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# Alternative Spinal Fusion Fixation Rod Materials: Polyetheretherketone, Nitinol and Silicon Nitride

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# Alternative Spinal Fusion Fixation Rod Materials: Polyetheretherketone, Nitinol and Silicon Nitride

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## Abstract

Titanium and its alloys are the most commonly used fixation rod materials in spinal fusion surgery because of their biocompatibility, stability, and endurance. However, titanium may not be the best rod material for patients as it can cause adjacent segment degeneration (ASD), in which the spinal segments adjacent to the instrumented segment or segments experience increased force loading and begin to deteriorate. Through analysis of various studies, polyetheretherketone (PEEK), nitinol, and silicon nitride were found to be possible alternative spinal fusion fixation rod materials. To determine which of these materials is best suited for use as a spinal rod material, the osteointegration, current availability, stiffness, durability, corrosion resistance, and clinical efficacy of each material was analyzed. Although silicon nitride had strong osteointegrative properties, no testing could be found evaluating the material as a spinal fusion rod, indicating its current unavailability. Even though nitinol was determined to have better osteointegrative properties than PEEK, PEEK has an elastic modulus close to bone, a reinforcing material, carbon fiber, that allows for customization of the elastic modulus, no risk of corrosion, and strong clinical results. By implementing PEEK fixation rods in spinal fusion surgeries instead of titanium rods, the incidence of ASD may decrease as well as the risk of rod corrosion.

## Introduction

The stiffness, or elastic modulus, of titanium is much greater than that of cortical bone. Because of this disparity in stiffness, a large portion of the physiological force loading of the spine is shifted from the anterior spinal column to the titanium fixation rod system. This decrease in force on the spine at the instrumented segments produces greater forces at adjacent segments. These heightened forces on the adjacent segments can cause ASD. In some cases, ASD can necessitate another spinal fusion to repair the gradual damage to the adjacent segments caused by the first spinal fusion. Because of the increased risk of ASD development in patients who undergo spinal fusions with titanium rods, alternative spinal fusion fixation rod materials have been studied and tested. In this study, PEEK, nitinol, and silicon nitride were compared to determine which material offers the best combination of osteointegration, current availability, stiffness, durability, corrosion resistance, and clinical efficacy when compared to titanium.

## Results/Discussion

- Silicon nitride and nitinol were found to have better osteointegrative properties than PEEK, which had similar rates of osteointegration when compared to titanium.
- Biomechanical and clinical research articles on PEEK and nitinol as spinal fixation rods are currently available. However, no biomechanical or clinical research was found that focused on silicon nitride as a spinal fixation rod material.
- The elastic modulus of PEEK is much lower than titanium, which may reduce the incidence of ASD and subsequent spinal fusion revision surgeries. Carbon fiber reinforced PEEK (CFRP) allows for the customization of the elastic modulus, crucial for treating patients who have differing bone properties.
- Silicon nitride, although not tested as a spinal fusion fixation rod, and PEEK are both materials that are durable and would provide long-term support. Nitinol fixation rods can withstand more cyclic loading but have a much lower peak load than titanium rods.
- Nitinol and silicon nitride can improve corrosion resistance through surface treatment. However, PEEK is a non-corrosive material composed of carbon, hydrogen, and oxygen, all of which are organic elements. Carbon fiber reinforcement integrates carbon, an organic element as previously stated, into PEEK. If released in the body, organic elements would cause no adverse effects, but the release of toxic metal ions from nitinol or silicon nitride could cause damage.
- Clinical results demonstrate that PEEK has a high fusion success rate that is comparable to titanium. The fusion success rate of nitinol was not explicitly stated and was impossible to decipher on a presented graph in the clinical data.
- Both PEEK and nitinol fixation rods reduced back and leg pain in patients who underwent spinal fusions.

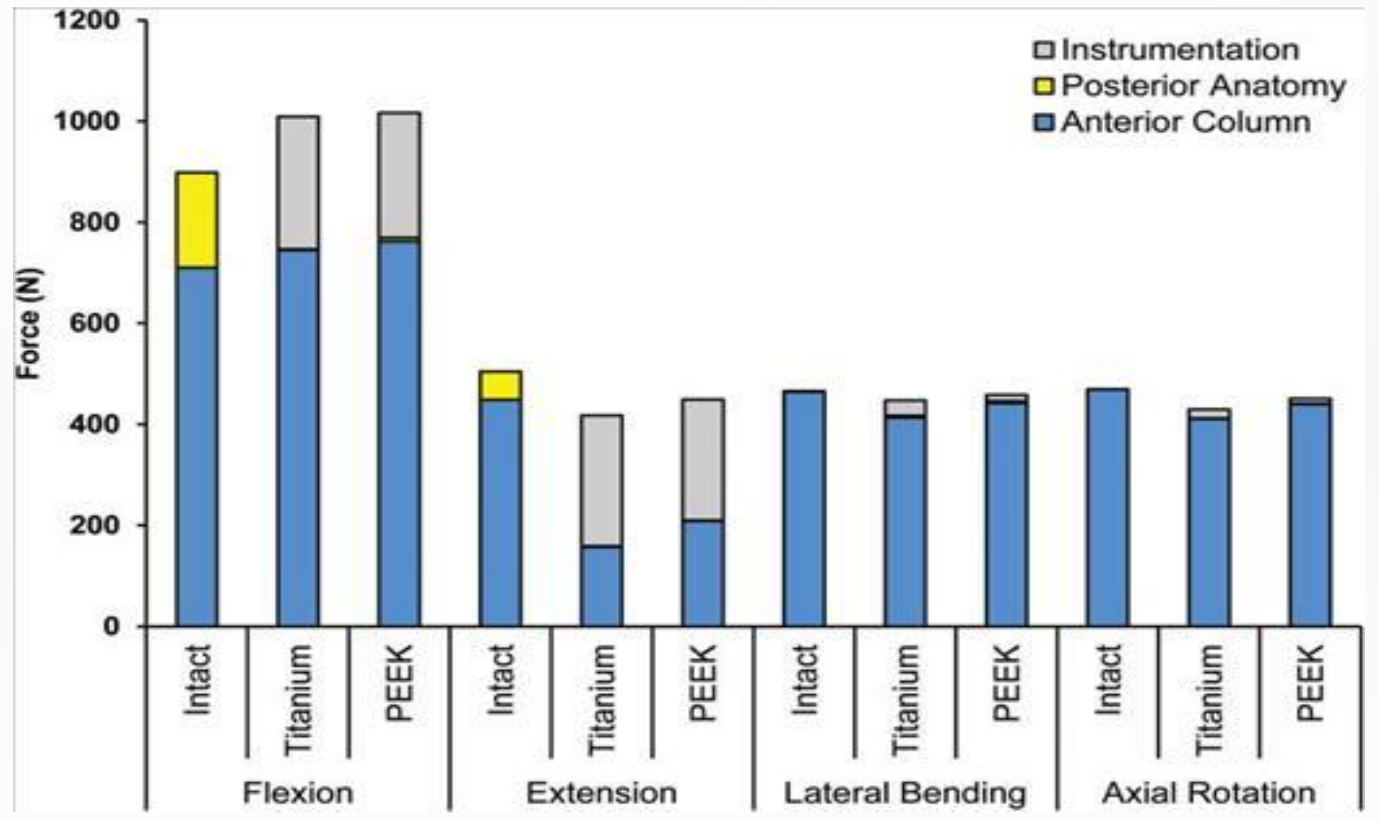


Figure 1. “Intra-level distribution of the axial load calculated in the instrumented L4-L5 motion segment of the spinal finite element model” (Gornet et al., 2011, p. 081009-8)

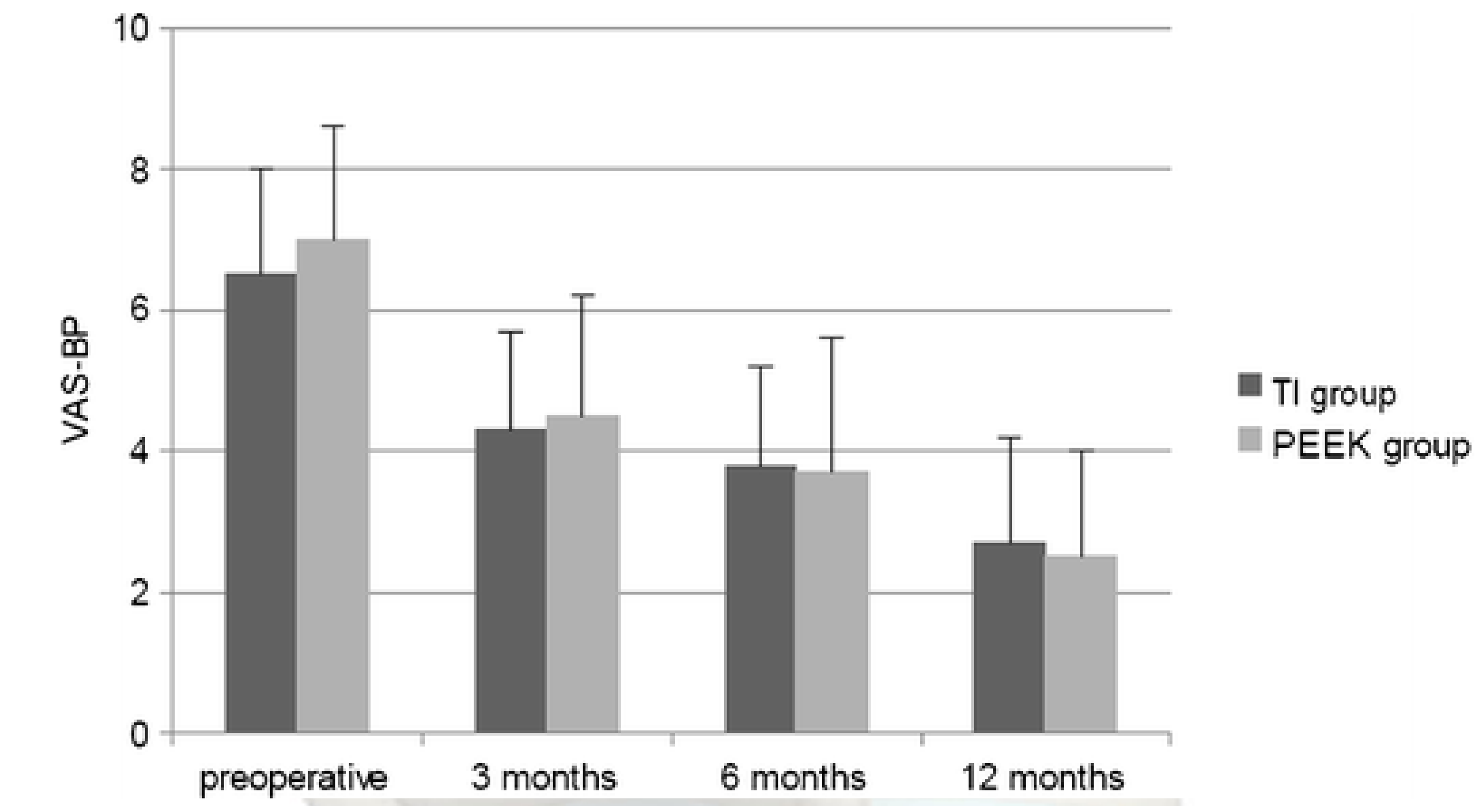


Figure 2. “Visual analog scale for back pain (VAS-BP) results of both groups over time. Error bars indicate single standard deviations” (Qi et al., 2013, p. 1190)

## Conclusion

PEEK is the most promising alternative spinal fusion fixation rod material when compared to silicon nitride and nitinol. PEEK has osteointegrative qualities similar to titanium, is currently available as a spinal fusion fixation rod material, has an elastic modulus close to bone, and has a reinforcing material, carbon fiber, which allows for customization of the elastic modulus. PEEK spinal fusion fixation rods are similar in durability to titanium, have no risk of corrosion, have high fusion success rates, and reduce patients’ leg and back pain.

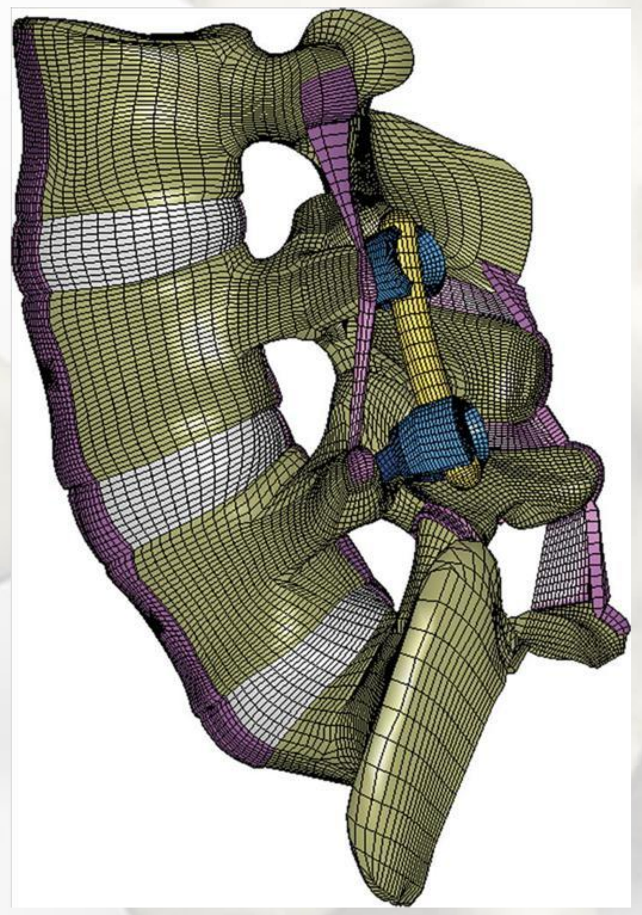

Figure 3. “Finite element model of the posteriorly instrumented lumbar spine used to determine intra-level load sharing with either PEEK or titanium rods” (Gornet et al., 2011, p. 081009-5)

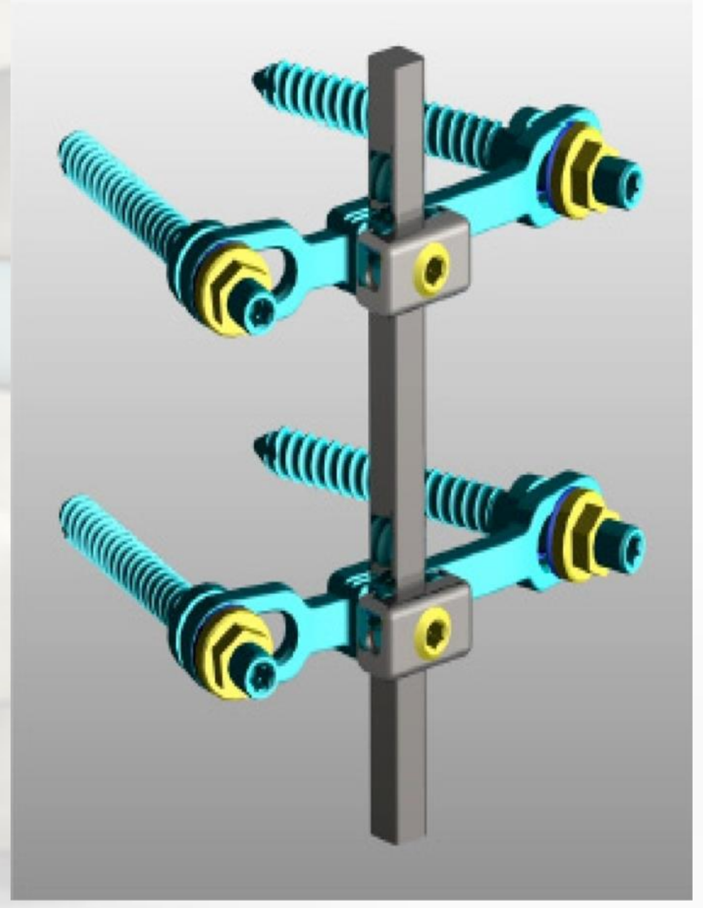

Figure 4. “The single rod Memory Metal Spinal System” (Kok et al., 2012, p. 221)

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