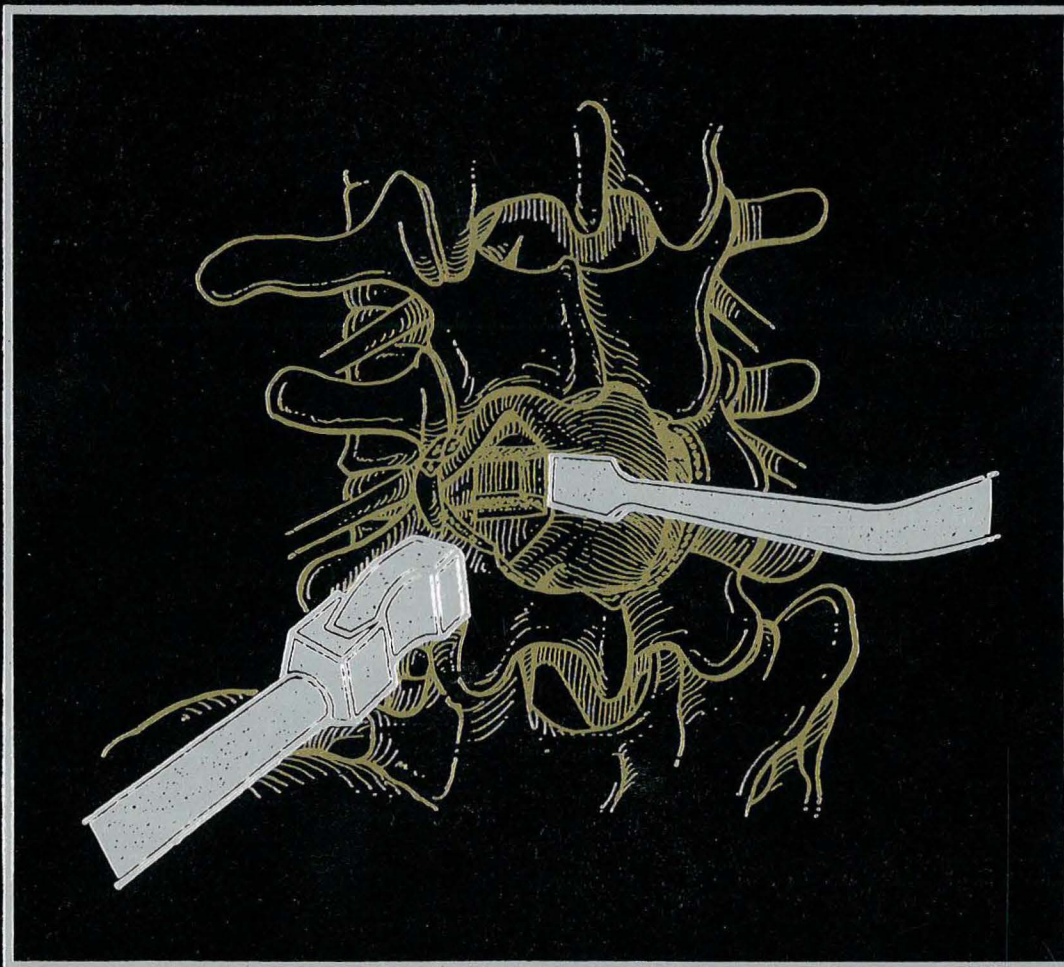


LUMBAR INTERBODY FUSION TECHNIQUES

Cages, Dowels, and Grafts



Edited by

Regis W. Haid, Jr. • Mark R. McLaughlin • Richard G. Fessler

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Printed in the United States of America.

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PUBLISHER Karen Berger
ASSOCIATE EDITOR Michelle Berger
DEVELOPMENTAL EDITOR Donna Rothenberg
PRODUCTION Carolyn Reich, Susan Trail
BOOK DESIGN Susan Trail
COVER DESIGN David Berger
COVER ART Bill Winn

Quality Medical Publishing, Inc.
11970 Borman Drive, Suite 222
St. Louis, Missouri 63146
Telephone: 1-800-348-7808
Web site: <http://www.qmp.com>

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Lumbar interbody fusion techniques : cages, dowels, and grafts / edited by Regis W. Haid, Jr., Mark R. McLaughlin, Richard G. Fessler.

p. ; cm.

Includes bibliographical references and index.

ISBN 1-57626-121-2 (hardcover)

1. Lumbar vertebrae—Surgery. 2. Spinal fusion.

[DNLM: 1. Spinal Fusion—instrumentation. 2. Spinal Fusion—methods. 3. Low Back Pain—surgery. 4. Lumbar Vertebrae—surgery. WE 725 L9563 2003] I. Haid, Regis W. II. McLaughlin, Mark R. III. Fessler, Richard G.

RD768 .L846 2003

617.5'6059—dc21

2002001825

QM/SB/SB

5 4 3 2 1

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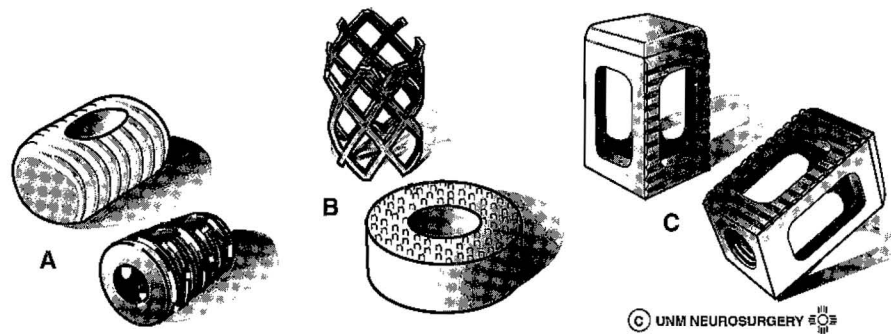
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■■■■ **FIGURE 3-2.** Current cage designs basically follow the pattern of threaded horizontal cylinders (A), vertical rings (B), or open boxes (C). A variety of materials including bone, metals, and polymers are used in the manufacture of these devices. (Reproduced with permission from the Division of Neurosurgery, University of New Mexico, Albuquerque, New Mexico.)

DEVICE MATERIALS

A number of nonbiological materials have also been used to create various designs of interbody fusion devices. Metals ranging from stainless steel to titanium to tantalum are included in this group. Nonmetallic materials such as polymers and carbon fiber compounds were also used. All of the various interbody cage designs can generally be described as horizontal cylinders, vertical rings, or open boxes (Fig. 3-2).¹³ The horizontal cylinder devices currently in clinical use are typically threaded devices.

BIOMECHANICS

The three basic biomechanical tests that describe the characteristics of a spine implant are strength, fatigue, and stability. Strength testing evaluates the failure load of the device. The fatigue test provides a measure of the longevity of the device under conditions of repetitive loading or motion. The stability test measures the capability of the device to provide multidirectional stability to the injured spine.¹⁴ The commonly available intervertebral body cage and bone dowels all have been shown to have exceptionally good strength qualities. In compressive testing of the Brantigan carbon fiber cage (essentially the Lumbar I/F Cage, DePuy AcroMed, Inc., Raynham, Mass.), average load to failure was 5288 newtons. The vertebral body endplates generally failed before device failure occurred.⁷ The average yield load of threaded cortical bone dowels is greater than 24,000 newtons.¹⁵ Likewise, the yield strength for the threaded cylindrical titanium cages has been demonstrated to exceed several thousand newtons for all of the commonly available devices.

Fatigue strength of a spinal implant refers to its resistance to dynamic loading. This is characterized by the number of cycles to failure under defined loading conditions. Normal physiologic loads at the lumbar intervertebral motion segment range from approximately 1000 newtons when standing, to 3000 newtons when sitting, and approximately 10,000 newtons for very heavy lifting.¹⁵⁻¹⁷ Only the very strongest individuals

would be expected to have the capability of generating a 10,000 newton spinal compressive load. Spinal motion segments in cadavers have failure strength in the neighborhood of 6000 newtons, on average.^{7,18} With the placement of paired threaded interbody implants, the mean maximum compressive load that will be transmitted through the implants is approximately 3000 newtons.¹⁹ The BAK cage (Sulzer Spine-Tech, Inc., Minneapolis, Minn.) has been tested with cyclical loading to 9600 newtons, and the device was able to withstand this load through five million cycles without failure.²⁰ Likewise, threaded cortical bone dowels have been shown to withstand 500,000 cycles of flexion loading at load values much greater than physiologic numbers without failure.¹⁵

Strength of Device-Bone Interfaces

Another important characteristic of strength with interbody implants is the consideration of the strength of the implant-bone interface. The strength of this interface essentially dictates the limitation to pullout or retropulsion of the device. The Brantigan carbon fiber cage has a number of small teeth or ridges that penetrate into the bony endplate to provide resistance to device dislodgment.^{7,13} In comparison with non-threaded donor bone dowels, the pullout force required for the carbon fiber device was three times greater (353 newtons vs. 126 newtons).⁷ In a similar study comparing the pullout strength of the threaded BAK interbody cage versus the pullout strength of nonthreaded bone dowels, the BAK cage pullout strength averaged 564 newtons versus 271 newtons for the bone plugs.²⁰ The greater value for the pullout strength of the non-threaded bone plugs in this study is probably explained by the fact that in this study an axial compressive preload of 1100 newtons was applied before testing pullout strength. In another study comparing the pullout strength for the BAK cage with the pullout strength of the threaded interbody fusion device (Medtronic Sofamor Danek, Memphis, Tenn.), Rapoff et al.²¹ found that the pullout loads were similar for the two cages and exceeded 600 newtons for both types. Insertional torque was also similar for the BAK cage and the threaded interbody fusion device, and there was also a close correlation between insertional torque and pullout strength.²¹

Material Considerations

The common materials in use for construction of interbody cages today include bone, titanium, and carbon fiber. A tantalum material containing a foam-like structural composition is also under development and may soon be approved for human implantation. The use of bone provides a number of significant advantages. Bone is incorporated into the fusion construct, thus making its biological composition attractive. Bone also has a modulus of elasticity that is similar to the adjacent vertebral bodies, and this provides the ideal device stiffness for use in spine fusion constructs. Furthermore, if revision surgery is later needed, bone represents far less of a challenge to the surgeon than any of the metal devices. Titanium, a commonly used metal, is advantageous because of its high degree of tissue compatibility.² Additionally, titanium is more radiolucent than stainless steel in CT scanning, and it creates less artifact with MRI scanning than stainless steel.² With carbon fiber, a major advantage is that the material is completely radiolucent. Bone healing can therefore be imaged by standard radiographic techniques.⁷ A