The Biomechanics of Spine Cages

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Summary

- Anatomy of the Spine
- Rationale for Spine Fusions
- Types of Spine Cages and Compositions
- Biomechanics of Spine Cages
- Spine Fusion Operation Example
- Spine Fusion Complications
Anatomy of the Spine

- Lumbar Region
  - Peripheral Nerves
  - Weight Loading
- Laminae
- Processes
  - Spinus
  - Transverse
- Pedicles
- Nerve Roots
- Discs
Rationale for Spine Fusion

- Degenerated Disc
  - Disease may onset at age 20
- Herniated Disc
- Cancer
- Trauma
- Pinched Nerves
Fused Spine with Cage
## Quantification of Back Pain

<table>
<thead>
<tr>
<th>Numerical Value</th>
<th>Pain</th>
<th>Function</th>
<th>Use of Medication</th>
<th>Work Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excruciating, unbearable</td>
<td>Totally incapacitated</td>
<td>- 10 Tylenol with Codeine, or - 6 Percodan</td>
<td>- Unable to perform normal tasks around the home</td>
</tr>
<tr>
<td>2</td>
<td>Severe</td>
<td>- Daily activities at home</td>
<td>- 6-9 Tylenol with Codeine, or - 3-5 Percodan</td>
<td>- Some tasks around home - Unable to work</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>- Social activities</td>
<td>- 3-5 Tylenol</td>
<td>- Able to work at light or sedentary capacity</td>
</tr>
<tr>
<td>4</td>
<td>Mild</td>
<td>- Regular social and</td>
<td>- Occasional Tylenol, or - Nonsteroidal anti-inflammatory</td>
<td>- Able to work at moderate capacity or previous occupation with some pain</td>
</tr>
<tr>
<td>5</td>
<td>None</td>
<td>- Regular social and</td>
<td>- None, or - Occasional Tylenol</td>
<td>- Able to work at heavy capacity or previous occupation with no pain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recreational activities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Spine Cages

Harms

LT Cage

Threaded Femoral Bone Dowel

Brantigan Cage

BAK Cage
Expandable Cages

- Harms (non-expandable)
- Synex-C (Titanium)
- Synex-C (PEEK)

Advantage: achieve correct angle between vertebrae
Biodegradable Cages

A. Metallic Threaded Hollow Porous Titanium BAK Cage
B. Pure Polymer (poly(L-lactide-co-D-, L-lactide)
C. Polymer plus 10 µm size hydroxyapatite
D. Polymer plus 10 µm size hydroxyapatite plus nano-sized hydroxyapatite
Composition

- Titanium
- Types of Cementing
  - Autograft
  - Hydroxyapatite
  - Calcium Phosphate & bone marrow aspirate
## Size Comparison

<table>
<thead>
<tr>
<th>Implant</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Material</th>
<th>Distraction Height (mm)</th>
<th>Average Height (mm)</th>
<th>Width (mm)</th>
<th>Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone graft</td>
<td>N/A</td>
<td>N/A</td>
<td>Iliac crest</td>
<td>N/A</td>
<td>26.3</td>
<td>13.3</td>
<td>14.4</td>
</tr>
<tr>
<td>Harms</td>
<td>Non-expandable</td>
<td>DePuy AcroMed</td>
<td>Titanium</td>
<td>N/A</td>
<td>25.9</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>ADD</td>
<td>Expandable</td>
<td>Ulrich</td>
<td>Titanium</td>
<td>24-40</td>
<td>26.2</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Synex-C</td>
<td>Expandable</td>
<td>Mathys</td>
<td>Titanium</td>
<td>20-30</td>
<td>26.0</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Synex-C</td>
<td>Expandable</td>
<td>Mathys</td>
<td>PEEK</td>
<td>20-30</td>
<td>25.9</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>
Summary of Different Types

- Threaded or Non-threaded
- Biodegradable or Titanium
- Expandable or Non-expandable
- Implementation using one cage or two cages (360°)
  - Posterior Instrumentation
- Vertical or Horizontal placement
- No significant difference in strength and stability

Pedicle Screws
Biomechanics
Anterior Approach – 2 level

- **Flexion**
  - 60% of intact motion

- **Extension**
  - Approximately the same as intact motion

- **Axial Rotation**
  - 60% of intact motion
  - < 60% stabilization with poor fusion

- **Lateral Bending**
  - 50% of intact motion
Anterior Approach Graph
Posterior Approach – 2 level

- Flexion
  - 60% of intact motion
- Extension
  - Approximately the same as intact motion
- Axial Rotation
  - +25% of intact motion
- Lateral Bending
  - 50% of intact motion
Posterior Approach Graph

Posterior Cage Stabilization

Ratio of Cage to Intact Motion

- Tencer [33]
- Hoshijima [18]
- Lund [22]

Loading Direction

Flexion  Extension  Axial Rotation  Lateral Bending
Anterior and Posterior Cage Comparison

[Diagram showing comparison between anterior and posterior cages under various loading directions: flexion, extension, axial rotation, and lateral bending.]
Posterior and Anterior Instrumentation Effect

![Graph showing the effect of posterior instrumentation on cage to intact motion ratio in different loading directions.](image-url)
Compressive Strength

- Typical compressive loads range from 200N – 1200N during daily activities
- Compressive strength at cage-vertebrae interface α bone density
- Compressive strength does not change with supplementary pedicle screw fixation
The Operation

- Clips from Posterior Lumbar Decompression and Fusion with Instrumentation and Bone Graft at the University of Maryland Medical Centre in Baltimore, MD:
  

From 3:50
Clips from the Operation

Myelogram with canal narrowing

CT scan

Forward subluxation of L4 on L5

Degenerative facet changes
Other examples

MRIs of Spinal Stenosis

- Normal Disc
- Degenerative Disc
- Nerve roots
- Spinal Fluid
Rehabilitation and Costs

- Rehabilitation:
  - Variable but about 6 months to recover completely from a 2-level spine fusion

- Cost for 2-level Lumbar Spinal Fusion:
  - Cages: ~ $7000 (In Canada, all cages about the same)
  - Screws: $2000
  - Hospital Fees: ~$9000
  - Ex: Michigan: Patient paying $53 000 in the US
Fusion

Sentinel Sign
Complications

- Fusion not always successful:
  - Difficult to determine radiographically if fusion has occurred
  - No set standard describing a successful fusion
  - Biomechanical tests of stability not always accurate
- Cages can move and screws can break (rarely)
- Possible nerve damage (posterior, ~3% of cases)
- Device-related osteopenia
- Infection
- Injury to blood vessels (anterior, ~1% of cases)
References

- [http://www.spineuniverse.com/print.php/article1523.html](http://www.spineuniverse.com/print.php/article1523.html)
- Kandziora, Frank, Pflugmacher, Robert, et al., “Biomechanical Analysis of biodegradable Interbody Fusion Cages Augmented With Poly(Propylene Glycol-co-Fumaric Acid)”.