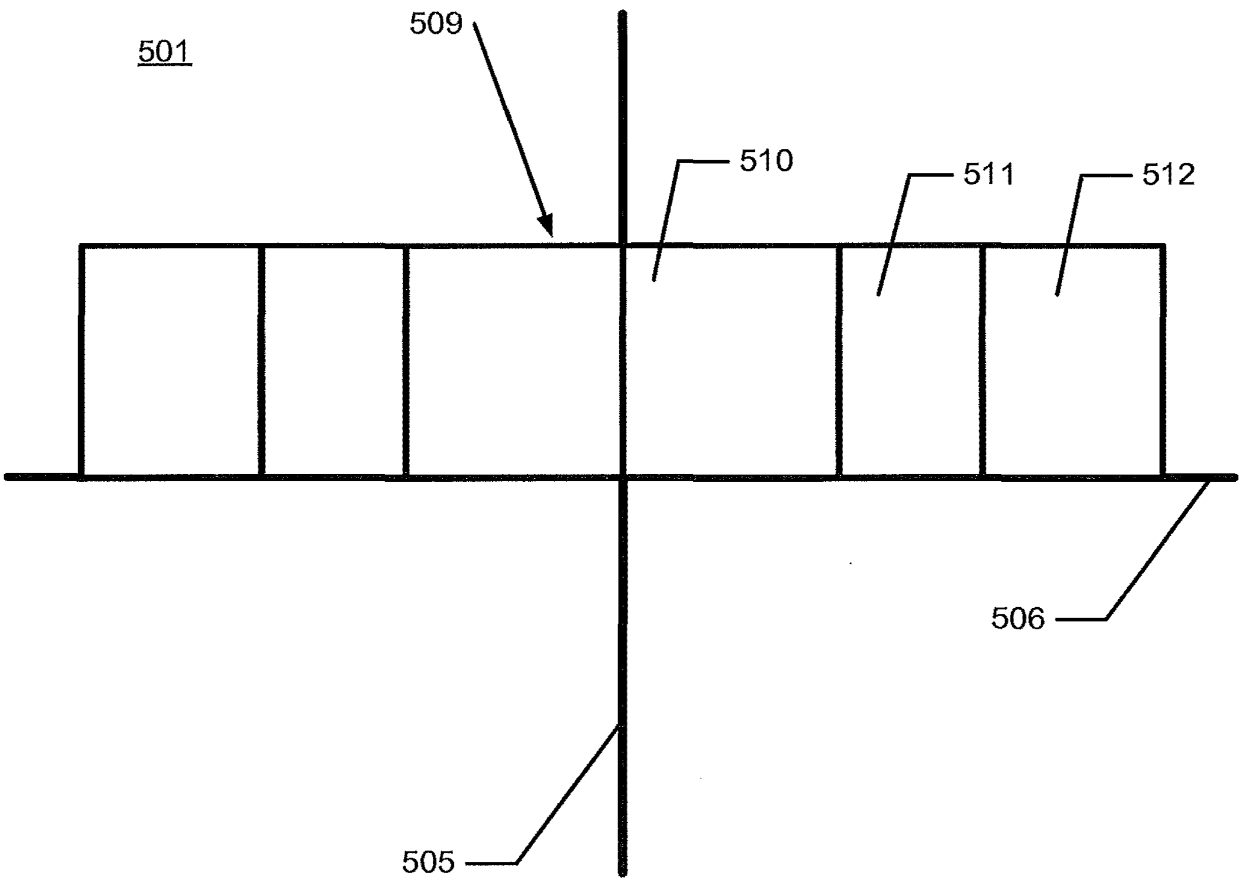
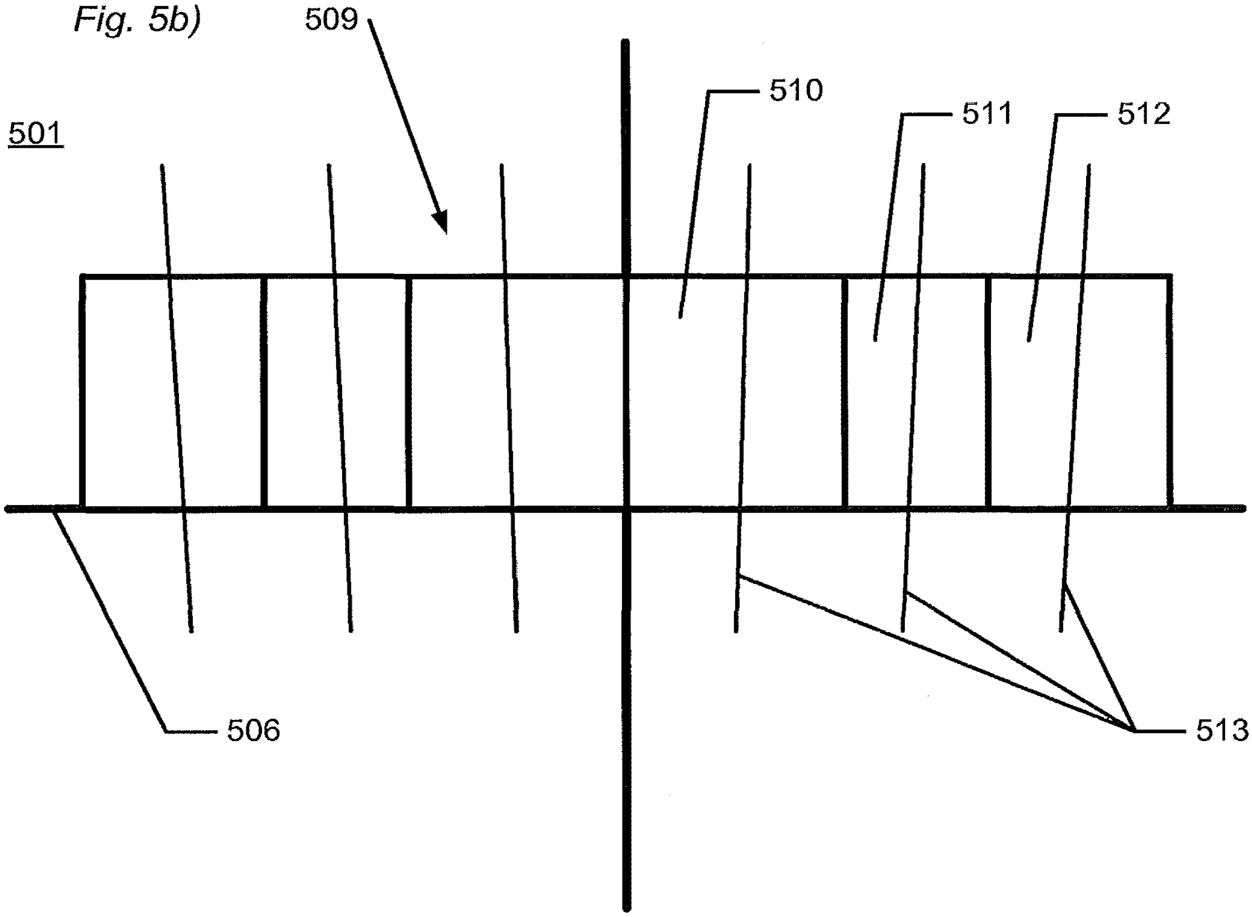


Fig. 5a)

Fig. 5b)



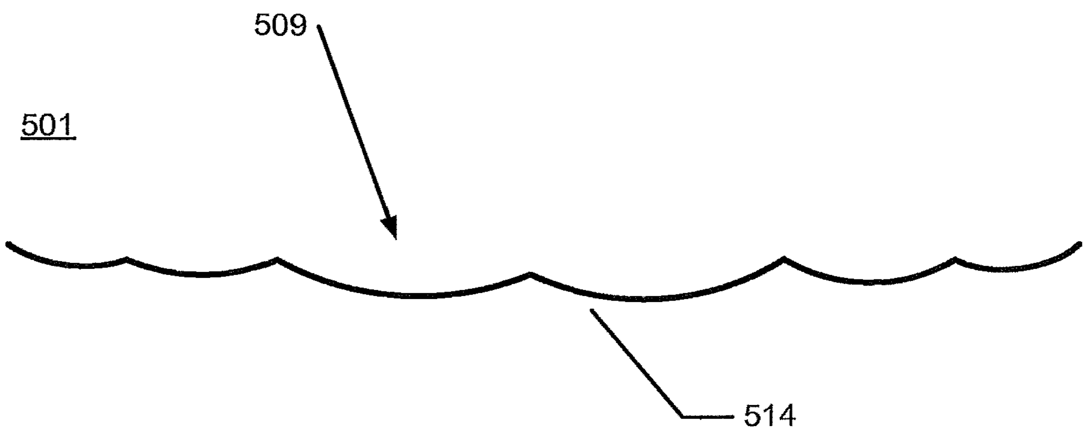
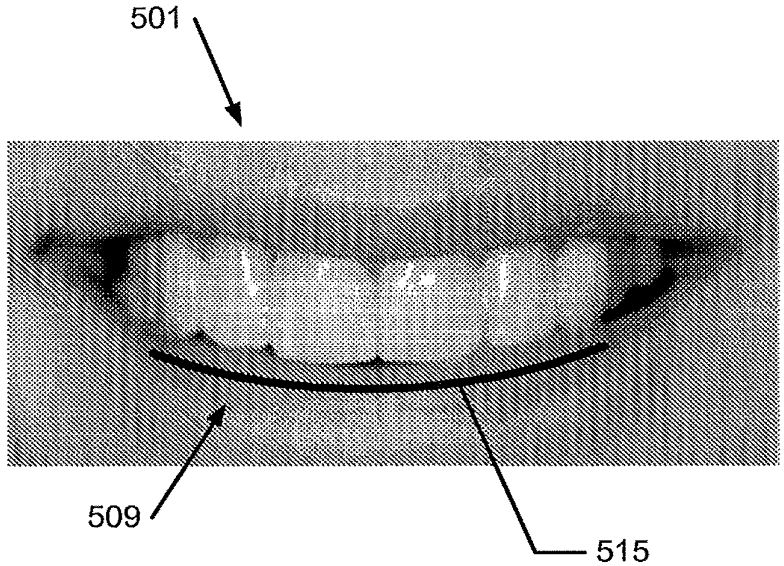


Fig. 5c)

Fig. 5d)



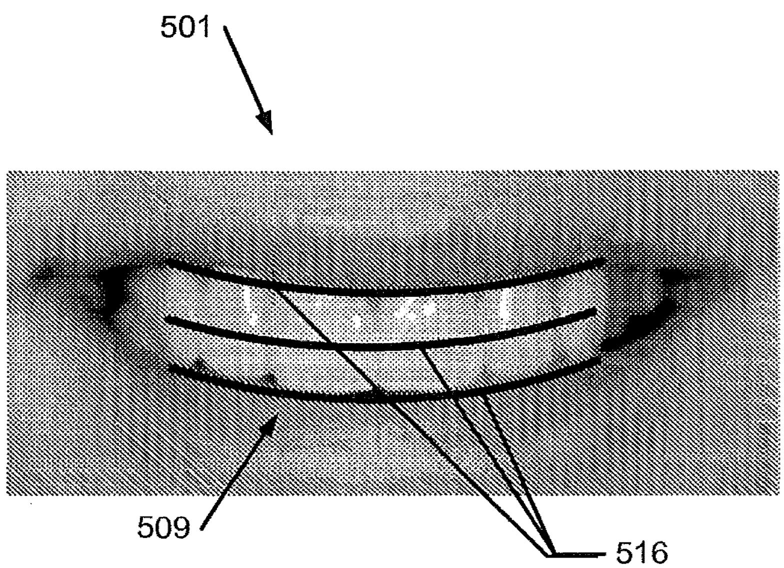


Fig. 5e)

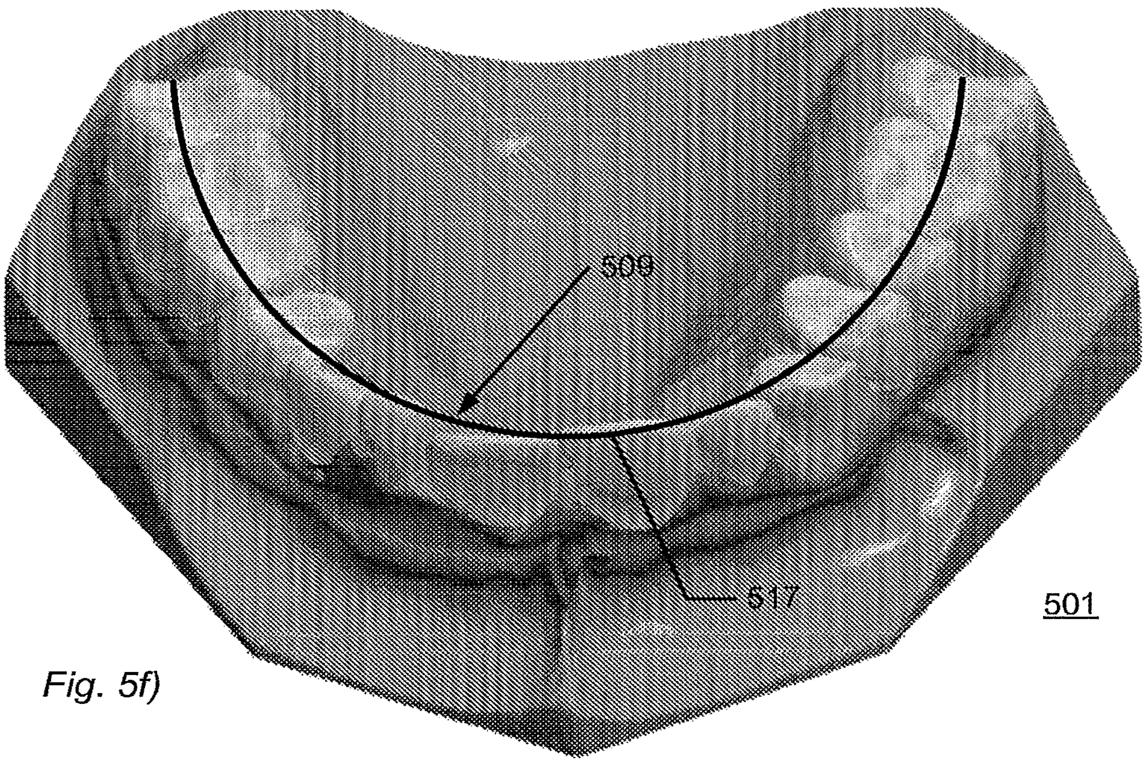
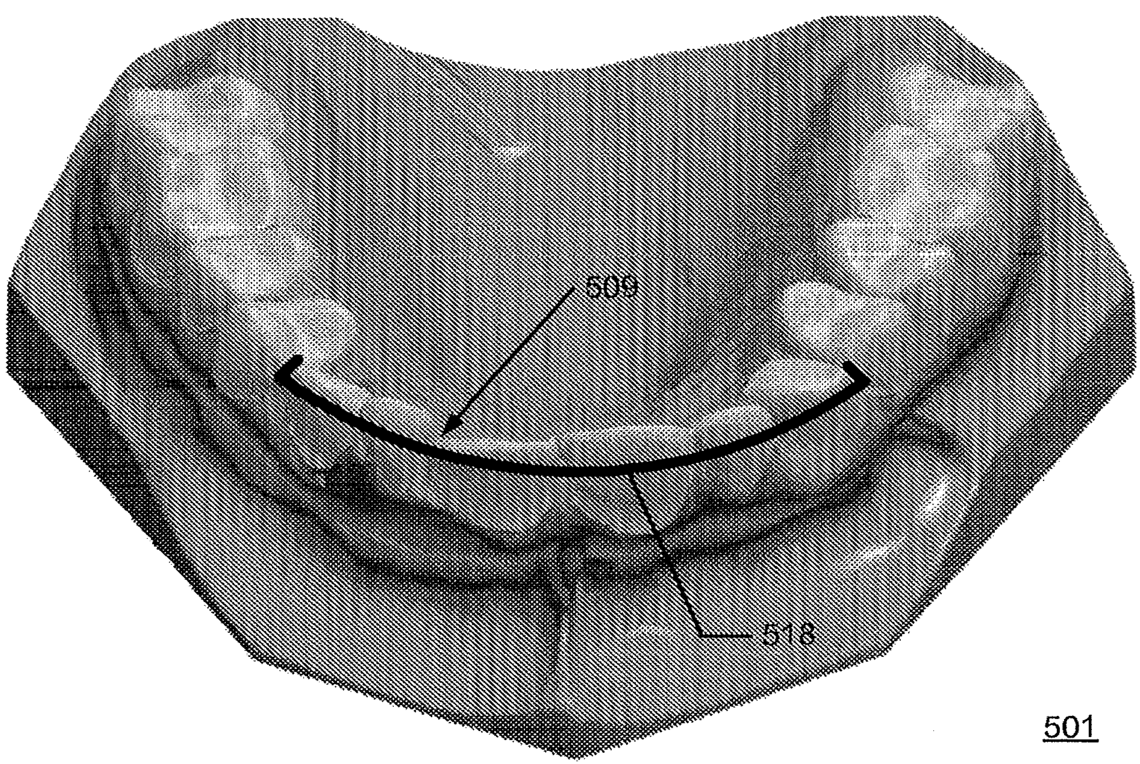


Fig. 5f)

Fig. 5g)



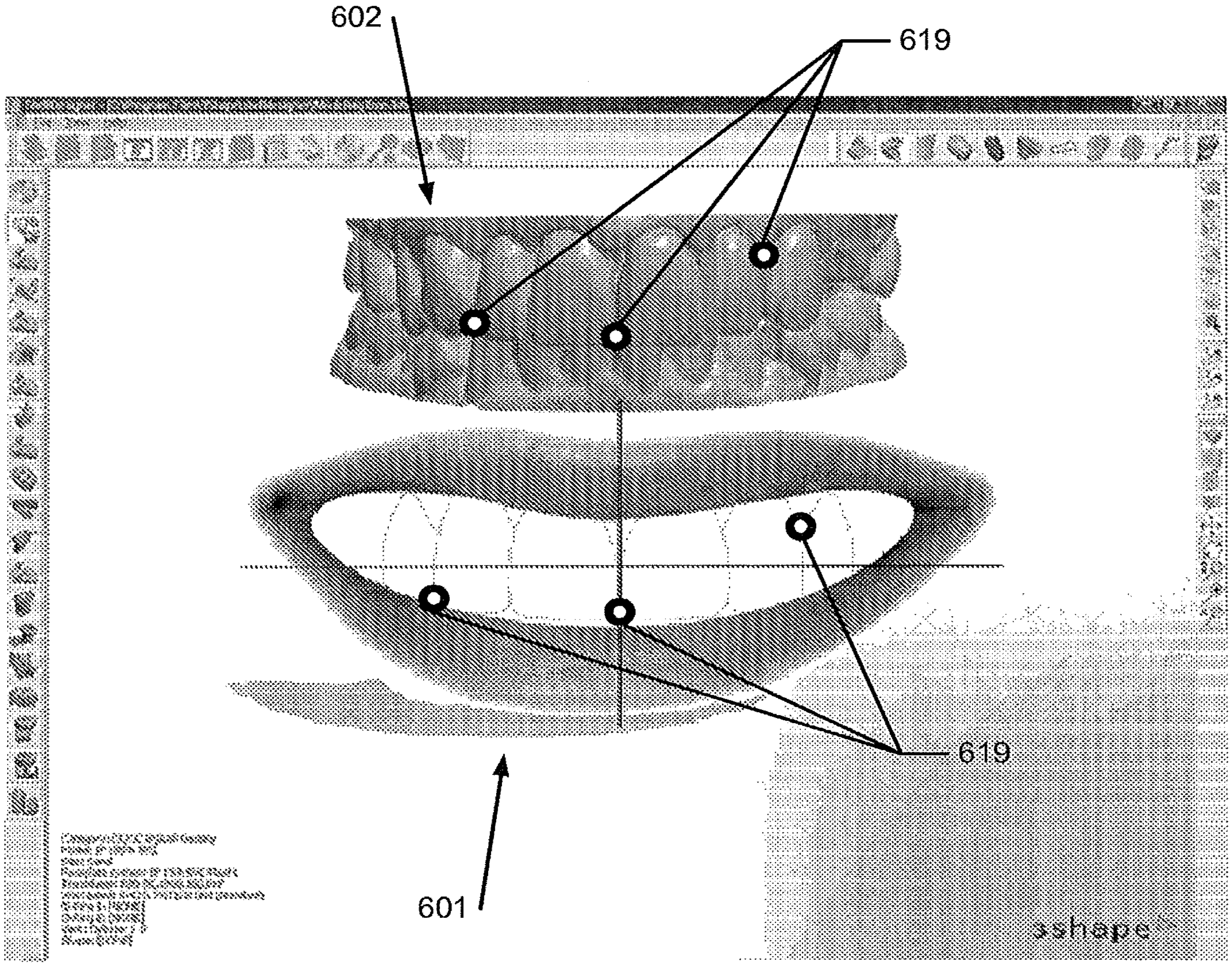


Fig. 6a)

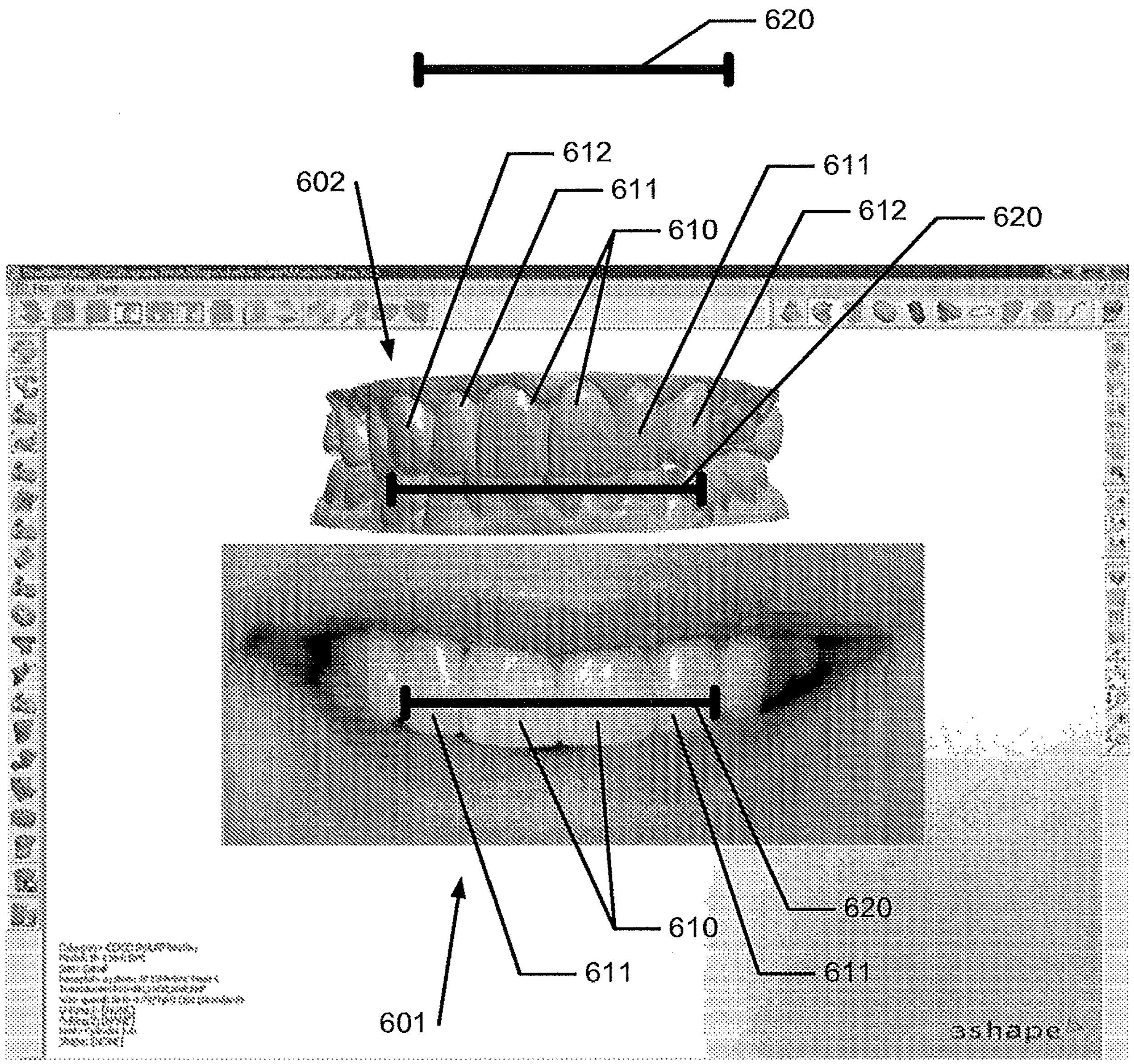


Fig. 6b)

Fig. 7

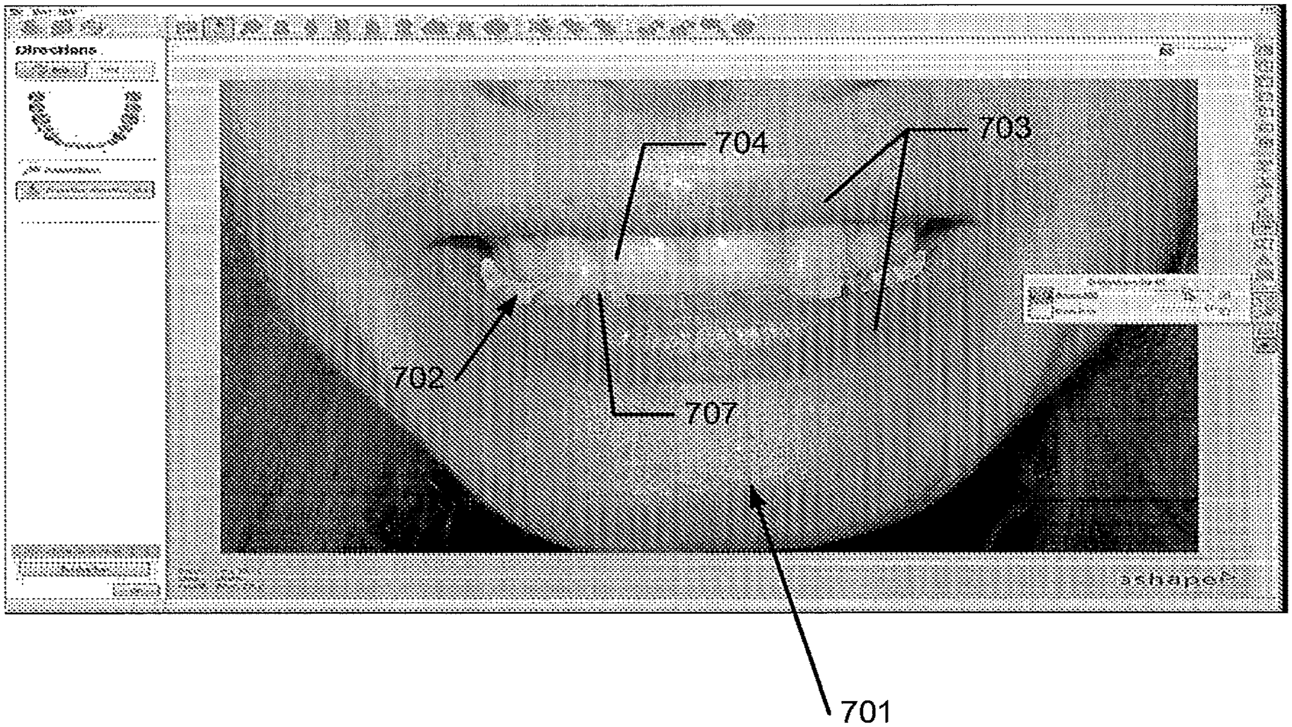


Fig. 8

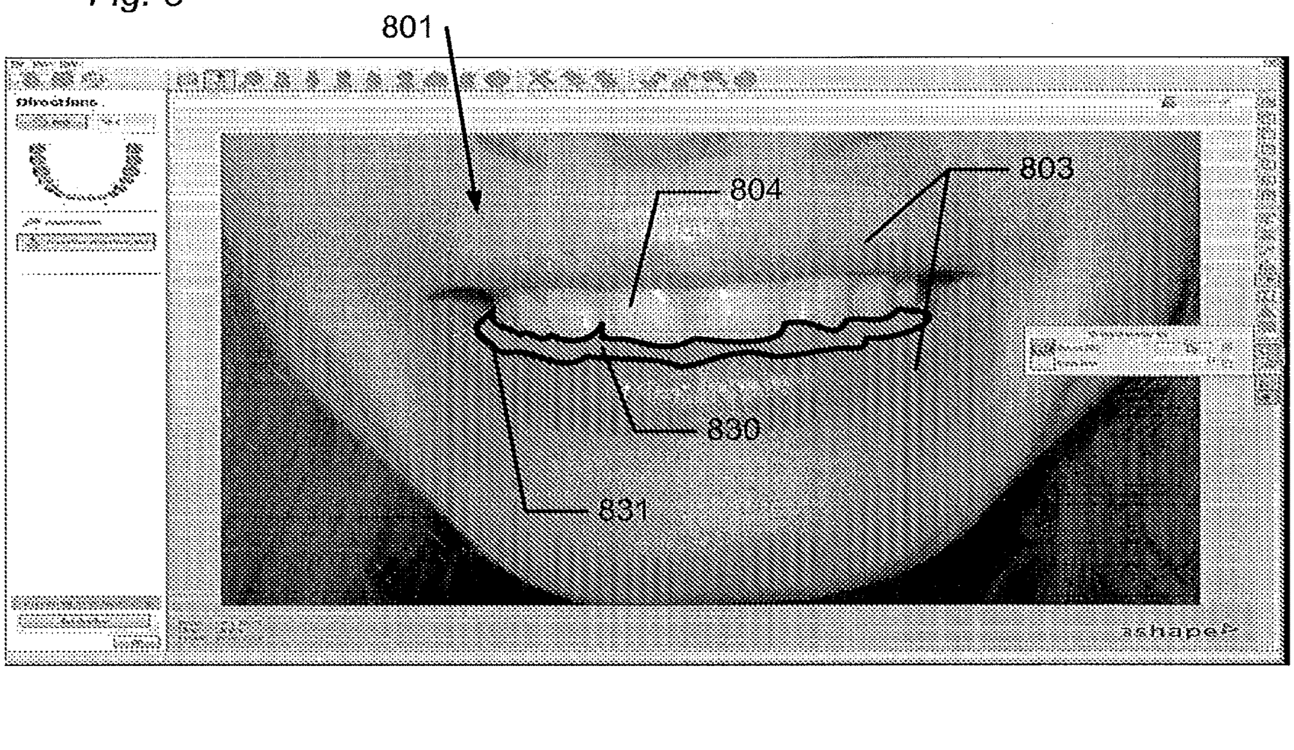


Fig. 9

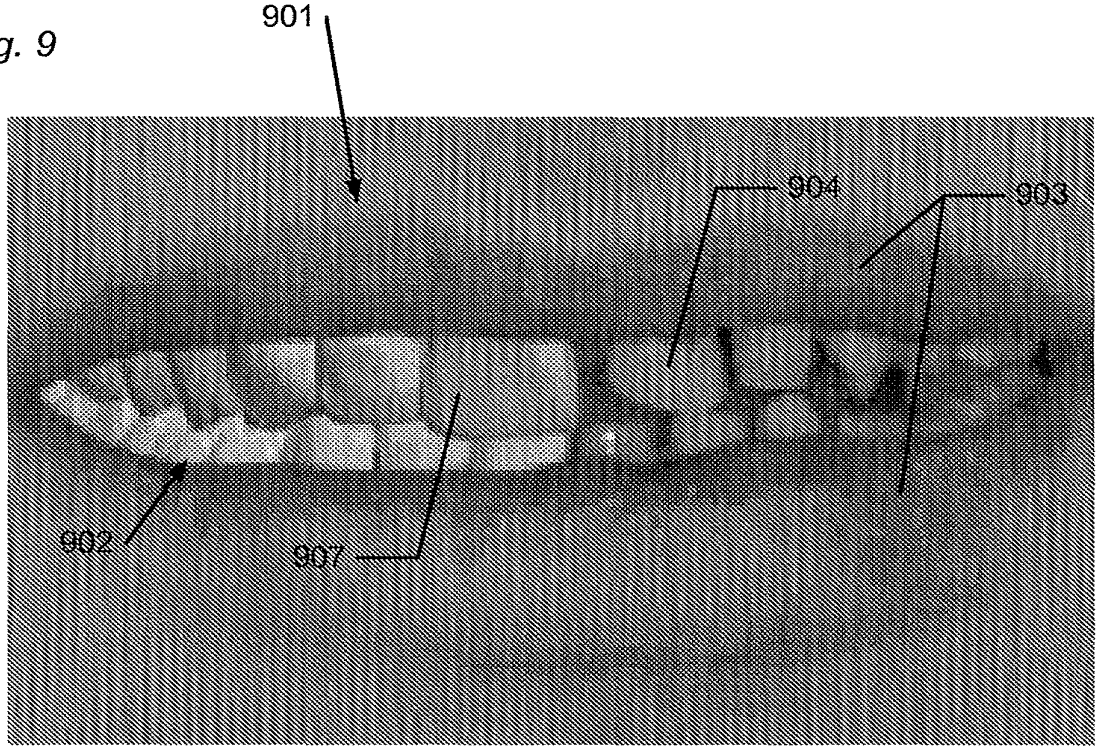
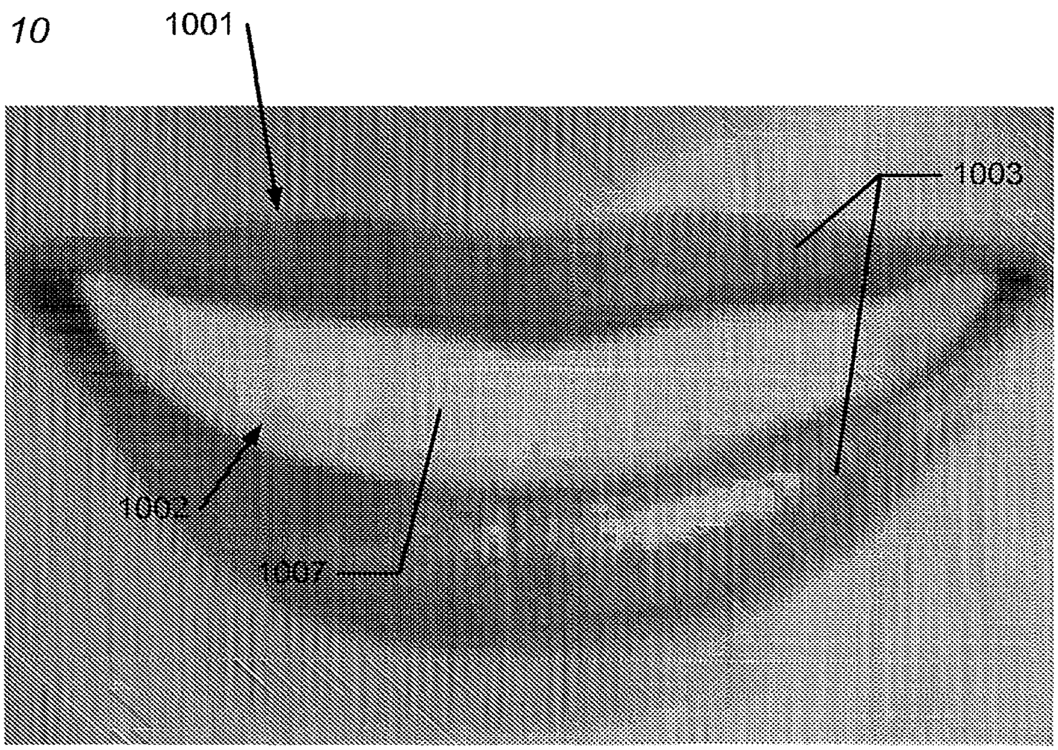


Fig. 10



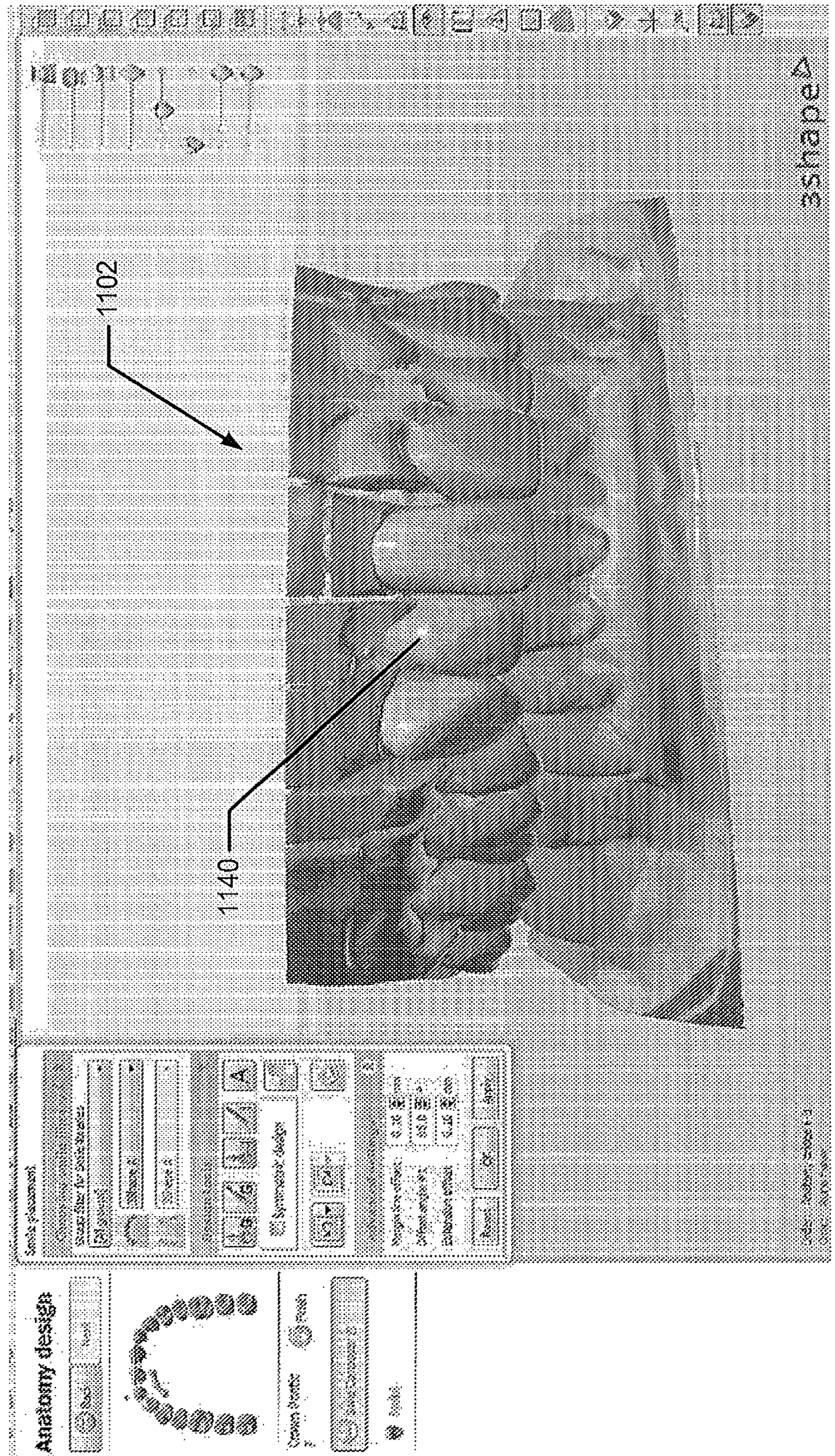


Fig. 11a)

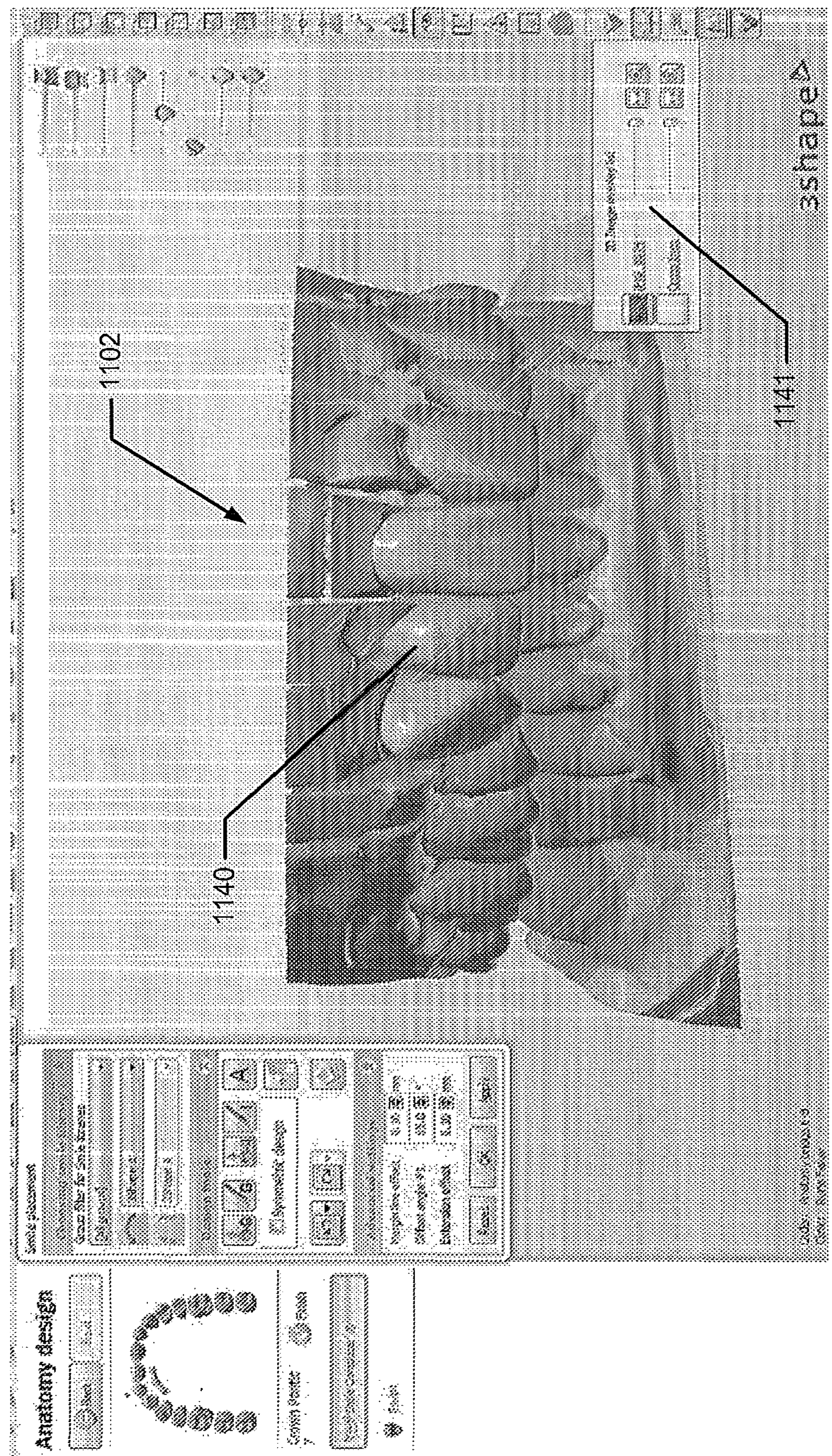


Fig. 11b)

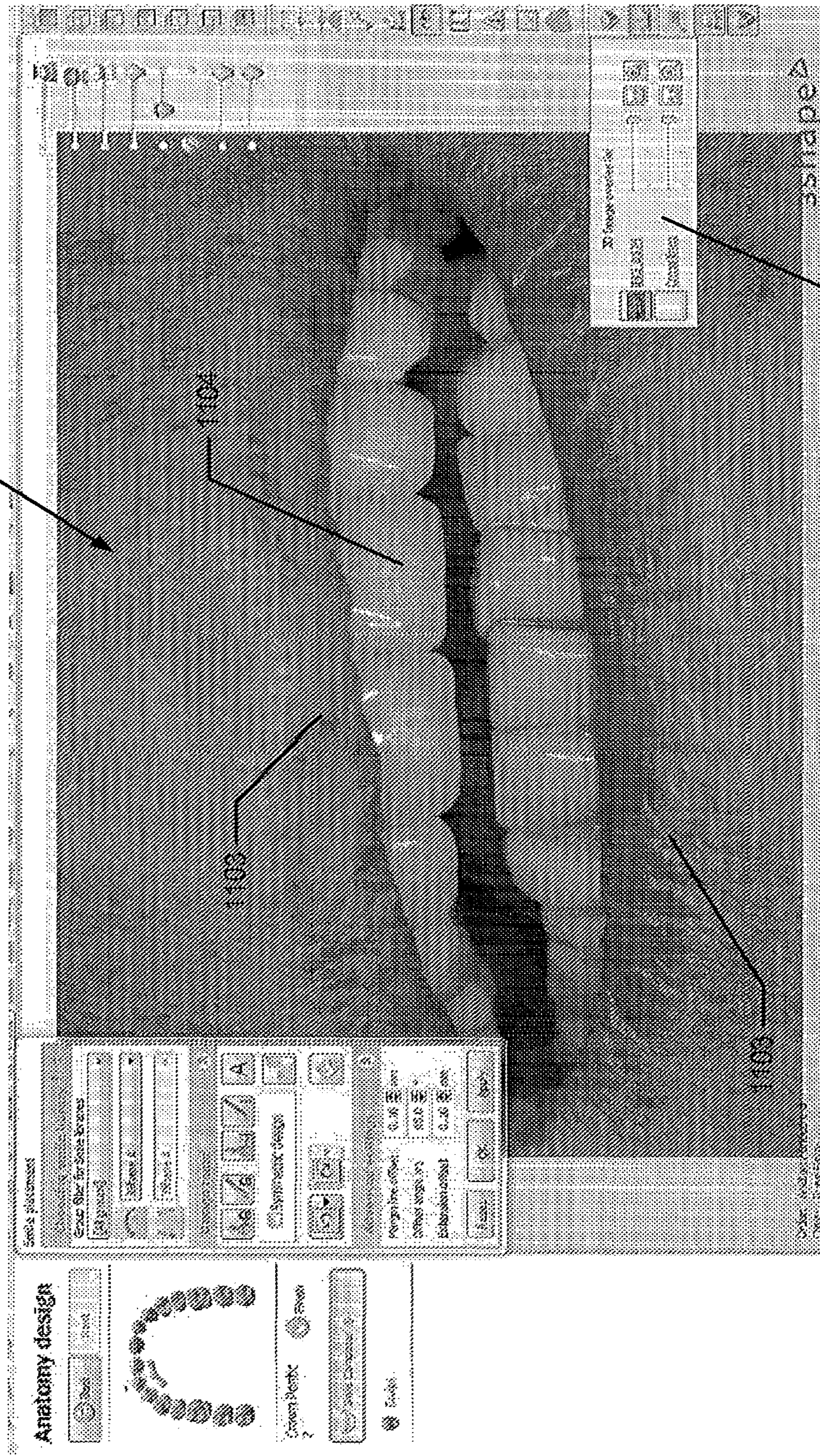
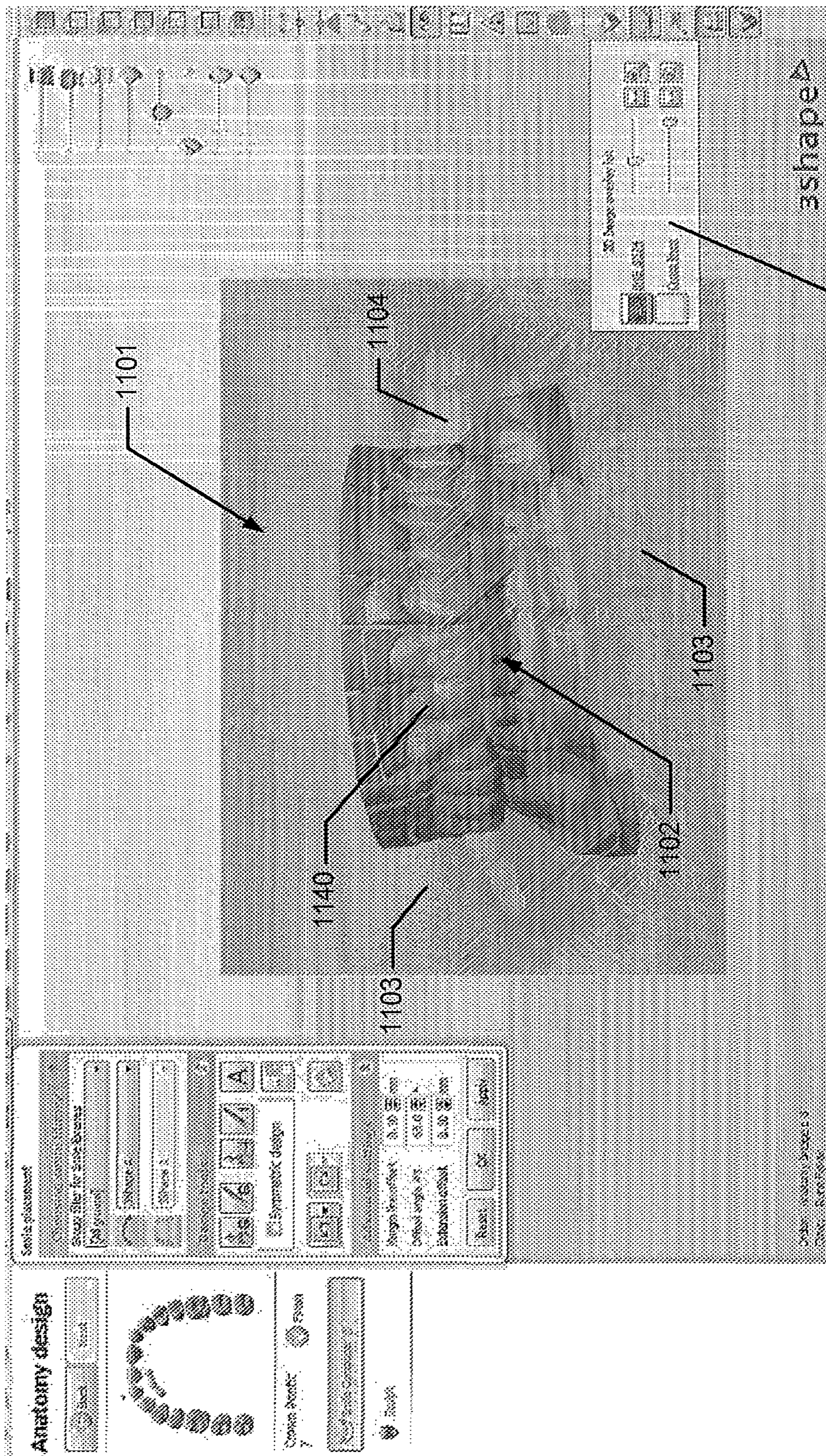


Fig. 11c)

Fig. 11d)



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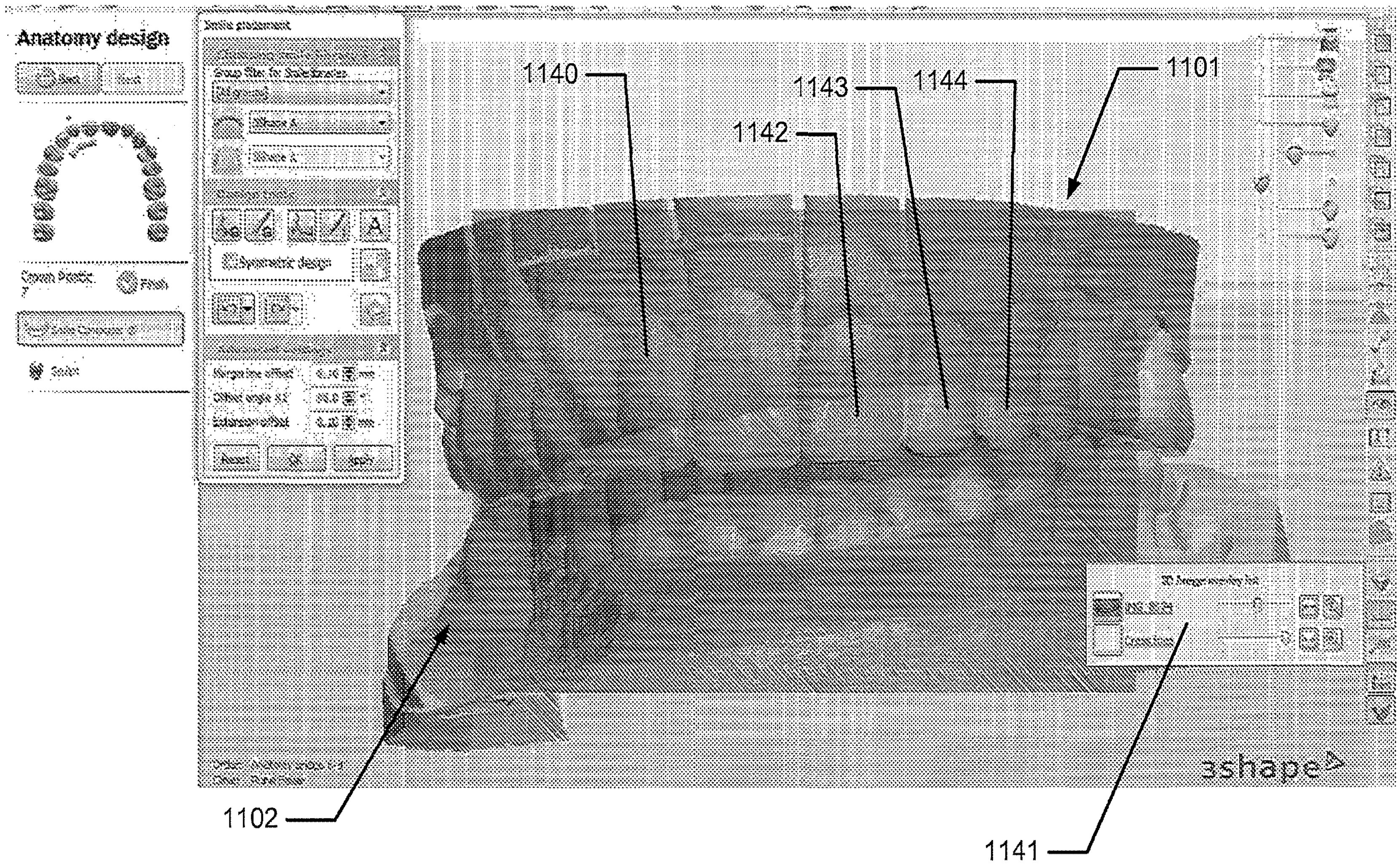
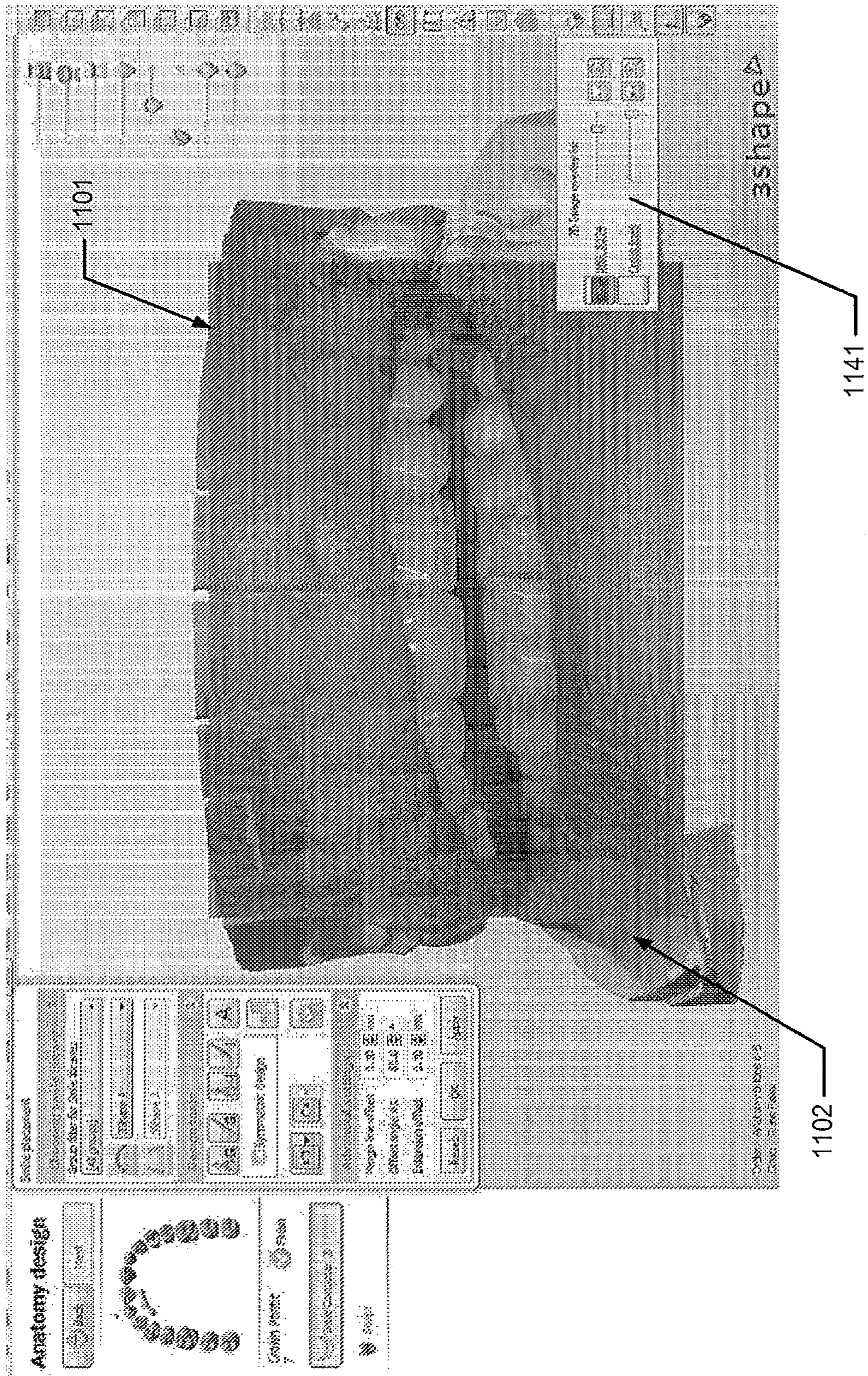


Anatomy design
Symmetric design
1140
1143
1144
1101
1142
1102
1141
3shape

Fig. 11f)



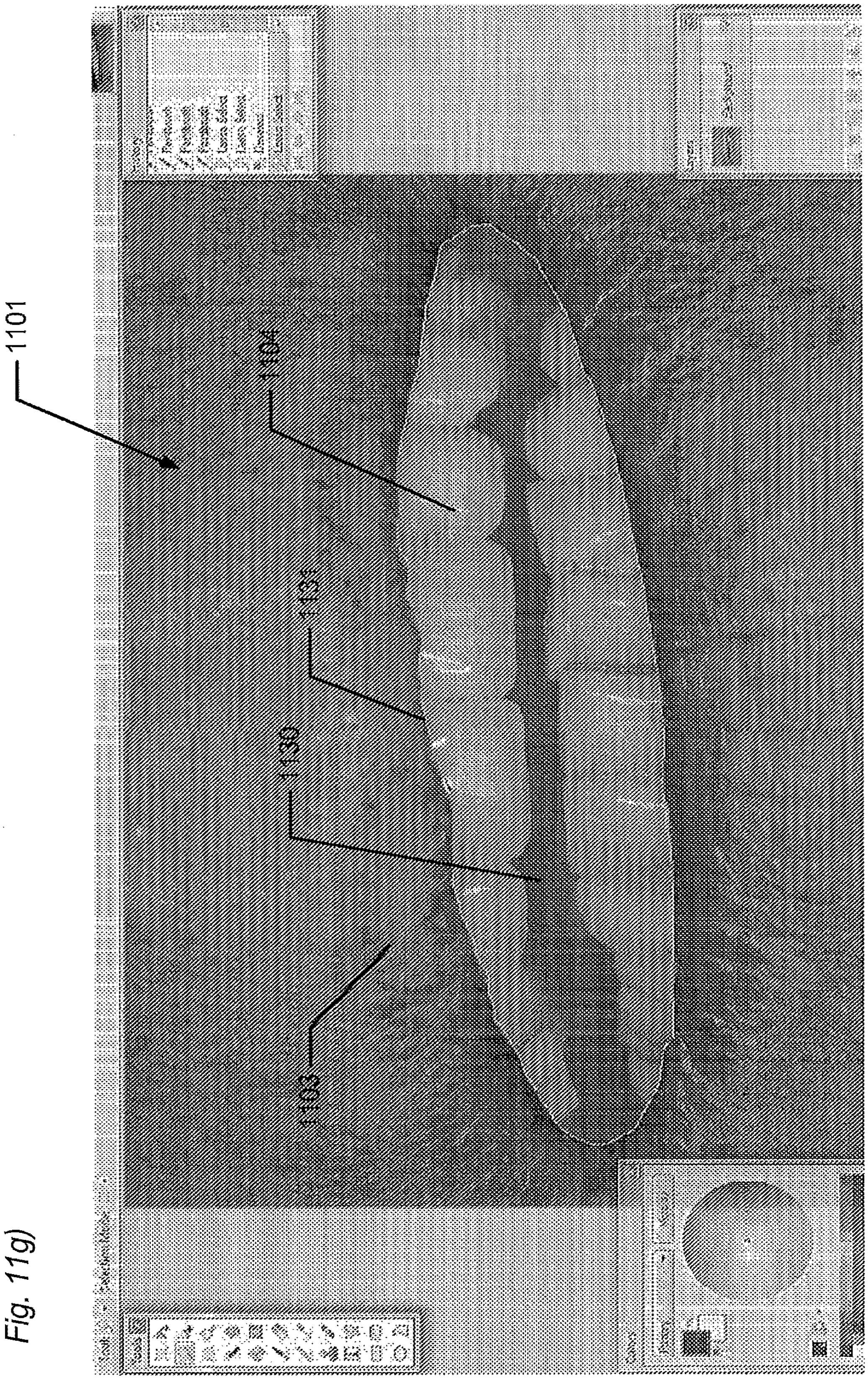


Fig. 11g)

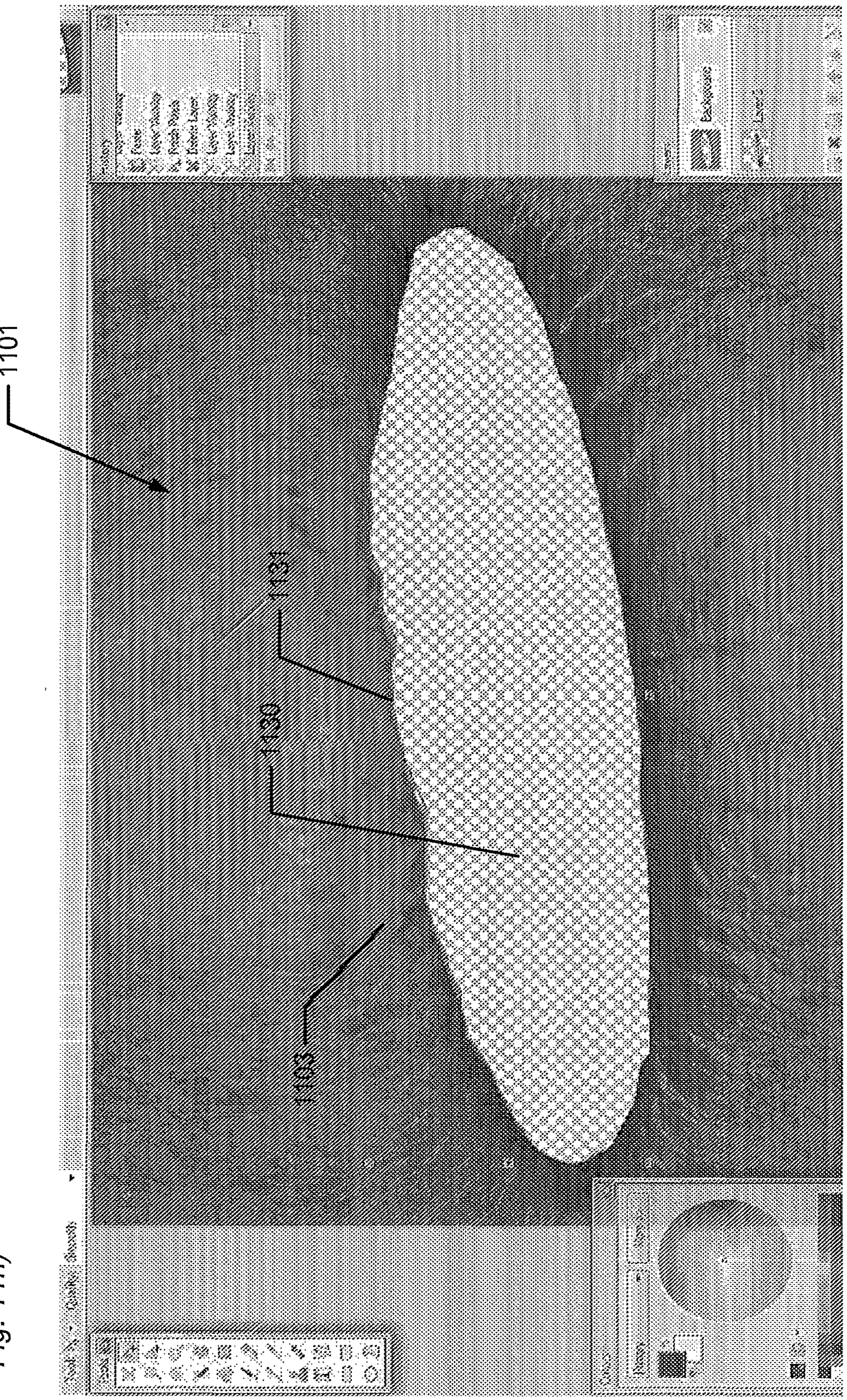
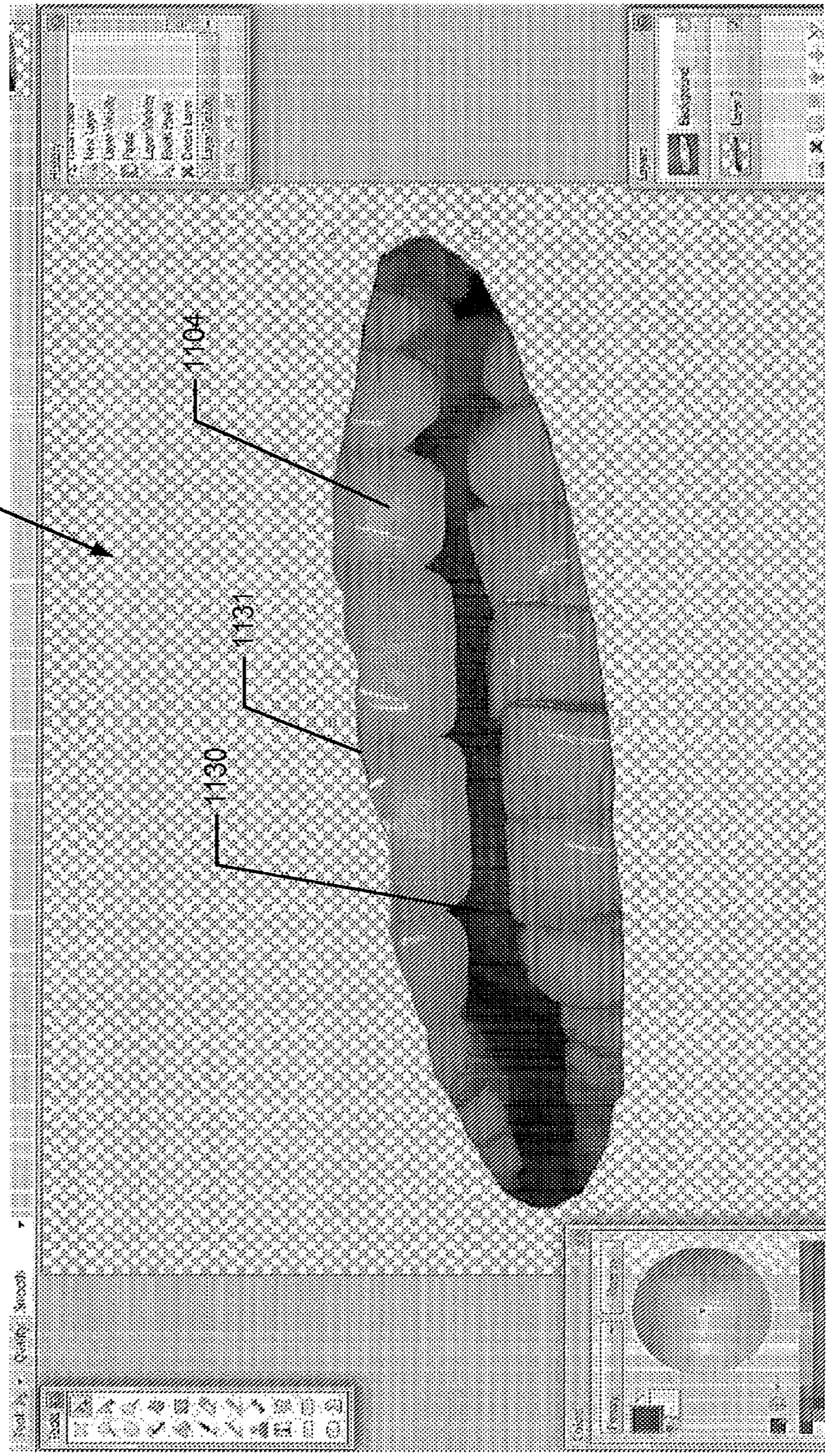


Fig. 11h)

Fig. 11i)



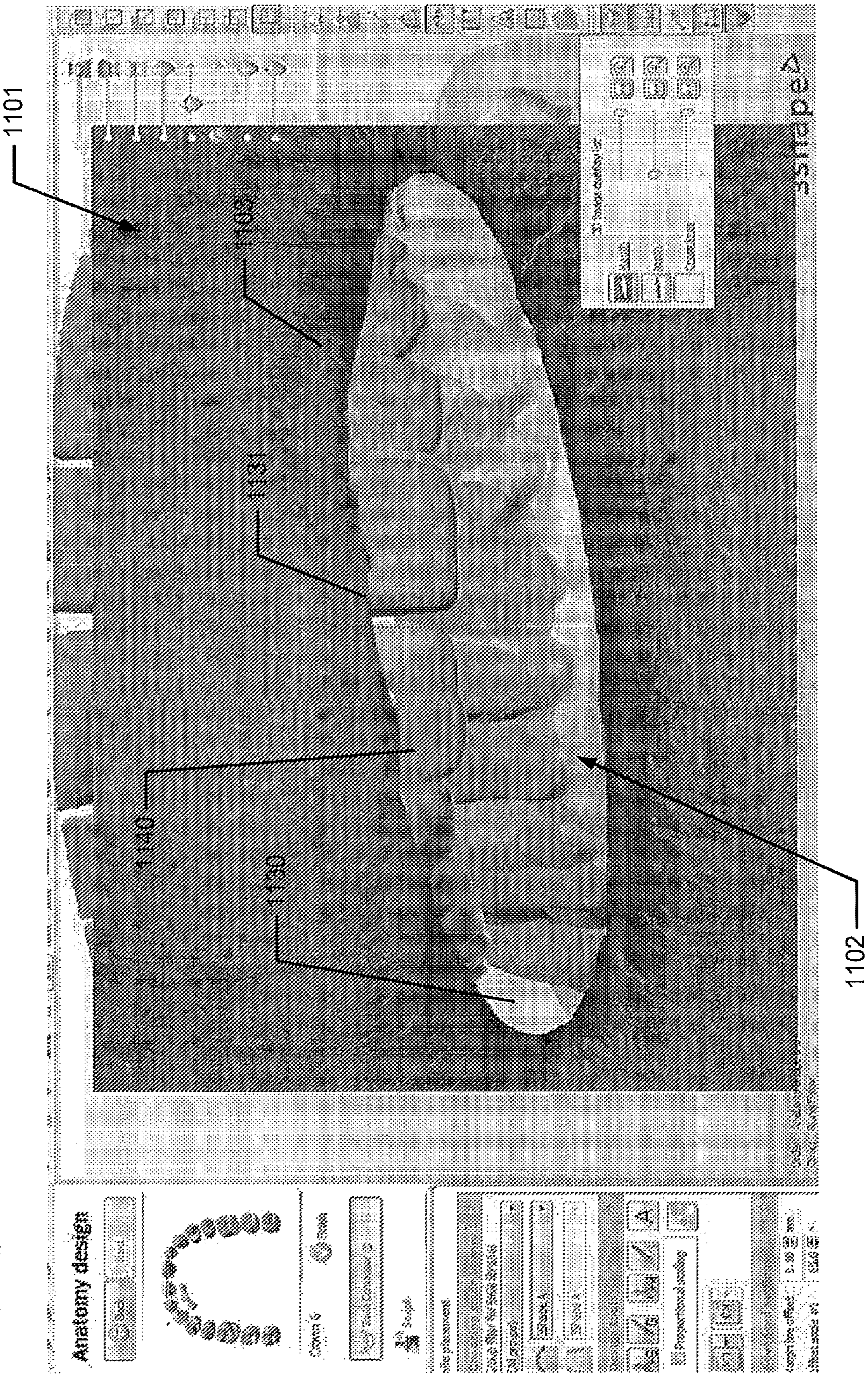


Fig. 11j)

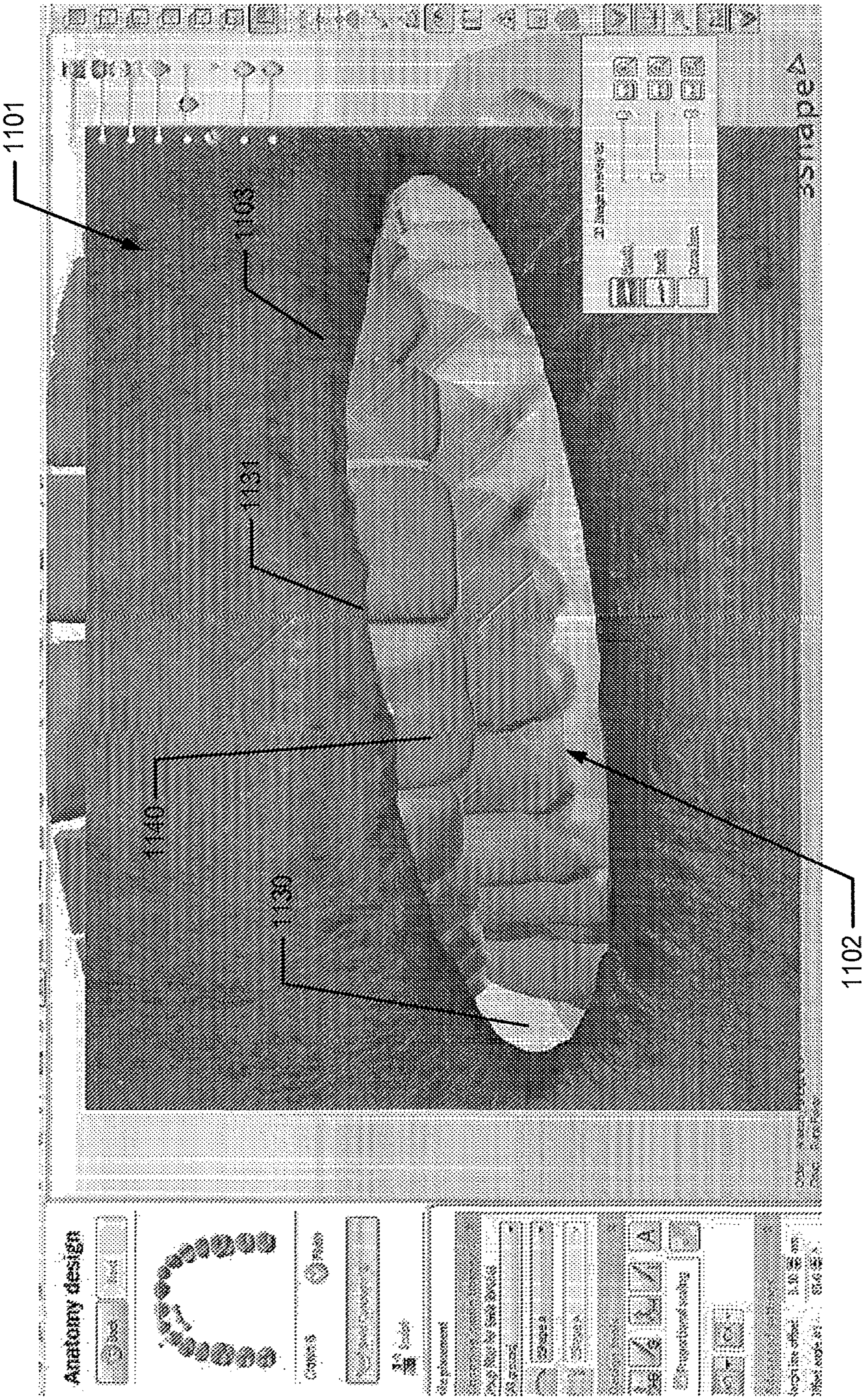


Fig. 11k)

ADVANCE E-MAIL

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PCT

NOTIFICATION CONCERNING SUBMISSION, OBTENTION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

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St. Kongensgade 59 A
DK-1264 Copenhagen K
DANEMARK

Date of mailing *(day/month/year)* 14 July 2011 (14.07.2011)	
Applicant's or agent's file reference P2638PC00	**IMPORTANT NOTIFICATION**
International application No. PCT/DK2011/050246	International filing date *(day/month/year)* 29 June 2011 (29.06.2011)
International publication date *(day/month/year)* **Not yet published**	Priority date *(day/month/year)* 29 June 2010 (29.06.2010)
Applicant 3SHAPE A/S et al	

The applicant is hereby notified of the date of receipt (or of obtaining by the International Bureau) of the priority document(s) relating to all earlier application(s) whose priority is claimed. Unless otherwise indicated by the letters "NR", in the right-hand column or by an asterisk appearing next to the date of receipt, **the priority document concerned was submitted or transmitted to or obtained by the International Bureau in compliance with Rule 17.1(a), (b) or (b-*bis*)**. This Form replaces any previously issued notification concerning submission, transmittal or obtaining of priority documents.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
29 June 2010 (29.06.2010)	PA 2010 00568	DK	11 July 2011 (11.07.2011)
29 June 2010 (29.06.2010)	61/359,454	US	07 July 2011 (07.07.2011)
18 March 2011 (18.03.2011)	PA 2011 00191	DK	11 July 2011 (11.07.2011)
18 March 2011 (18.03.2011)	61/454,200	US	07 July 2011 (07.07.2011)

The letters "NR" denote a priority document which, on the date of mailing of this Form, had not yet been received or obtained by the International Bureau in compliance with Rule 17.1(a), (b) or (b-*bis*). Where the applicant has failed to either submit, request to prepare and transmit or obtain and transmit, or to request the International Bureau to obtain the priority document within the applicable time limit under that Rule, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

An asterisk "*" next to a date of receipt, denotes a priority document submitted or transmitted to or obtained by the International Bureau but not in compliance with Rule 17.1(a), (b) or (b-*bis*) (the priority document was received after the time limit prescribed in Rule 17.1(a); the request to prepare and transmit the priority document was submitted to the receiving Office after the applicable time limit under Rule 17.1(b) or the request to the receiving Office or the International Bureau to obtain the priority document was made after the applicable time limit under Rule 17.1(b-*bis*)). Even though the priority document was not furnished in compliance with Rule 17.1(a), (b) or (b-*bis*), the International Bureau will nevertheless transmit a copy of the document to the designated Offices, for their consideration. In case such a copy is not accepted by the designated Office as the priority document, Rule 17.1(c) provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 70 80	Authorized officer Nora Lindner e-mail pt11.pct@wipo.int Telephone No. +41 22 338 74 11

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 Y	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 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

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"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 02/09/2011	Date of mailing of the international search report 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

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.	

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	
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Espacenet

Bibliographic data: EP1124487 (A1) — 2001-08-22

DENTAL IMAGE PROCESSING METHOD AND SYSTEM

Inventor(s): KOPELMAN AVI [IL]; TAUB ELDAD [IL] ± (KOPELMAN, AVI, ; TAUB, ELDAD)

Applicant(s): CADENT LTD [IL] ± (CADENT LTD)

Classification:
- international: ***A61B5/107; A61B6/00; A61B6/14; G06T1/00; G06T3/00;*** (IPC1-7): A61B6/00; A61B6/14
- cooperative: **A61B6/14**; **A61B6/501**; A61C9/004

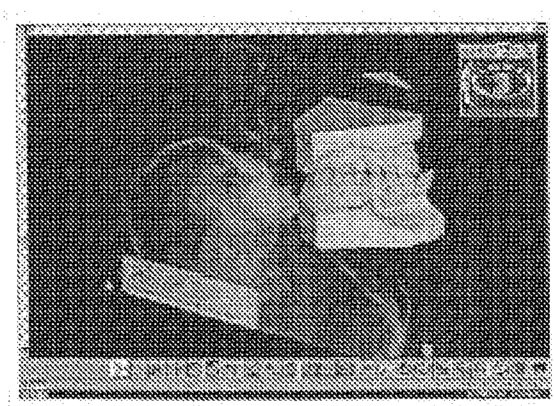
Application number: EP19990952782 19991101

Priority number (s): WO1999IL00577 19991101 ; IL19980126838 19981101

Also published as: EP1124487 (B1) WO0025677 (A1) US2003169913 (A1) US6845175 (B2) JP2002528215 (A) more

Abstract not available for EP1124487 (A1)
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.



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(54) **Title:** COMPUTER-ASSISTED CREATION OF A CUSTOM TOOTH SET-UP USING FACIAL ANALYSIS

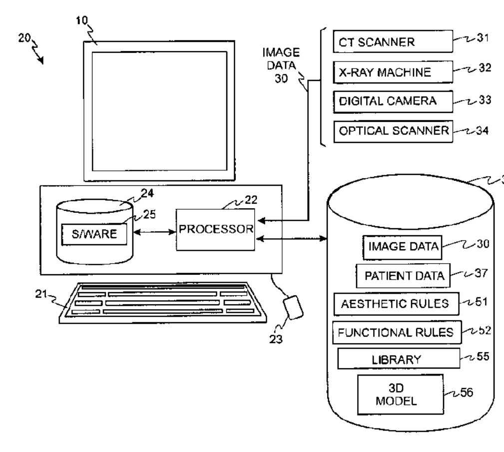

Fig. 1

(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.

Functional analysis (steps 64, 65, Figure 2)

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

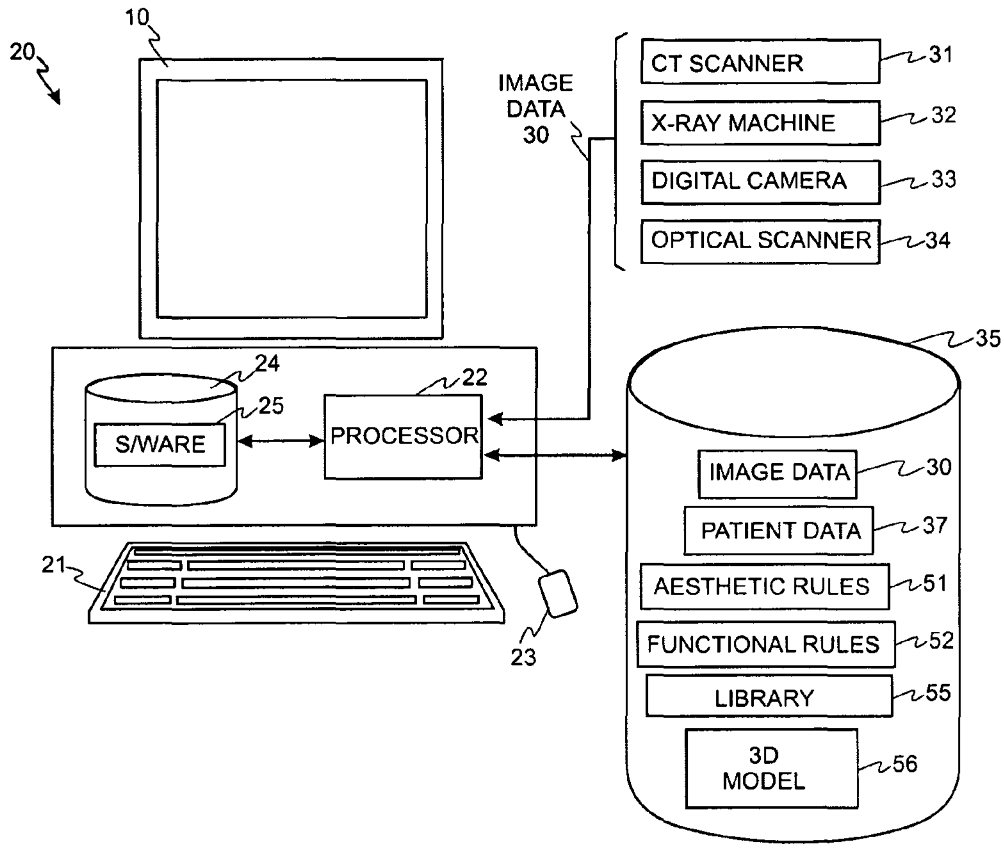
a processor which is arranged to:

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.


20
10
IMAGE
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PROCESSOR
IMAGE DATA
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PATIENT DATA
37
AESTHETIC RULES
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FUNCTIONAL RULES
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LIBRARY
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Fig. 1

2/7

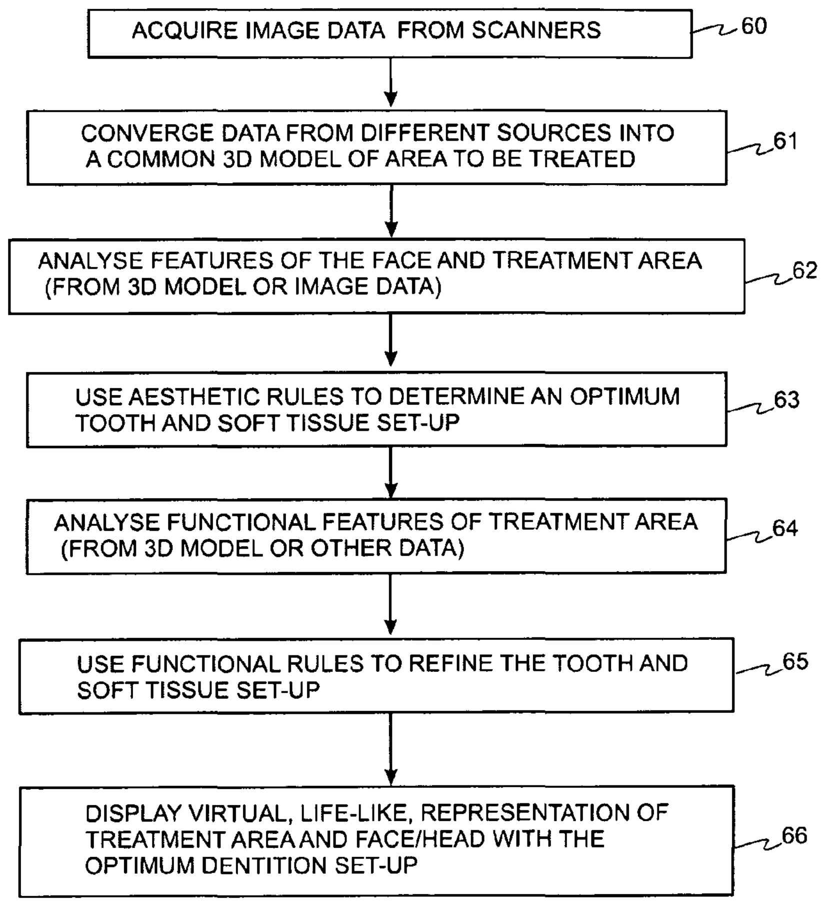
ACQUIRE IMAGE DATA FROM SCANNERS
60
CONVERGE DATA FROM DIFFERENT SOURCES INTO A COMMON 3D MODEL OF AREA TO BE TREATED
61
ANALYSE FEATURES OF THE FACE AND TREATMENT AREA (FROM 3D MODEL OR IMAGE DATA)
62
USE AESTHETIC RULES TO DETERMINE AN OPTIMUM TOOTH AND SOFT TISSUE SET-UP
63
ANALYSE FUNCTIONAL FEATURES 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

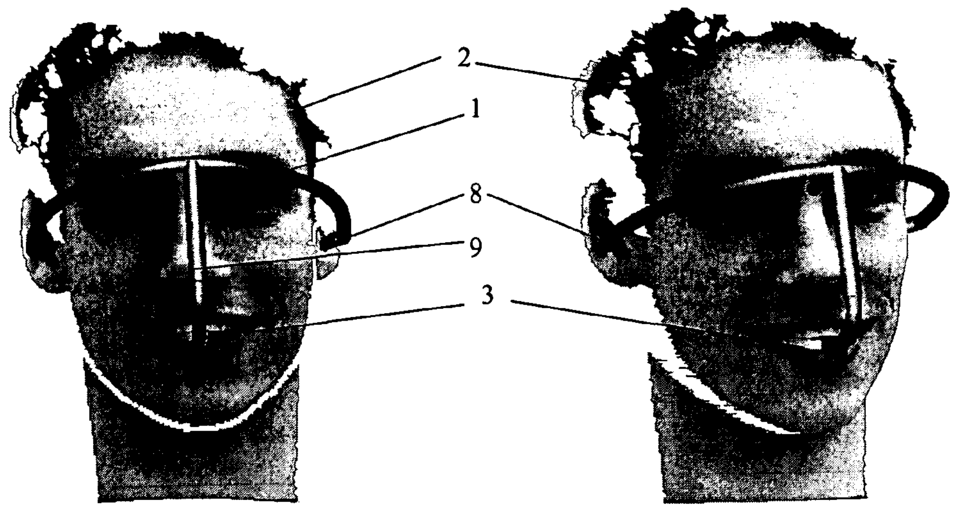

Fig. 3

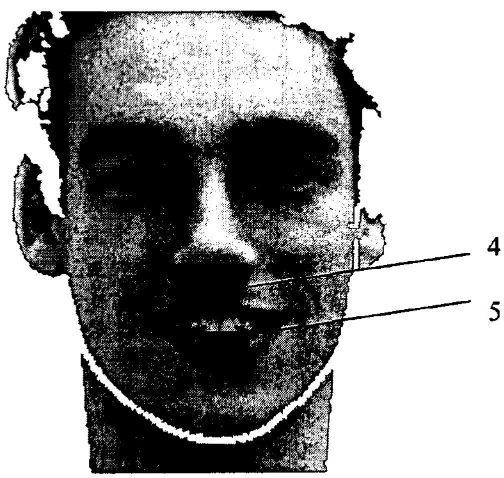

Fig. 4

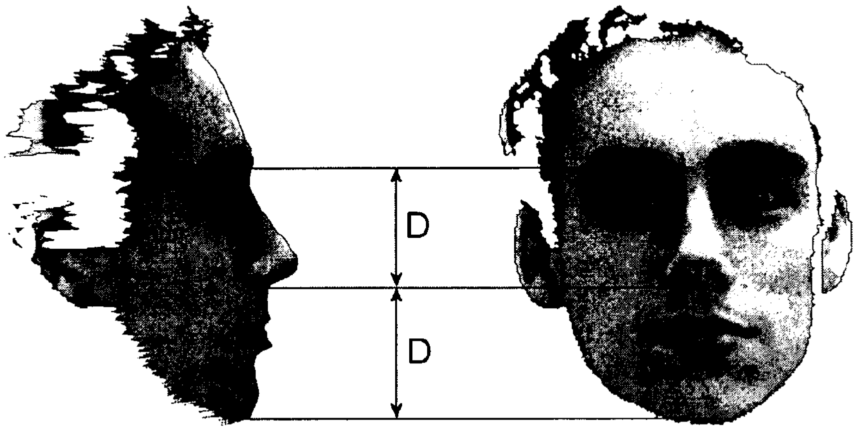

Fig. 5

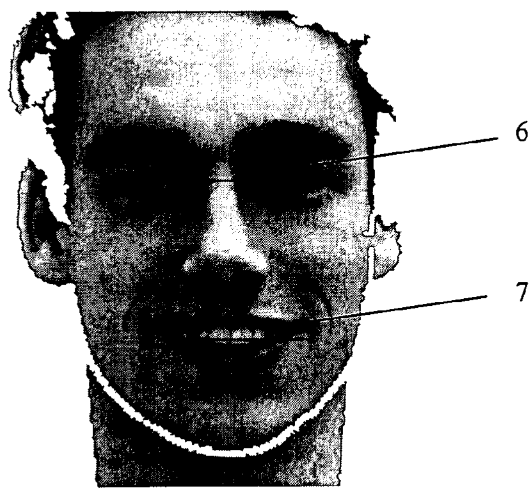

Fig. 6

Fig. 7

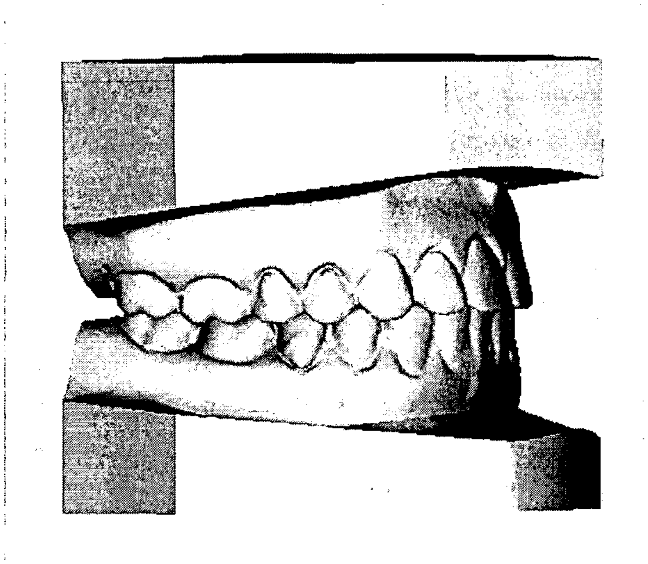

Fig. 8

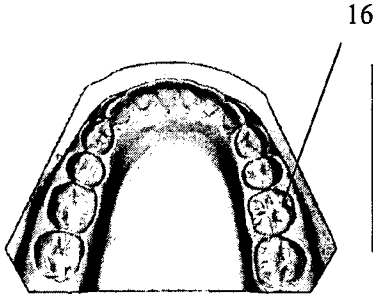

Fig. 9A

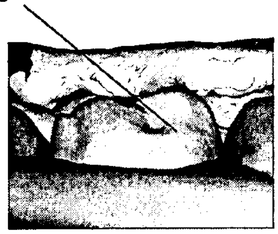

Fig. 9B

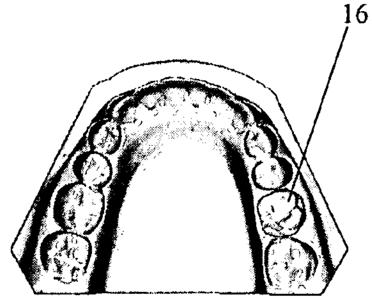

Fig. 9C

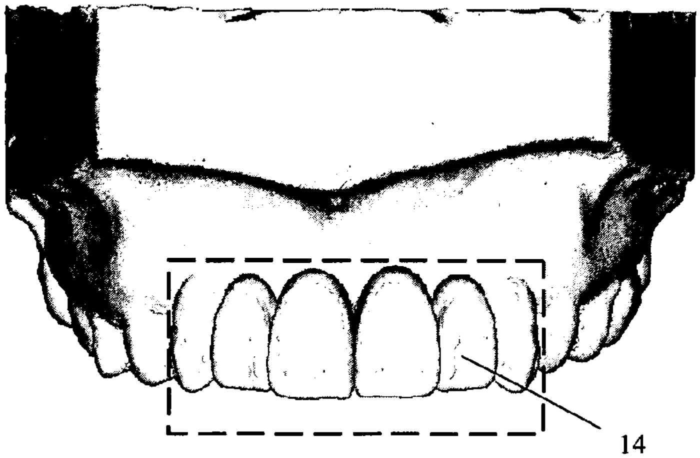

Fig. 10

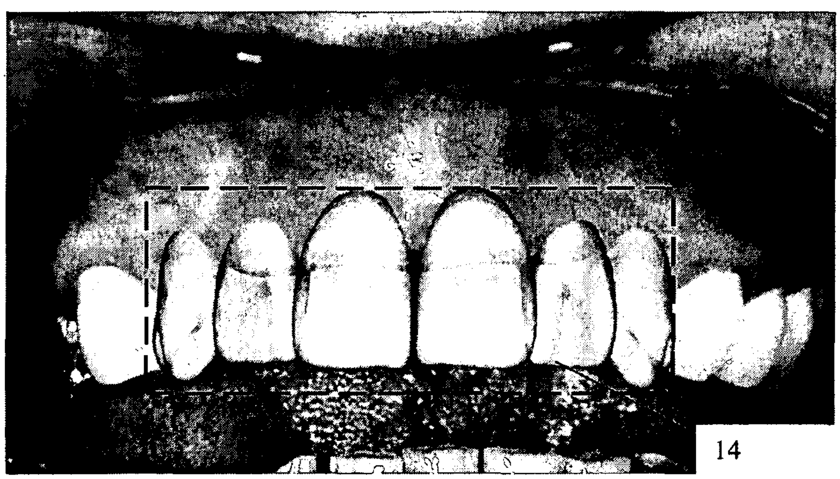

Fig. 11

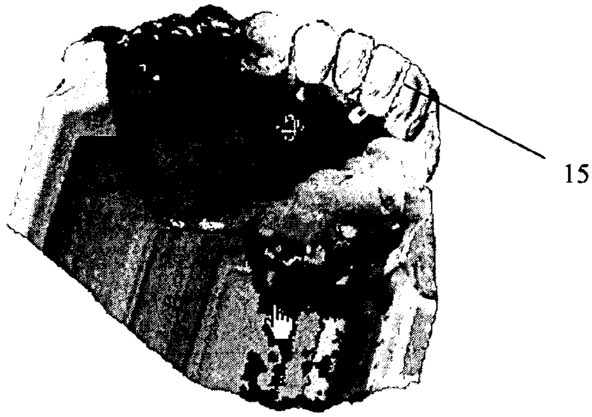

Fig. 12

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

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[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

Form PCT/ISA/210 (second sheet) (April 2005)

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

Form PCT/ISA/210 (patent family annex) (April 2005)

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International Bureau

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(25) Filing Language: English

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61/205,797	23 January 2009 (23.01.2009)	US

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(72) Inventors; and

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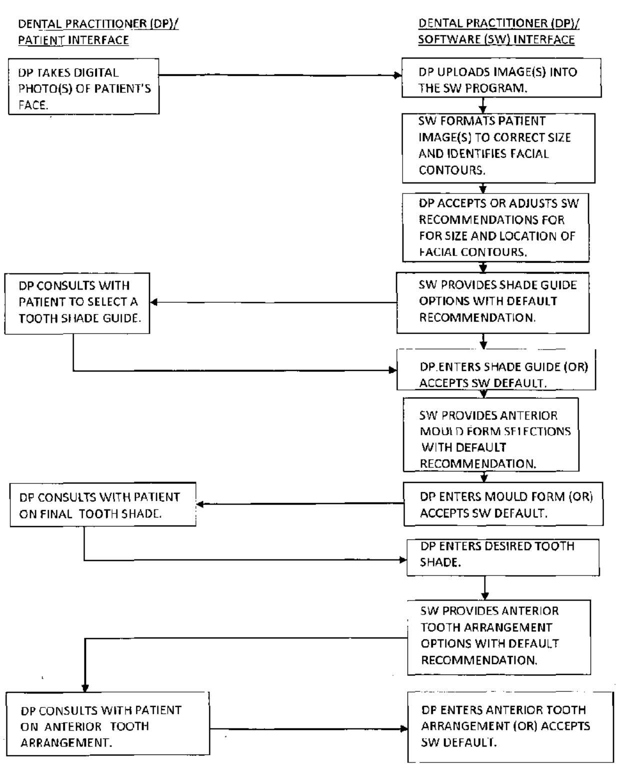
(74) Agents: **BIEBER, James, B.** et al.; Dentsply International Inc., 570, West College Avenue, P.o. Box 872, York, PA 17405-0872 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, 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,

[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.

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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 cxample, 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^{o}); (tapered at 20^{o}) and Anatoline® (tapered at 10^{o}), 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

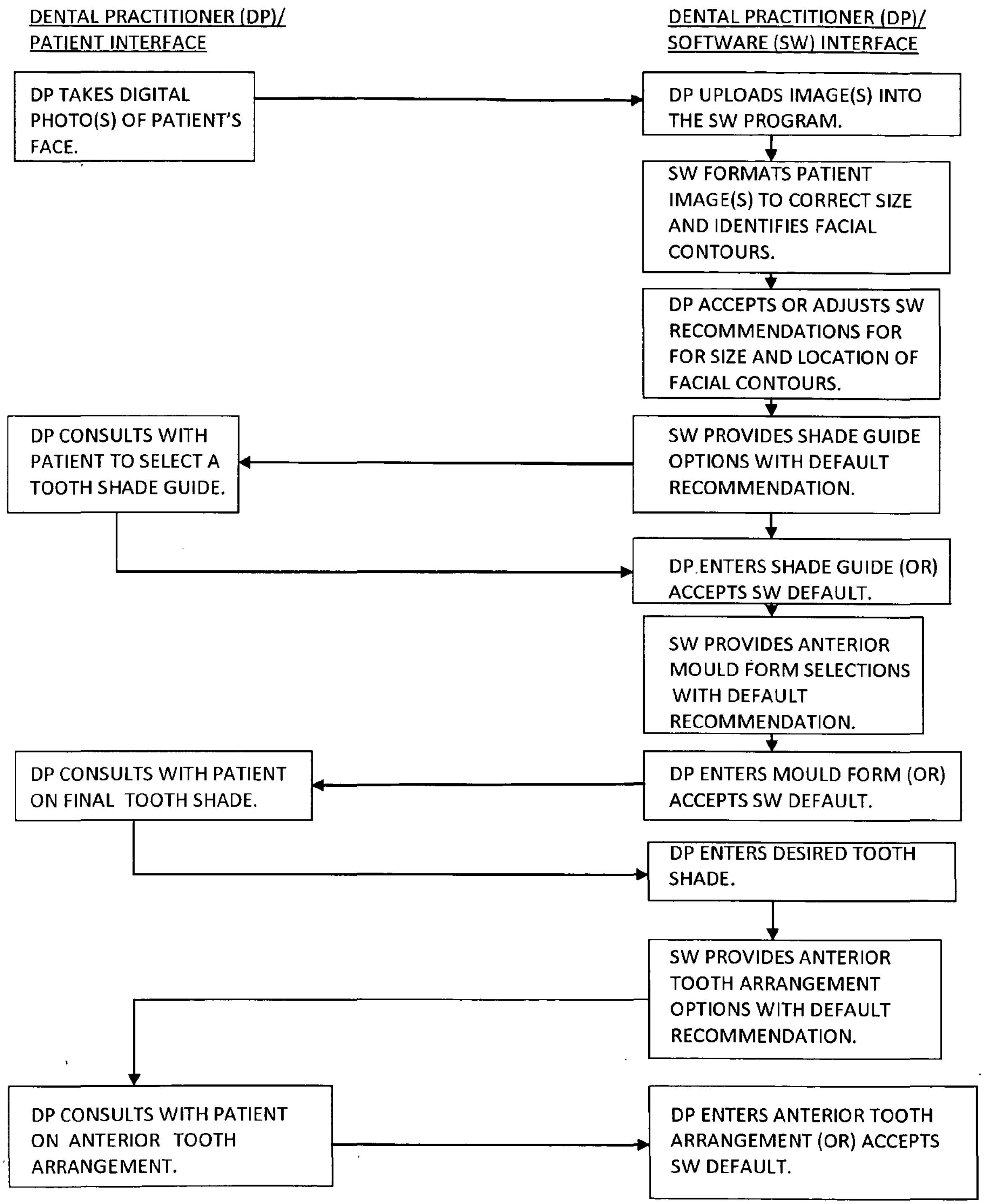

DENTAL PRACTITIONER (DP)/ PATIENT INTERFACE
DENTAL PRACTITIONER (DP)/ SOFTWARE (SW) INTERFACE
DP TAKES DIGITAL PHOTO(S) OF PATIENT'S FACE.
DP UPLOADS IMAGE(S) INTO THE SW PROGRAM.
SW FORMATS PATIENT IMAGE(S) TO CORRECT SIZE AND IDENTIFIES FACIAL CONTOURS.
DP ACCEPTS OR ADJUSTS SW RECOMMENDATIONS FOR FOR SIZE AND LOCATION OF FACIAL CONTOURS.
DP CONSULTS WITH PATIENT TO SELECT A TOOTH SHADE GUIDE.
SW PROVIDES SHADE GUIDE OPTIONS WITH DEFAULT RECOMMENDATION.
DP ENTERS SHADE GUIDE (OR) ACCEPTS SW DEFAULT.
SW PROVIDES ANTERIOR MOULD FORM SELECTIONS WITH DEFAULT RECOMMENDATION.
DP CONSULTS WITH PATIENT ON FINAL TOOTH SHADE.
DP ENTERS MOULD FORM (OR) ACCEPTS SW DEFAULT.
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)

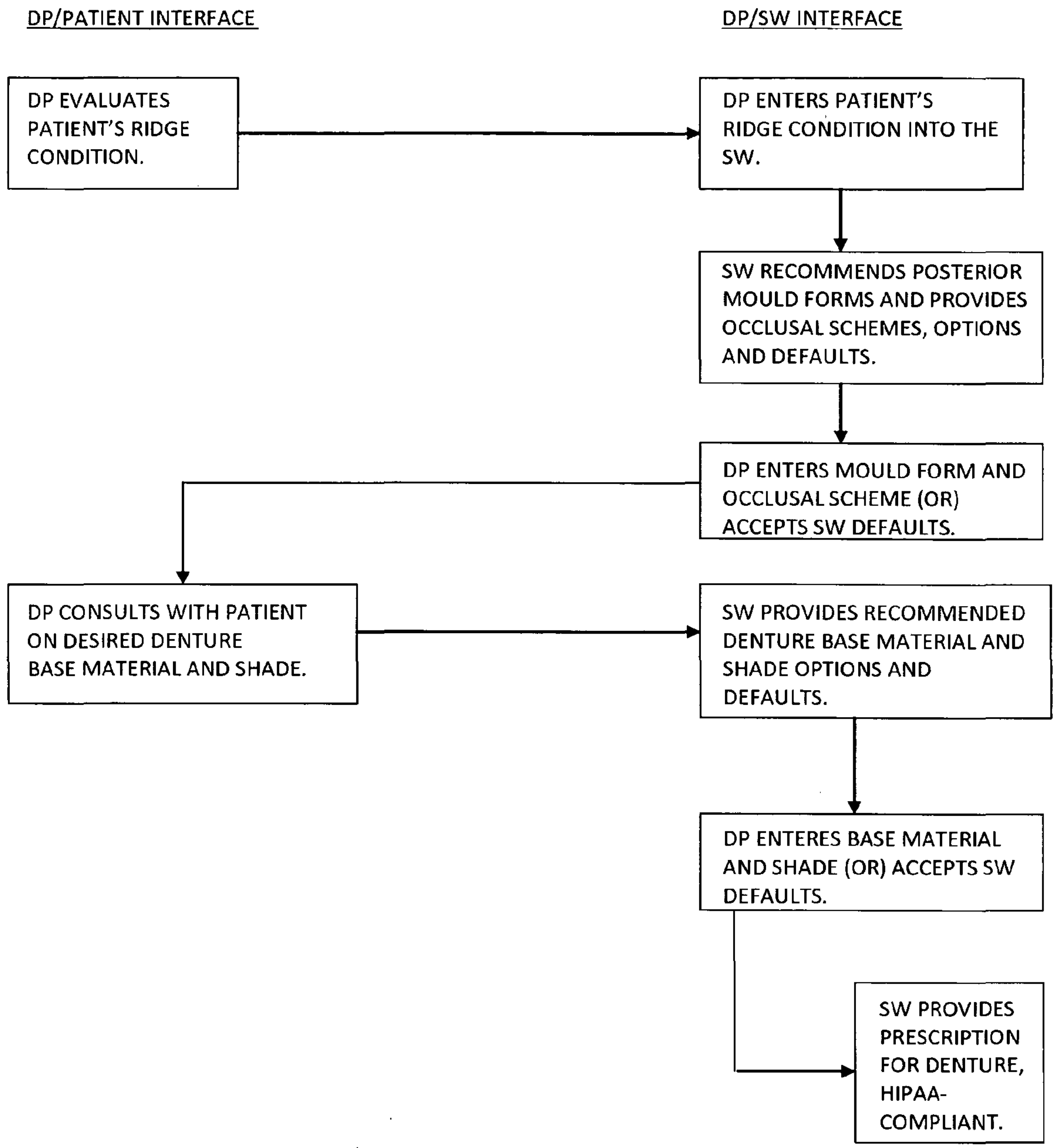


FIGURE 2

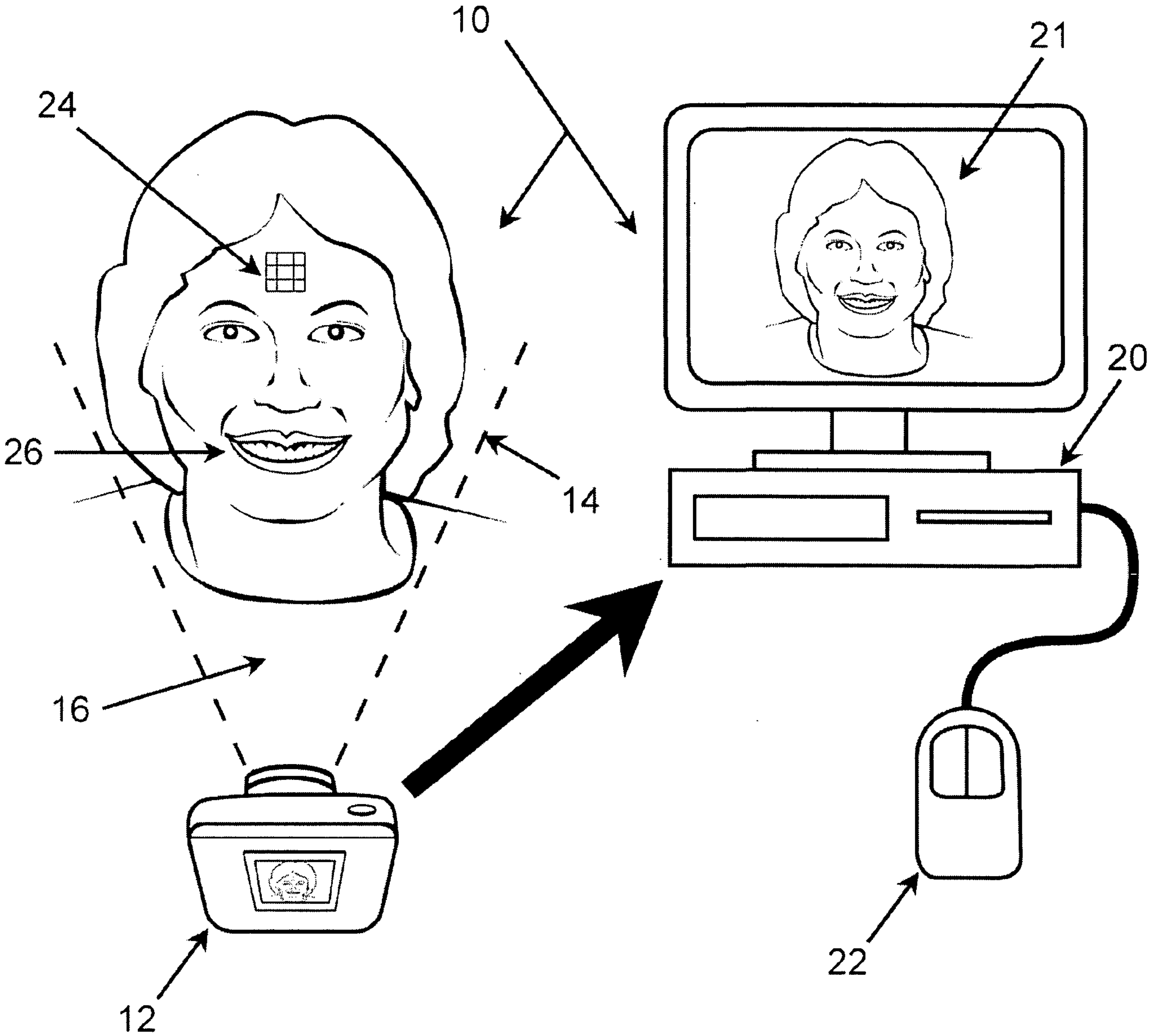


FIGURE 3

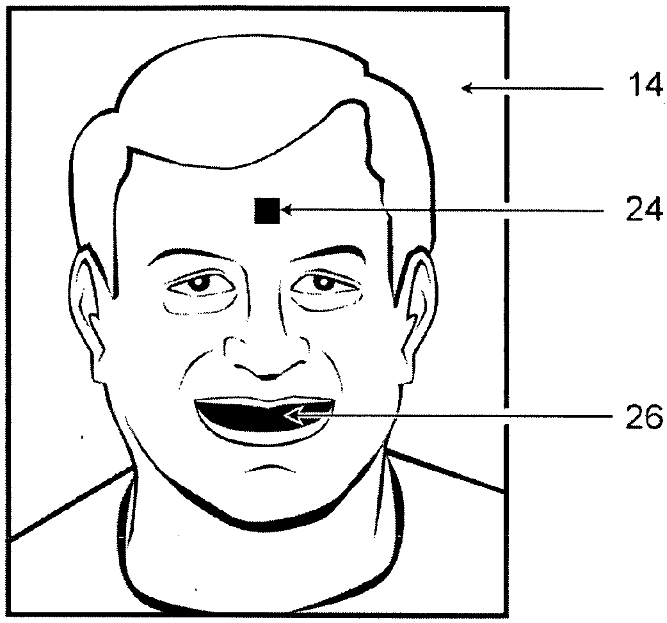


FIGURE 4A

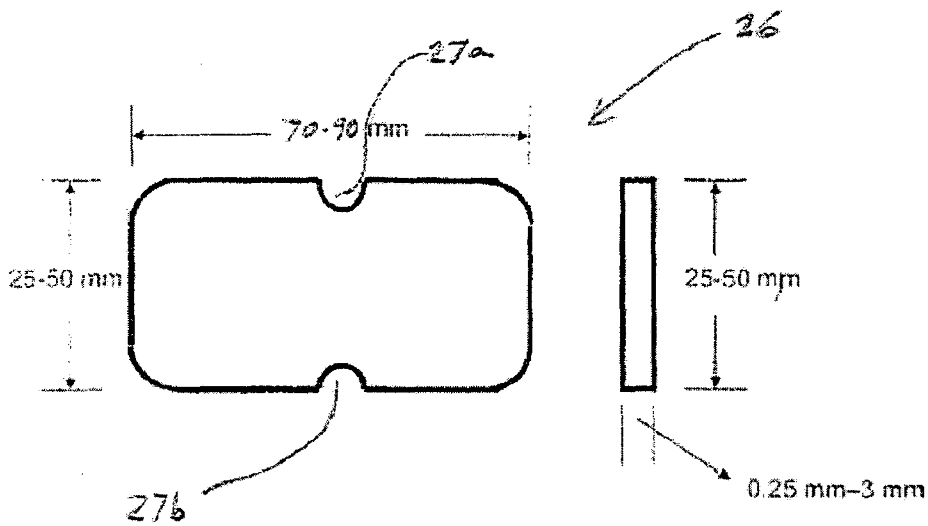


FIGURE 4B

FIG. 4B

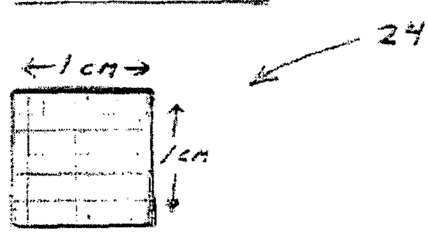


FIGURE 5

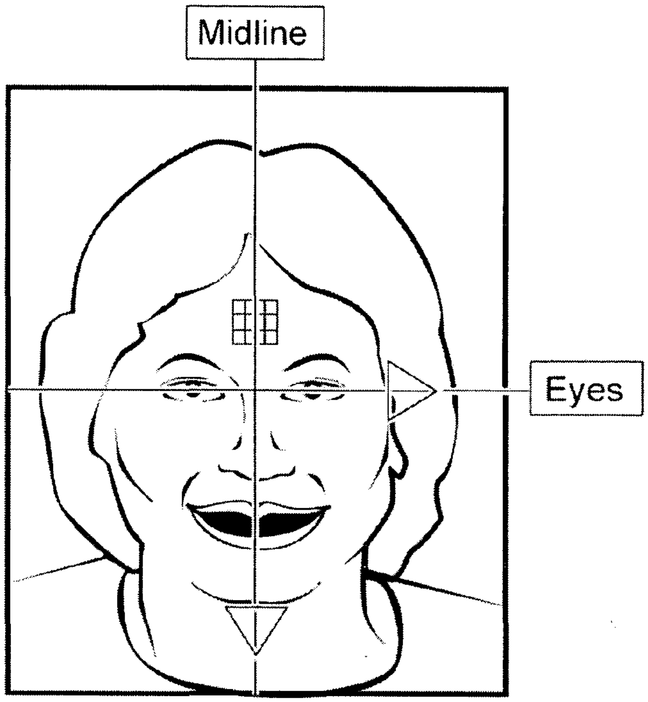
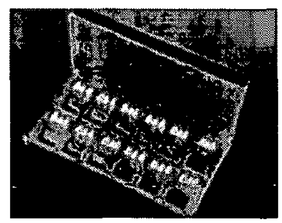


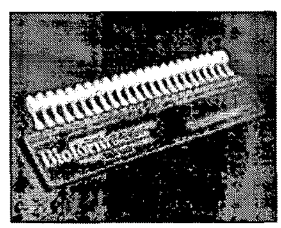
FIGURE 6

DENTAL SHADE GUIDES

TRUBYTE PORTRAIT IPN



TRUBYTE BIOBLEND IPN



TRUBYTE BIOFORM IPN

FIGURE 7

ANTERIOR MOULD FORMS

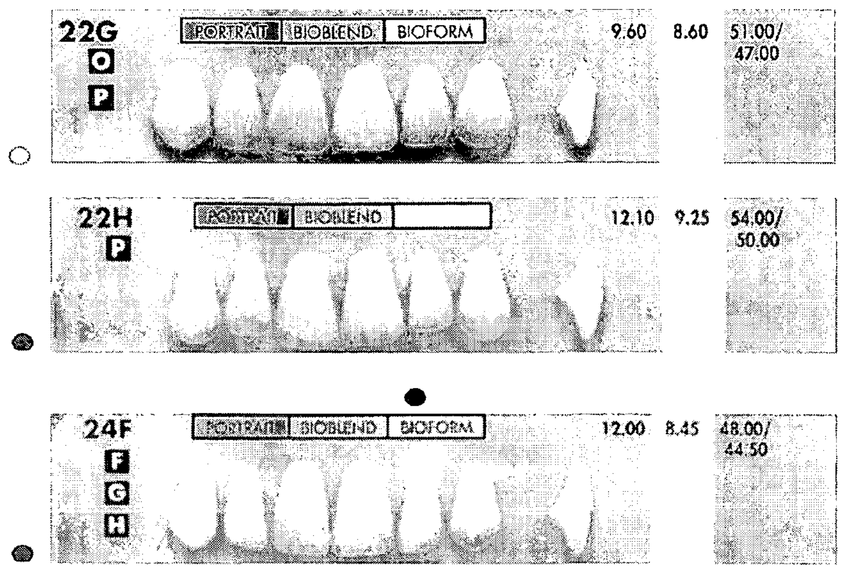
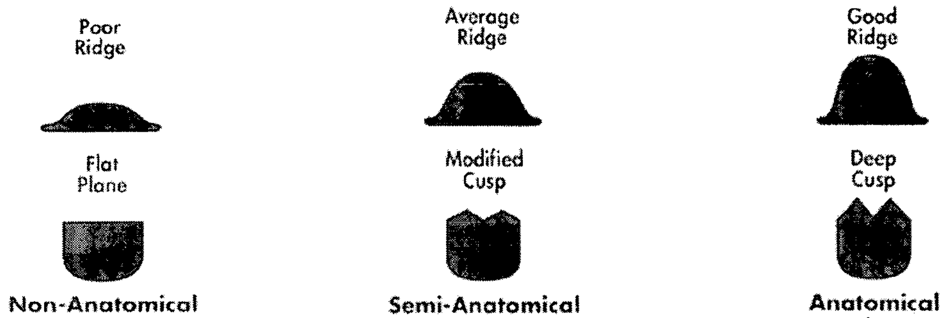


FIGURE 8

EDENTULOUS RIDGE CONDITION



(Select One)

Non-Anatomical
- ○ Portrait IPN 0^{0}Posteriors
- ○ 0^{0} Monoline

(Select One)

Semi-Anatomical
- ○ 22^{0} Biostabil
- ○ 20^{0}
- ○ 10^{0} Anatoline

(Select One)

Anatomical
- ○ 40^{0} Euroline
- ○ 33^{0}
- ○ 30^{0} PT

FIGURE 9

OCCLUSAL SCHEMES

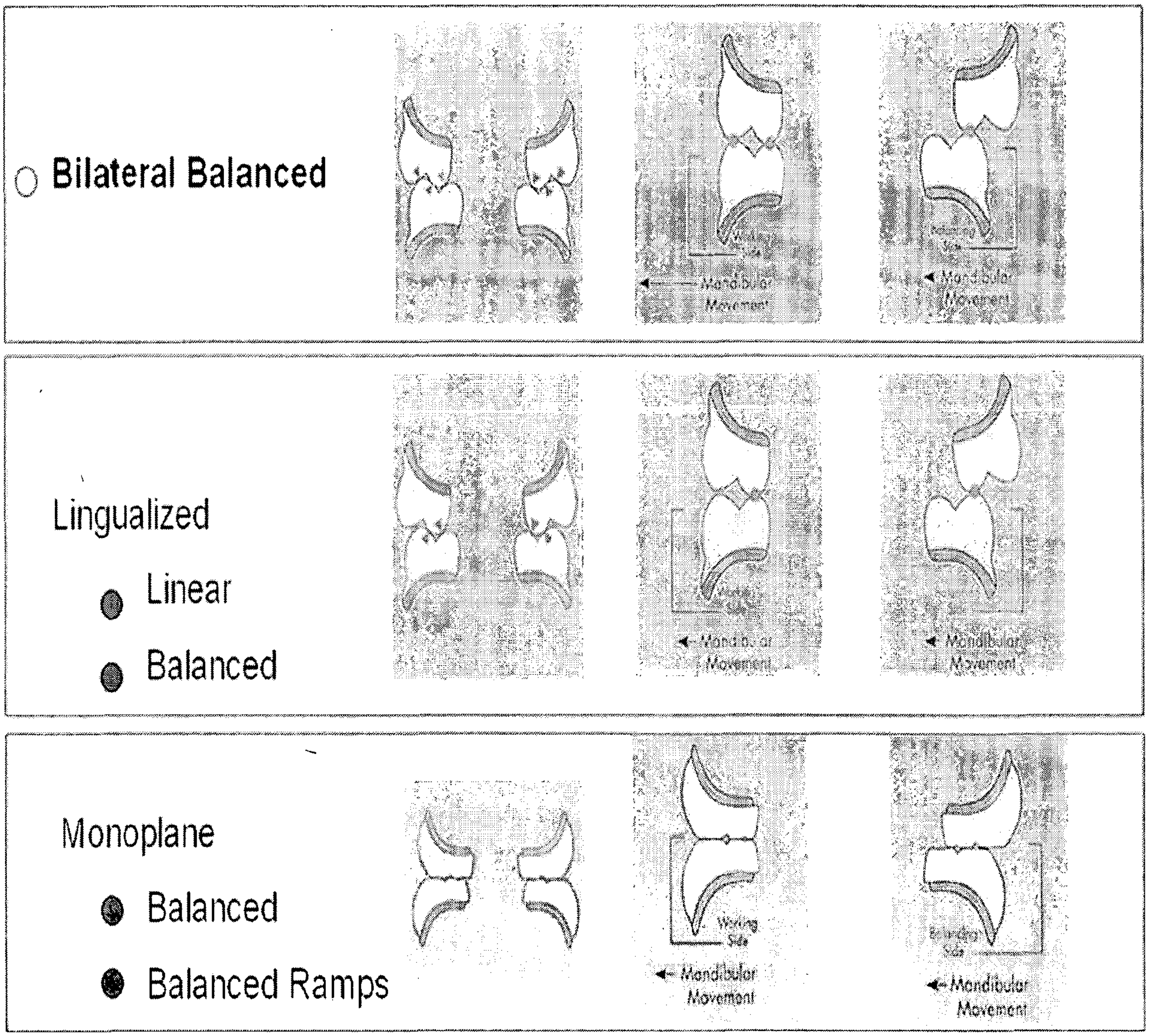
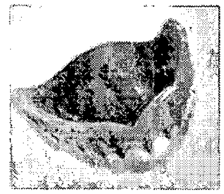


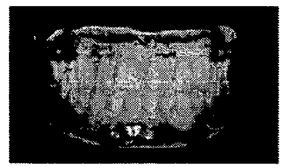
FIGURE 10

DENTURE BASEPLATE MATERIAL

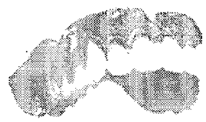
LUCITONE 199



ECLIPSE CLEAR BASE PLATE AND
LUCITONE 199



ECLIPSE



DENTURE BASEPLATE SHADE

BasePlate

ORIGINAL

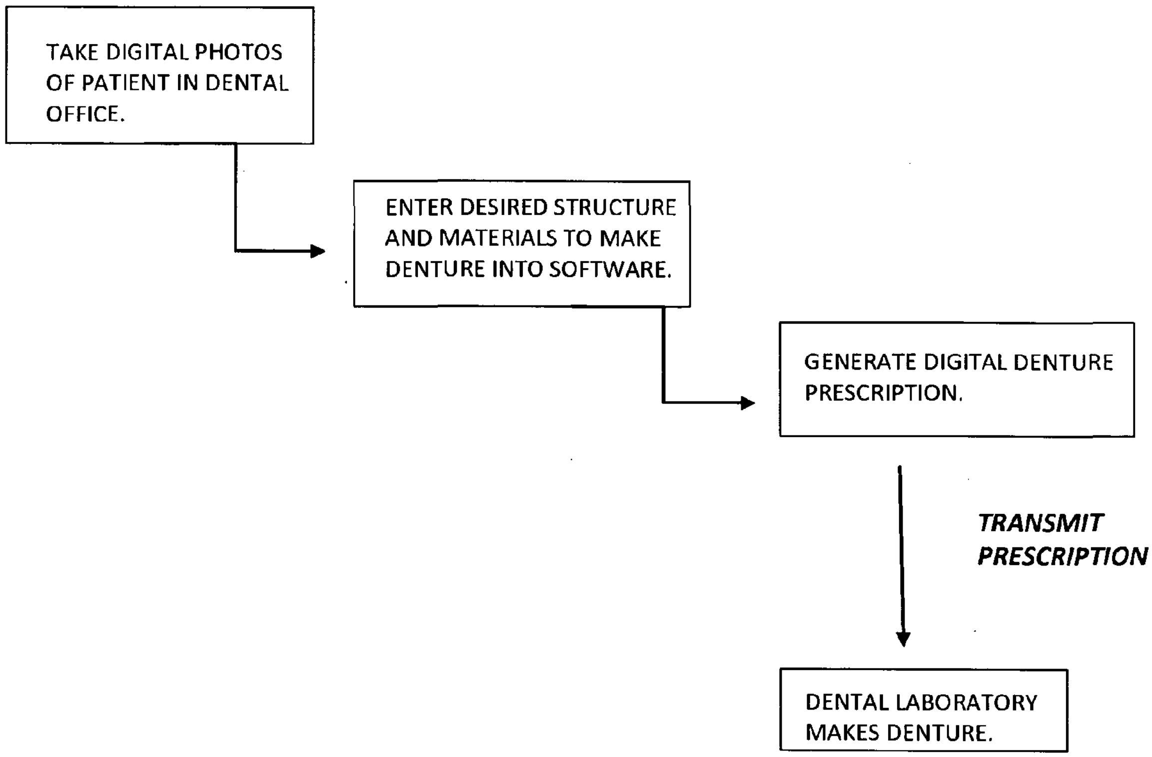
LIGHT PINK

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 :

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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
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

Form PCT/ISA/210 (second sheet) (April 2005)

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

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61/098,255 19 September 2008 (19.09.2008) US

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(74) Agent: **HØIBERG A/S**; St. Kongensgade 59A, DK-1264 Copenhagen K (DK).

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(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, SM, 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))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) **Title**: TOOLS FOR CUSTOMIZED DESIGN OF DENTAL RESTORATIONS

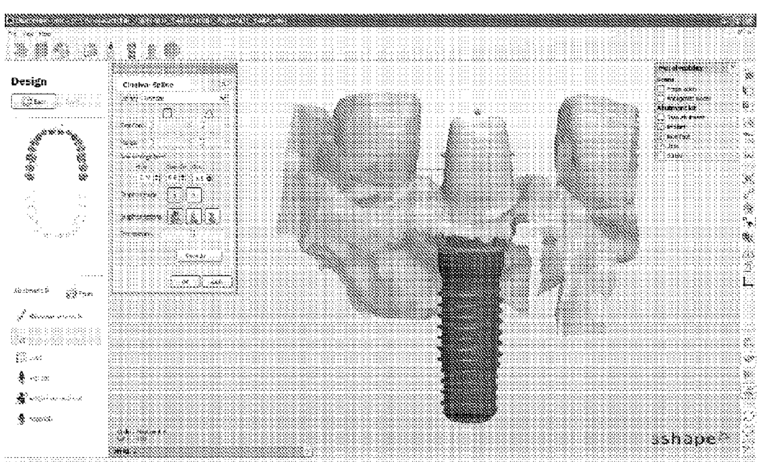

Fig. 15

(57) **Abstract**: The present invention relates to tools in a system for the design of customized three- dimensional models of dental restorations for subsequent manufacturing. Dental restorations such as implant abutments, copings, crowns, wax-ups, bridge frameworks,. Moreover, the invention relates to a computer-readable medium for implementing such a system on a computer.

WO 2010/031404 A1

Tools for customized design of dental restorations

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

Background of invention

The present invention is related to the field of designing and manufacturing of dental restorations such as crowns, bridges, copings, abutments and implants. When a patient requires a dental restoration the dentist will prepare the teeth e.g. a damaged tooth is grinded down to make a preparation where the crown is glued onto. An alternative treatment is to insert implants (titanium screws) into the jaw of the patient and mount crowns or bridges on the implants.

CAD technology for manufacturing dental restorations is rapidly expanding resulting in improved quality, reduced cost and facilitation of the possibility to manufacture in attractive materials otherwise not available. The first step in the CAD manufacturing process is to create a 3-dimensional dental model of the patient's teeth. This is provided by 3D scanning of one or both of the dental gypsum models or by scanning impressions of the teeth. The 3-dimensional replicas of the teeth are imported into a CAD program, where the entire dental restoration or 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.

Systems for designing dental restorations are known in the art, e.g. 3Shape DentalDesigner™ and 3Shape AbutmentDesigner™, which are generally used by dental specialists such as dental technicians. Users of such design tool systems are working with a three dimensional dental model of the patient trying to fit the dental restoration model into the dental model. During dental restoration of a patients teeth the typical procedure could be to secure an implant abutment in the jaw of the patient, a coping is then attached (e.g. by glue) to the abutment and finally a crown is glued onto the coping. However, both abutment, coping and crown must be designed to fit the patient, both physically and visually. I.e. the abutment, the coping and the crown must be customized for each tooth of each patient.

In the following the term “dental restoration” can be an implant abutment, a coping, a crown or any combination of these. Correspondingly a “dental restoration model” can be an abutment model, a coping model, a crown model or any combination of these.

In the design phase of a dental restoration a three dimensional model of the dental restoration is typically provided by the system and the task of the dental specialist is to shape the dental restoration model to provide a perfect fit in the dental model, whereby the patient can end up with a tooth implant that matches the other teeth of the patient. A dental specialist (i.e. a user of the system) is typically working with a dental model with at least one attached dental restoration model on a screen and the 3D models can typically be rotated around any axis, zoomed, panned and the like. Thus the user will typically be able to specify and change the orientation and viewing angle of the dental model and the dental restoration model. The task of a user is to shape and customize the dental restoration model into the dental model by translating, rotating, dragging, tilting, widening and/or narrowing the 3D dental restoration model (which preferably is fixed in the dental model). This is typically provided by use of an electronic screen pointing tool, such as a mouse, a ball pen or the like. In the following any reference to a “mouse cursor” or a “mouse marker” is a reference to the element on the screen representing the electronic screen pointing tool.

The dental restoration model can be customizably shaped by means of the pointing tool by shaping (“dragging”) the dental restoration model with origin in specific points on the dental restoration model. These points are in the following termed “control points” and can be seen in fig. 1. The control points are typically located in carefully and preferably automatically selected positions on the dental restoration model. For example in fig. 1 showing an abutment model where the control points are located on the top center, each of the four sides and around the lower bottom rim (i.e. the lower collar of the abutment).

Summary of invention

When creating a dental restoration model certain rules must be applied, for example in terms of distance to adjacent teeth and gingival ridge and integration into the gingival. Measuring and checking these distances can be a cumbersome process during the design and creation of a dental restoration model, thus an object of the invention is to provide an intuitive and quick indication of distances between neighbouring and adjacent objects in the process of creating a custom dental restoration.

This is achieved by a system for designing at least one dental restoration, said system having a display, such as a computer screen, and comprising:

- means for acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted,
- means for displaying a plurality of control points at the three dimensional model of the dental restoration, the control points preferably located at the edges of the dental restoration model and each of said control points providing means for manually customizing the dental restoration model.

The invention further relates to method for designing at least one dental restoration at a display, a display such as a computer screen, said method comprising the steps of:

- acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted,
- displaying a plurality of control points at the three dimensional model of the dental restoration, the control points preferably located at the edges of the dental restoration model and each of said control points providing means for manually customizing the dental restoration model.

In a further embodiment of the invention means for displaying an arrow at at least one of the control points is provided. The length of said arrow is preferably determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated.

Thus, for a dental specialist in the process of creating a dental restoration this invention provides a quick real-time distance indicator when shaping the dental restoration model. For example when the dental specialist is varying the width of the dental restoration model by dragging the model in a control point, an arrow with origin in the specific control point will, by the length of said arrow, indicate a certain distance from the dental restoration model. The length of the arrow is determined by the user (i.e. the dental specialist in this case), thus if the user in advance knows that the distance from the dental restoration to the neighbouring tooth should be 1.5 mm, the length of the arrow is specified to 1.5 mm and when widening the dental restoration model by dragging a control point, the arrow with origin in said control point will indicate for the user when the distance to the neighbouring tooth is 1.5 mm. Thus, adjusting a dental restoration model to the correct width can be provided within seconds by the system and method according to the invention.

In a further embodiment of the invention means for displaying a grid at at least one control point is comprised. The size of the grid is determined by a user defined value. This grid provides the user with yet another way of measuring the distance to adjacent objects. The grid can have the appearance of a square divided into smaller and preferably equally sized squares, for example the grid can be a square of height and width of 1 mm divided into 4 squares of height and width 0.5 mm, or 16 squares of height and width 0.25 mm. An example of a grid can be seen in fig. 7. Unlike an arrow a grid can provide an indication of a distance between two unaligned points, i.e. the grid can provide the orthographic projection distance between two points.

A second embodiment of the invention relates to a system for designing at least one dental restoration, said system having a display, such as a computer screen, and comprising:

- means for acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted, and

- means for displaying an arrow adjacent to the edge of the dental restoration model, the length of said arrow determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated, and/or

- means for displaying a grid adjacent to the edge of the dental restoration model, the size of said grid determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated.

Correspondingly the invention relates to a method for designing at least one dental restoration at a display, a display such as a computer screen, said method comprising the steps of:

- acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted, and

- displaying an arrow adjacent to the dental restoration model, the length of said arrow determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated, and/or

- displaying a grid adjacent to the dental restoration model, the size of said grid determined by a user defined value, whereby the distance to neighbouring objects can be indicated.

Preferably the arrow and/or the grid is located at the edge of the dental restoration model, preferably pointing towards a neighbouring object. Naturally the arrow and/or the grid may also be displayed adjacent to, preferably at the edge of, a neighbouring object (such as the dental model).

Detailed description of the invention

If each control point of the dental restoration model is showing an arrow or a grid, a confusing picture will be provided to the user. Thus in a preferred embodiment of the invention an arrow or a grid of a control point is only displayed under certain circumstances, preferably when the control point is activated. In a preferred embodiment activation of a control point is provided when the mouse cursor is close to a control point. “Close to” in the meaning of within a certain number of pixels on the screen and/or within a certain distance from the control point. Thus, an arrow or a grid of a control point is preferably only visible when the mouse marker is close to said control point. In another embodiment of the invention an arrow or a grid is only visible when the mouse marker is close to the origin of said arrow or grid.

In specific embodiments of the invention an arrow or grid is only visible when the mouse cursor is within a distance of preferably 10 pixels from a corresponding control point and/or the origin of said arrow or grid, such as within a distance of 100 pixels, such as within a distance of 80 pixels, such as within a distance of 60 pixels, such as within a distance of 40 pixels, such as within a distance of 30 pixels, such as within a distance of 20 pixels, such as within a distance of 15 pixels, such as within a distance of 12 pixels, such as within a distance of 8 pixels, such as within a distance of 6 pixels, such as within a distance of 5 pixels, such as within a distance of 4 pixels, such as within a distance of 3 pixels, such as within a distance of 2 pixels, such as within a distance of 1 pixel from a corresponding control point and/or the origin of said arrow or grid.

The length of an arrow or the size of a grid can be defined by the user, e.g. by a graphical menu. However, means for varying the length of an arrow or the size of a grid can advantageously be provided to the user simultaneous with an activation of a control point. Thus, in a preferred embodiment of the system the length of an arrow or the size of a grid can be adjusted when a control point is activated. This adjustment can preferably be provided by means of user interaction, such as a screen pointing tool action, e.g. by turning the scroll wheel of the mouse. In this case a specific revolution of the scroll wheel is transferred to a specific increase or decrease of the length of the arrow or the size of the grid. For example a revolution of 5 degrees of the scroll wheel could correspond to a change in 0.1 mm in the length of an arrow or the size of a grid.

Correspondingly for other types of screen pointing tools with or without variable buttons, scroll wheels and/or the equivalents of that. For practical reasons the numerical value of the length of the arrow or the size of the grid may be displayed to the user on the screen concurrently with the user interaction, e.g. the user can see the numerical value of the length of an arrow while turning the scroll wheel of the mouse.

When customizing the dental restoration model in a dental model it might be necessary to both expand, tilt and rotate the dental restoration model. A solution where each control point has only one functionality (e.g. the functionality of “rotation”) requires a great number of control points on the dental restoration model, possibly creating a confusing Graphical User Interface (GUI) for the user. In a preferred embodiment of the invention the functionality of at least one control point is variable, i.e. at least one of the control points has more than one function and the user can shift between these functions. Shifting the functionality of a control point can be provided in numerous ways in the GUI (e.g. by means of menus, buttons and/or the like). However, for the user a quick shift in functionality is advantageous, preferably without moving the mouse away from the control point, i.e. the user can preferably change the functionality of a control point when said control point is activated. For practical reasons the specific functionality of a control point can be indicated by a symbol on the screen to ease the user interaction. E.g. a specific symbol near a control point corresponds to a specific current functionality of the control point. Examples of functionality symbols are illustrated in fig. 14.

Furthermore, the functionality of a control point can preferably be changed by some specific activation of the mouse. A known specific activation is the “double-click” of a mouse button. Another specific activation is a “quick click” on a mouse button. By a “quick click” is understood a click on a mouse button executed within a certain time interval, for example with 0.5 seconds. I.e. the mouse button is activated in a time period less than the specified time interval. If the click execution is slower (i.e. the mouse button is activated in a time period longer than the specified time interval) nothing will happen. The time interval may be predefined and/or may be specified by a user. This “quick click” feature greatly enhances the dental restoration modelling experience for the user. Within seconds the dental restoration model can be dragged, widened, tilted and/or rotated by just few clicks on the mouse.

However, not all possible functionalities of a control point are always relevant. For example when the dental model and the dental restoration model are seen from the side. In this case a rotation of the dental restoration around the long axis is irrelevant to the user. And when a dental restoration model is seen from the top a variation of the height of the dental restoration is also irrelevant for the user. Thus, in a preferred embodiment of the invention the functionality of at least one control point is depending on the orientation of the dental restoration model. I.e. orientation in the meaning of the view angle of the dental restoration model seen by the user.

The orientation of the dental model and the dental restoration model is also relevant in other circumstances. The user will typically shape the dental restoration model when viewed along with the dental model. However, because the dental restoration is typically located between adjacent teeth the dental model can block the view of the dental restoration model for the user for certain view angles. Thus, the display of at least a part of the dental model is preferably depending of the orientation of the dental model, i.e. the view angle for the user. This dental restoration view blocking can preferably be solved by letting at least part of the dental model be invisible for certain orientations, preferably the invisible part of the dental model is the part that is between the user and the dental restoration model. Thereby the dental restoration model can be seen by the user for any orientation of the dental model.

In one embodiment of the invention the control points of the dental restoration model are a central part of the system. However, the appearance of all the control points can disturb the image of the dental restoration model when trying to create the perfect fit into the dental model. In a preferred embodiment of the invention the control points are only visible when the mouse marker (cursor) is within a specific distance from the dental restoration model. This specific distance can be a specific number of pixels on the screen or a specific distance related to the dental model and the dental restoration model. The dental model is a replica of a patient's teeth, thus the specific dimensions of the dental model are known exactly and at least one coordinate system is embedded in the system according to the invention. Thus, it can be specified in the system that the control points are only visible when the mouse marker is within a distance of a specific number of millimetres.

In specific embodiments of the invention the control points are only visible when the mouse cursor is within a distance of preferably 10 pixels from the dental restoration model, such as within a distance of 500 pixels, such as within a distance of 300 pixels, such as within a distance of 200 pixels, such as within a distance of 100 pixels, such as within a distance of 80 pixels, such as within a distance of 60 pixels, such as within a distance of 40 pixels, such as within a distance of 30 pixels, such as within a distance of 20 pixels, such as within a distance of 15 pixels, such as within a distance of 12 pixels, such as within a distance of 8 pixels, such as within a distance of 6 pixels, such as within a distance of 5 pixels, such as within a distance of 4 pixels, such as within a distance of 3 pixels, such as within a distance of 2 pixels, such as within a distance of 1 pixel from the dental restoration model.

A situation where the user is working on at least two dental restoration models in the same dental model can occur. This can for example be the case when two adjacent abutments are being designed. In this case the appearance of control points in both dental restoration models can confuse the image for the user. This can preferably be overcome by only showing the control points on the dental restoration model closest to the mouse marker.

A significant part of a dental restoration may be located below the gingival, especially when the dental restoration mode is an abutment model. Thus, when customizing a dental restoration model in a dental model, a part of the dental restoration model is hidden by the gingival of the dental model. It was previously indicated that if the dental model is blocking the view of the dental restoration model the blocking part of the dental model would advantageously become invisible to the user. However this is not a good solution in all cases, because if the dental model was invisible when trying to shape the dental restoration model to fit into the gingival of dental model, a perfect fit would be almost impossible. This can be solved by changing the transparency of the dental model. Thus, in a preferred embodiment of the invention the transparency of the dental model is variable. The transparency of the dental model is preferably automatically adjusted when needed, for example when the mouse cursor is close to a control point below the surface of the dental model. This is very helpful to the user, because the entire dental restoration model and the control points are thereby visible and the dental restoration model can be shaped to fit a dental model that is still visible but transparent. The transparency can for example be adjusted to 50%, where 0%

transparency is the normal image, i.e. see through is impossible, and 100% transparency is totally invisible.

The systems and methods according to the invention furthermore regard the embodiments wherein the dental restoration is an implant abutment, a coping, a crown and/or any combination of these. Correspondingly, the invention regards the embodiments wherein a dental restoration model is an abutment model, a coping model, a crown model or any combination of these.

The invention furthermore includes a computer program product having a computer readable medium, said computer program product comprising means for carrying out any of the listed methods.

Description of Drawings

The invention will now be explained in greater details with reference to the figures showing embodiments of the invention where the dental restoration is one or more abutments.

Fig. 1	shows a 3D model of a dental restoration model, in this case an implant abutment with 6 control points, the mouse marker is close to the abutment,
Fig. 2	shows a 3D model of the abutment in fig. 1, but the control points are hidden because the mouse marker is not near the abutment,
Fig. 3	shows two abutments with control points on only the left abutment where the mouse marker is located,
Fig. 4	shows an abutment surrounded and partly hidden by a dental model,
Fig. 5	shows the abutment in fig. 4; when the mouse marker is close to the abutment the dental model becomes transparent whereby control points beneath the surface of the dental model become visible,
Fig. 6	shows an arrow in one of the control points, the arrow having a user defined length indicating the distance between an implant abutment and the adjacent tooth in the surrounding dental model,
Figs. 7 & 8	shows a grid in a control point, the grid having user defined partitions into squares indicating the distance between an implant abutment and the adjacent tooth (fig. 7) and the gingival ridge (fig. 8) respectively,
Fig. 9	shows an abutment and the surrounding dental model,
Fig. 10	is a rotated view of fig. 9 where the part of the dental model obstructing a user the view of the abutment is invisible,
Fig. 11	shows an abutment surrounded by a dental model and a grid at one of the lower control points with a translational functionality, and
Fig. 12	shows the abutment in fig. 13 rotated to a top view where the control point, that in fig. 13 was a translational control point and displaying a grid when activated, has now changed functionality to become a rotational control point because of the changed point of view.
Fig. 13	shows a close up of a control point in fig. 12,
Fig. 14	shows four views of the same abutment being customized, the control points in the top part shift functionality, and

Fig. 15 is a screen shot of one embodiment of the system according to the invention.

Detailed description of the drawings

A 3D model of an implant abutment is shown in figs. 1 and 2. When the finished abutment is inserted into the mouth of the patient, the threaded part 5 of the abutment goes into the jaw of the patient with the collar 6 just below the gingival. A crown is glued onto the abutment. In fig. 2 the sides 7, 7' and the top part 8 of the abutment is indicated. In fig. 1 an abutment model corresponding to the abutment model in fig. 2 is shown along with a plurality of control points, 2, 2', 2", 3, 3', 4. The control points are located along the edges of the abutment model, i.e. round the collar 2, 2', 2", at the sides 3, 3' and at the top 4 of the abutment model. The control points are visible because the mouse cursor 1 is near the abutment model. In most of the figures the mouse cursor 1 is represented by a white arrow pointing up and left.

Fig. 3 shows two adjacent abutment models, however control points are only visible at the left abutment model because the mouse cursor 1 is located at said left abutment model.

Fig. 4 shows an abutment model surrounded by a dental model wherein the abutment model must be fitted. The mouse cursor 1 is in the bottom left corner of fig. 4. Part of the abutment model is hidden below the dental model, e.g. the collar of the abutment model is invisible. Fig. 5 shows the abutment and dental model of fig. 4 when the mouse cursor 1 is near the abutment model. The control points are now visible, also the three control points 2, 2', 2" round the collar of the abutment model, and the transparency of the dental model has changed whereby the previously hidden parts of the abutment model is now visible through the dental model.

Fig. 6 shows an abutment model surrounded by a dental model with visible control points. The mouse cursor is very close to one of the control points along the left side of the abutment, whereby an arrow 9 is visible. The length of the arrow 9 can be defined by the user, the length defined as the length from the origin to the tip of the arrow, the origin being the edge of the abutment model at the control point. The arrow 9 can thereby indicate a distance from the abutment to an object. In fig. 6 the arrow 9 is indicating the distance from the abutment to the adjacent tooth 11. Thus when customizing the abutment model, e.g. widening the abutment model by dragging the model in a control point, the arrow 9 can in real-time (i.e. concurrently with dragging the model) indicate the distance to the neighbouring tooth.

Fig. 7 shows a close up of an abutment model in a partly transparent dental model. The mouse cursor is close to a control point at the collar of the abutment model thereby initiating the display of the grid 10. The size of the grid 10 is preferably defined by the user, the size being the length of the sides of the grid. The arrow 9 shown in fig. 6 can indicate direct distances, whereas the grid 10 can indicate projected distances. For example the collar of an abutment must be a certain distance below the gingival. However the gingival might not be directly above the collar of the abutment. By the grid 10 shown in fig. 7 the orthographic projection from the top of the gingival between teeth to the abutment collar represented by a control point is indicated. Another example is shown in fig. 8 where a grid is shown to indicate the orthographically projected distance between the abutment collar represented by a control point and the gingival ridge 12.

Fig. 9 shows an abutment model surrounded by a dental model. If the view angle of these models was changed, e.g. by the user, the dental model would hide the abutment model when seen from the side. However, as shown in fig. 10, the system and method according to the invention can provide for that part of the dental model becomes invisible when blocking the view to the abutment model.

Fig. 11 shows an abutment model displaying a grid at a control point 2' at the abutment collar and near the mouse cursor. Fig. 12 shows the corresponding abutment model seen from above with the identical control point 2'. Near said control point 2' is no longer a grid because a grid would be irrelevant to the customization of the abutment model when the abutment model is seen from above. Instead a curved double-arrow 13 is shown near the control point 2'. This can be seen more clearly in fig. 13, which is a close up of the control point 2' and the arrow 13 in fig. 12. By dragging the control point 2' the abutment model can be rotated. This rotation can be necessary to align the top ridge of the abutment model with top ridges of adjacent teeth. Thus, the control point 2' has different functionalities depending on the orientation, i.e. the view angle for the user, of the abutment and dental models. Thereby the necessary number of displayed control points can be reduced, i.e. simplifying the view for the user and increasing the user-friendliness.

Fig. 14 shows the same abutment model four times illustrating that a control point can have different functionalities independent of the orientation of the abutment model. To the left the control point at the top of the abutment model has the functionality of increasing the height of the abutment model. The functionality is illustrated by a symbol with an arrow pointing up. However by just a single click on the mouse the functionality of the top control point in the second picture from the left has changed functionality to “tilt”, i.e. the abutment model can be tilted from side to side by dragging the control point. The tilt functionality is illustrated by arrows pointing to each side along the top edge of the abutment model. In the third picture from the left the abutment model has been tilted to the left and in the rightmost picture the functionality of the control point is changed back into variation of the height. This shift of functionality of a control point could very well be provided by other means, i.e. a drop down menu in the GUI or the like. However, by the preferred method of changing the functionality by a single click with the mouse, the design process is kept quick and simple, because the user does not have to move the mouse cursor on the screen, but can just keep the mouse cursor on one control point.

Fig. 15 is a screenshot example from one embodiment of the system according to the invention showing an abutment model surrounded by a dental model and a plurality of the menus, buttons and the like, all part of the GUI of the system. This is normal for any graphics design system. However, by the system and methods according to the invention the user-friendliness has been improved, because a plurality of features / tools that would normally be provided or changed by means of buttons and pull-down menus, in this case is automatically provided or provided by a few clicks on a mouse button.

Claims

1. A system for designing at least one dental restoration for tooth crowns, said system having a display, such as a computer screen, and comprising:
   - means for acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted,
   - means for displaying a plurality of control points at the three dimensional model of the dental restoration, the control points preferably located at the edges of the dental restoration model and each of said control points providing means for manually customizing the dental restoration model, and
   - means for displaying an arrow at at least one of the control points, the length of said arrow determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated, and/or
   - means for displaying a grid at at least one of the control points, the size of said grid determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated.

2. A system according to claim 1, wherein the dental restoration is an implant abutment, whereby the dental restoration model is an implant abutment model.

3. A system according to claim 1, wherein the dental restoration is a coping, whereby the dental restoration model is a coping model.

4. A system according to claim 1, wherein the dental restoration is a tooth crown, whereby the dental restoration model is a tooth crown model.

5. A system according to any of the preceding claims, wherein a control point is activated by moving the mouse cursor close to said control point, such as within a distance of 10 pixels from the control point.

6. A system according to any of the preceding claims, wherein the arrow or a grid of a control point is only displayed when said control point is activated.

7. A system according to any of the preceding claims, wherein the length of an arrow or the size of a grid can be adjusted by a user when a control point is activated, such as adjusted by means of the mouse scroll wheel.

8. A system according to any of the preceding claims, wherein the functionality of at least one control point is variable.

9. A system according to any of the preceding claims, wherein the functionality of at least one control point can be changed by a user when said control point is activated.

10. A system according to any of the preceding claims, wherein the functionality of at least one control point can be changed by a quick click on a mouse button when a control point is activated, a quick click being a single activation of a mouse button, such as a mouse button click executed within 800 milliseconds, such as within 600 milliseconds, such as within 500 milliseconds, such as within 400 milliseconds, such as within 300 milliseconds, such as within 200 milliseconds, such as within 100 milliseconds, such as within 50 milliseconds.

11. A system according to any of the preceding claims, wherein the functionality of at least one control point is depending on the orientation of the dental restoration model.

12. A system according to any of the preceding claims, wherein the view / display of at least a part of the dental model is orientation dependent.

13. A system according to any of the preceding claims, wherein at least a part of the dental model is invisible when said part of the dental model is between the user and the dental restoration model, whereby the dental restoration model is viewable and accessible for the user.

14. A system according to any of the preceding claims, wherein the control points are only visible when the mouse cursor is within a distance of 10 pixels from the dental restoration model.

15. A system according to any of the preceding claims, wherein at least two dental restoration models are shown simultaneously and wherein only the control points of the dental restoration model closest to the mouse cursor are visible.

16. A system according to any of the preceding claims, wherein the transparency of the dental model is increased when the mouse cursor is close to a control point beneath the occluding model surface, whereby the control point and the dental restoration model can be seen through the dental model.

17. A method for designing at least one dental restoration at a display, a display such as a computer screen, said method comprising the steps of:
   - acquiring and displaying a three dimensional model of the dental restoration and/or a three dimensional dental model wherein the dental restoration must be fitted,
   - displaying a plurality of control points at the three dimensional model of the dental restoration, the control points preferably located at the edges of the dental restoration model and each of said control points providing means for manually customizing the dental restoration model, and
   - displaying an arrow at at least one of the control points, the length of said arrow determined by a user defined value, whereby the distance between the dental restoration model and neighbouring objects can be measured or indicated, and/or
   - displaying a grid at at least one of the control points, the size of said grid determined by a user defined value, whereby the distance to neighbouring objects can be indicated.

18. A method according to claim 17, wherein the dental restoration is an implant abutment, i.e. the dental restoration model is an implant abutment model.

19. A method according to claim 17, wherein the dental restoration is coping, i.e. the dental restoration model is a coping model.

20. A method according to claim 17, wherein the dental restoration is a tooth crown, i.e. the dental restoration model is a tooth crown model.

21. A method according to any of claims 17 to 20, wherein a control point is activated by moving the mouse cursor close to said control point, such as within a distance of 10 pixels from the control point.

22. A method according to any of claims 17 to 21, wherein the arrow or a grid of a control point is only displayed when said control point is activated.

23. A method according to any of claims 17 to 22, wherein the length of an arrow or the size of a grid can be adjusted by a user when a control point is activated, such as adjusted by means of the mouse scroll wheel.

24. A method according to any of claims 17 to 23, wherein the functionality of at least one control point is variable.

25. A method according to any of claims 17 to 24, wherein the functionality of at least one control point can be changed by a user when said control point is activated.

26. A method according to any of claims 17 to 25, wherein the functionality of at least one control point can be changed by a quick click on a mouse button when a control point is activated, a quick click being a single activation of a mouse button, such as a mouse button click executed within 800 milliseconds, such as within 600 milliseconds, such as within 500 milliseconds, such as within 400 milliseconds, such as within 300 milliseconds, such as within 200 milliseconds, such as within 100 milliseconds, such as within 50 milliseconds.

27. A method according to any of claims 17 to 26, wherein the functionality of at least one control point is depending on the orientation of the dental restoration

model.

28. A method according to any of claims 17 to 27, wherein the view of at least a part of the dental model is orientation dependent.

29. A method according to any of claims 17 to 28, wherein at least a part of the dental model is invisible when said part of the dental model is between the user and the dental restoration model, whereby the dental restoration model is viewable and accessible for the user.

30. A method according to any of claims 17 to 29, wherein the control points are only visible when the (mouse) cursor is within a distance of 10 pixels from the dental restoration model.

31. A method according to any of claims 17 to 30, wherein at least two dental restoration models are shown simultaneously and wherein only the control points of the dental restoration model closest to the (mouse) cursor are visible.

32. A method according to any of claims 17 to 31, wherein the transparency of the dental model is increased when the mouse cursor is close to a control point beneath the occluding model surface, whereby the control point and the dental restoration model can be seen through the dental model.

33. A computer program product having a computer readable medium, said computer program product providing a system for designing at least one dental restoration, said computer program product comprising means for carrying out the steps of the methods according to any of the claims 17 to 32.

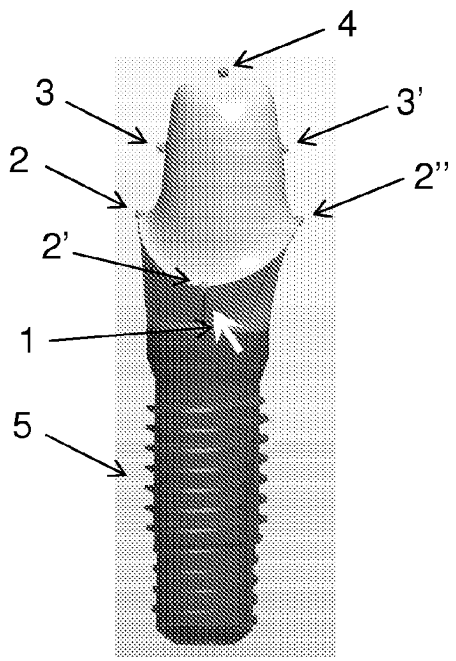

Fig. 1

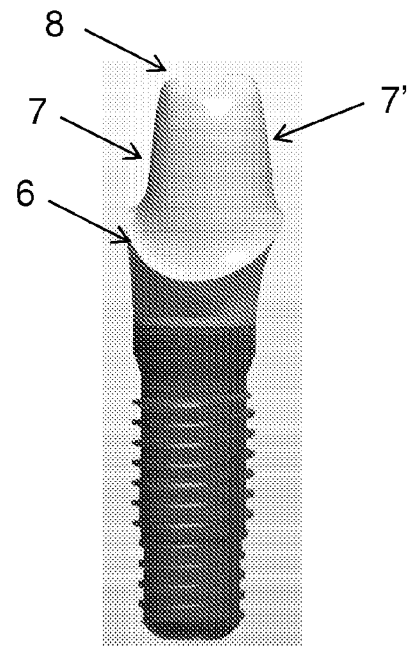

Fig. 2

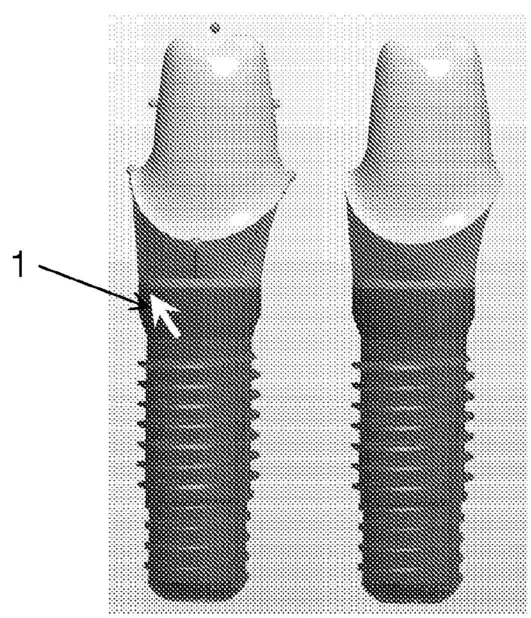

Fig. 3

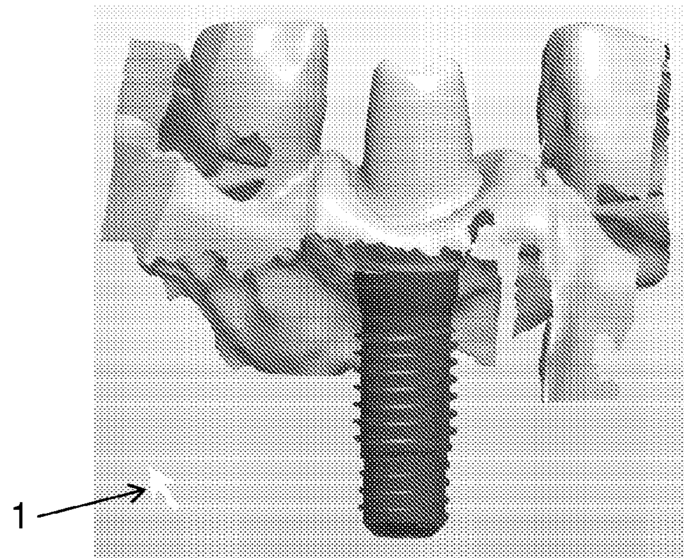

Fig. 4

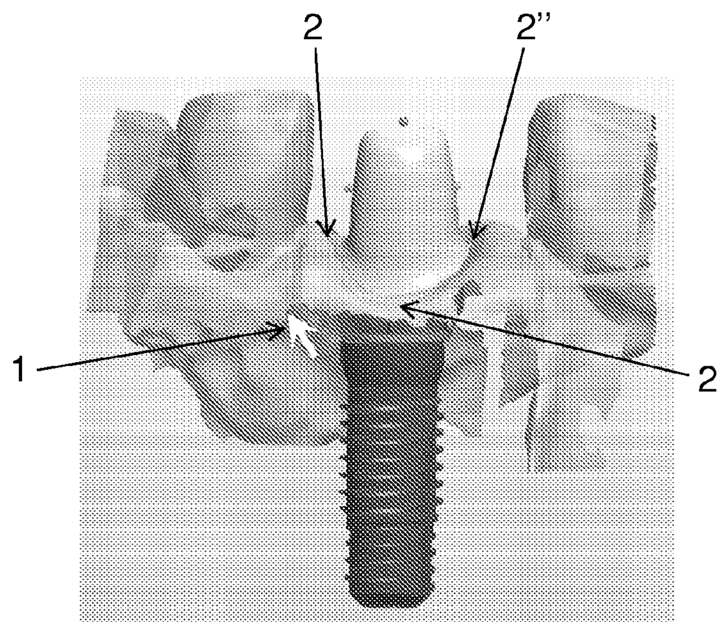

Fig. 5

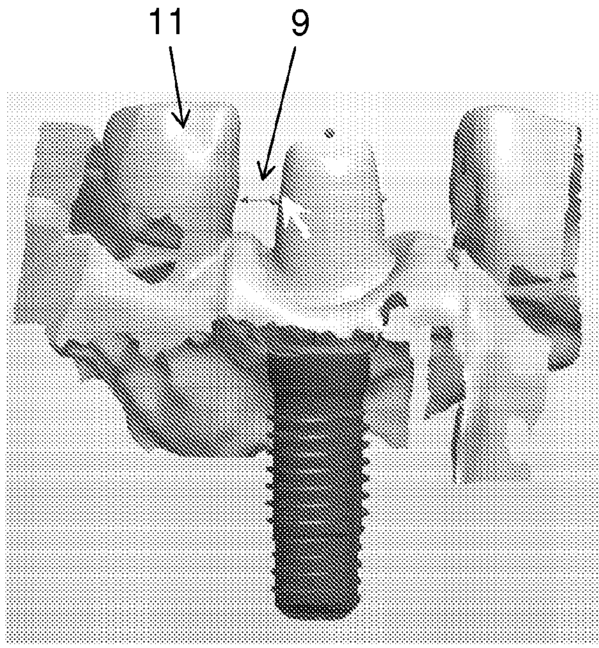

Fig. 6

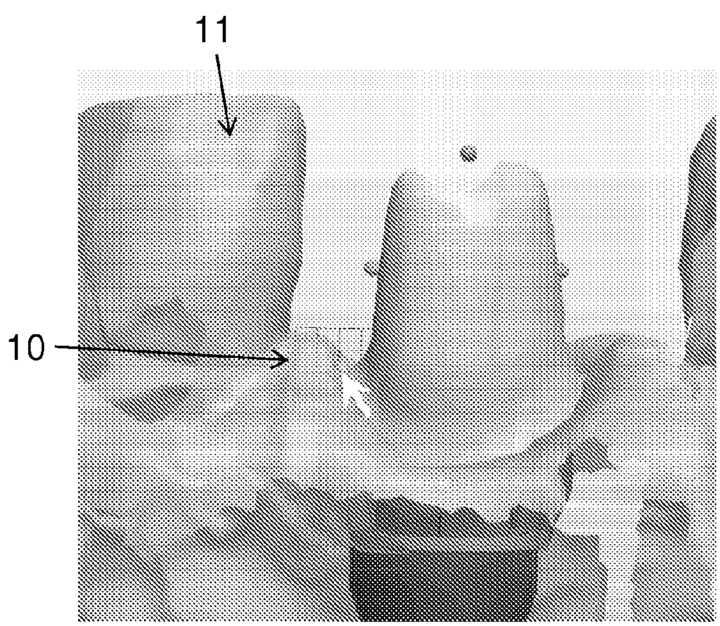

Fig. 7

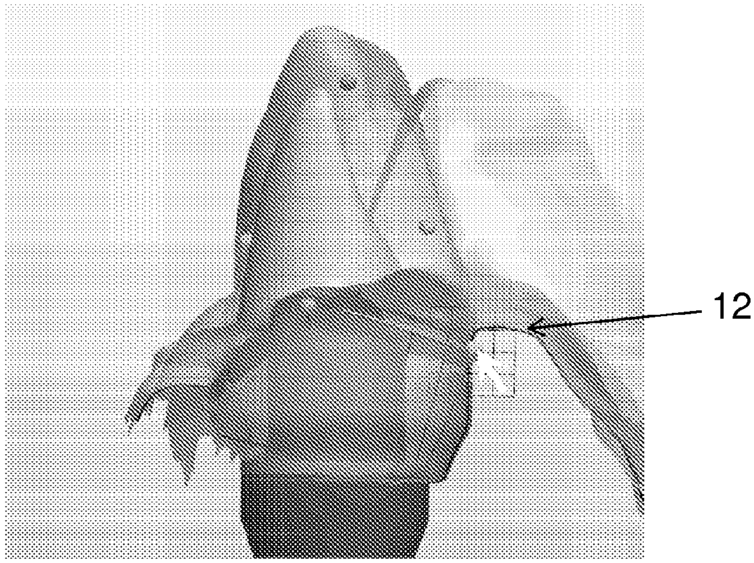

Fig. 8

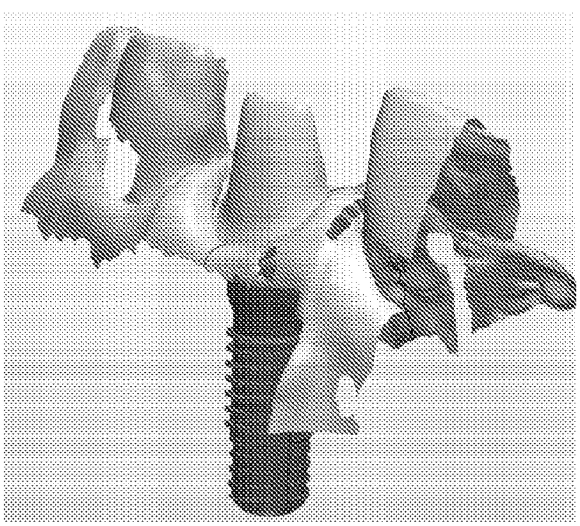

Fig. 9

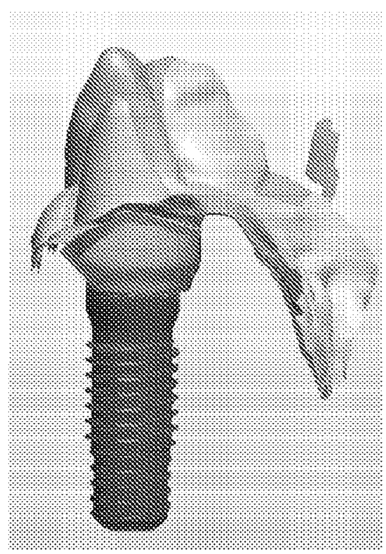

Fig. 10

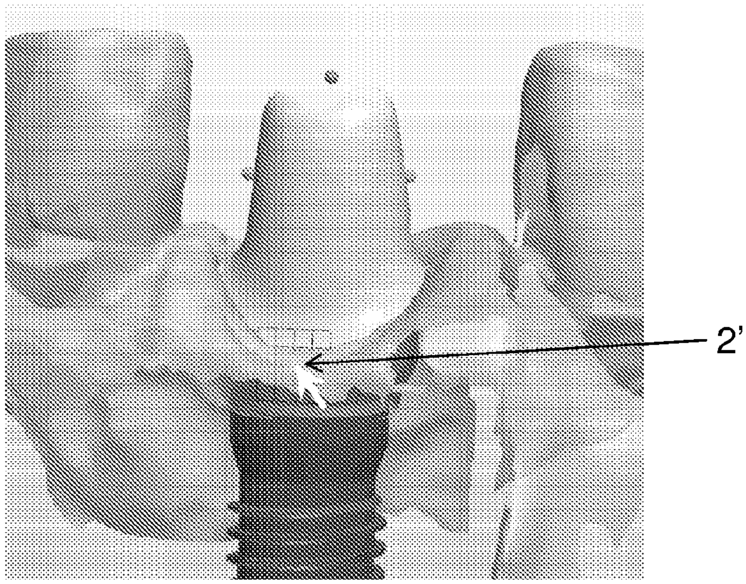

Fig. 11

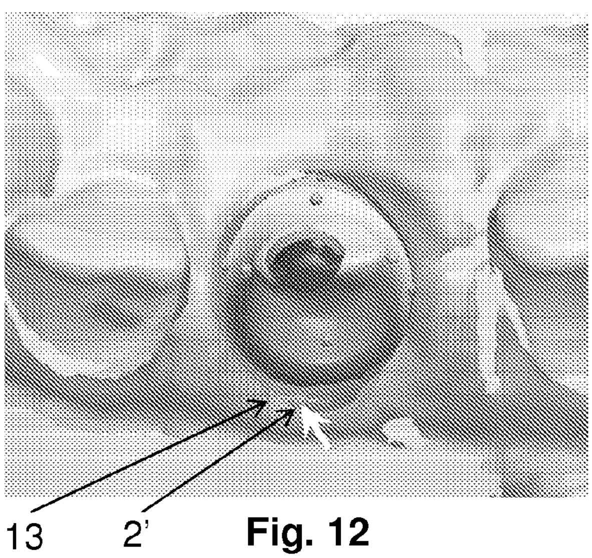

Fig. 12

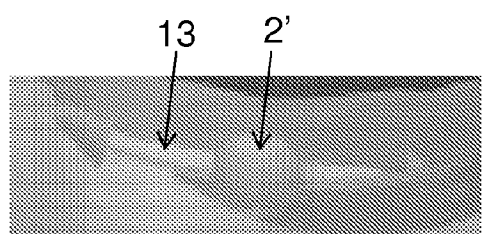

Fig. 13

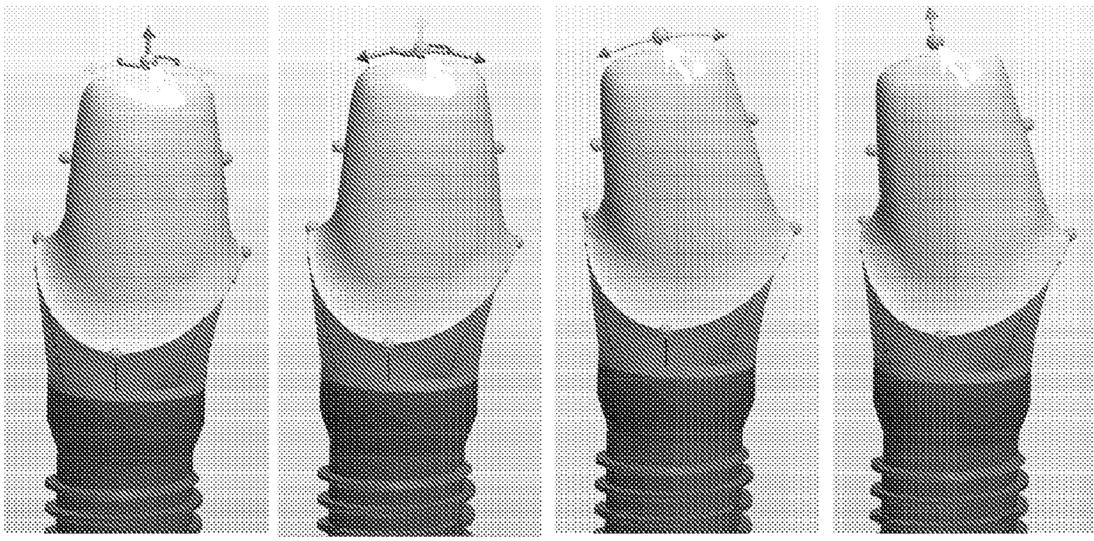

Fig. 14

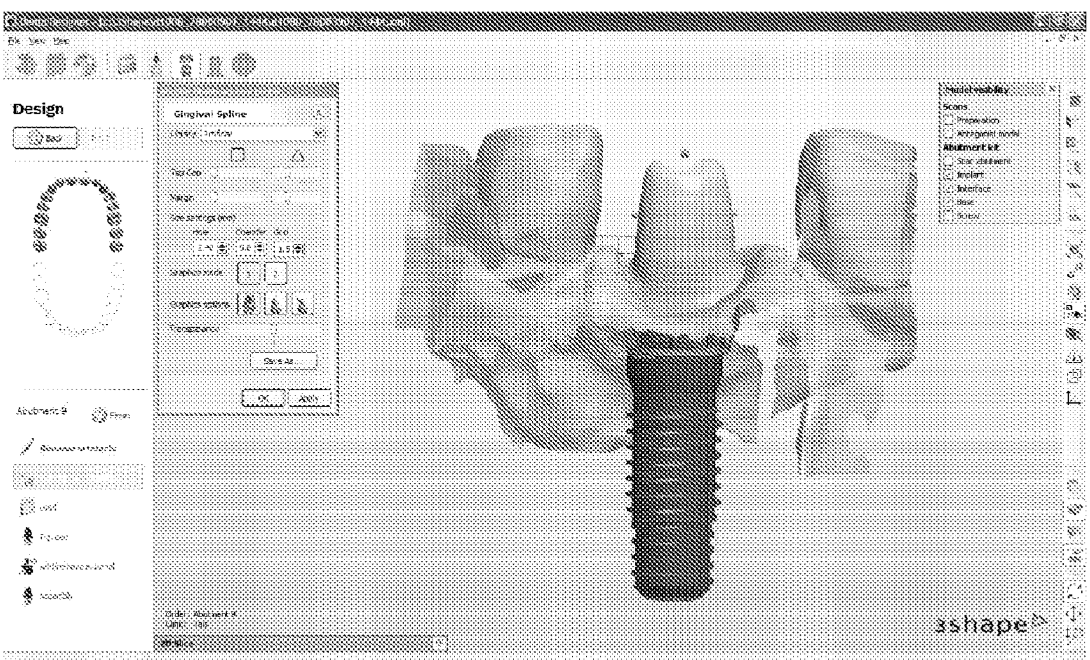

Fig. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2009/050243

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.
Y	WO 2008/066891 A2 (SENSABLE TECHNOLOGIES INC [US]; STEINGART BOB [US]; RAWLEY CURT [US];) 5 June 2008 (2008-06-05) paragraphs [0008], [0010], [0035] figures 5a,5b	1-33
Y	Martin Vogel: "AutoCad LT Tutorial - Seite 27" 5 May 2008 (2008-05-05), XP002569266 Retrieved from the Internet: URL:http://web.archive.org/web/20080505112041/http://www.martinvogel.de/acadlt/autocad-anleitung-tutorial-einfuehrung-27.htm> [retrieved on 2010-02-18] the whole document	1-33

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[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
18 February 2010	05/03/2010

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	Kerner, Bodo

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Form PCT/ISA/210 (second sheet) (April 2005)

International application No
PCT/DK2009/050243

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Martin Vogel: "AutoCad LT Tutorial - Seite 10" 5 May 2008 (2008-05-05), XP002569267 Retrieved from the Internet: URL:http://web.archive.org/web/20080505111948/http://www.martinvogel.de/acadlt/autocad-anleitung-tutorial-einfuehrung-10.htm> [retrieved on 2010-02-18] the whole document -----	1-33
Y	Martin Vogel: "AutoCad LT Tutorial - Seite 18" 5 May 2008 (2008-05-05), XP002569268 Retrieved from the Internet: URL:http://web.archive.org/web/20080505112014/http://www.martinvogel.de/acadlt/autocad-anleitung-tutorial-einfuehrung-18.htm> [retrieved on 2010-02-18] the whole document -----	1-33
Y	Martin Vogel: "AutoCad LT Tutorial - Seite 19" 15 May 2008 (2008-05-15), XP002569269 Retrieved from the Internet: URL:http://web.archive.org/web/20080515044246/http://www.martinvogel.de/acadlt/autocad-anleitung-tutorial-einfuehrung-19.htm> [retrieved on 2010-02-18] the whole document -----	1-33
Y	Martin Vogel: "AutoCad LT Tutorial - Seite 6" 15 May 2008 (2008-05-15), XP002569270 Retrieved from the Internet: URL:http://web.archive.org/web/20080515044241/http://www.martinvogel.de/acadlt/autocad-anleitung-tutorial-einfuehrung-06.htm> [retrieved on 2010-02-18] the whole document -----	1-33

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/DK2009/050243

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008066891 A2	05-06-2008	CA 2671052 A1	05-06-2008
		EP 2101677 A2	23-09-2009
		US 2008261165 A1	23-10-2008

Form PCT/ISA/210 (patent family annex) (April 2005)

Sheet No. ....

Box No. VIII (ii) DECLARATION: ENTITLEMENT TO APPLY FOR AND BE GRANTED A PATENT

The declaration must conform to the standardized wording provided for in Section 212; see Notes to Boxes Nos. VIII, VIII (i) to (v) (in general) and the specific Notes to Box No. VIII (ii). If this Box is not used, this sheet should not be included in the request.

Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent (Rules 4.17(ii) and 51*bis*.1(a)(ii)), in a case where the declaration under Rule 4.17(iv) is not appropriate:

In relation to the international application No. PCT/DK2011/050246

3Shape A/S is entitled to apply for and be granted a patent by virtue of the following:

an assignment from CLAUSEN, Tais; FISKER, Rune; DEICHMANN, Nikolaj; and ÖJELUND, Henrik to 3Shape A/S, dated 2, 3 and 4 October 2011 (02.10.2011, 03.10.2011, 04.10.2011)

☐ This declaration is continued on the following sheet, "Continuation of Box No. VIII (ii)".

PCT REQUEST

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0	**For receiving Office use only**	
0-1	International Application No.	**PCT/DK2011/050246**
0-2	International Filing Date	**2011-06-29**
0-3	Name of receiving Office and "PCT International Application"	**RO/DK**

0-4	**Form PCT/RO/101 PCT Request**	
0-4-1	Prepared Using	PCT Online Filing Version 3.5.000.225 MT/FOP 20020701/0.20.5.20
0-5	**Petition** The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	**Receiving Office (specified by the applicant)**	Danish Patent and Trademark Office (RO/DK)
0-7	**Applicant's or agent's file reference**	P2638PC00
I	**Title of Invention**	2D image arrangement
II	**Applicant**	
II-1	This person is	Applicant only
II-2	Applicant for	All designated States except US
II-4	Name	3SHAPE A/S
II-5	Address	Holmens Kanal 7, 4 1060 Copenhagen K Denmark
II-6	State of nationality	DK
II-7	State of residence	DK

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III-1	**Applicant and/or inventor**	
III-1-1	This person is	Applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	CLAUSEN, Tais
III-1-5	Address	Signe Löfdahls Väg 12 21851 Klagshamn Sweden
III-1-6	State of nationality	DK
III-1-7	State of residence	SE
III-2	**Applicant and/or inventor**	
III-2-1	This person is	Applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	FISKER, Rune
III-2-5	Address	Kaplevej 87 2830 Virum Denmark
III-2-6	State of nationality	DK
III-2-7	State of residence	DK
III-3	**Applicant and/or inventor**	
III-3-1	This person is	Applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	DEICHMANN, Nikolaj
III-3-5	Address	Järnolofs Väg 10 21851 Klagshamn Sweden
III-3-6	State of nationality	DK
III-3-7	State of residence	SE

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III-4	**Applicant and/or inventor**	
III-4-1	This person is	Applicant and inventor
III-4-2	Applicant for	US only
III-4-4	Name (LAST, First)	ÖJELUND, Henrik
III-4-5	Address	Kulsvierparken 55 2800 Lyngby Denmark
III-4-6	State of nationality	SE
III-4-7	State of residence	DK
IV-1	**Agent or common representative; or address for correspondence** The person identified below is hereby/ has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	Agent
IV-1-1	Name	HØIBERG A/S
IV-1-2	Address	St. Kongensgade 59 A 1264 Copenhagen K Denmark
IV-1-3	Telephone No.	+4533320337
IV-1-4	Facsimile No.	+4533320384
IV-1-5	e-mail	hoiberg@hoiberg.com
IV-1-5(a)	E-mail authorization The receiving Office, the International Searching Authority, the International Bureau and the International Preliminary Examining Authority are authorized to use this e-mail address, if the Office or Authority so wishes, to send notifications issued in respect of this international application:	as advance copies followed by notific-ations
IV-1-6	Agent's registration No.	100061385
V	**DESIGNATIONS**	
V-1	**The filing of this request constitutes under Rule 4.9(a), the designation of all Contracting States bound by the PCT on the international filing date, for the grant of every kind of protection available and, where applicable, for the grant of both regional and national patents.**	

PCT REQUEST

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VI-1	**Priority claim of earlier national application**	
VI-1-1	Filing date	**29 June 2010 (29.06.2010)**
VI-1-2	Number	**PA 2010 00568**
VI-1-3	Country	**DK**
VI-2	**Priority claim of earlier national application**	
VI-2-1	Filing date	**29 June 2010 (29.06.2010)**
VI-2-2	Number	**61/359,454**
VI-2-3	Country	**US**
VI-3	**Priority claim of earlier national application**	
VI-3-1	Filing date	**18 March 2011 (18.03.2011)**
VI-3-2	Number	**PA 2011 00191**
VI-3-3	Country	**DK**
VI-4	**Priority claim of earlier national application**	
VI-4-1	Filing date	**18 March 2011 (18.03.2011)**
VI-4-2	Number	**61/454,200**
VI-4-3	Country	**US**
VI-5	**Priority document request** The International Bureau is requested to obtain from a digital library a certified copy of the earlier application(s) identified above as item(s):	**VI-2, VI-4**
VI-6	**Priority document request** The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	**VI-1, VI-3**

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VI-7	**Incorporation by reference :** where an element of the international application referred to in Article 11(1)(iii)(d) or (e) or a part of the description, claims or drawings referred to in Rule 20.5(a) is not otherwise contained in this international application but is completely contained in an earlier application whose priority is claimed on the date on which one or more elements referred to in Article 11(1)(iii) were first received by the receiving Office, that element or part is, subject to confirmation under Rule 20.6, incorporated by reference in this international application for the purposes of Rule 20.6.	
VII-1	**International Searching Authority Chosen**	Nordic Patent Institute (ISA/XN)
VII-2	**Request to use results of earlier search; reference to that search**	
VII-2-1	Filing date	18 March 2011 (18.03.2011)
VII-2-2	Application Number	PA 2011 00191
VII-2-3	Country (or regional Office)	DK
VII-2-5	Documents are available to the ISA in a form and manner acceptable to it and therefore do not need to be submitted by the applicant to the ISA (Rule 12bis.1(f)):	A copy of the results of the earlier search A copy of the earlier application A copy of any document cited in the results of the earlier search
VII-3	**Request to use results of earlier search; reference to that search**	
VII-3-1	Filing date	29 June 2010 (29.06.2010)
VII-3-2	Application Number	PA 2010 00568
VII-3-3	Country (or regional Office)	DK
VII-3-5	Documents are available to the ISA in a form and manner acceptable to it and therefore do not need to be submitted by the applicant to the ISA (Rule 12bis.1(f)):	A copy of the results of the earlier search A copy of the earlier application A copy of any document cited in the results of the earlier search

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VIII	**Declarations**	Number of declarations	
VIII-1	Declaration as to the identity of the inventor	-	
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-	
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-	
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-	
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-	
IX	**Check list**	Number of sheets	Electronic file(s) attached
IX-1	Request (including declaration sheets)	6	✓
IX-2	Description	52	✓
IX-3	Claims	15	✓
IX-4	Abstract	1	✓
IX-5	Drawings	27	✓
IX-7	TOTAL	101	
	Accompanying Items	Paper document(s) attached	Electronic file(s) attached
IX-8	Fee calculation sheet	-	✓
IX-18	PCT-SAFE physical media	-	-
IX-19	Other	Pre-conversion archive	✓
IX-20	**Figure of the drawings which should accompany the abstract**	11k	
IX-21	**Language of filing of the international application**	English	
X-1	**Signature of applicant, agent or common representative**	(PKCS7 Digital Signature)	
X-1-1	Name	HØIBERG A/S	
X-1-2	Name of signatory	DK, Hoiberg A/S, N.-M. Nicolaisen 24757	
X-1-3	Capacity	(Representative)	

P2638PC00

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FOR RECEIVING OFFICE USE ONLY

10-1	**Date of actual receipt of the purported international application**	**2011-06-29 11:40:54** (29.06.2011)
10-2	**Drawings:**	
10-2-1	Received	
10-2-2	Not received	
10-3	**Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application**	
10-4	**Date of timely receipt of the required corrections under PCT Article 11(2)**	
10-5	**International Searching Authority**	**ISA/XN**
10-6	**Transmittal of search copy delayed until search fee is paid**	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	**Date of receipt of the record copy by the International Bureau**	

1111

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

July 07, 2011

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: ***61/359,454***
FILING DATE: ***June 29, 2010***

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS ***US61/359,454***

UNITED STATES PATENT AND TRADEMARK OFFICE · DEPARTMENT OF COMMERCE

Certified by

David J. Kappos

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (04-07)
Approved for use through 06/30/2010 OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 [Remove]

Given Name	Middle Name	Family Name	City	State	Country i
Tais		Clausen	Klagshamn		SE

Inventor 2 [Remove]

Given Name	Middle Name	Family Name	City	State	Country i
Rune		Fisker	Virum		DK

Inventor 3 [Remove]

Given Name	Middle Name	Family Name	City	State	Country i
Nikolaj		Deichmann	Klagshamn		SE

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. [Add]

Title of Invention	2D Image Arrangement
Attorney Docket Number (if applicable)	3SHAPEP008P

Correspondence Address

Direct all correspondence to (select one):

(●) The address corresponding to Customer Number	( ) Firm or Individual Name
Customer Number	64974

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

(●) No.

( ) Yes, the name of the U.S. Government agency and the Government contract number are:

Doc Code: **TR.PROV**
Document Description: Provisional Cover Sheet (SB16)

PTO/SB/16 (04-07)
Approved for use through 06/30/2010 OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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Entity Status

Applicant claims small entity status under 37 CFR 1.27

(●) Yes, applicant qualifies for small entity status under 37 CFR 1.27

( ) No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Fredrik Mollborn/			Date (YYYY-MM-DD)	2010-06-29
First Name	Fredrik	Last Name	Mollborn	Registration Number (If appropriate)	48587

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

Privacy Act Statement

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 paten. 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.

The information provided by you in this form will be subject to the following routine uses:

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 disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
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, t o a n other 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 inspection 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.

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.

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.

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 is 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.

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.

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 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 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 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. 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.

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

50. 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.

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)

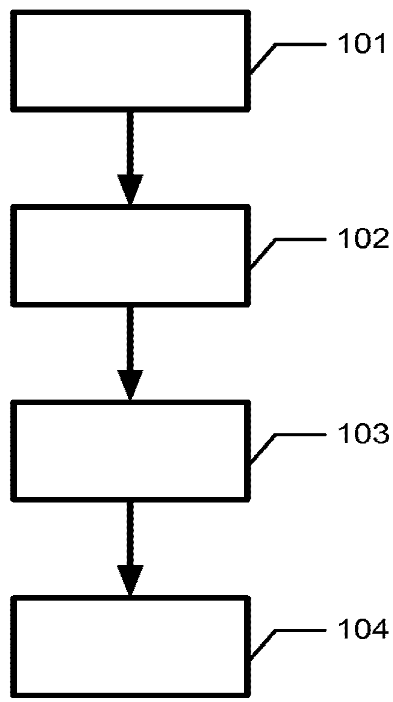


Fig. 1

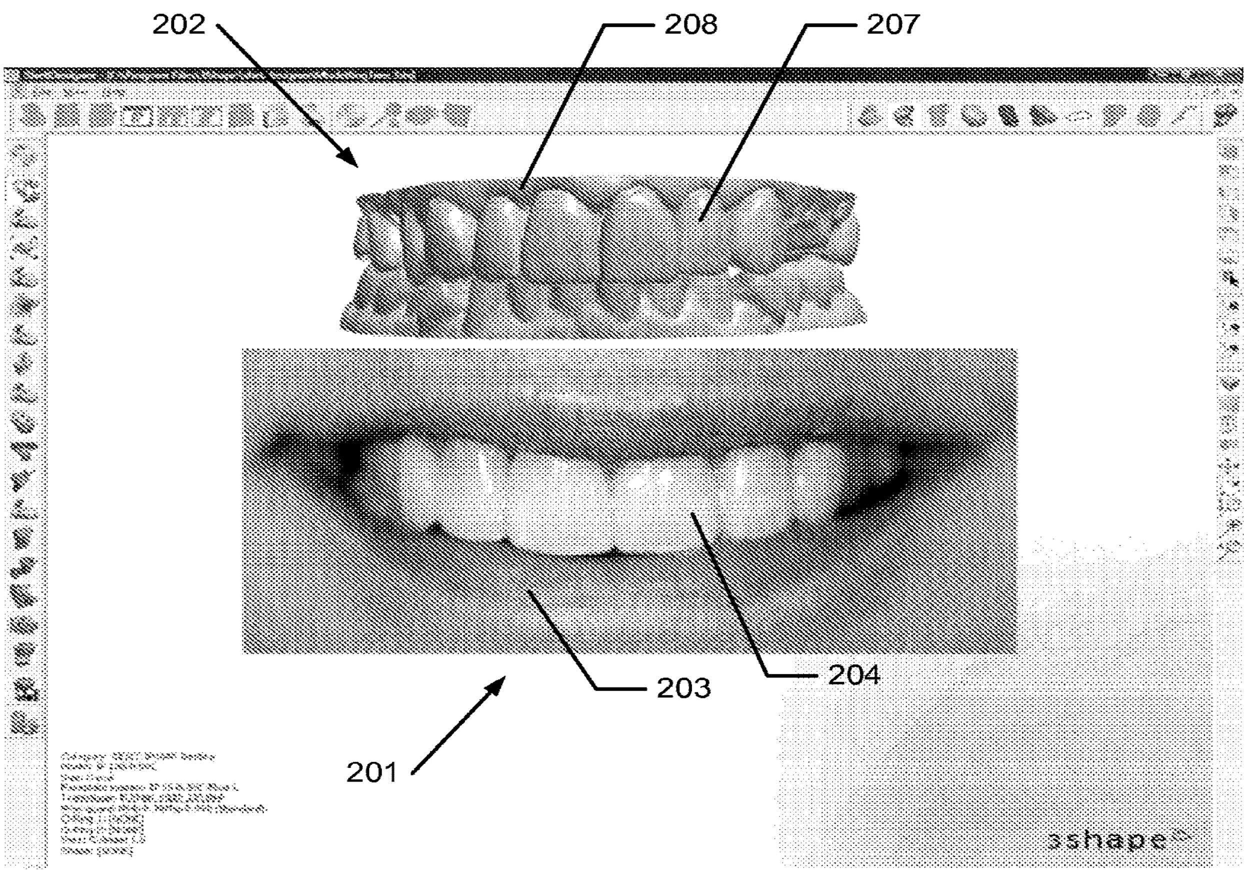


Fig. 2a)

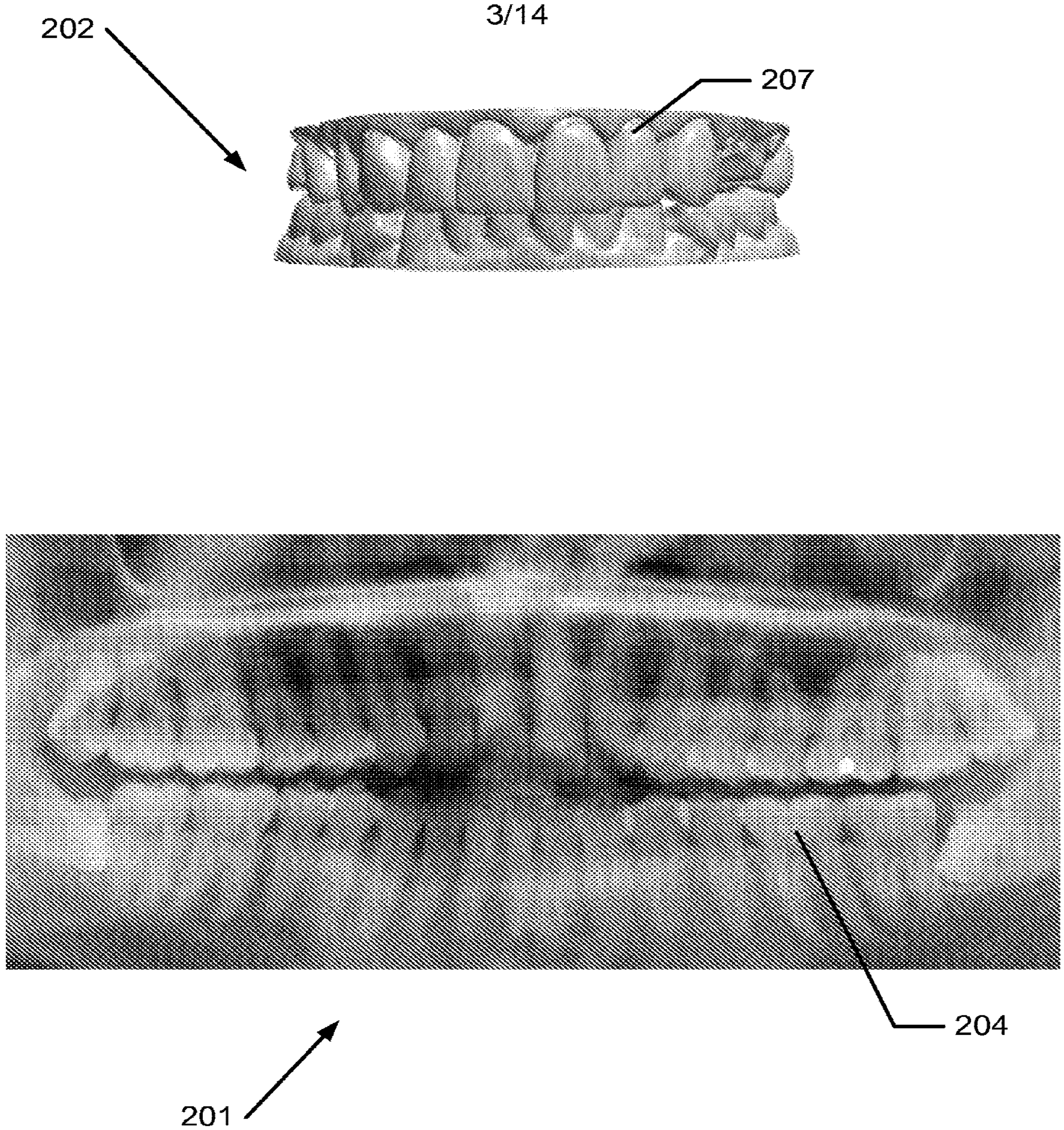


Fig. 2b)

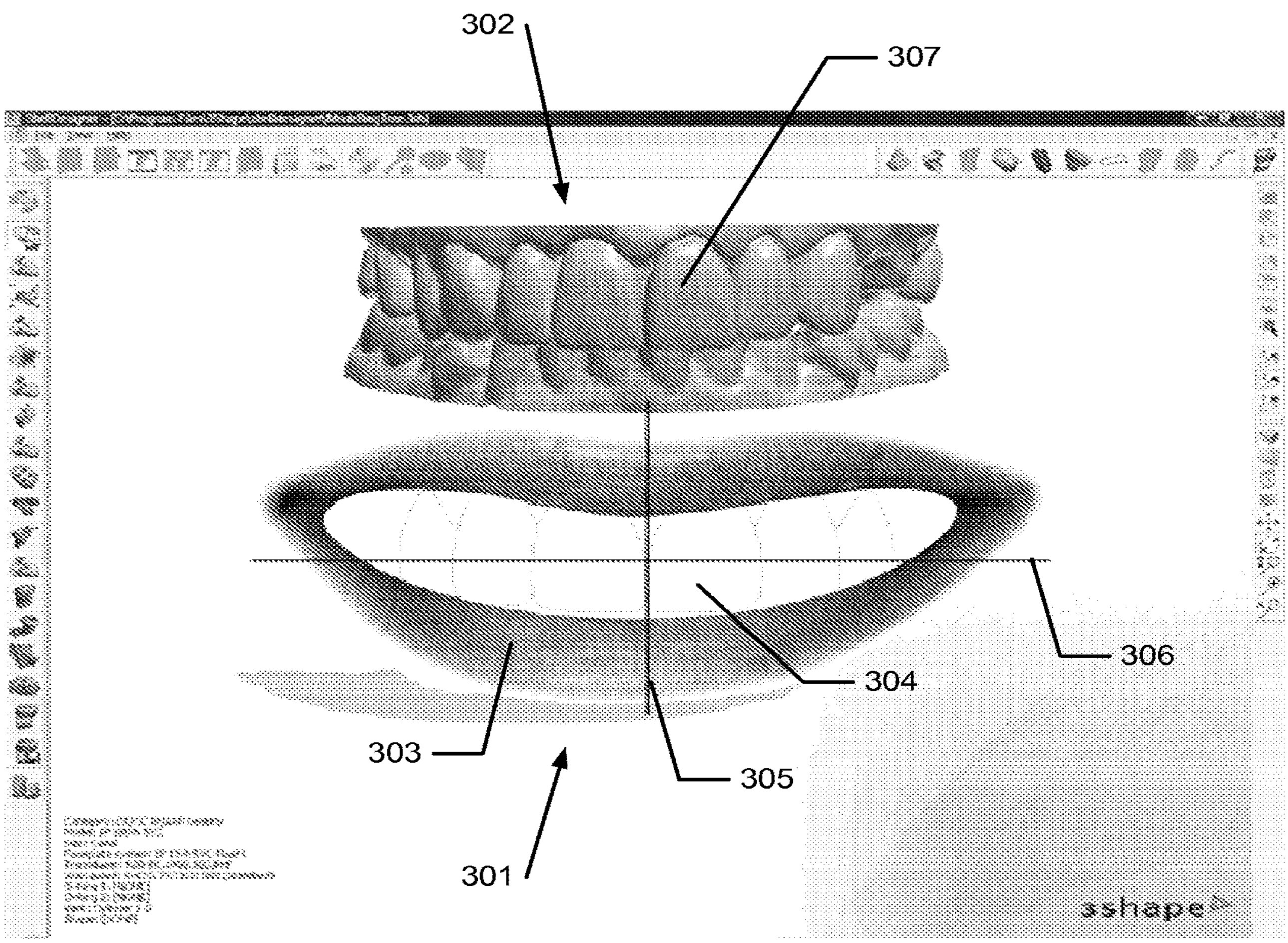


Fig. 3a)

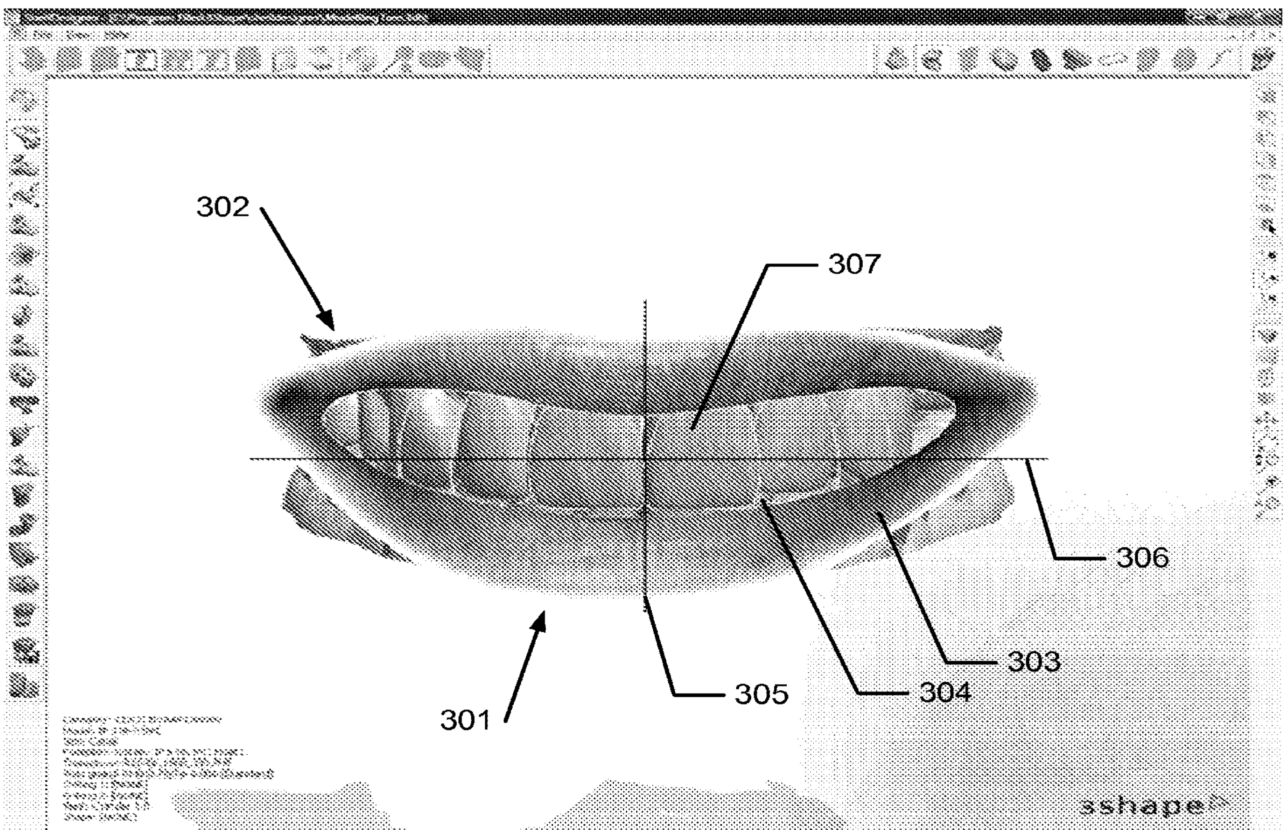


Fig. 3b)

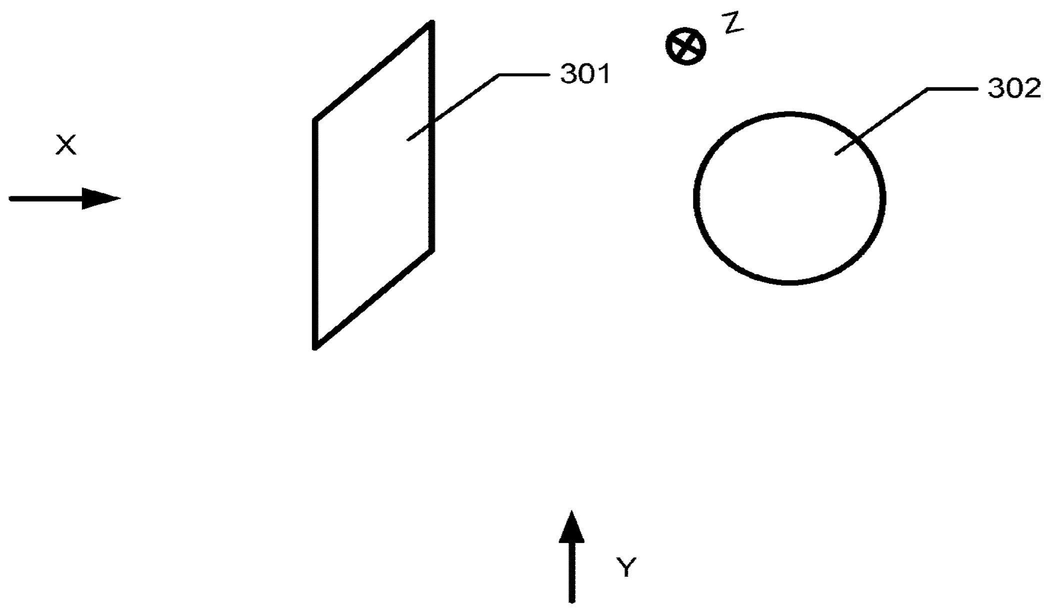


Fig. 3c)

Fig. 4a)

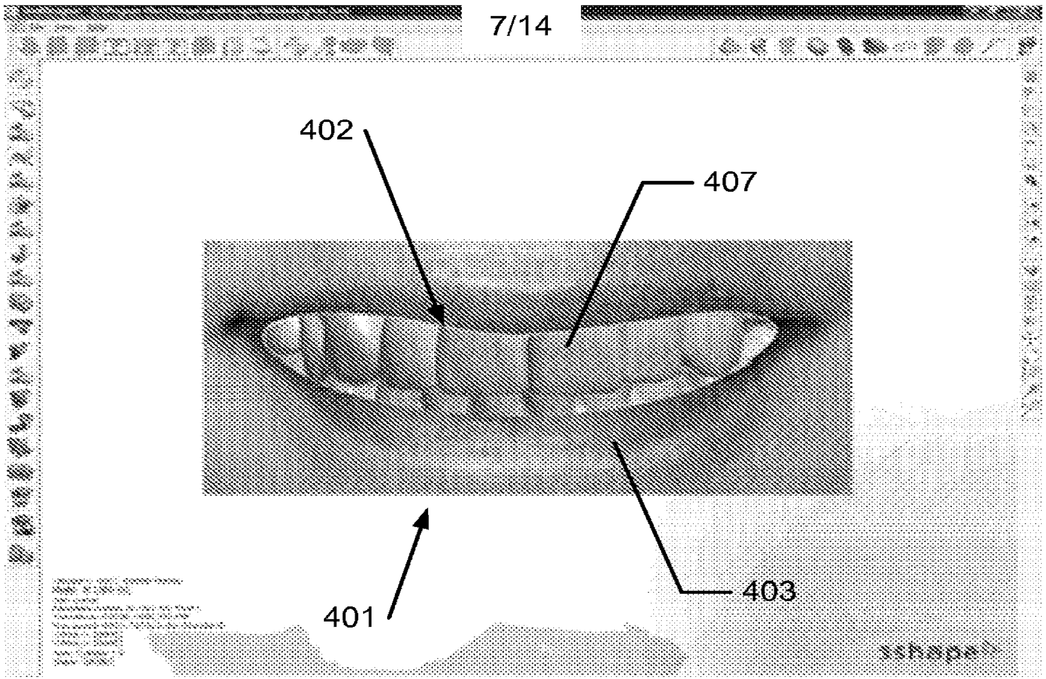
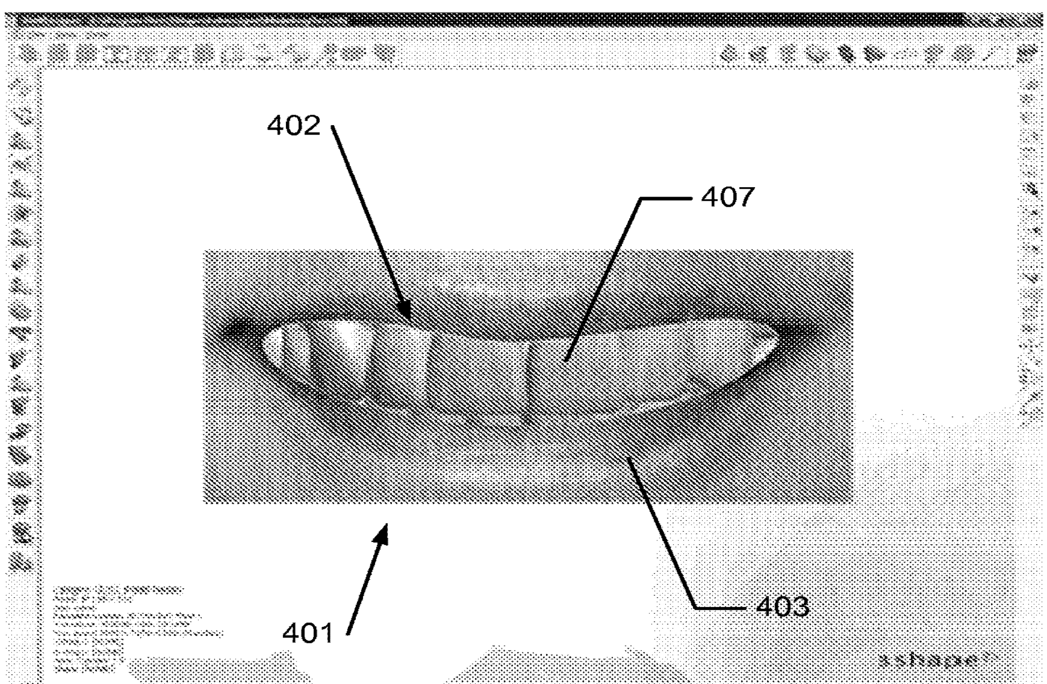


Fig. 4b)



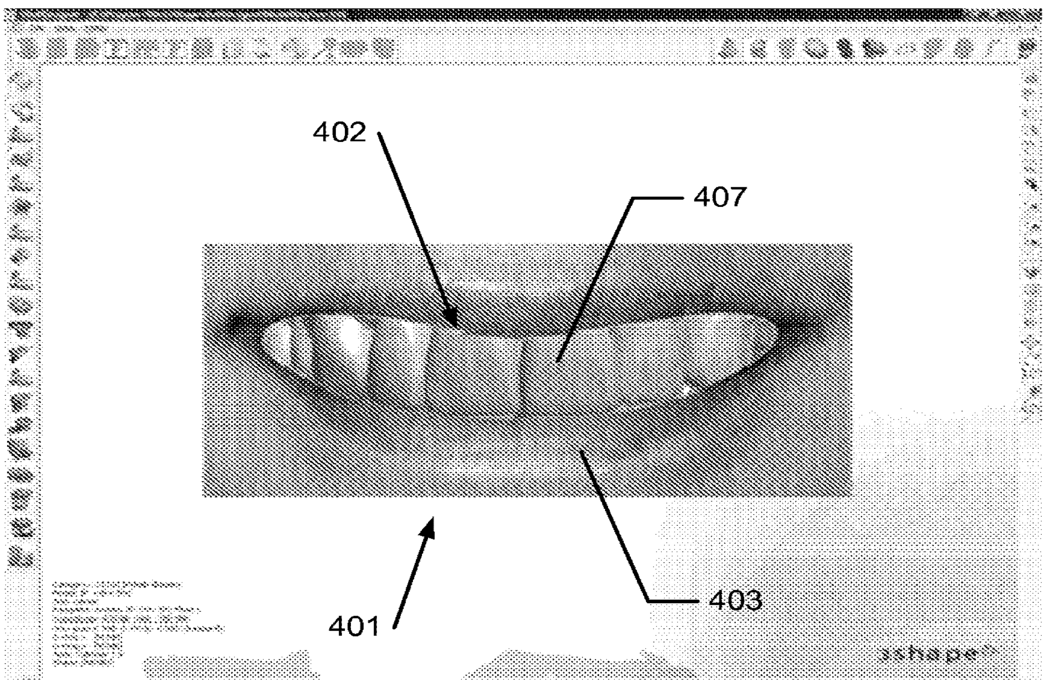


Fig. 4c)

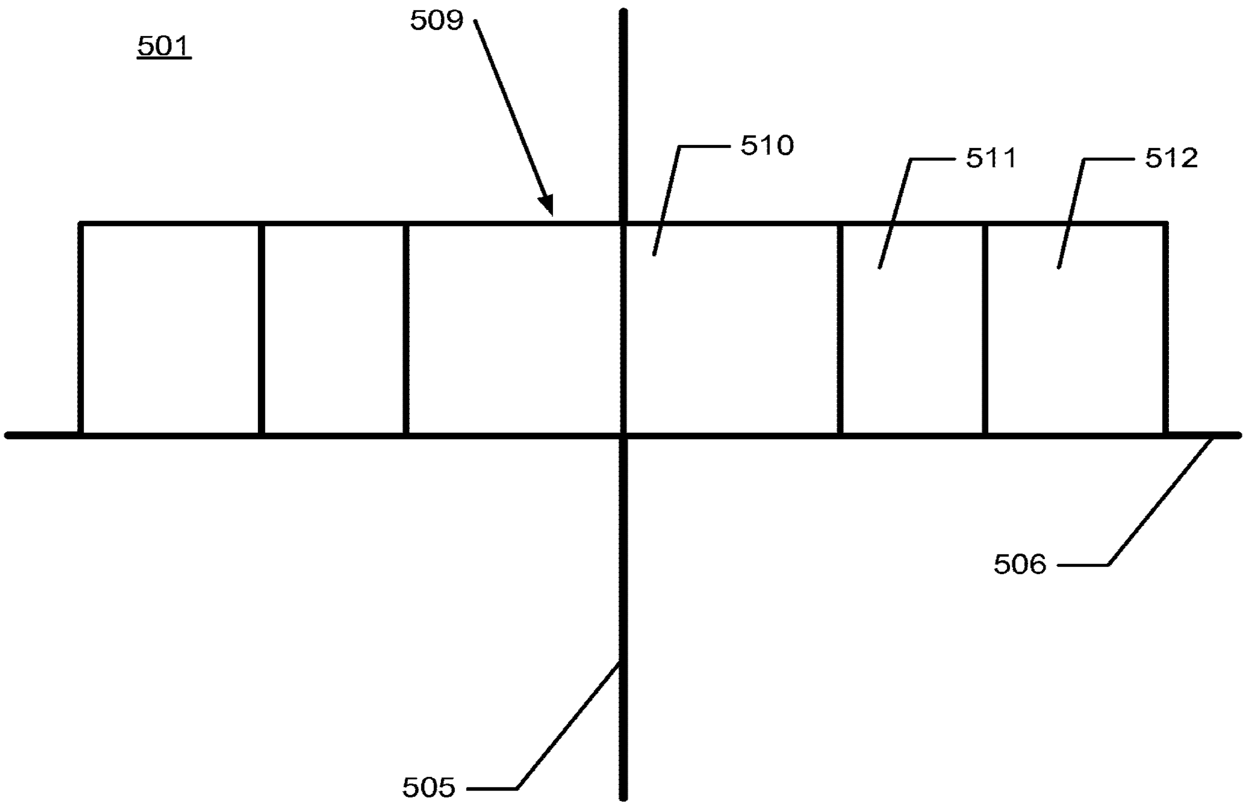
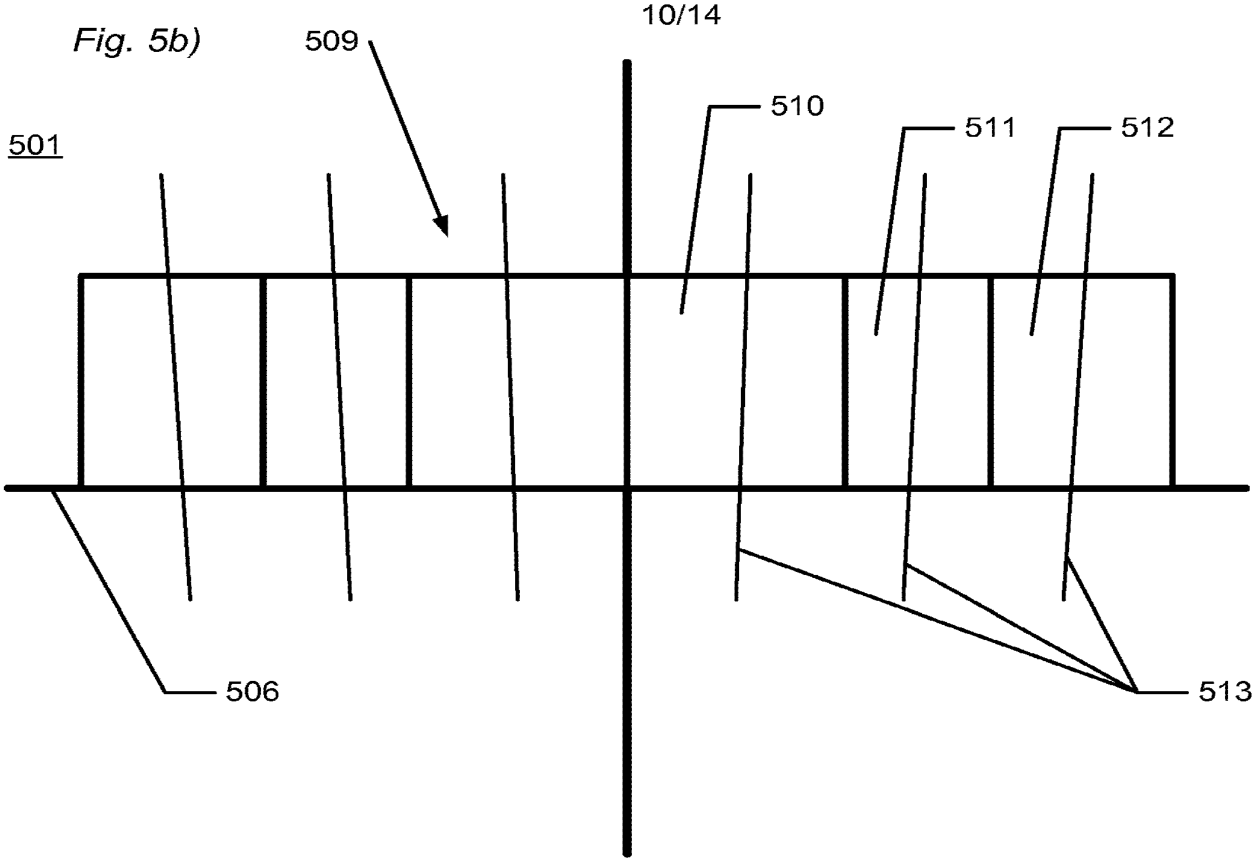


Fig. 5a)

Fig. 5b)



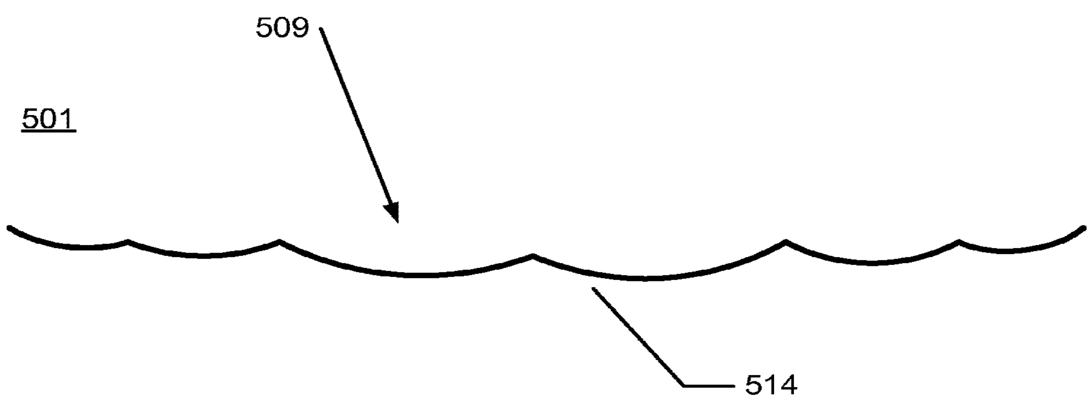
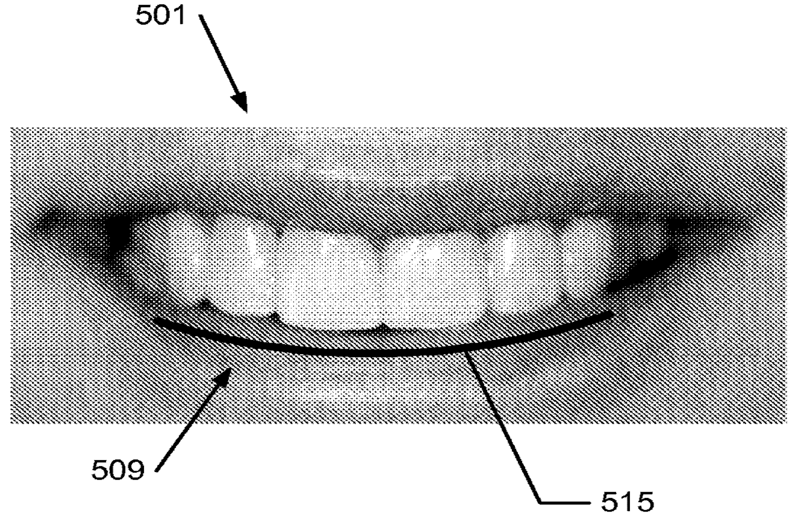


Fig. 5c)



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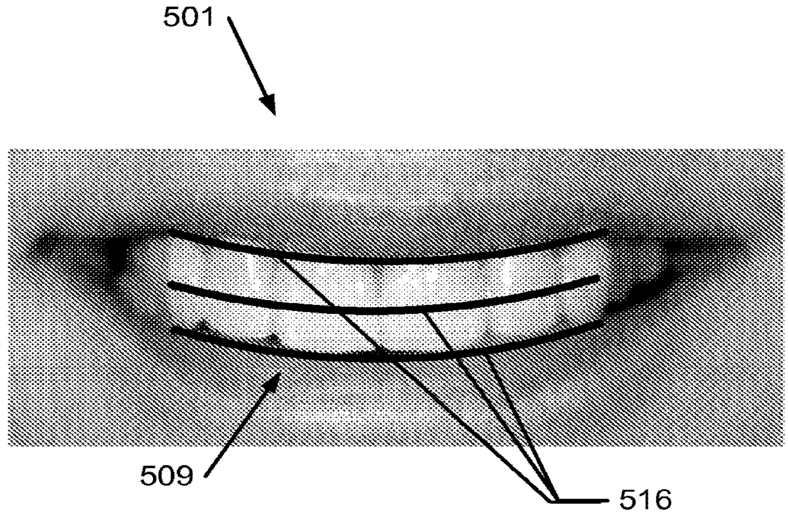


Fig. 5e)

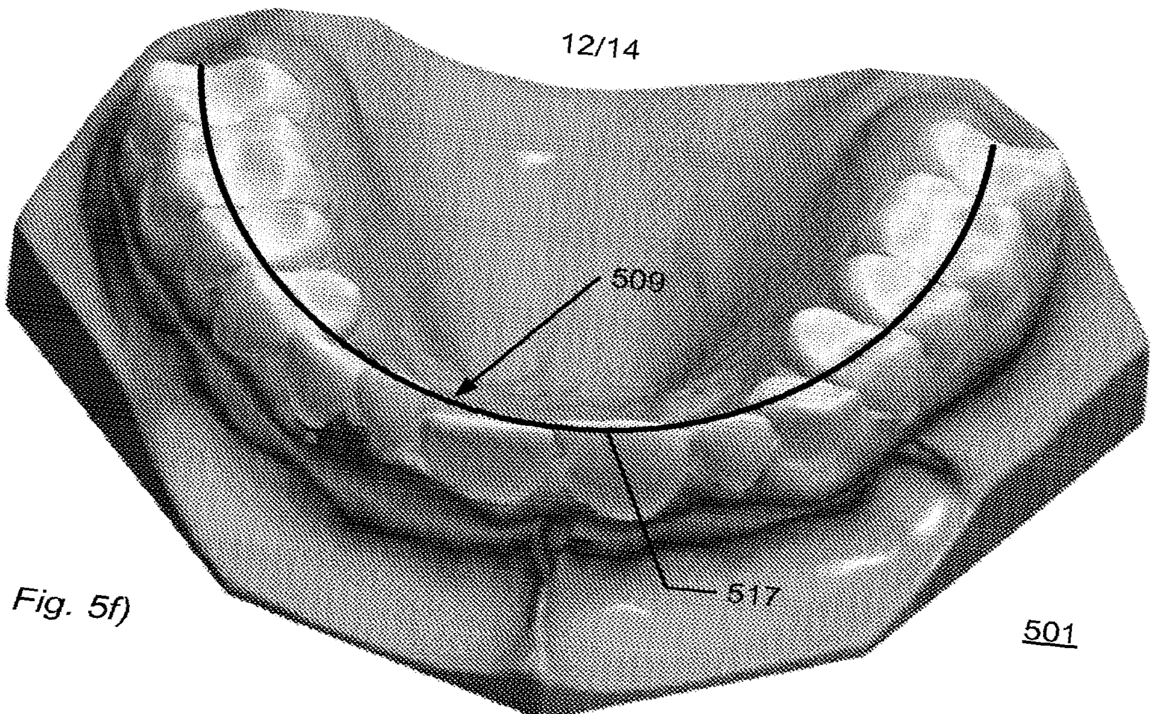
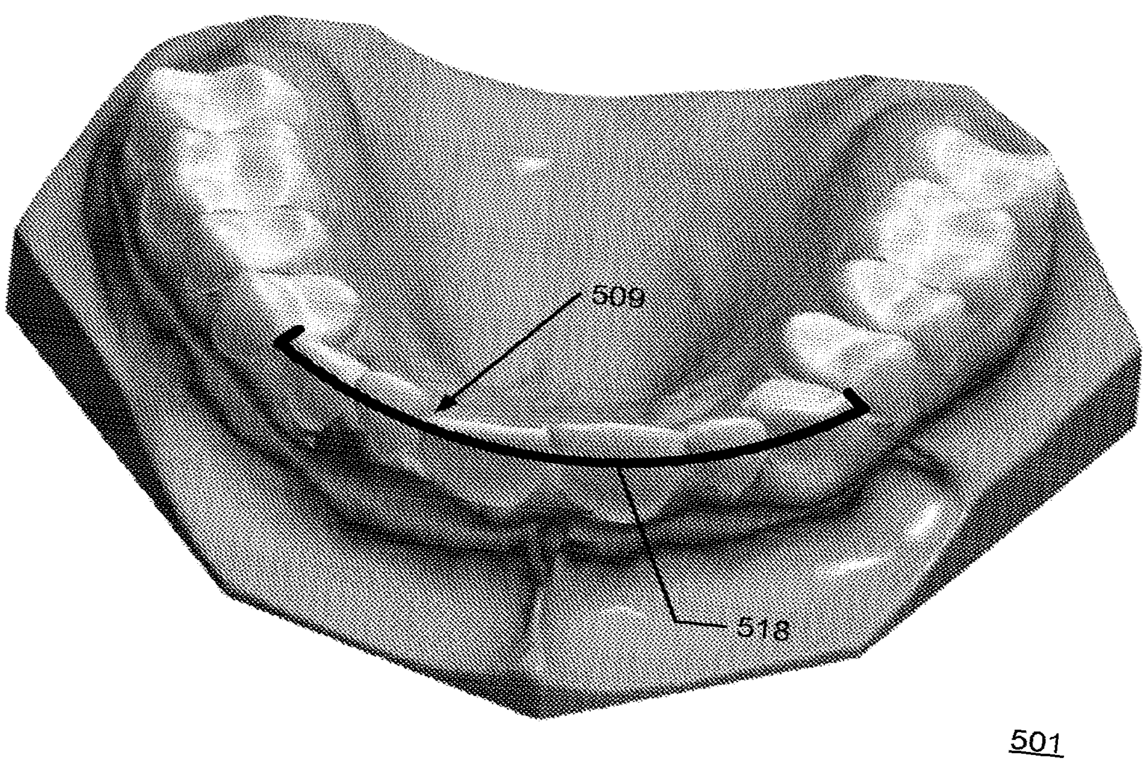


Fig. 5f)

Fig. 5g)



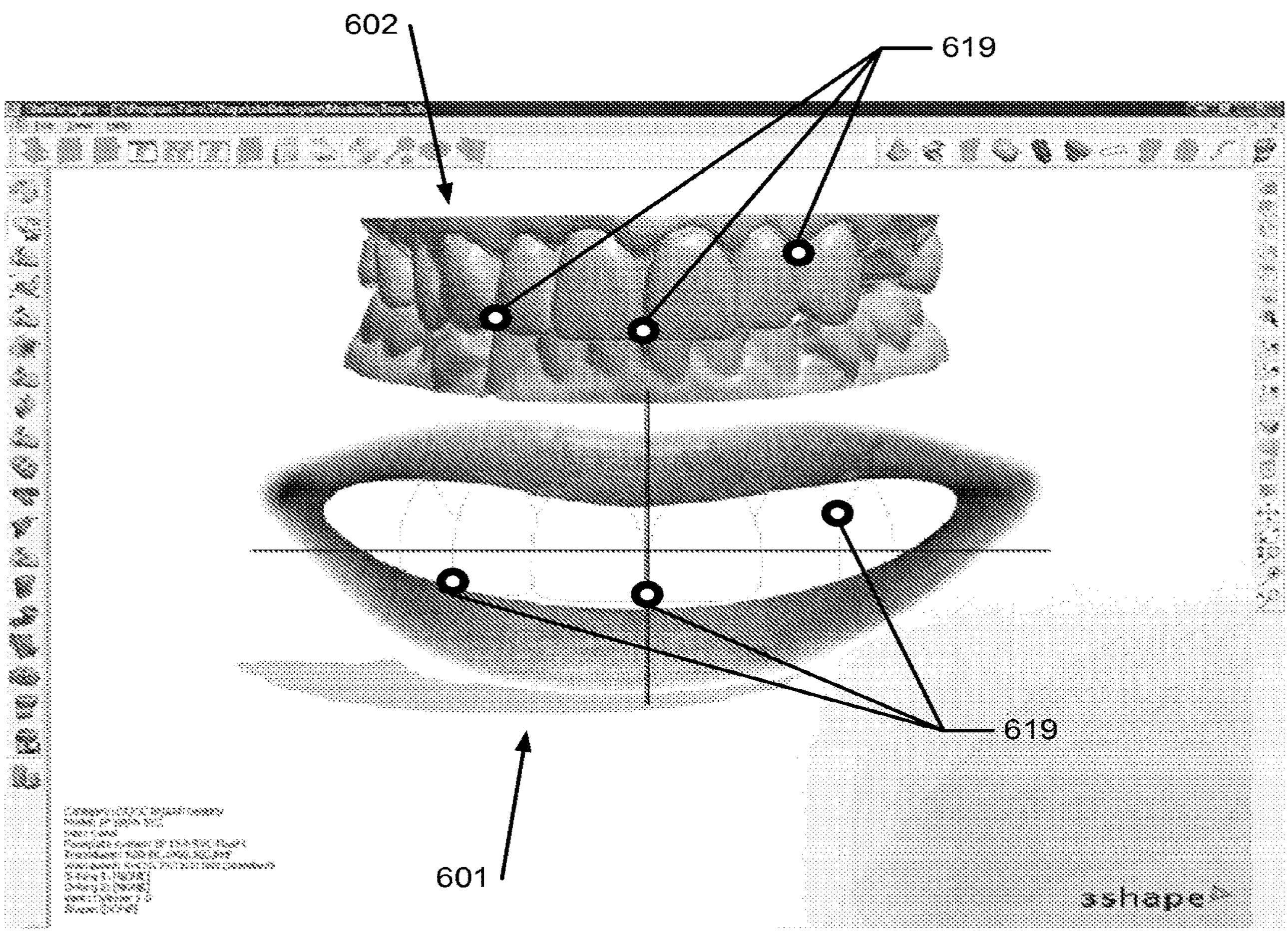


Fig. 6a)

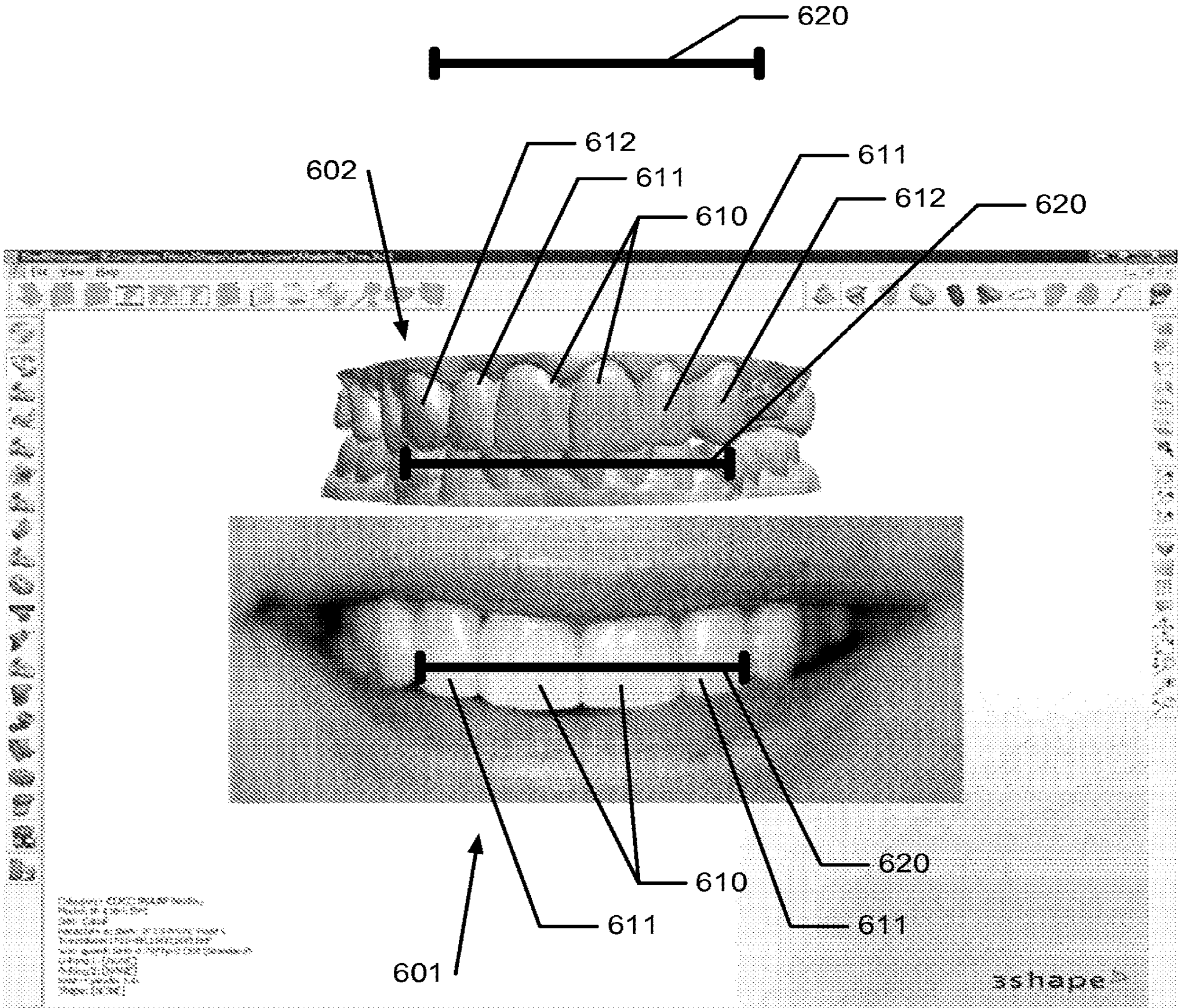


Fig. 6b)

Electronic Acknowledgement Receipt

EFS ID:	7913764
Application Number:	61359454
International Application Number:	
Confirmation Number:	1986
Title of Invention:	2D Image Arrangement
First Named Inventor/Applicant Name:	Tais Clausen
Customer Number:	64974
Filer:	Fredrik Mollborn
Filer Authorized By:	
Attorney Docket Number:	3SHAPEP008P
Receipt Date:	29-JUN-2010
Filing Date:	
Time Stamp:	13:02:08
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$110
RAM confirmation Number	11686
Deposit Account	
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File Listing:

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

1	Provisional Cover Sheet (SB16)	ProvisionalSB.pdf	1000140 3e1dd2302218a7317a33123955e99ff18187f684	no	3
Warnings:					
Information:					
2		Provisional_Spec_Claims_Abstract.pdf	130358 0ad37af157387a7982a367b1d521a1851cc53414	yes	35
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Specification		1	26	
	Claims		27	34	
	Abstract		35	35	
Warnings:					
Information:					
3	Drawings-only black and white line drawings	Drawings.pdf	3611891 31a98e8600a982672777623fef4f6b9bcf876c91	no	14
Warnings:					
Information:					
4	Fee Worksheet (PTO-875)	fee-info.pdf	28966 d986c22870fdf1988bdb9b13dfdebb148b2c520f	no	2
Warnings:					
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		Total Files Size (in bytes):	4771355		

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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.

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.

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DOCUMENT MADE AVAILABLE UNDER THE PATENT COOPERATION TREATY (PCT)

International application number:		**PCT/DK2011/050246**
International filing date:		**29 June 2011 (29.06.2011)**
Document type:		**Certified copy of priority document**
Document details:	Country/Office:	**US**
	Number:	**61/359,454**
	Filing date:	**29 June 2010 (29.06.2010)**
Date of receipt at the International Bureau:		**07 July 2011 (07.07.2011)**

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-*bis*)

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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92*bis*.1 and Administrative Instructions, Section 422)

To:

MÜNZER, Marc
Guardian IP Consulting I/S
Diplomvej, Building 381
DK-2800 Kgs. Lyngby
DANEMARK

Date of mailing *(day/month/year)* 24 May 2012 (24.05.2012)	
Applicant's or agent's file reference P1269PC00	**IMPORTANT NOTIFICATION**
International application No. PCT/DK2011/050246	International filing date *(day/month/year)* 29 June 2011 (29.06.2011)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

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	Facsimile No. +4533320384	
	E-mail address hoiberg@hoiberg.com	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☒ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address	State of Nationality	State of Residence
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	Facsimile No. +45 70 27 53 62	
	E-mail address mail@gipc.dk ☐ Notifications by e-mail authorized	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☐ the receiving Office
☐ the International Searching Authority
☐ the Authority(ies) specified for supplementary search
☐ the International Preliminary Examining Authority
☒ the designated Offices concerned
☐ the elected Offices concerned
☒ other: HØIBERG A/S

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 338 82 70	Authorized officer Blanc Veronique e-mail pt03.pct@wipo.int Telephone No. +41 22 338 74 03

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VIII-4-1	**Declaration: Inventorship (only for the purposes of the designation of the United States of America)** Declaration of Inventorship (Rules 4.17(iv) and 51bis.1(a)(iv)) for the purposes of the designation of the United States of America:	I hereby declare that I believe I am the original, first and sole (if only one inventor is listed below) or joint (if more than one inventor is listed below) inventor of the subject matter which is claimed and for which a patent is sought. This declaration is directed to international application PCT/DK2011/050246 (if furnishing declaration pursuant to Rule 26ter). I hereby declare that my residence, mailing address, and citizenship are as stated next to my name. I hereby state that I have reviewed and understand the contents of the above-identified international application, including the claims of said application. I have identified in the request of said application, in compliance with PCT Rule 4.10, any claim to foreign priority, and I have identified below, under the heading "Prior Applications", by application number, country or Member of the World Trade Organization, day, month, and year of filing, any application for a patent or inventor's certificate filed in a country other than the United States of America, including any PCT international application designating at least one country other than the United States of America, having a filing date before that of the application on which foreign priority is claimed.
VIII-4-1-1	Prior applications:	PA 2010 00568, DK, 29 June 2010 (29.06.2010) ;PA 2011 00191, DK, 18 March 2011 (18.03.2011) ;61/359,454, US, 29 June 2010 (29.06.2010) ;61/454,200, US, 18 March 2011 (18.03.2011)

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		I hereby acknowledge the duty to disclose information that is known by me to be material to patentability as defined by 37 C.F.R. § 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the PCT international filing date of the continuation-in-part application. 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.
VIII-4-1-1-1	Name (LAST, First)	CLAUSEN, Tais
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VIII-4-1-1-4	Citizenship:	DK
VIII-4-1-1-5	Inventor's Signature: (The signature must be that of the inventor, not that of the agent)	[signature]
VIII-4-1-1-6	Date:	3/10-2011
VIII-4-1-2-1	Name (LAST, First)	FISKER, Rune
VIII-4-1-2-2	Residence: (city and either US State, if applicable, or country)	Virum, Denmark
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VIII-4-1-2-4	Citizenship:	DK
VIII-4-1-2-5	Inventor's Signature: (The signature must be that of the inventor, not that of the agent)	[signature]
VIII-4-1-2-6	Date	4-10-2011

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VIII-4-1-3-3	Mailing address:	Järnolofs Väg 10 21851 Klagshamn Sweden
VIII-4-1-3-4	Citizenship:	DK
VIII-4-1-3-5	Inventor's Signature: (The signature must be that of the inventor, not that of the agent)	
VIII-4-1-3-6	Date	3 october 2011
VIII-4-1-4-1	Name (LAST, First)	ÖJELUND, Henrik
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VIII-4-1-4-3	Mailing address:	Kulsvierparken 55 2800 Lyngby Denmark
VIII-4-1-4-4	Citizenship:	SE
VIII-4-1-4-5	Inventor's Signature: (The signature must be that of the inventor, not that of the agent)	Henrik Öjelund
VIII-4-1-4-6	Date	3/10 2011

Kongeriget Danmark

Patent application No.:	PA 2011 00191
Date of filing:	18 March 2011
Applicant: (Name and address)	3Shape A/S Holmens Kanal 7 DK-1060 København K Denmark

Title: 2D image arrangement

IPC: --

This is to certify that the attached documents are exact copies of the above mentioned patent application as originally filed.

Patent- og Varemærkestyrelsen
Økonomi- og Erhvervsministeriet

01 July 2011

Gitta Storch Priess

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.

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 any of the preceding claims, wherein the alignment of the at least one 2D image and the 3D model is performed automatically.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

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

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)

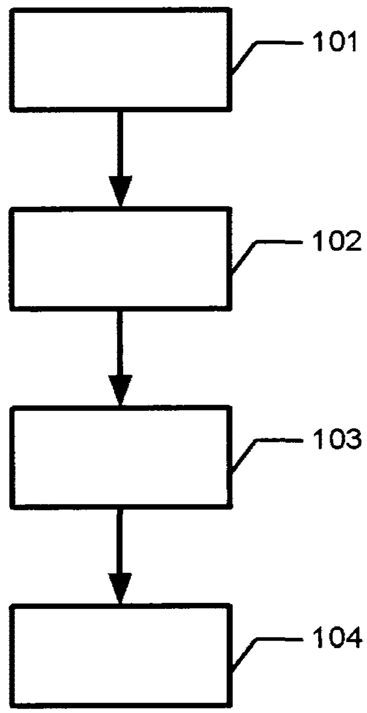


Fig. 1

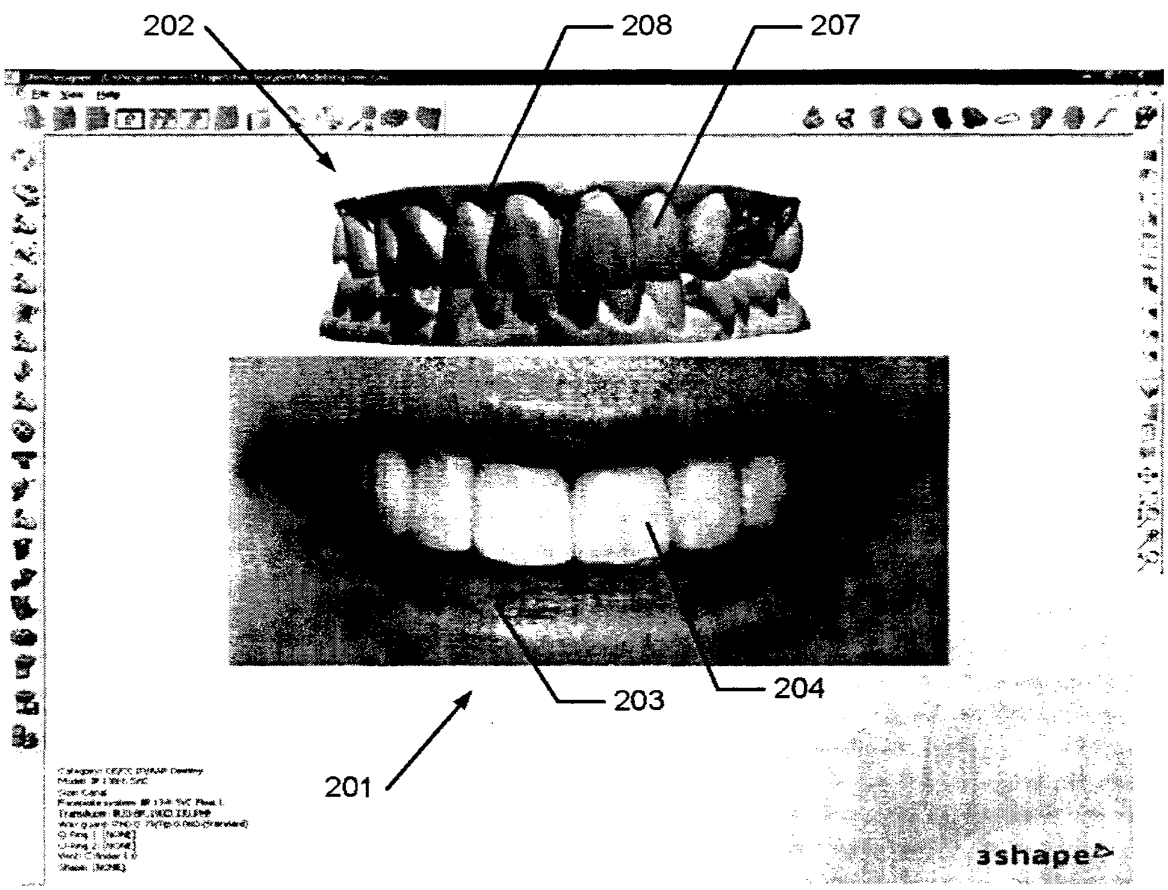


Fig. 2a)

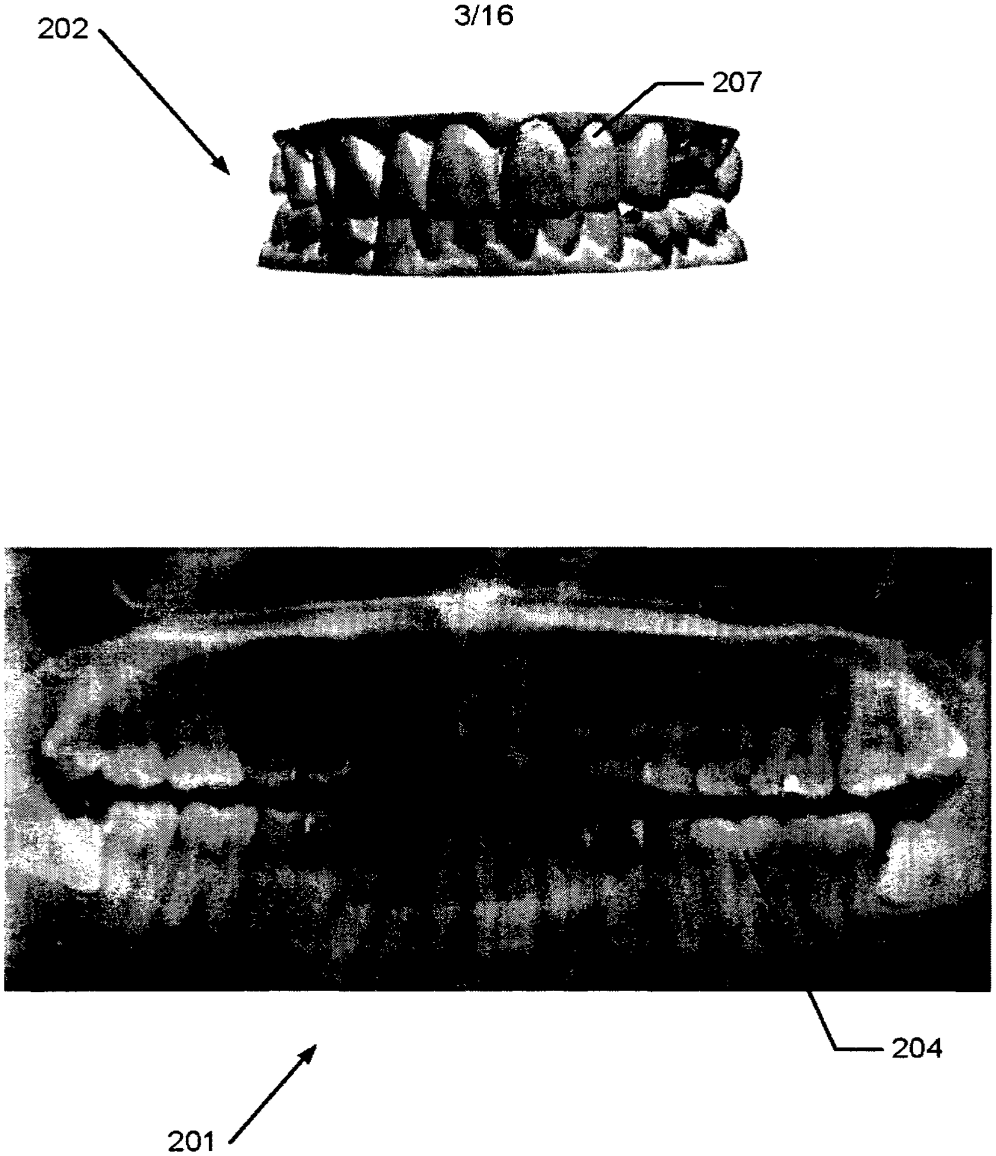


Fig. 2b)

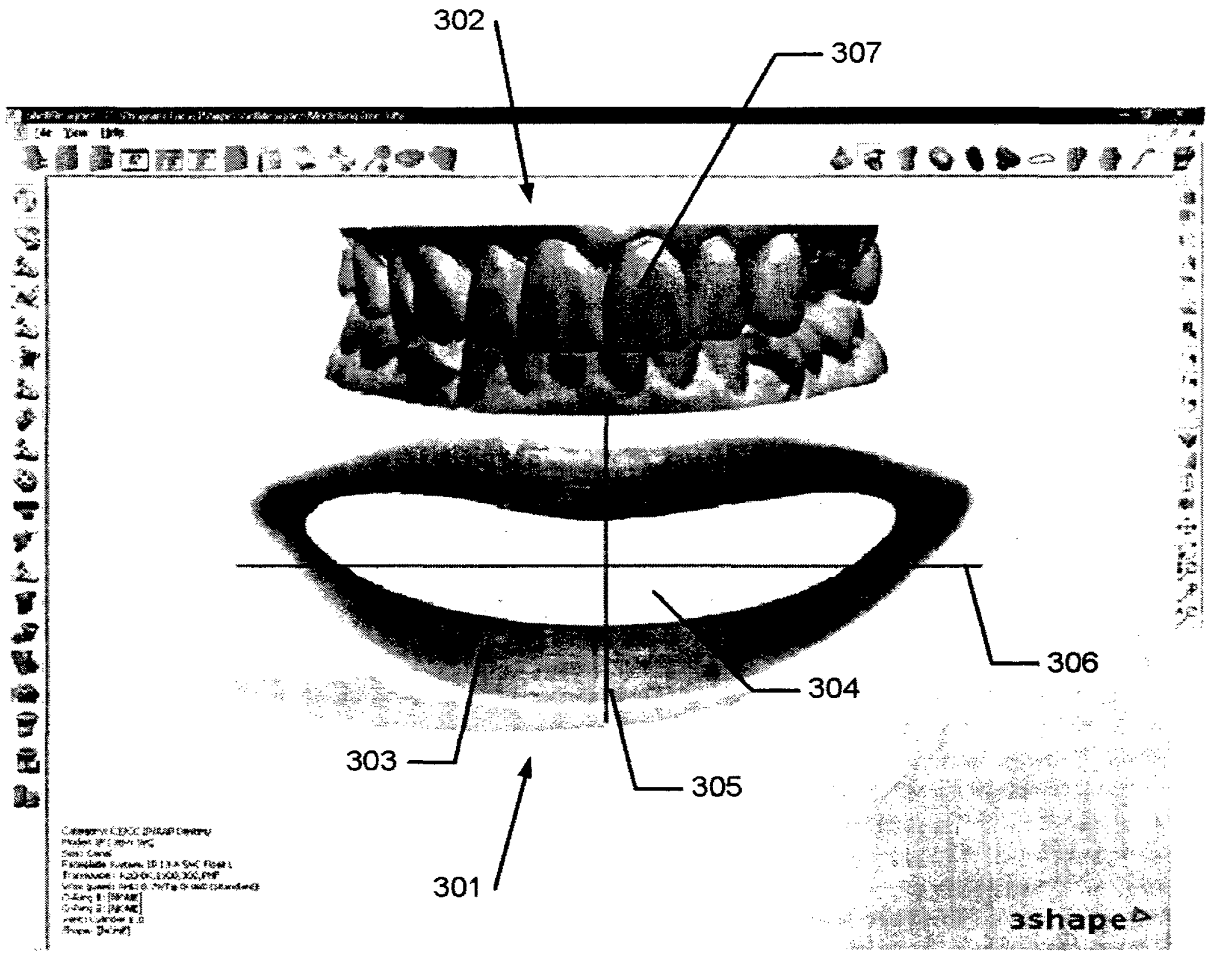


Fig. 3a)

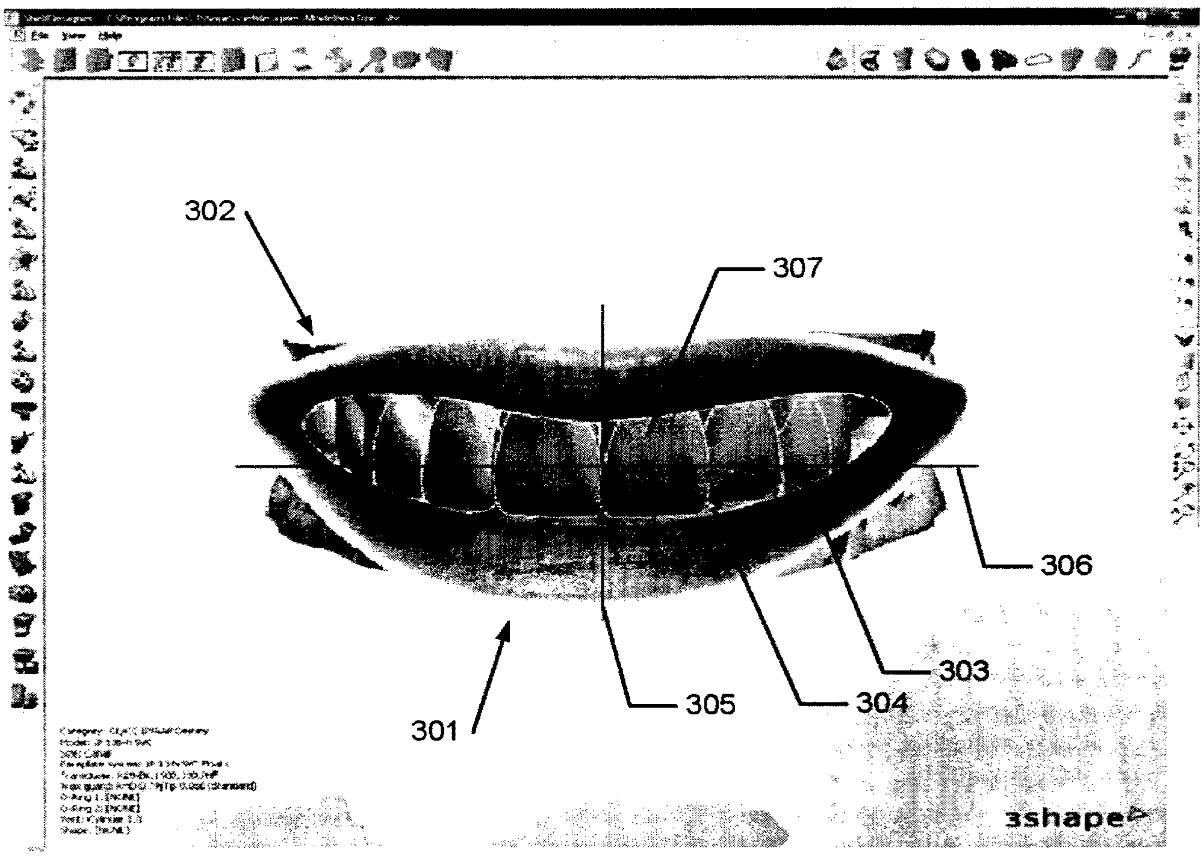


Fig. 3b)

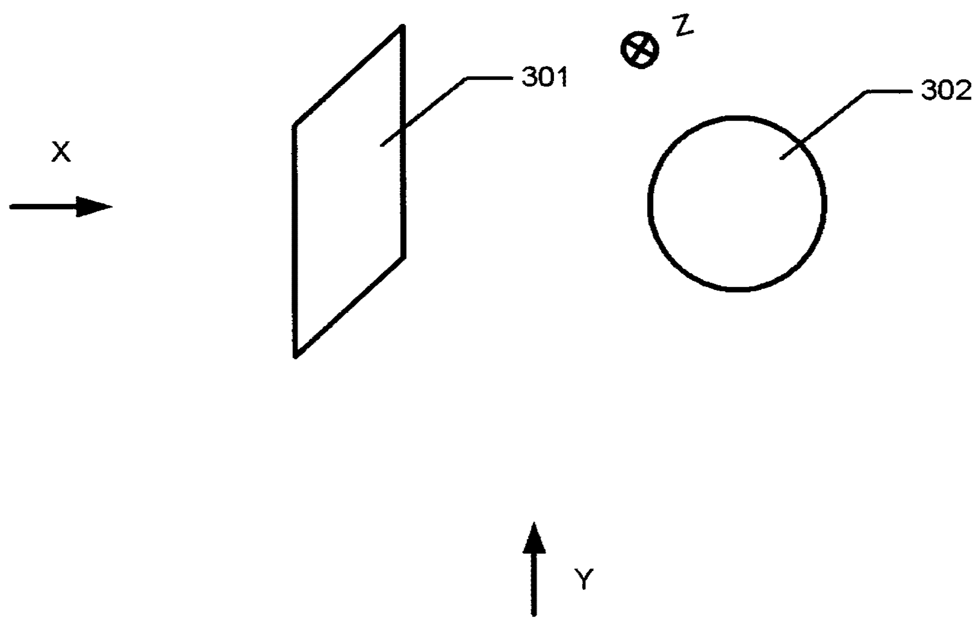


Fig. 3c)

Fig. 4a)

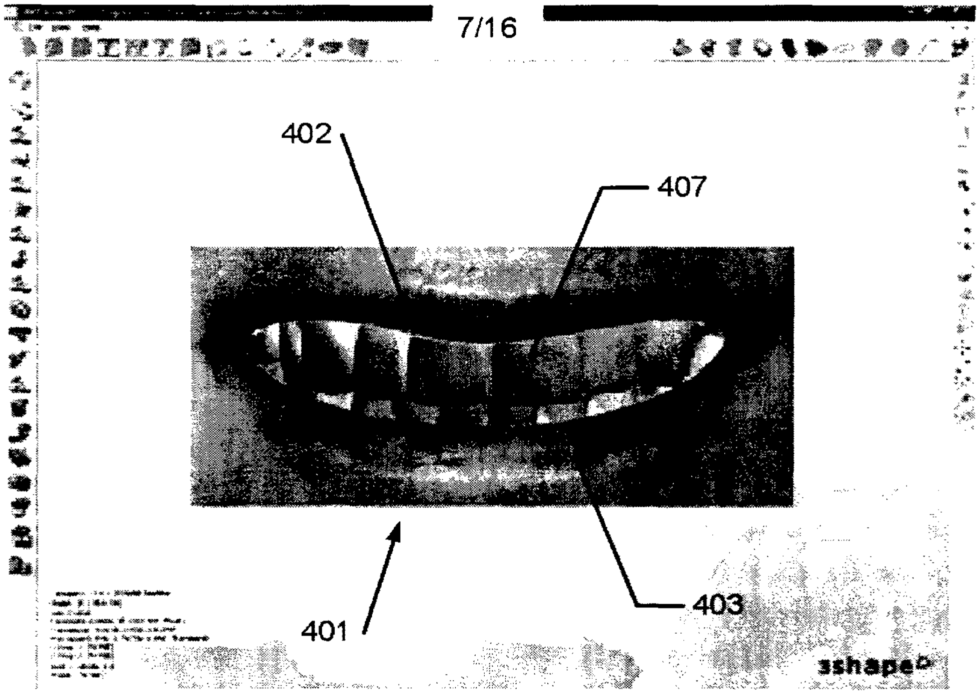
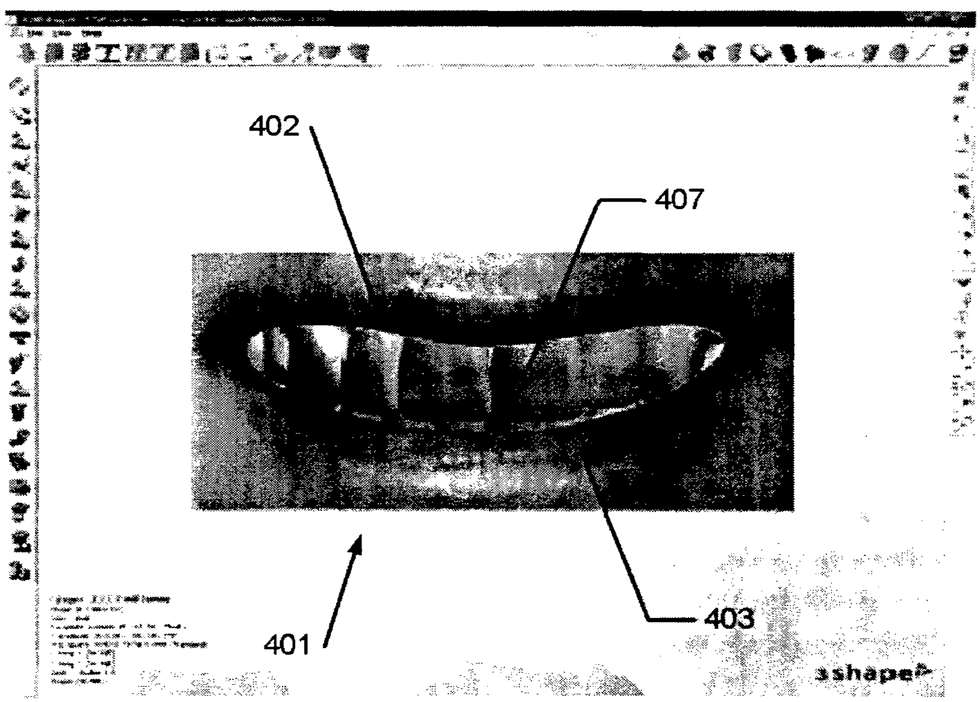


Fig. 4b)



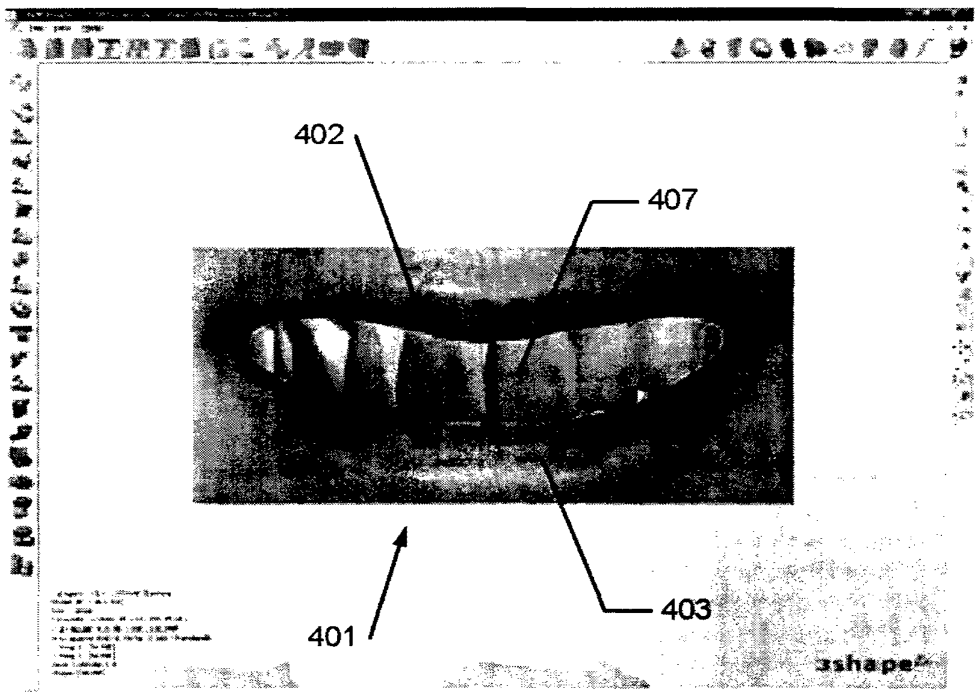


Fig. 4c)

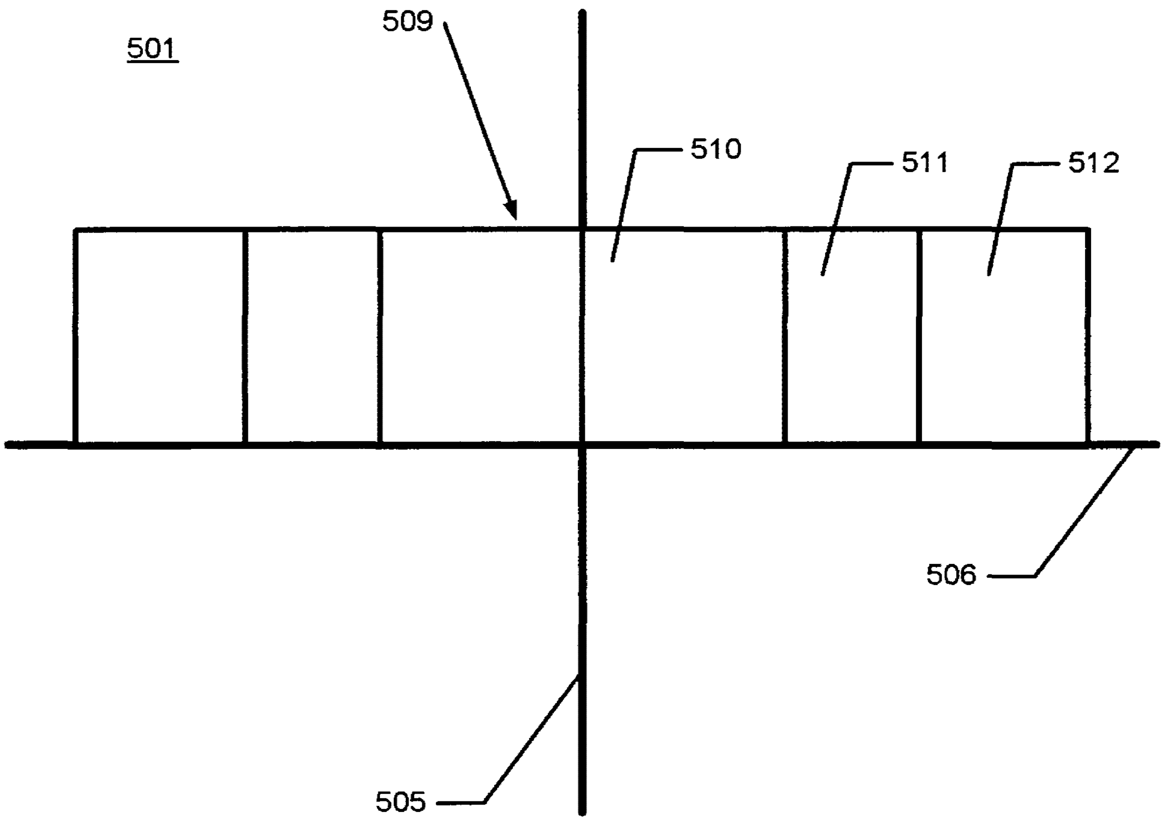
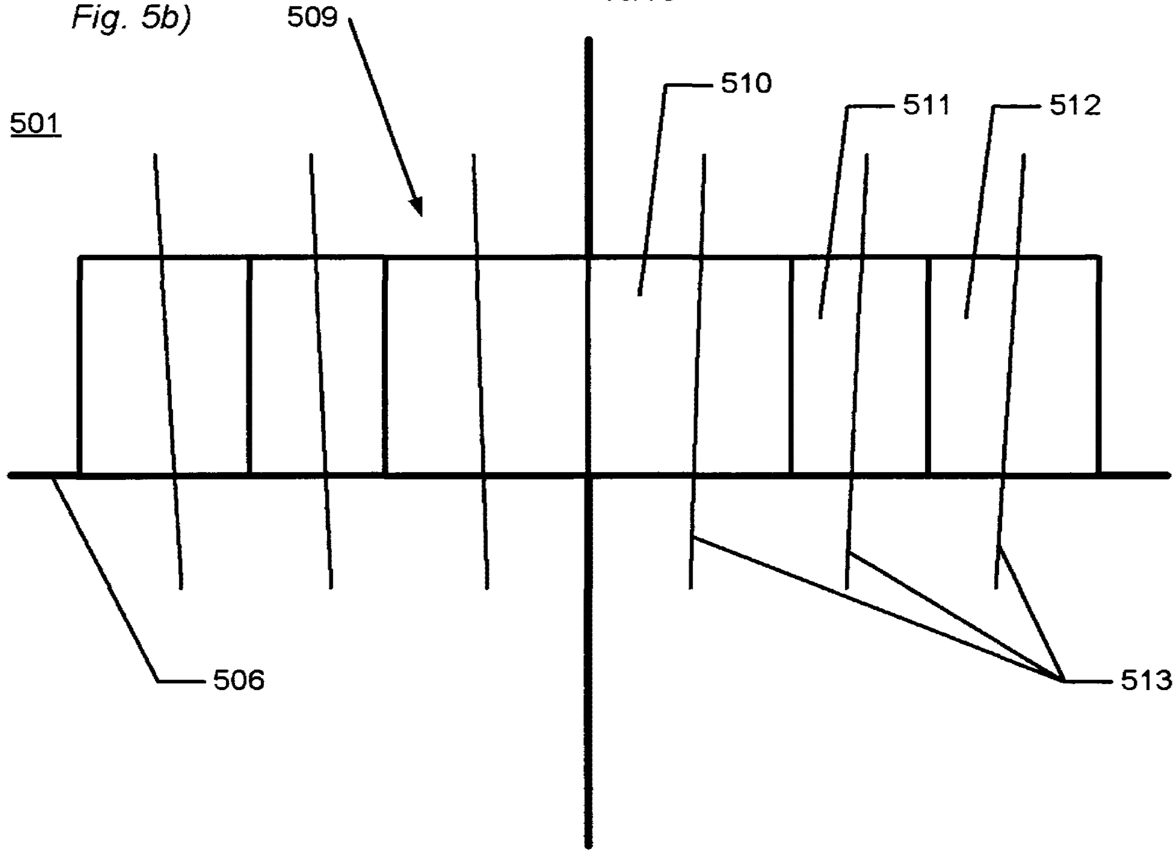


Fig. 5a)

Fig. 5b)



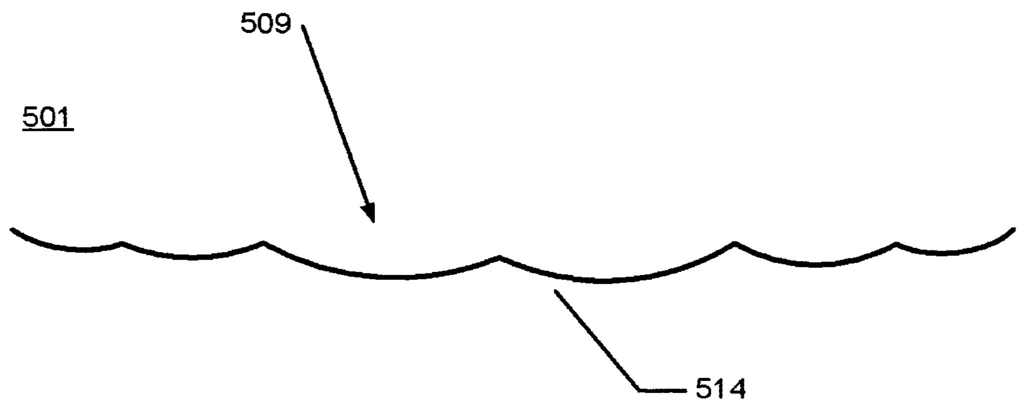
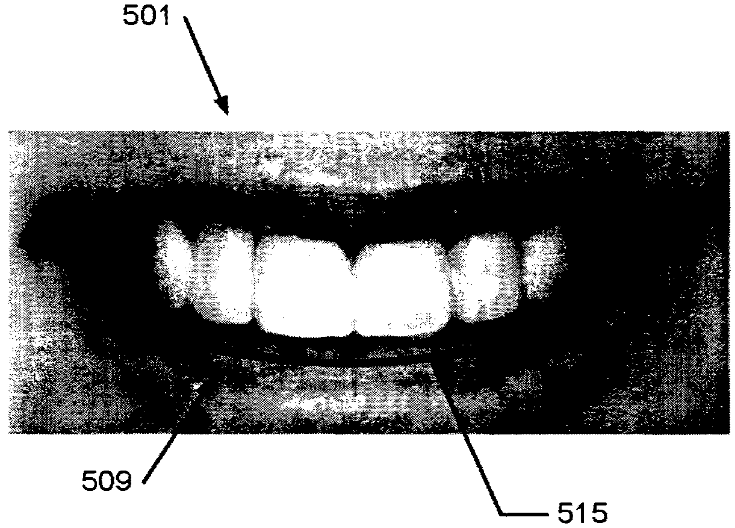


Fig. 5c)

Fig. 5d)



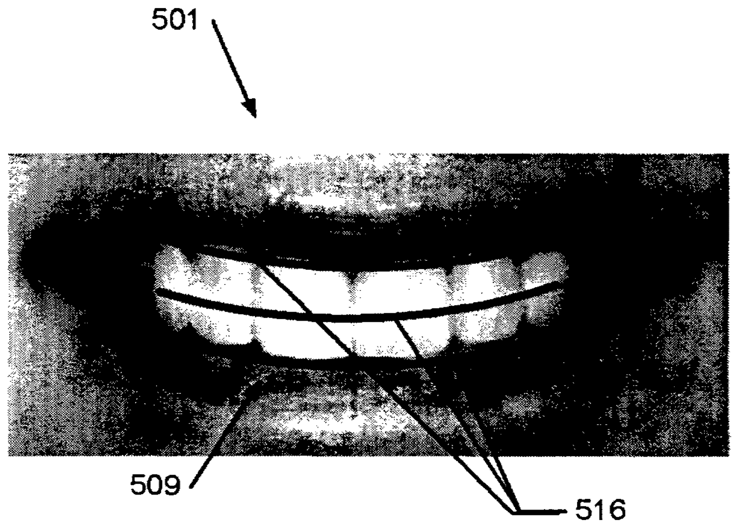
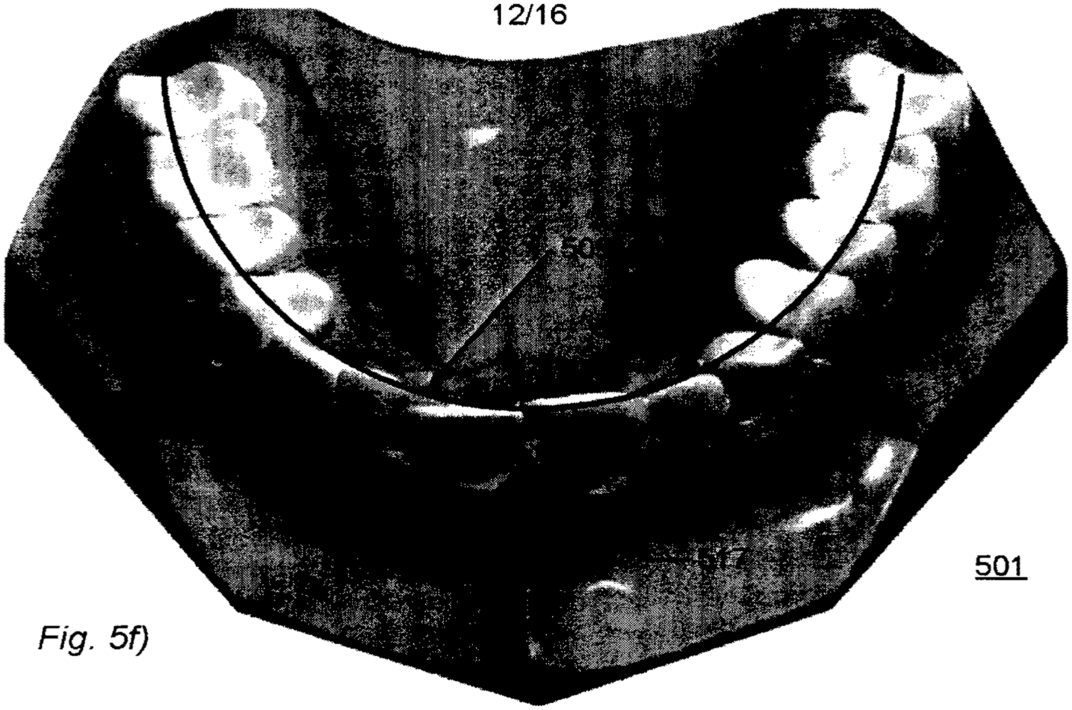


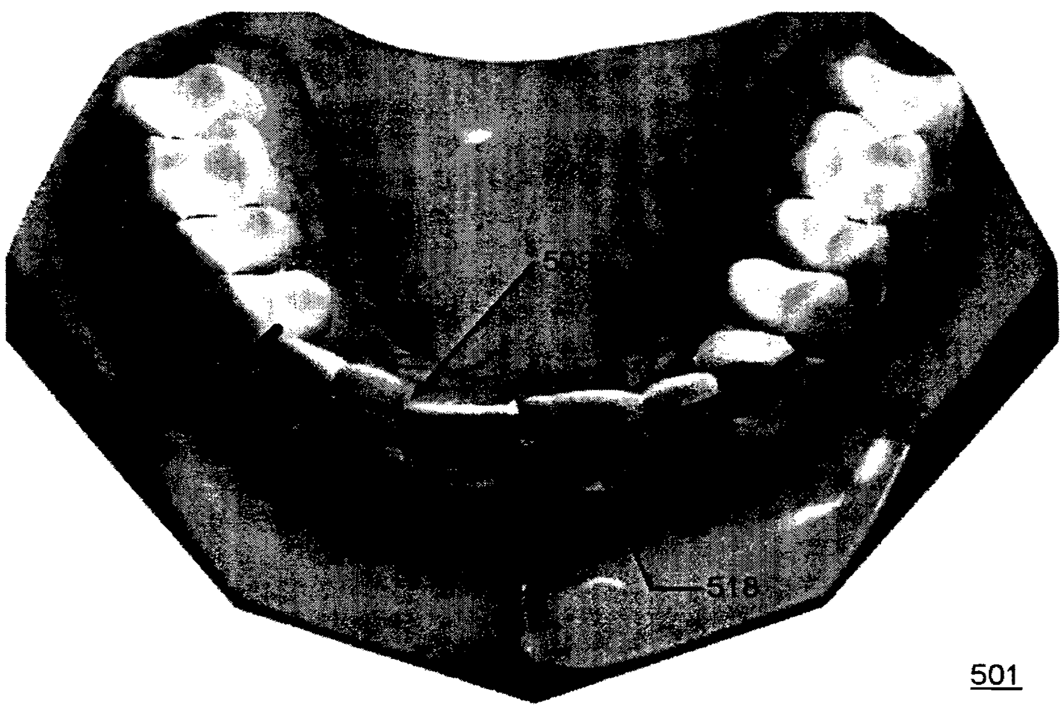
Fig. 5e)



501

Fig. 5f)

Fig. 5g)



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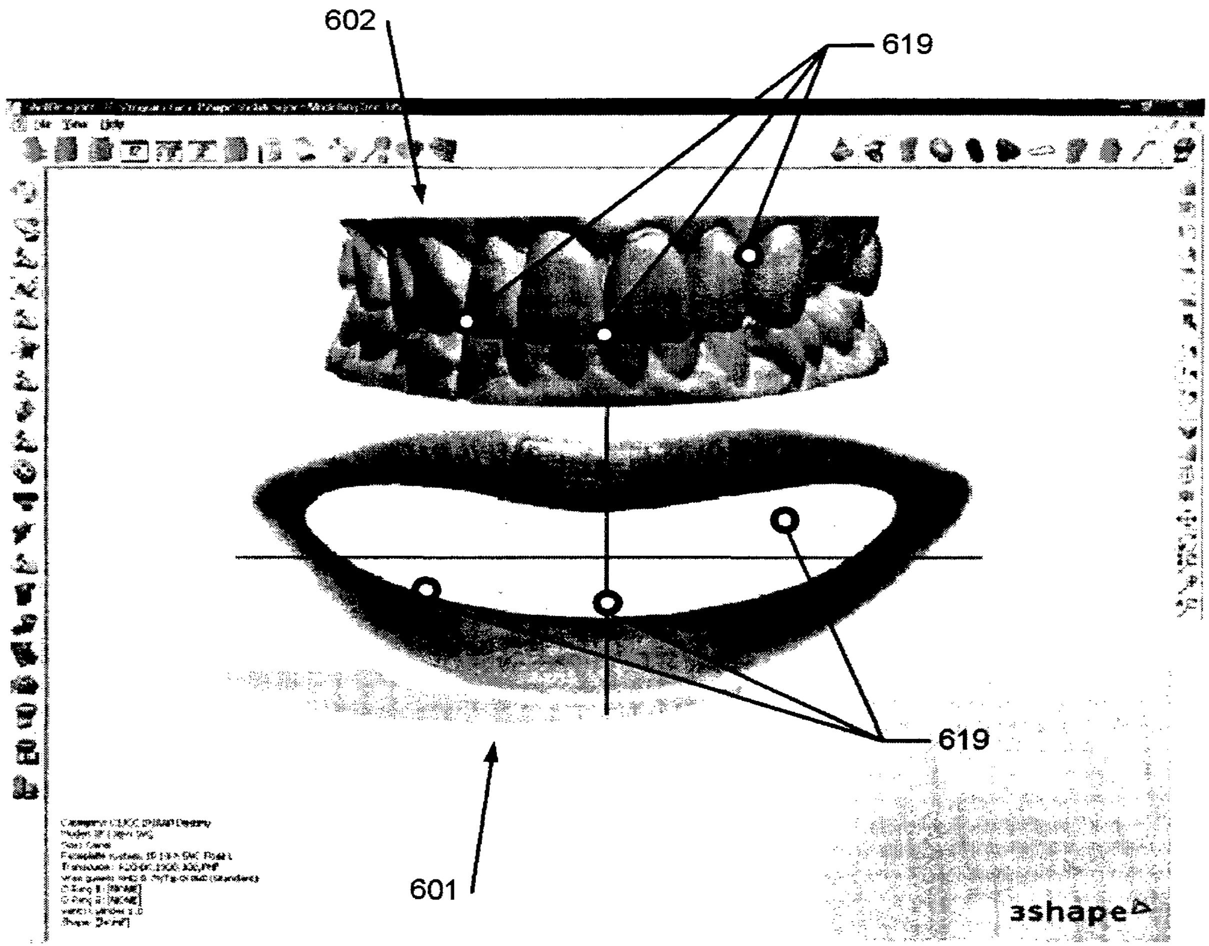


Fig. 6a)

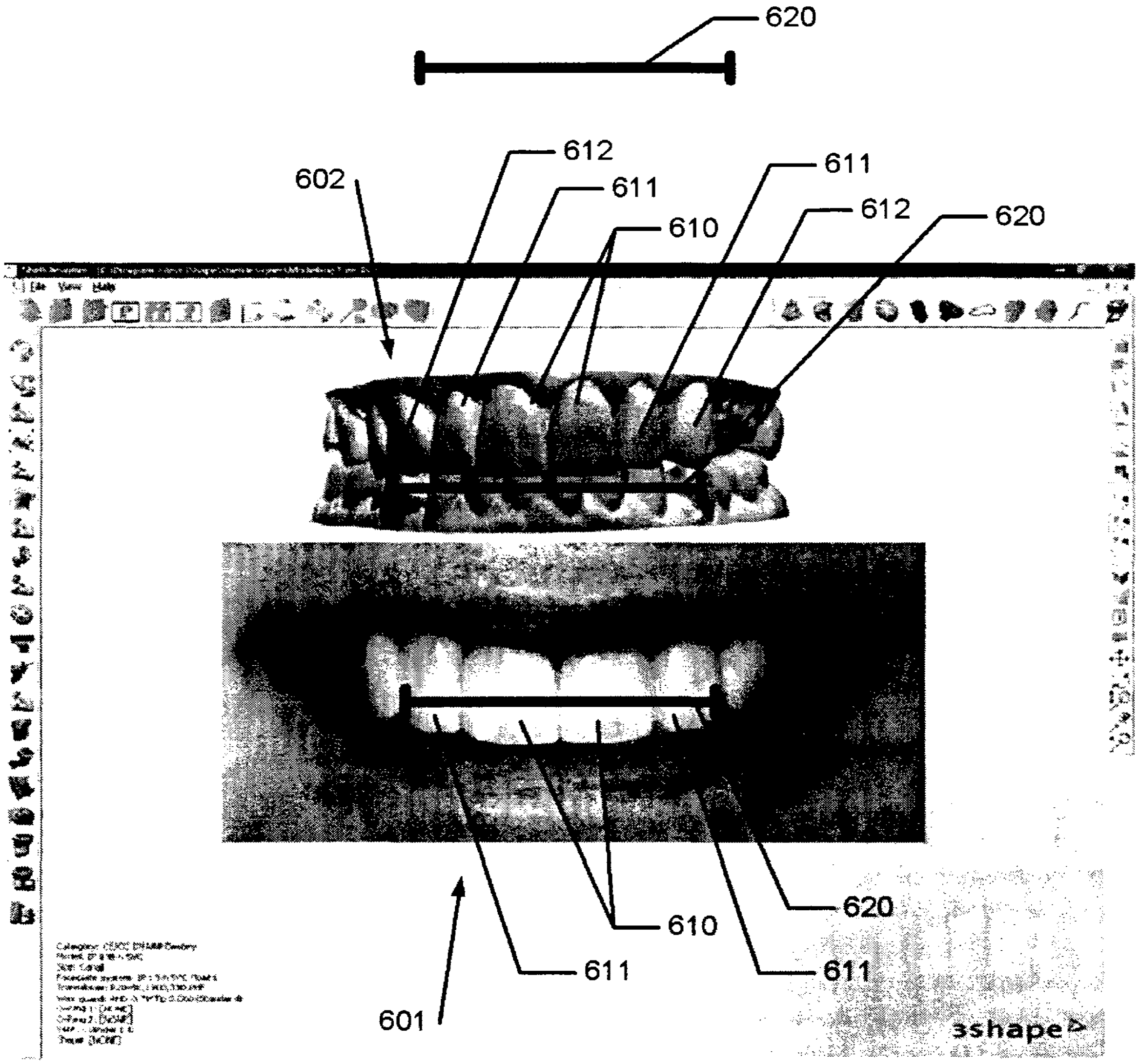
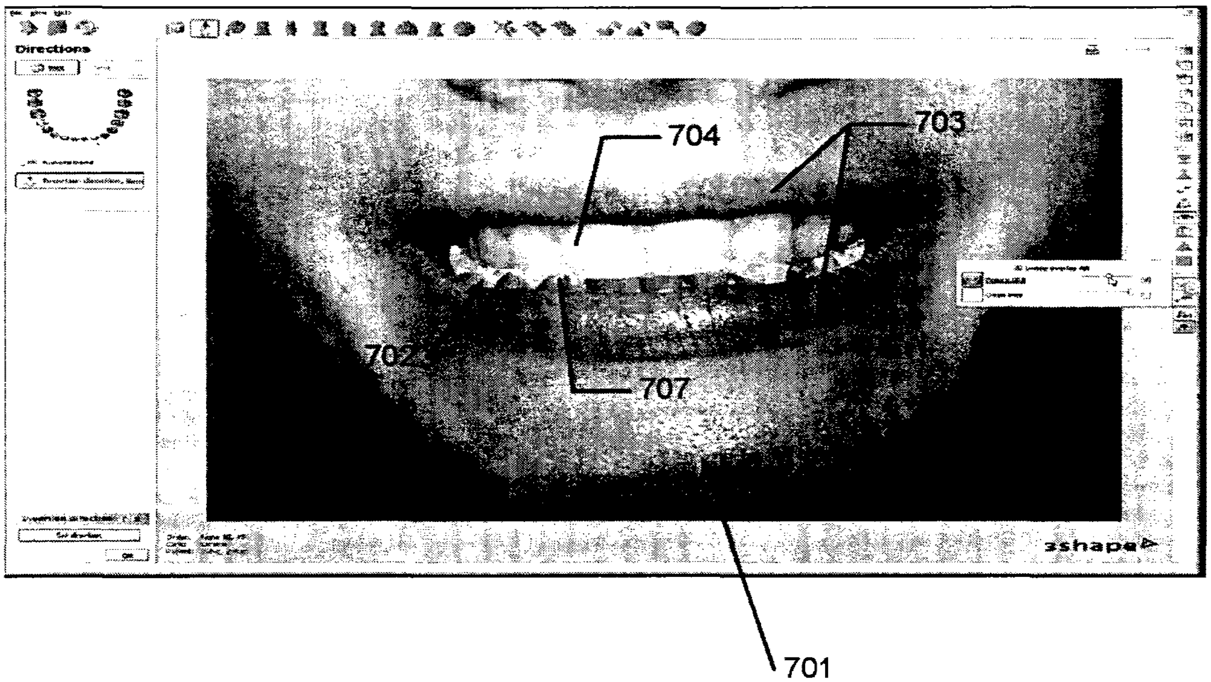


Fig. 6b)

Fig. 7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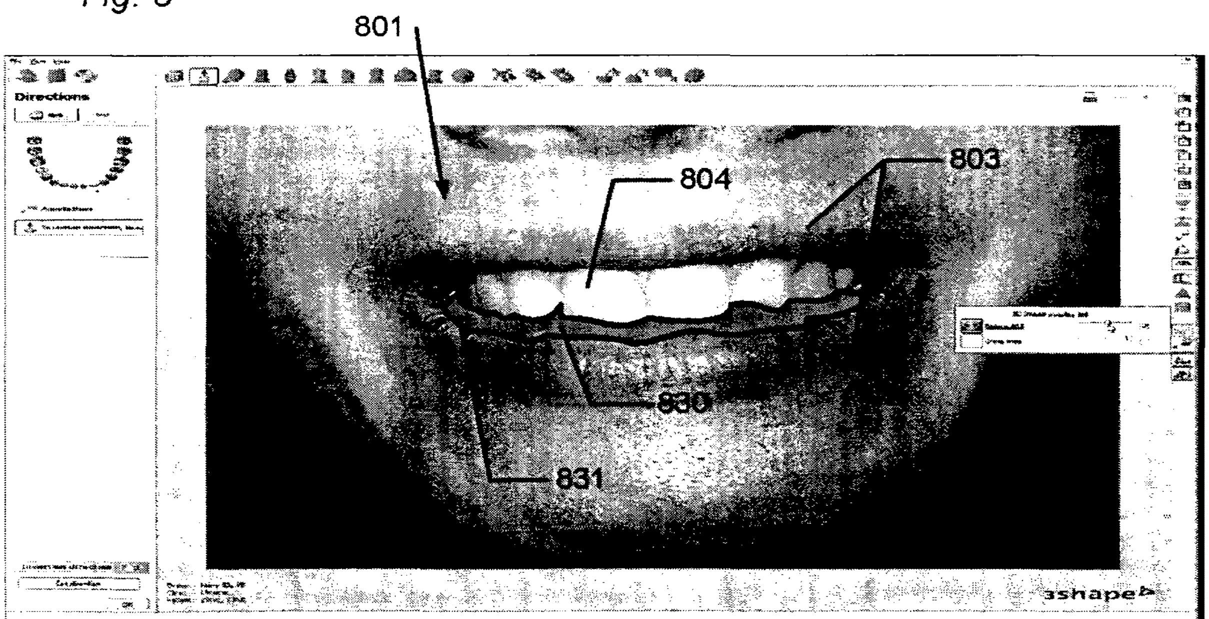
703
702
707
701
Directions
3shape

Fig. 8


801
804
803
830
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Directions
3shape

Fig. 9

901

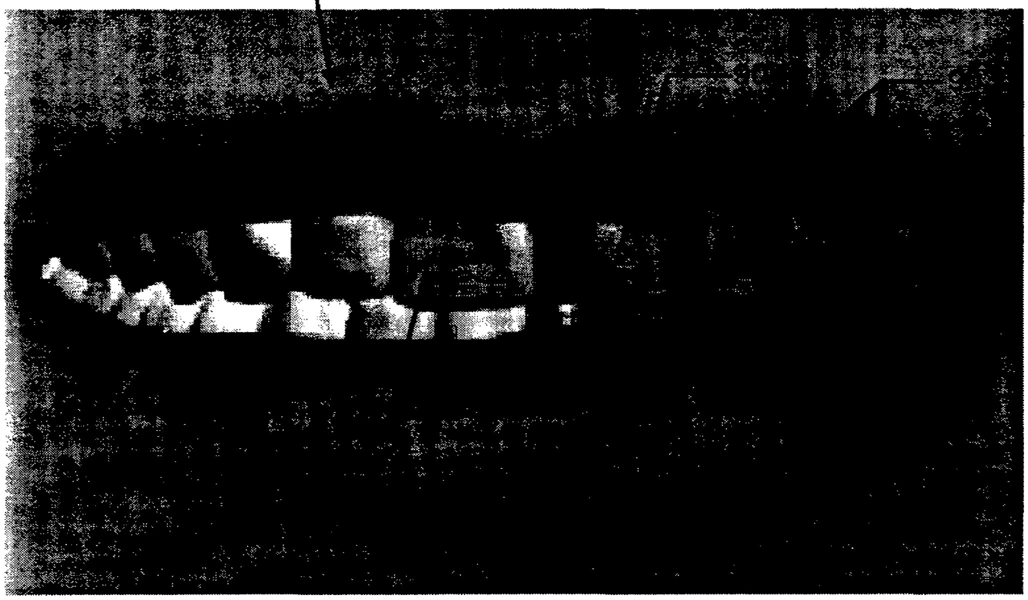
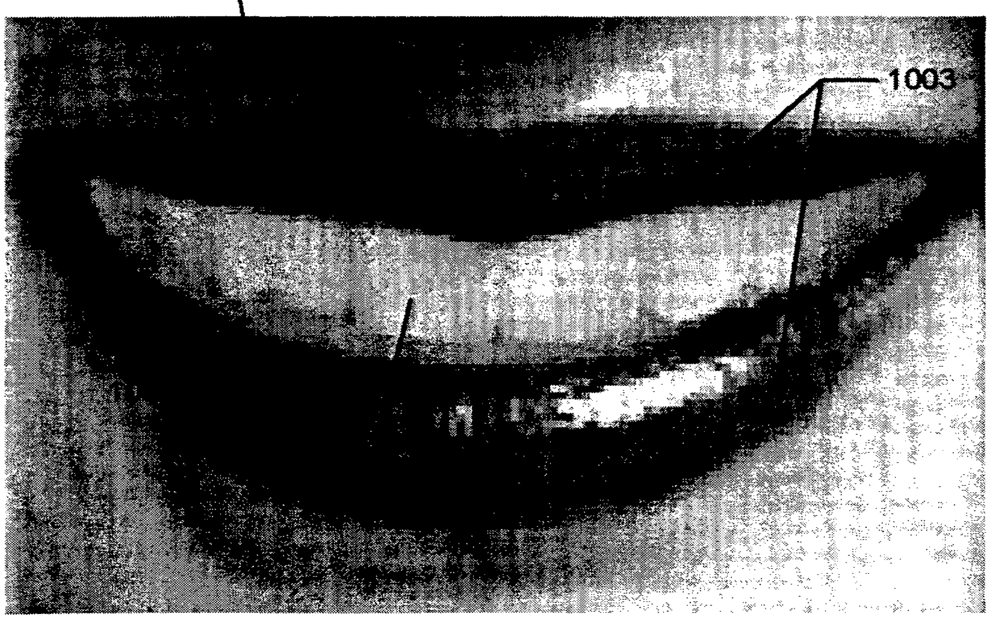


Fig. 10

1001



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Applicant: (Name and address)	3Shape A/S Holmens Kanal 7, 4. DK-1060 København K Denmark

Title: 2D image arrangement

IPC: A 61 C 7/00

This is to certify that the attached documents are exact copies of the above mentioned patent application as originally filed.

Patent- og Varemærkestyrelsen
Økonomi- og Erhvervsministeriet

01 July 2011

Gitta Storch Priess

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.

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.

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 is 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.

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.

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 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 a template for supporting designing and/or modeling the patient's teeth.

5. 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.

6. 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.

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

8. 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.

9. 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.

10. 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.

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)

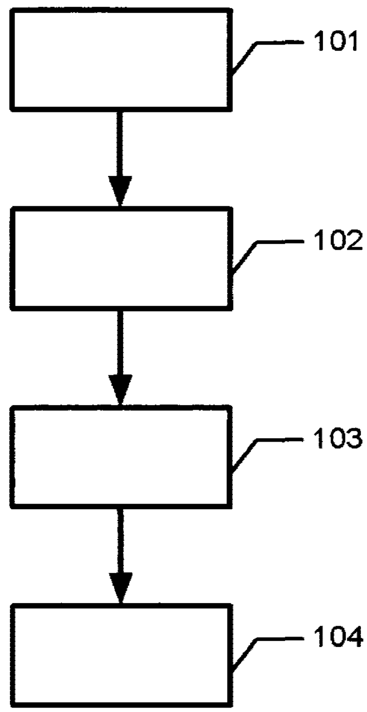


Fig. 1

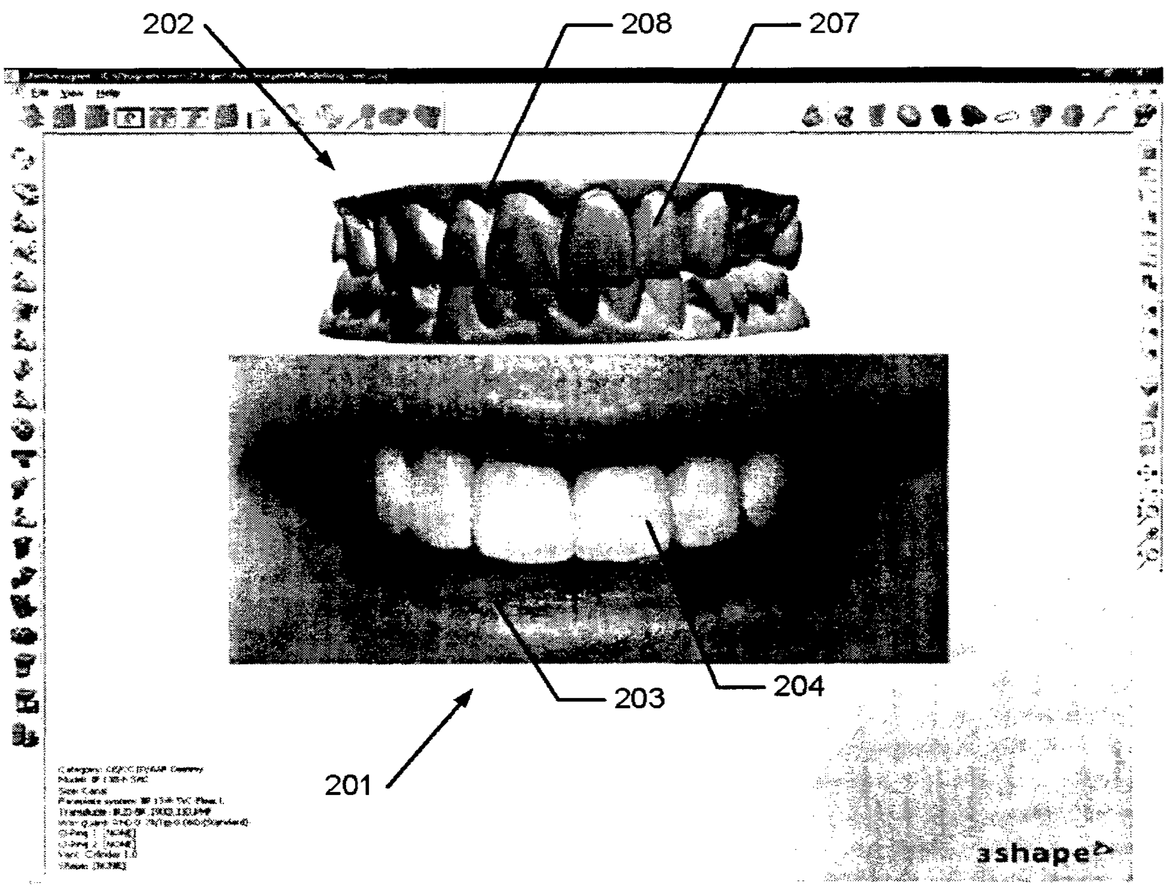


Fig. 2a)

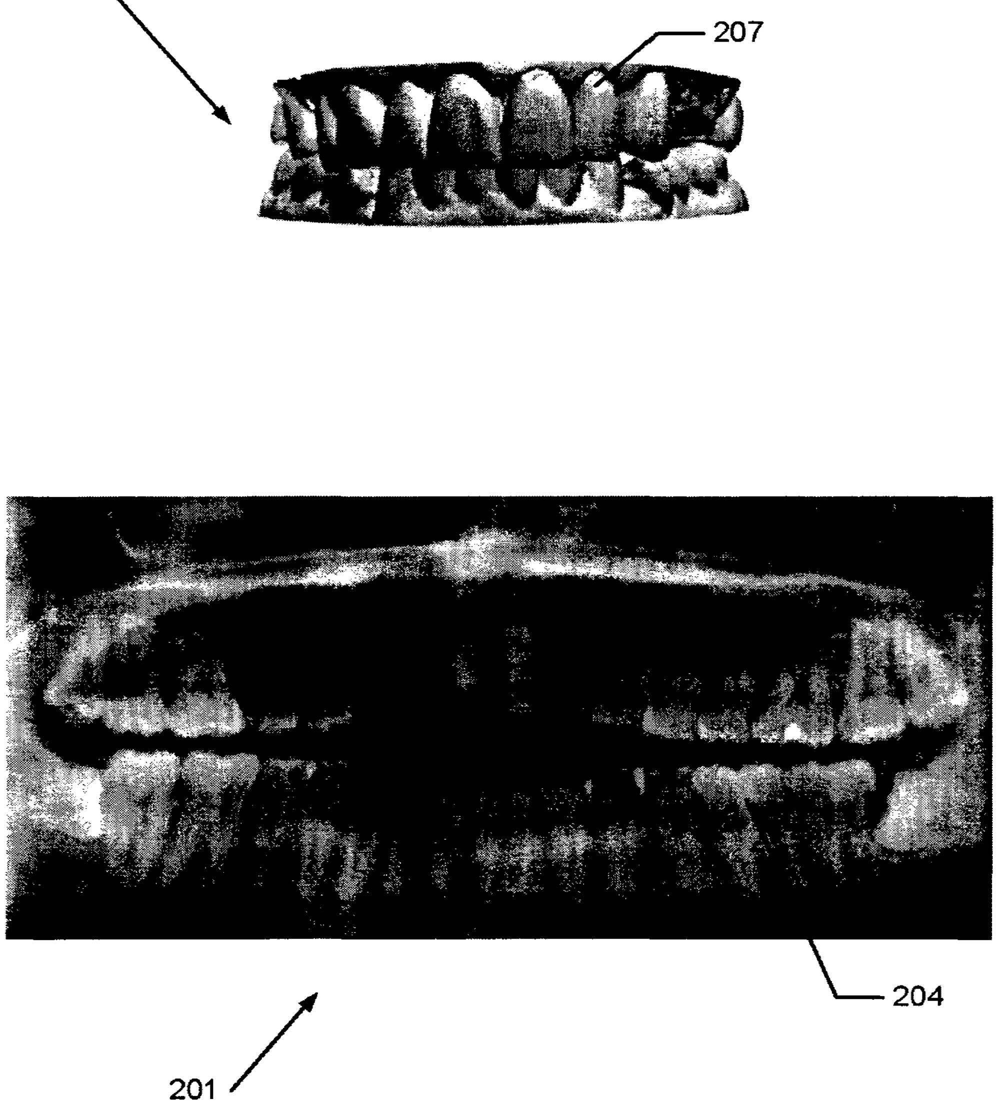


Fig. 2b)

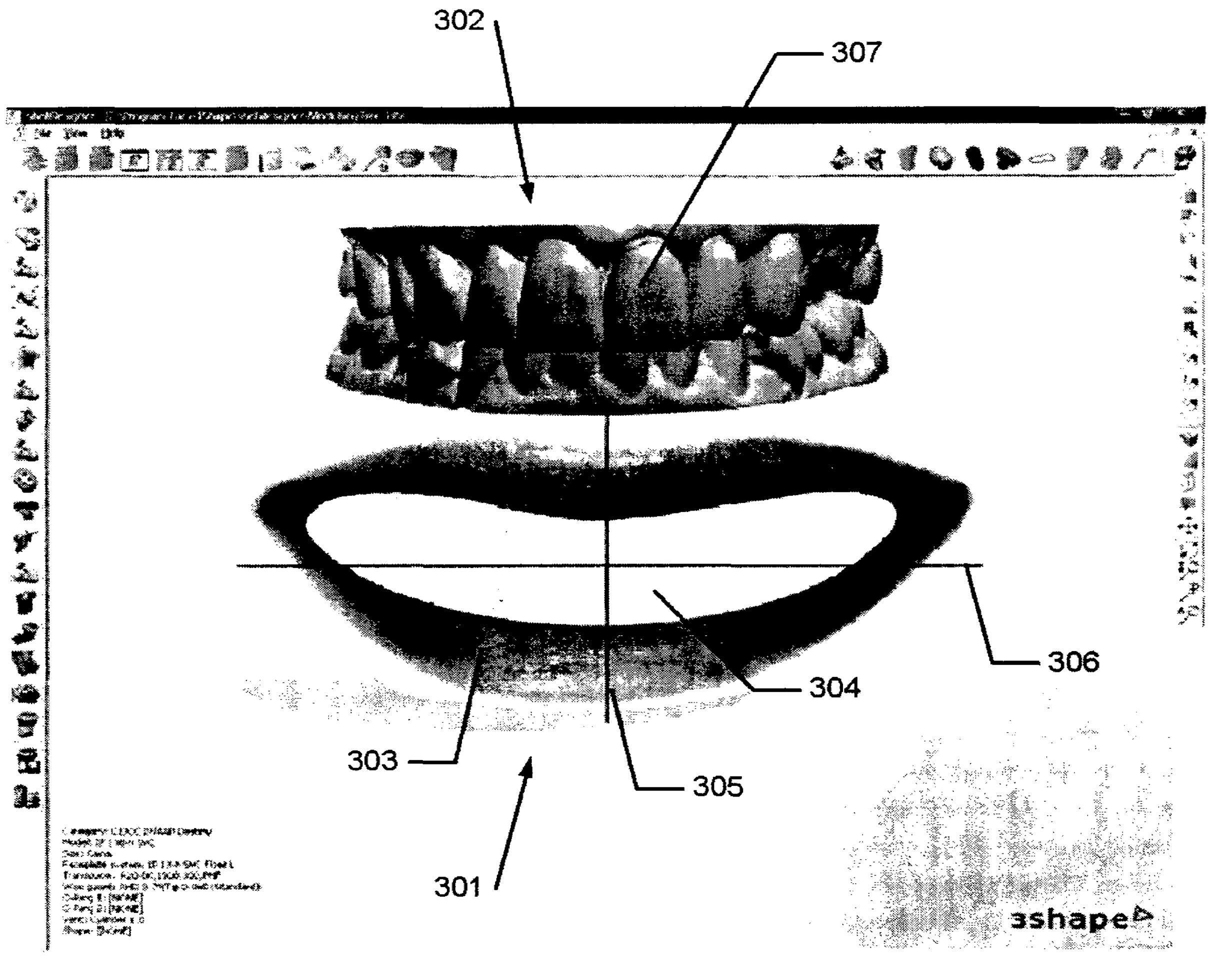


Fig. 3a)

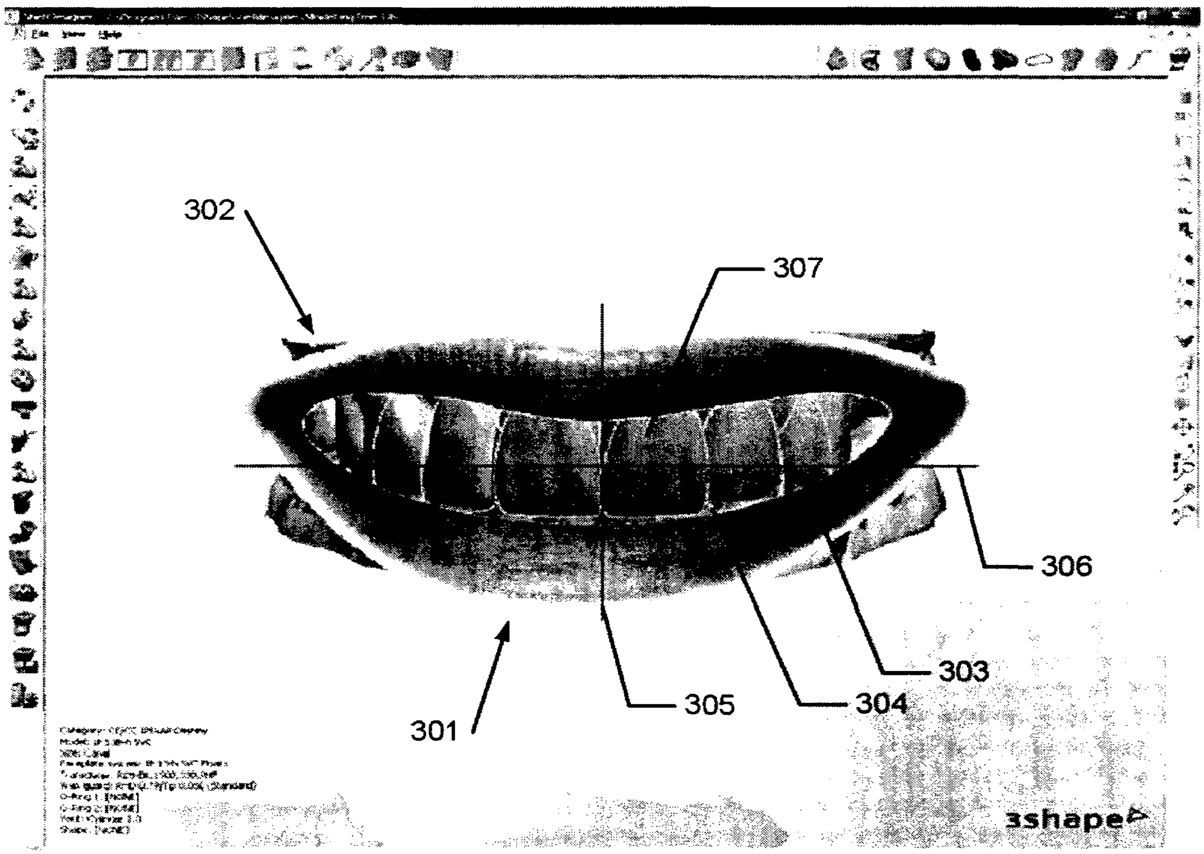


Fig. 3b)

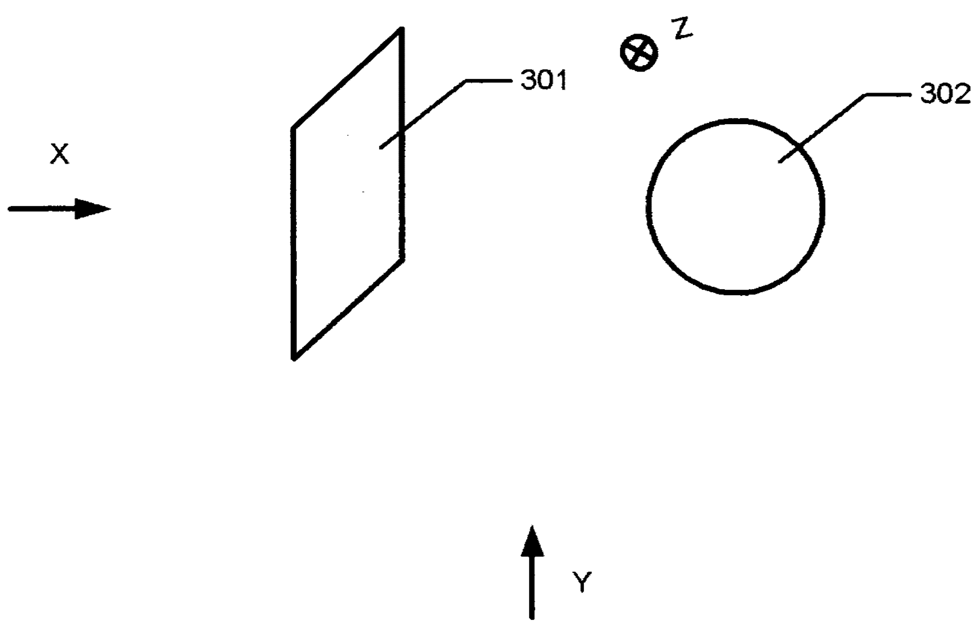


Fig. 3c)

Fig. 4a)

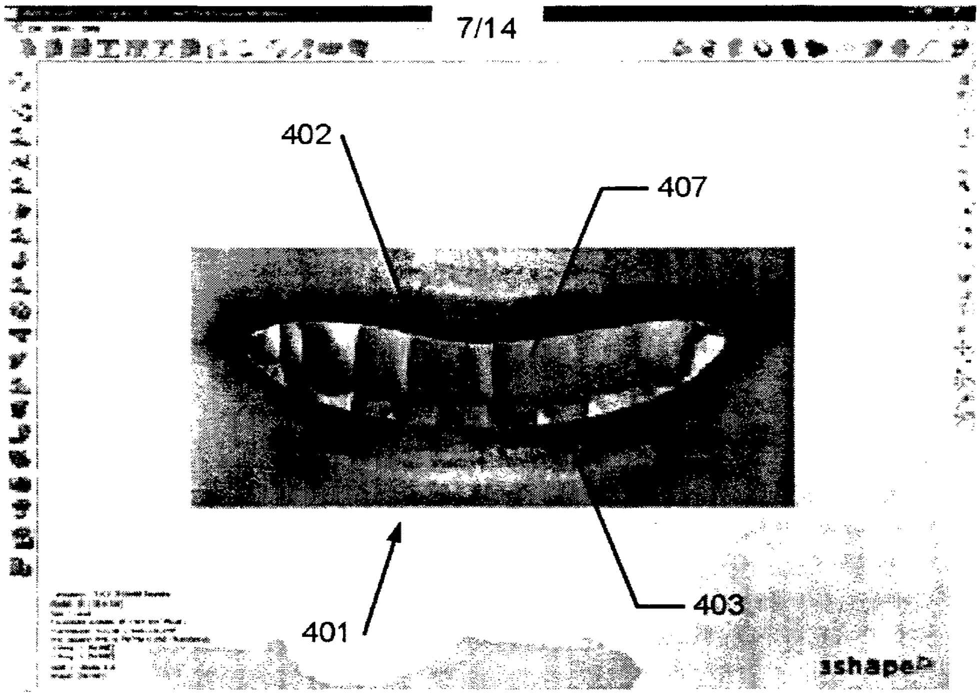
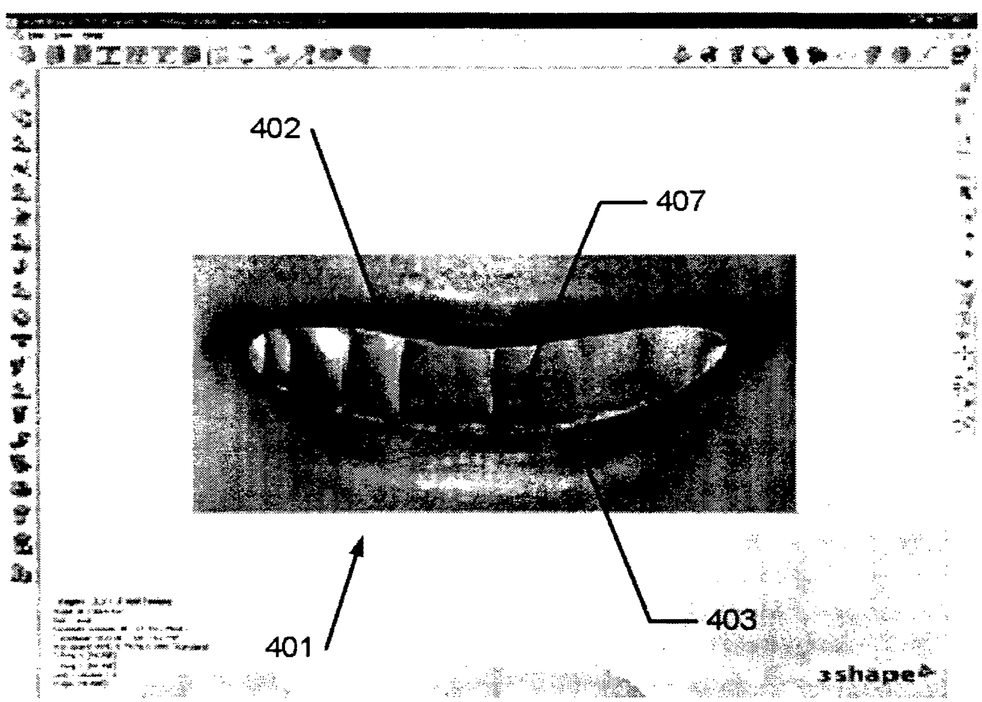


Fig. 4b)



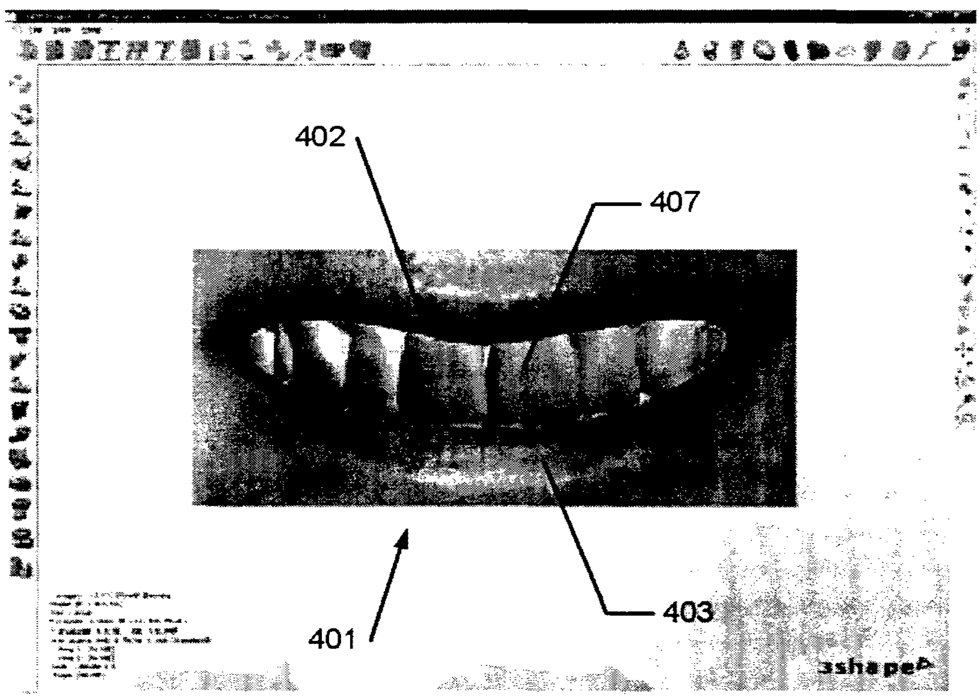


Fig. 4c)

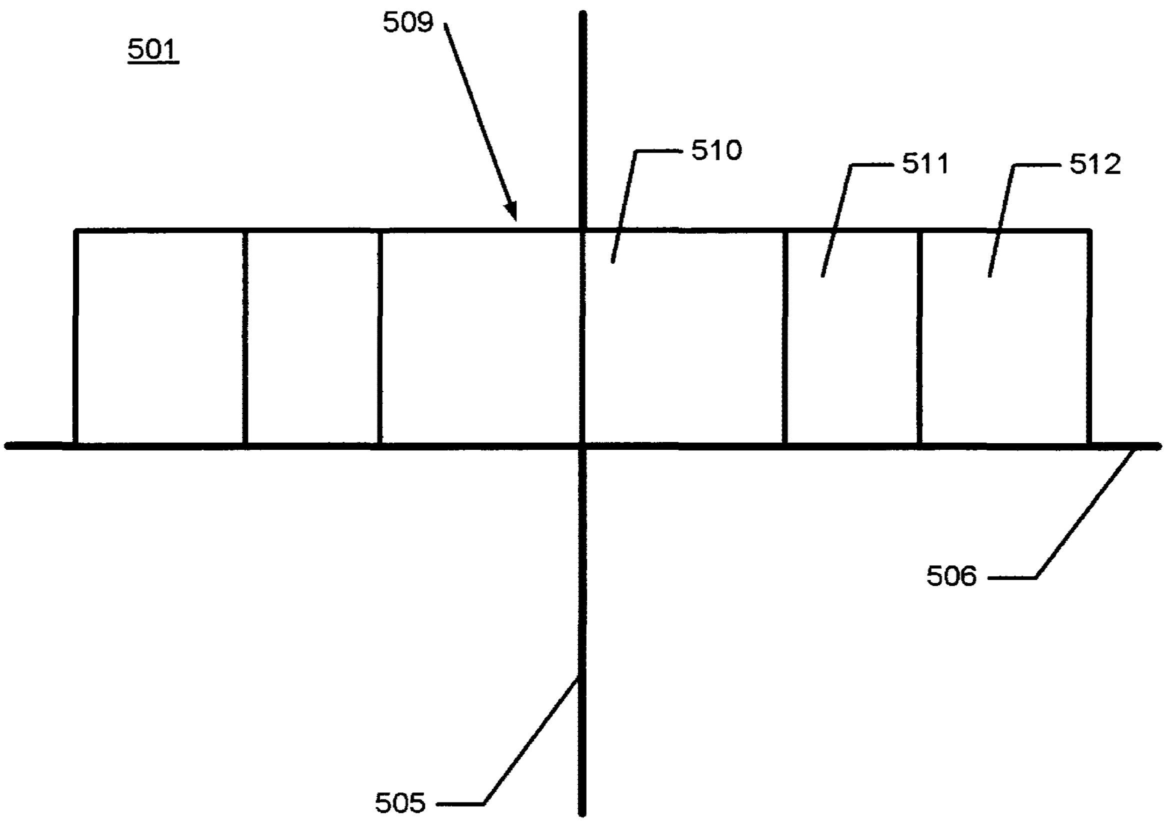
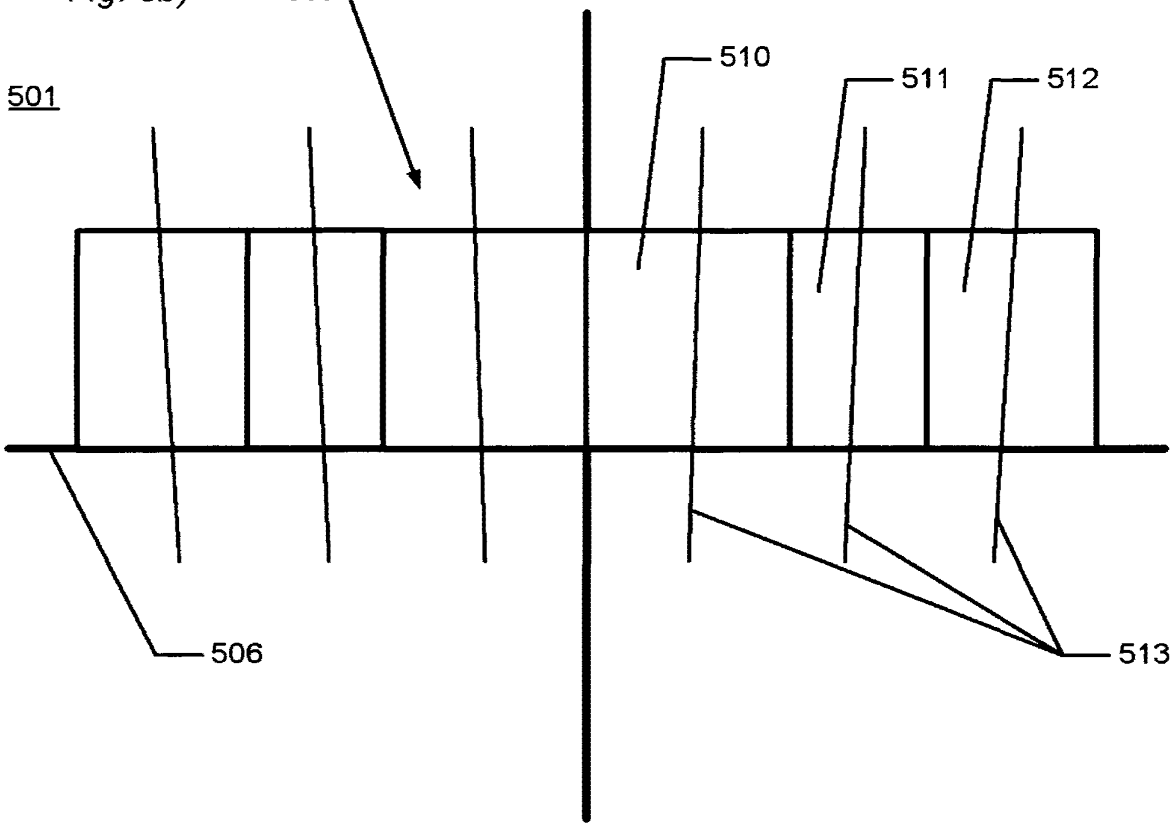


Fig. 5a)

Fig. 5b)



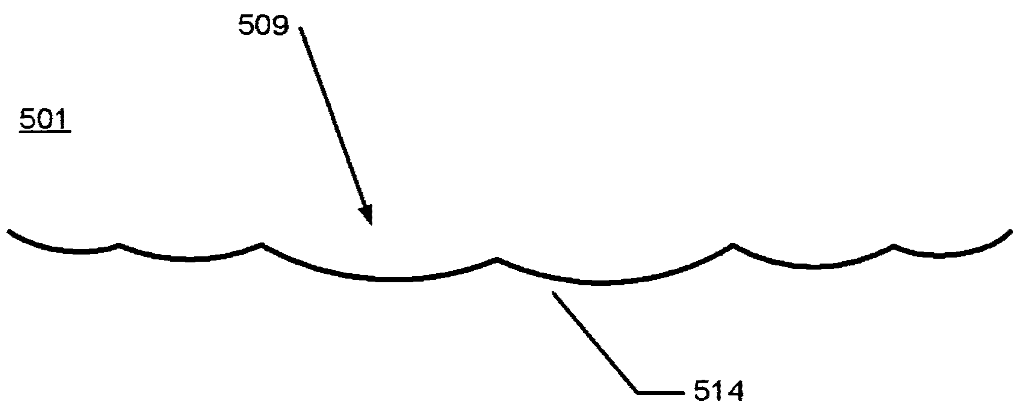
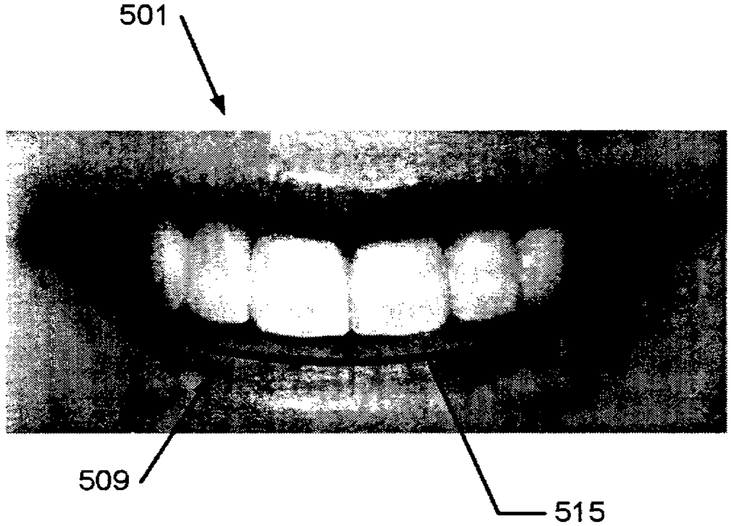


Fig. 5c)

Fig. 5d)



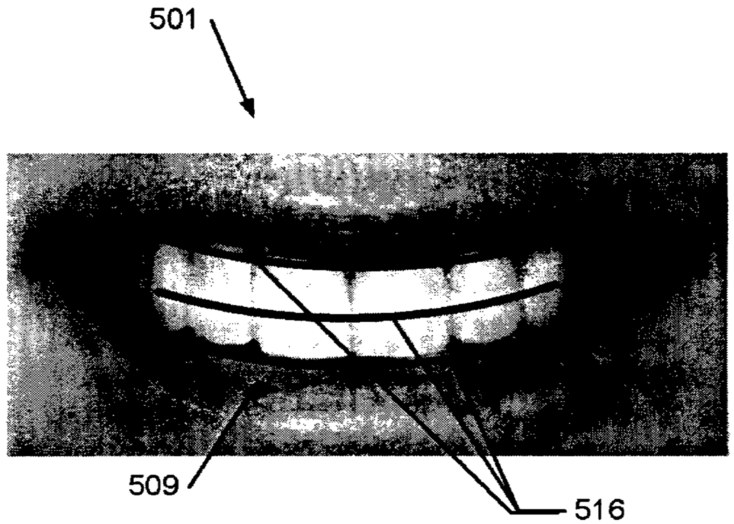


Fig. 5e)

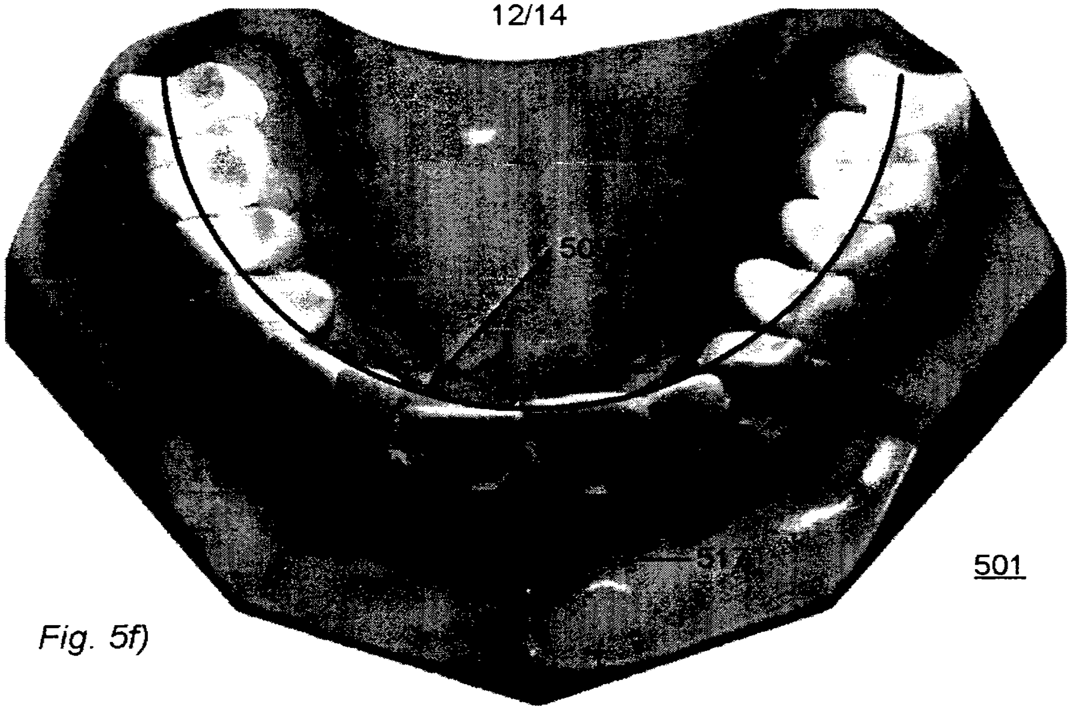


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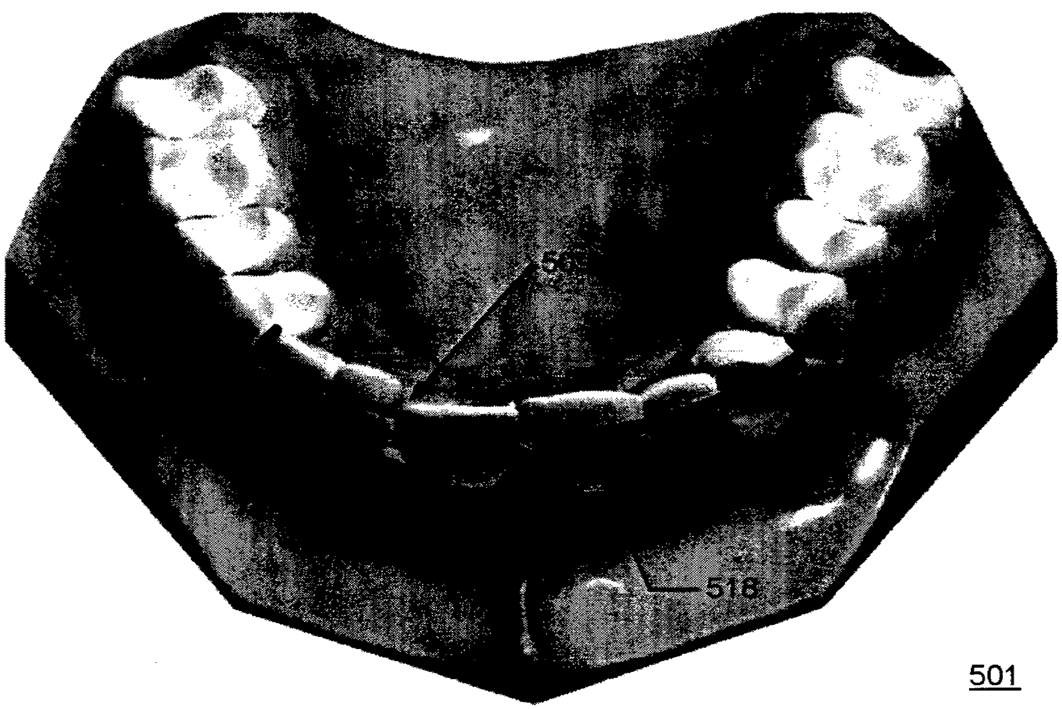
Fig. 5f)

Fig. 5g)



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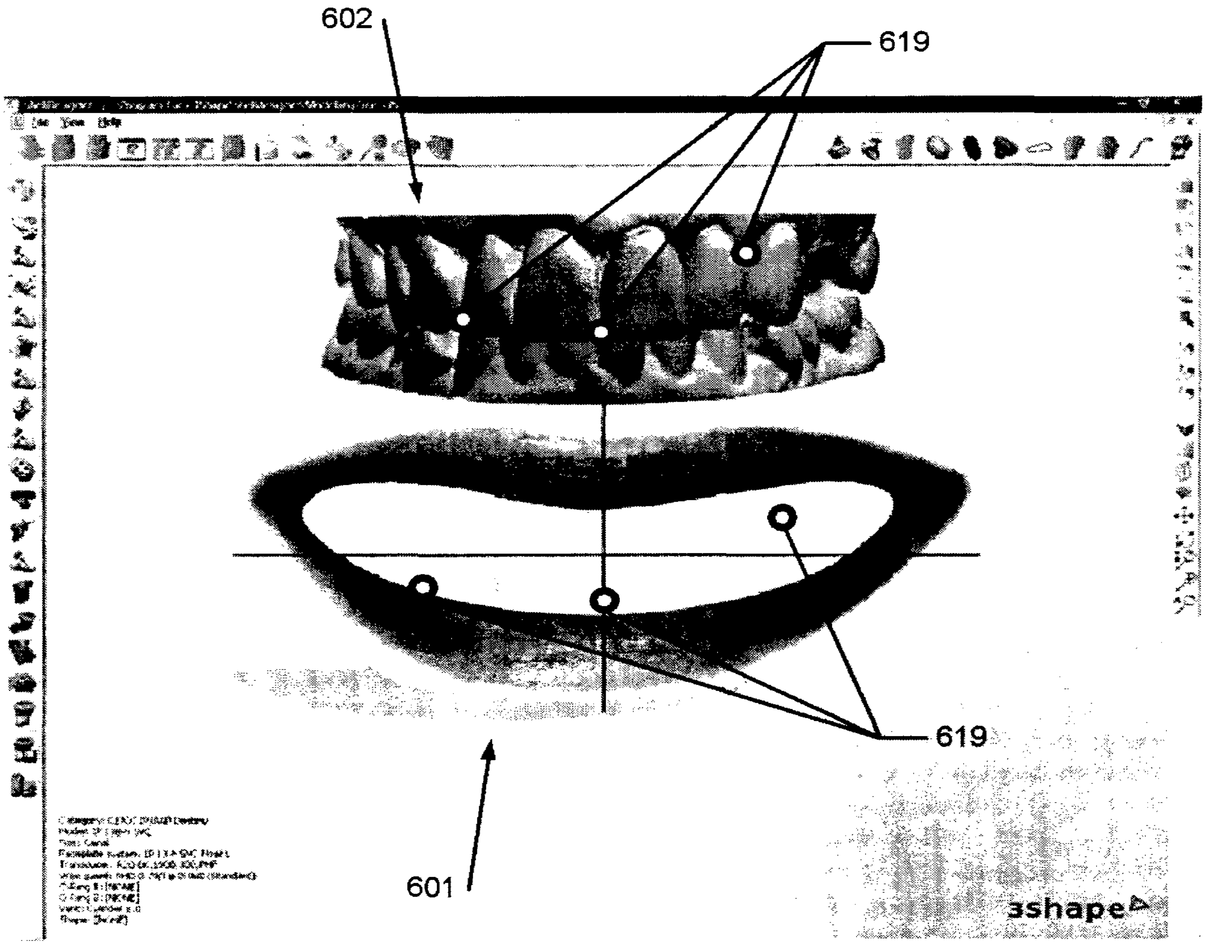

Fig. 6a)

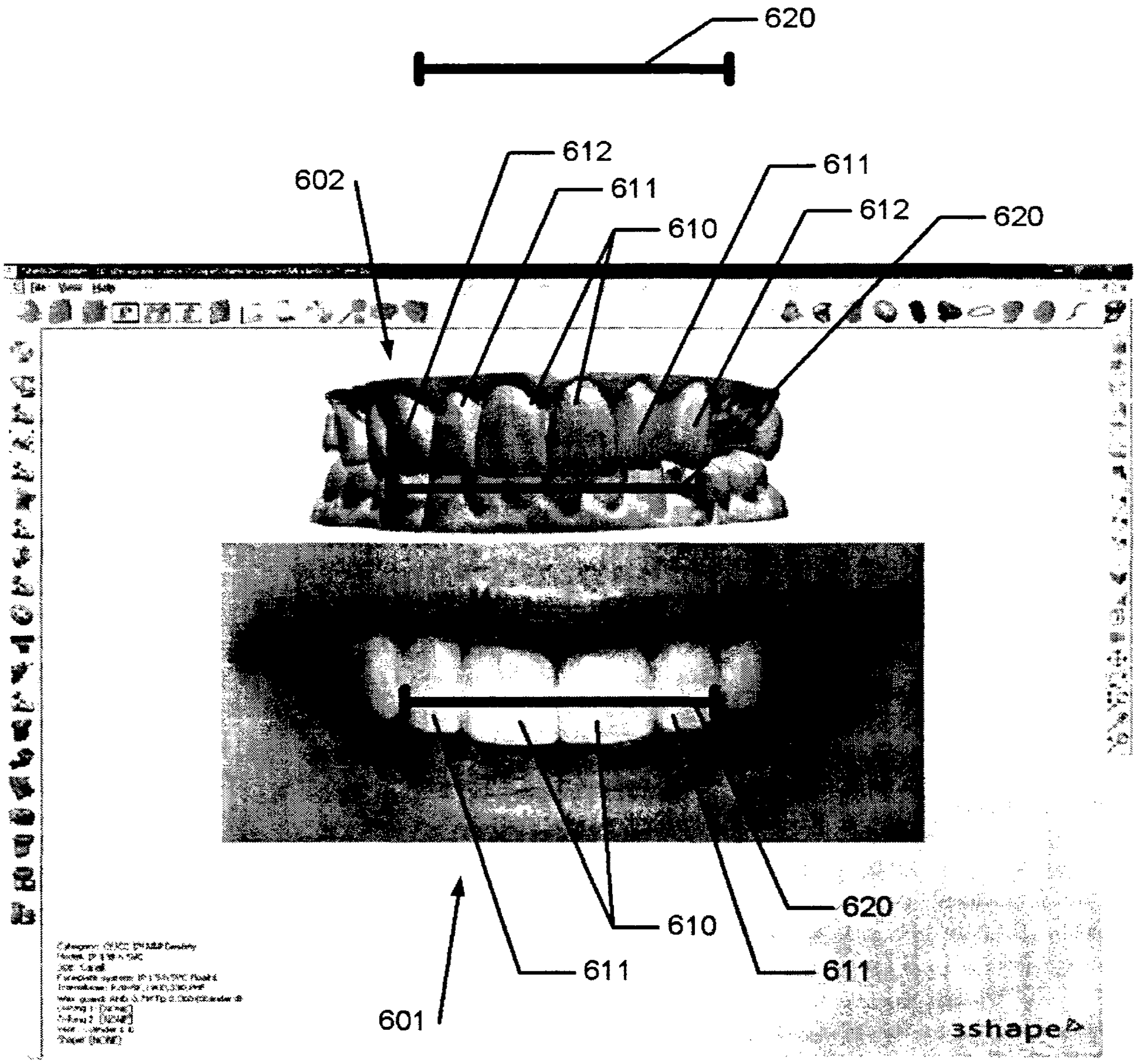

Fig. 6b)

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APPLICATION NUMBER: ***61/454,200***
FILING DATE: ***March 18, 2011***

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS ***US61/454,200***

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. § 1.53(c).

Docket No.	0079124-000004	Type a plus sign (+) inside this box	+

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FISKER	Rune		Virum, Denmark
DEICHMANN	Nikolaj		Klagshamn, Sweden

TITLE OF THE INVENTION (500 characters maximum)

2D IMAGE ARRANGEMENT

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ENCLOSED APPLICATION PARTS (check all that apply)

☒	Specification/Claims/Abstract	# of Pages	48	☐	CD(s) Number
☒	Drawings	# Sheets	16	☒	Other (specify): Form PTO/SB/39
	Total Pages in Spec/Drawings		64		
☒	Application Data Sheet. See 37 CFR 1.76				

METHOD OF PAYMENT OF FILING FEES (check one)

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