Comparison of Posterior Rod Strain of Traditional Four-Rod Inline and Novel Ames-Deviren-Gupta Four-Rod Techniques in Pedicle Subtraction Osteotomies for Adult Spinal Deformity Correction: An In Silica Study

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Background

• PSO associated with high revision rates due to rod fractures at the PSO level
  – Rod fracture rates as high as 22% [1]

• Multi-rod constructs aim to alleviate strain on rod [2]
  – Traditional 4-rod reconstruction has short accessory rods affixed via rod-to-rod, *inline* with primary rods
  – Technique still requires extensive rod contouring

• Ames-Deviren-Gupta (ADG) propose alternative 4-rod technique [1,3]
  – Short accessory rod spans PSO
  – Long primary rod placed *dorsal* to accessory rod connects to remaining screws
  – Technique does not require sharp bending of primary rods and may reduce rod fracture

• Comparisons between these techniques have not been published to the author’s knowledge

Novel ADG 4-rod technique with short accessory rods spanning the PSO level, and longer primary rods connecting adjacent screw [1]
Purpose

- Investigate reductions in rod strain of two 4-rod techniques, thus explaining the reduced rates of rod fracture seen clinically following PSO
Methods

Validation

• In Silica model (T12-S)
  – Bone/discs meshed using solid elements
  – Collagen fibers modeled as springs
  – Ligaments modeled as tension-only spring elements
  – Facet joints assumed to be frictionless

• Model validated with cadaveric range of motion (n=6)
  – Conditions:
    • 10Nm at T12
    • S1 fixed
  – Planes of Motion
    • Flexion-Extension (FE)
    • Lateral bending (LB)
    • Axial Rotation (AR)
Methods

Reconstruction

• PSO simulated at L3
  – Lumbar lordosis = 70°
  – Construct Materials
    • Titanium rods/screws at L1-S1
    • [E =113.8 GPa]

• 4-Rod Inline Construct (Fig A)
  • Short accessory rod affixed to longer primary rod across PSO
  • Domino rod-to-rod connectors

• 4-Rod AGD Construct (Fig B)
  • Accessory rods affixed to L2-L4
  • Primary rod affixed to L1, L5-S1

(A) 4-rod Inline and (B) 4-rod AGD techniques
Methods

Simulation

• Conditions
  – Flexion-extension
  – 10Nm applied at T12
  – S1 fixed

• Motion-induced surface strain measured
  – Location:
    • Primary rod strain at PSO and lumbosacral junction
    • S1 screw strain
  – Averaged to Ti 2-rod (control)

Examples of (A) surface strain; (B) 4-rod construct strain; (C) screw strain
Results: Primary Rod Contouring

- Novel Ames-Deviren-Gupta short rod technique proposed in literature [1,3]
  - Short accessory rod spans PSO
  - Long primary rod placed *dorsal* to accessory rod connects to remaining screws
  - Technique does not require sharp bending of primary rods, and may reduce rod fracture

- Simulated model had 70° of lumbar lordosis following PSO

- Primary rod contour angle
  - 4-rod Inline = 129.7°
  - 4-rod ADG = 115.5°
Results: Posterior Rod Strain Patterns

- Position of the accessory rod affects region of maximum strain on rod
  - 4-rod Inline
    - Interface of rod-2-rod domino connector
  - 4-rod ADG
    - Apex of rod bend just superior to L4
Results: Primary and Accessory Rod Strain

Surface Rod Strain at PSO Normalized to Ti 2-Rod

<table>
<thead>
<tr>
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<th>Normalized Rod Strain (%)</th>
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<tbody>
<tr>
<td></td>
<td>PSO Primary Rod</td>
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<tr>
<td>4-Rod Inline</td>
<td>48.8</td>
</tr>
<tr>
<td>4-Rod AGD</td>
<td>77.1</td>
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Discussion

• Both 4-rod techniques reduced mechanical demand along the rods at the PSO and lumbosacral junction
  – Novel 4-rod ADG reconstruction shifts region of maximum strain distally

• The 4-rod Inline technique observed greater strain reduction on the primary rod at the PSO than 4-rod ADG reconstruction
  – Inline: 48.8% vs. ADG: 77.1%

• Inline reconstruction transferred strain to accessory rod and lumbosacral junction
  – Primary rod: 48.8% vs. Accessory rod: 58.7%
  – PSO: 48.8% vs. L5-S1: 84.8%

• Results suggest loss of bony fixation points along primary rod, inherent to ADG technique, make the technique less effective in reducing primary rod strain
References

