

Gzj kdkv'2007"

ADVANCES IN ANTICALCIFIC AND ANTIDEGENERATIVE TREATMENT OF HEART VALVE BIOPROSTHESES

*Proceedings of the Fourth Scientific Meeting
of the International Association
for Cardiac Biological Implants*

EDITED BY _____

Shlomo Gabbay, M.D.
Department of Cardiothoracic Surgery
UMDNJ-New Jersey Medical School
Newark, NJ

David J. Wheatley, M.D.
Department of Cardiac Surgery
University of Glasgow
Glasgow, Scotland

**ADVANCES IN ANTICALCIFIC AND
ANTIDEGENERATIVE TREATMENT OF HEART
VALVE BIOPROSTHESES**

*Proceedings of the Fourth Scientific Meeting
of the International Association
for Cardiac Biological Implants*

Held in Washington, D.C. on May 4, 1997.

Copyright © 1997.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the International Association for Cardiac Biological Implants or Silent Partners, Inc.

Printed in the United States of America.

ISBN 1-878353-42-X

Published by

S i l e n t P a r t n e r s , I n c .

8727 Shoal Creek Blvd.

Austin, TX 78757-6815 USA

Telephone: 512-458-1191

FAX: 512-458-1234

CHAPTER 3

BIAXIAL MECHANICAL BEHAVIOR OF BIOPROSTHETIC HEART VALVE CUSPS SUBJECTED TO ACCELERATED TESTING

M.S. Sacks, K.L. Billiar

Department of Biomedical Engineering
University of Miami
Coral Gables, Florida

Abstract

The effects of *in vivo* cyclic loading on the mechanical behavior of porcine bioprosthetic heart valves are largely unknown, and are undoubtedly related to their continued poor long-term durability. To elucidate the mechanisms that eventually produce failure in porcine bioprosthetic heart valves, tension-controlled biaxial mechanical tests were performed on the cuspal tissue following 0, 1.4, 5.7, 10.1, 50, 100, and 200 million cycles of accelerated testing. A microstructural constitutive model was employed to estimate the changes in the effective mechanical behavior of the collagen fibers. Under a 60-N/m equibiaxial tension state, a trend toward increasing circumferential extensibility was found, with no trend in the corresponding radial extension. Simulations using the microstructural model demonstrated that slight specimen misalignments with respect to the biaxial test axes can potentially cause large variations in the measured extensibilities. When the model was used to fit representative data from a nonfatigued and a 200 million cycle fatigued valve, the effective fiber stiffness for the fatigued specimen was markedly lower than the nonfatigued specimen. Histologic studies revealed delaminations but no evidence of damage to the collagen fiber structure, suggesting that tissue damage occurs on a subfibril structural level. Overall, our results imply that long-term cyclic loading produces a gradual weakening of the collagen fiber network, potentially facilitating calcification and ultimately valve failure.

Introduction

Although bioprosthetic heart valves remain a popular choice for heart valve replacement, they continue to suffer from limited long-term durability. The mechanisms of valve material degeneration, especially when related to calcification, are not well understood.¹ *In vivo* structural deterioration of porcine aortic valve

FOR CORRESPONDENCE OR REPRINTS:

Michael Sacks, Ph.D.
Department of Biomedical Engineering
University of Miami
P.O. Box 248294

bioprostheses (PBHVs) is strongly time-dependent, increasing rapidly after 10 years postimplantation.^{1,2} Especially in bending, it is believed to potentiate mineralization. The chemical aspects of mineralization and valve deterioration have been studied intensively,⁵⁻⁷ little work has been completed on the effects of cyclic loading of chemically treated valve tissue.⁸

At present, "adequate" fatigue life of an intact valve is determined by testing. In this procedure, the PBHV is cycled at 150 cycles per minute at a rate in a pulsatile flow loop using sterile saline as the fluid. The magnitude and loading pattern are believed to adequately simulate the in vivo environment, with failure patterns generally similar to those observed in clinical studies of explanted tissue. In general, the study of the fatigue of valves requires an understanding of the gradual mechanical changes that lead to complete valve failure. A study of the subfailure mechanism requires progression with time (number of opening and closing cycles) to establish a quantitative representation of the fatigue process. The goal is to elucidate the predominant mechanisms and mechanisms of failure.

Broom⁸⁻¹⁰ completed a series of studies on the effects of cyclic tension and flexure on circumferential strips of glutaraldehyde cross-linked porcine mitral and porcine aortic valves. The circumferential strips failed markedly with as few as 2.3×10^6 cycles, and the failure rate increased with increased numbers of cycles.⁸ Collagen disruption was observed after pronounced flexure by 300×10^6 cycles. In porcine aortic valves, collagen disruption increased with the number of cycles and was observed after 10^6 cycles.⁹ Low pressure fixed porcine aortic valves showed minimal damage, whereas high pressure fixed valves showed significant damage similar to the mitral valve tissue. A comparison of the native collagen fiber crimp was found in all but the high pressure fixed valves in which the crimp pattern was already lost during fixation.

These uniaxial studies provide the only information on the effects of uniaxial mechanical loading of heart valve tissue found in the literature. Tissue strips, however, cannot mimic the heterogeneous loading conditions combined loading sequences found in the physiological environment. In uniaxial loading the collagen fiber architecture is disrupted in uniaxial loading. The complex interactions between the axes are lost. Accelerated testing preserves the 2-dimensional fiber network. Although the results are dependent upon the individual valve geometry and testing conditions, the stresses directly measured, the cuspal stresses more closely represent the stresses experienced in vivo. Materials tests performed on uniaxial strips at defined accelerated testing intervals could provide a quantitative measure of valve tissue subjected to realistic purely mechanical loading over a period of time. However, the gains of intact fatigue cycling are not known. The mechanics of the intact valve tissue, are not presently known. Testing is performed to assess the mechanical property

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.