Comparison of Rod Materials for Lumbar Fusion: A Systematic Review and Meta-Analysis

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Disclosure Statement

1. SIGNIFICANT FINANCIAL INTEREST
   • None

2. GENERAL AND OBLIGATION INTERESTS
   • None
Introduction

• The goal of lumbar spinal fusion surgery is to reduce or eliminate movement at the instrumented levels in patients presenting with chronic back and leg pain due to degenerative disease, stenosis, trauma, or tumor.
• Rigid rods composed of either titanium or cobalt chrome are the most commonly used rod types in lumbar fusion procedures.
• However, the use of rigid constructs can alter normal spine biomechanics and add a significant amount of force on the facet joints of the adjacent segments.
  • This can accelerate degenerative change at the non-fused adjacent segments above or below the fusion site. This degeneration is termed Adjacent Segment Disease (ASD).
  • ASD negatively impacts pain and functional outcomes and can require reoperation.
• Semi-rigid rods made of Polyetheretherketone (PEEK) are more flexible and thereby allow some motion and anteroposterior load sharing.
  • PEEK rods achieve a more uniform distribution of pressure throughout the intervertebral disc which is thought to reduce stress at adjacent levels and result in better outcomes.
  • Semi-rigid constructs are not widely used and it remains unclear whether they are an improvement over rigid rods in terms of patient outcomes.
• The purpose of this study was to evaluate the clinical effectiveness, safety, and utility of semi-rigid rods as compared to standard rigid rods. To this end, this review had three aims:
  1. Determine if semi-rigid rods are as effective in facilitating fusion.
  2. Assess whether pain and functional ability are improved by the use of semi-rigid rods.
  3. Evaluate the rate of complications arising from use of each material.
Methods

Search terms:
- Titanium rod”, “cobalt chrome rod”, “PEEK rod”, “polyether ether ketone rod”, “semi rigid rod fixation”, “rigid rod fixation”, “cobalt rod failure”, “titanium rod failure”, and “PEEK rod failure”

Data Sources: PubMed, EMBASE, and Cochrane databases

Study Selection criteria:
- Articles were included if they were published between January 1st 2000 and August 2nd 2019.
- Only studies evaluating the use of titanium, cobalt chrome, and PEEK rods in lumbar fusion procedures were included
- Only articles published in English were included
- Articles that did not have the full text available were excluded, as were case reports, animal studies, biomechanical studies, and in vitro studies.

Primary outcomes:
- Percentage of successful fusions
- Pain improvement as measured by the extracted Visual Analog Score (VAS) data
- Improvement in functional ability as determined by Oswestry Disability Index (ODI) scores
- Rates of rod fracture

Secondary outcomes:
- Reoperation rates
- Development of ASD
## Results

Figure 1. Flow diagram of study selection

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Rod material</th>
<th>n</th>
<th>Fusion Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavagna et al.</td>
<td>2008</td>
<td>Titanium</td>
<td>39</td>
<td>89.7</td>
</tr>
<tr>
<td>Kim et al.</td>
<td>2016</td>
<td>Titanium</td>
<td>17</td>
<td>88.2</td>
</tr>
<tr>
<td>Qi et al.</td>
<td>2013</td>
<td>Titanium</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Nayak et al.</td>
<td>2015</td>
<td>Titanium</td>
<td>56</td>
<td>94.6</td>
</tr>
<tr>
<td>Han et al.</td>
<td>2017</td>
<td>Titanium</td>
<td>50</td>
<td>66.0</td>
</tr>
<tr>
<td>Han et al.</td>
<td>2017</td>
<td>Titanium</td>
<td>34</td>
<td>67.6</td>
</tr>
<tr>
<td>Han et al.</td>
<td>2017</td>
<td>CoCr</td>
<td>20</td>
<td>90.0</td>
</tr>
<tr>
<td>Han et al.</td>
<td>2017</td>
<td>CoCr</td>
<td>50</td>
<td>90.0</td>
</tr>
<tr>
<td>Athanasakopoulos</td>
<td>2013</td>
<td>PEEK</td>
<td>52</td>
<td>96.2</td>
</tr>
<tr>
<td>Colangeli et al.</td>
<td>2015</td>
<td>PEEK</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>De Irure et al.</td>
<td>2012</td>
<td>PEEK</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>Ormond et al.</td>
<td>2016</td>
<td>PEEK</td>
<td>28</td>
<td>89.3</td>
</tr>
<tr>
<td>Qi et al.</td>
<td>2013</td>
<td>PEEK</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 1. Rate of fusion success using rigid rod systems
Figure 2. Plot of the rate of fusion success with (A) rigid rod systems and (B) semi-rigid rod systems. Analysis conducted using a Binary Random-Effects Model and 95% Confidence Interval. An arcsine transformation was applied as the data was not normally distributed.
### Table 2. Number of Patients Per Outcome Measure

<table>
<thead>
<tr>
<th>Rod Type</th>
<th>VAS-LP (n)</th>
<th>VAS-BP (n)</th>
<th>ODI (n)</th>
<th>Fracture Rate (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td>41</td>
<td>41</td>
<td>67</td>
<td>705</td>
</tr>
<tr>
<td>Semi-rigid</td>
<td>72</td>
<td>72</td>
<td>64</td>
<td>350</td>
</tr>
</tbody>
</table>

#### Figure 3. Pain and Function Improvement Based on Rod Material

![Percent Improvement from Baseline](Image)

**Table 2** and **Figure 3** provide data on the number of patients per outcome measure, showing the percentage improvement from baseline for different rod types: PEEK and Titanium.
Reoperation Rate
- We found no clear difference in reoperation rates between rod types. Revision rates for rigid rods were up to 14%, while semi-rigid rods had revision rates of 1.9% to 19%.

Rate of ASD Development
- Our results indicated that ASD developed 0 to 47% of the time in rigid rod systems.
  - ASD was noted in 0 to 11.9% of semi-rigid rod cases.

**Figure 4.** Fracture Rates Based on Rod Material


Discussion

• Clinical effectiveness, evaluated by fusion rates, ODI, and VAS, was comparable between the two rod materials
  • Although PEEK rods offer a slightly higher percentage of successful fusions, its advantage over rigid rods isn’t distinctive
  • Functional outcomes, as assessed by ODI improvements, were similar between the rigid rod and PEEK fusion groups (65.1% vs. 67.8%)
• The safety of the two rod rigidities was gauged by the fracture rates associated with their use.
  • Rigid rods had clearly higher rates of fracture compared to PEEK rods used in dynamic systems (18.7% vs. 0.58%).
• Utility was assessed by reoperation rates and development of ASD after initial surgery. We found no clear difference in reoperation rates between rod types.
• This review is limited by the number of studies evaluating each rod type and bias may have been introduced by unequal groupings. This review also cannot account for potential confounding variables such as number of instrumented levels, which can affect the degree of fusion and fracture rates. Lastly, all but one of the included studies lacked a control group.
Summary Points

• Semi-rigid rods provide similar rates of fusion.

• There was not a clear advantage in using semi-rigid rods in terms of lower rates of reoperation. Additionally, there was not a clinically significant difference in pain or function improvement between the two materials.

• However, semi-rigid rods were clearly superior in reducing the rates of implant failure. They also modestly improved rates of ASD.

• Further studies are necessary to make direct comparisons.