A Comprehensive Biomechanical Investigation of Crosslink Fixation Method on Kinematic Properties of the Lumbosacral Spine

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Background

- Crosslink Fixation
  - Biomechanically advantageous in multi-segmental reconstructions where torsional stresses can result in rotational loading of the rods (Kelly et al.)
  - Use of crosslinks in thoracic spinal reconstruction procedures demonstrated increased stiffness of the instrumented levels when comparing two rather than one crosslink and is recommended in longer reconstructions (Wang et al., Kuklo et al., Lehman et al.)
  - However, no studies to date have investigated the kinematic effects of placing crosslinks in tension by medial compression of the rods prior to tightening the crosslink in the lumbar spine

Study Objective

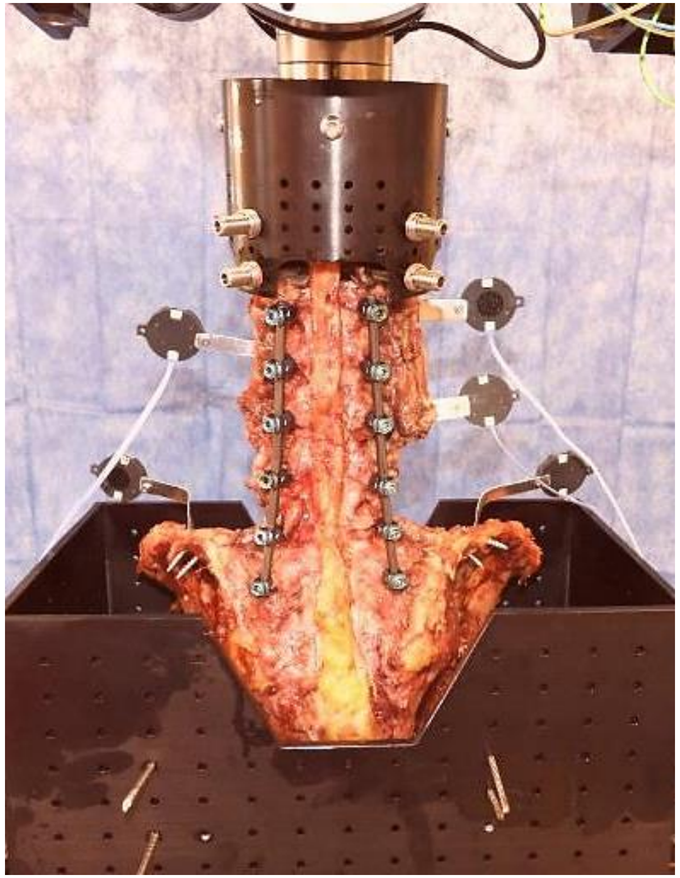
- The primary objective of the current investigation is to quantify and compare tensile loading of single and dual crosslinks on the biomechanical properties of the intact and destabilized lumbosacral spine.

Methods

- N=8 cadaveric thoracolumbar specimen (T9-iliac wings)
  - 5 Females and 3 Males

- Loading Parameters: Pure Moment
  - Flexion-Extension (± 10.0Nm X Axis)
  - Lateral Bending (± 10.0Nm Z Axis)
  - Axial Rotation (± 10.0Nm Y Axis)

- Experimental Endpoints: Range of Motion (±X, ±Y, ±Z)
  - 3-Level Construct: L3-Sacrum
  - 4-Level Construct: L2-Sacrum
  - 5-Level Construct: L1-Sacrum



Methods

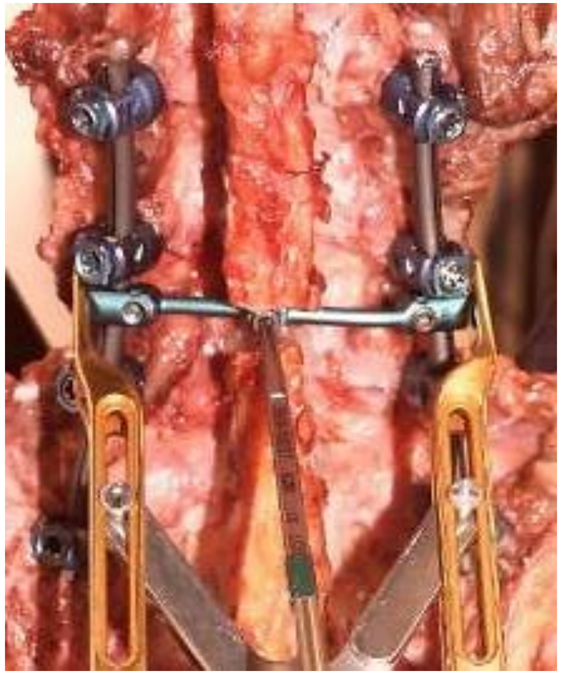
- Bone mineral density ([BMD], g/cm3) scans were conducted to calculate the BMD within the lower lumbar levels (L1–L4)
- Number of replaced pedicle screws due to loosening was recorded

- Data Analysis
  - All range of motion data was normalized to the intact condition (100%)
  - A Repeated Measures Analysis of Variance and Bonferroni post hoc test were performed to assess differences between groups
  - Correlation analysis between BMD and the number of replaced pedicle screws during testing was performed
    - Significance was indicated at $p<0.05$

Methods

- Reconstructions
  - 31 Total
  - Rods Alone, Single Crosslink, Dual Crosslinks
    - Crosslinks with and without tension*
    - 3-, 4-, and 5-level constructs
    - Intact model and destabilized model
      - Destabilized model: laminectomies and bilateral facetectomies

*Tension: achieved by compressing across the vertical rods, then locking the crosslink in place



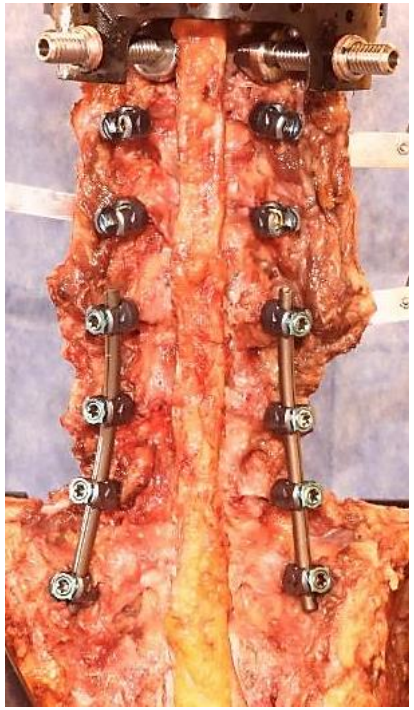
Testing Order:

1. Intact specimen (T12-Pelvis)
2. Intact L3-S1 rods alone
3. Intact L3-S1 rods with single CL (no tension)
4. Intact L3-S1 rods with single CL (tension)
5. Intact L3-S1 rods with dual CLs (tension)
6. Intact L3-S1 rods with dual CLs (no tension)
7. Intact L2-S1 rods alone
8. Intact L2-S1 rods with single CL (no tension)
9. Intact L2-S1 rods with single CL (tension)
10. Intact L2-S1 rods with dual CLs (tension)
11. Intact L2-S1 rods with dual CLs (no tension)
12. Intact L1-S1 rods alone
13. Intact L1-S1 rods with single CL (no tension)
14. Intact L1-S1 rods with single CL (tension)
15. Intact L1-S1 rods with dual CLs (tension)
16. Intact L1-S1 rods with dual CLs (no tension)
17. Destabilized L3-S1 rods alone
18. Destabilized L3-S1 rods with single CL (no tension)
19. Destabilized L3-S1 rods with single CL (tension)
20. Destabilized L3-S1 rods with dual CLs (tension)
21. Destabilized L3-S1 rods with dual CLs (no tension)
22. Destabilized L2-S1 rods alone
23. Destabilized L2-S1 rods with single CL (no tension)
24. Destabilized L2-S1 rods with single CL (tension)
25. Destabilized L2-S1 rods with dual CLs (tension)
26. Destabilized L2-S1 rods with dual CLs (no tension)
27. Destabilized L1-S1 rods alone
28. Destabilized L1-S1 rods with single CL (no tension)
29. Destabilized L1-S1 rods with single CL (tension)
30. Destabilized L1-S1 rods with dual CLs (tension)
31. Destabilized L1-S1 rods with dual CLs (no tension)

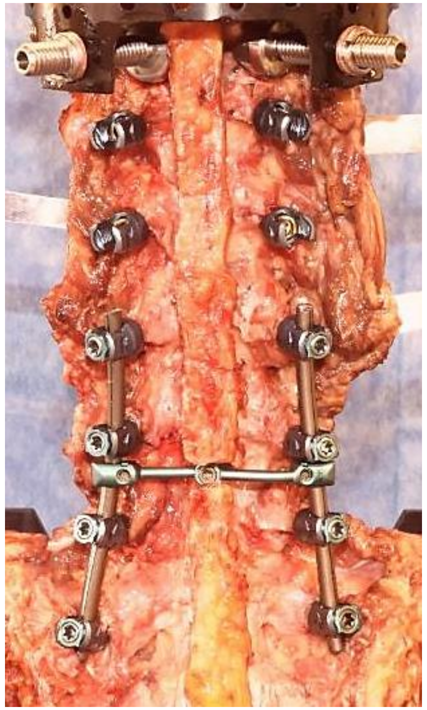
Methods

3-Level Construct: L3-S1

Intact Model
L3-S1 Rods

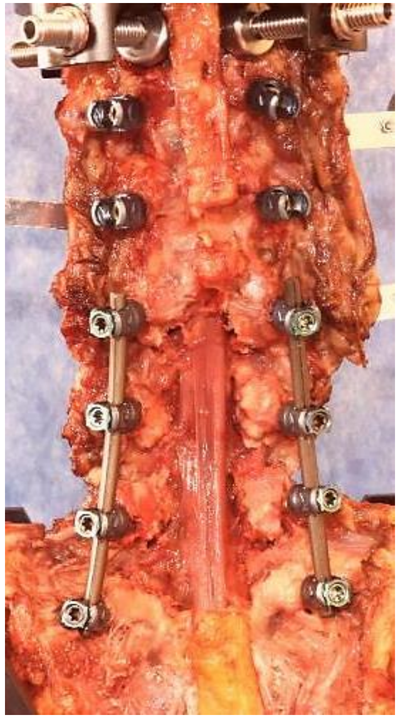


Intact Model
Single CL

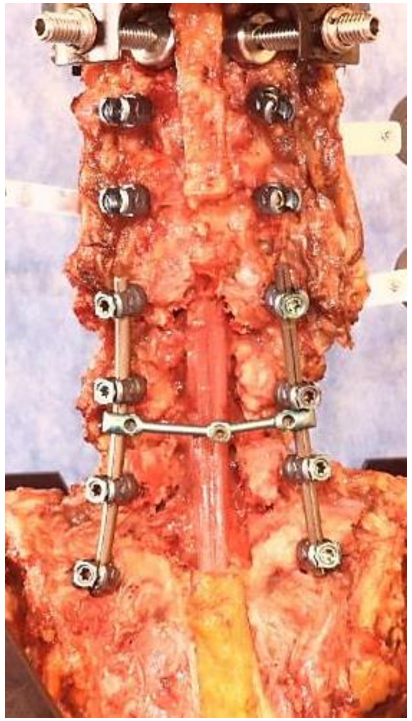


Intact Model
Dual CLs

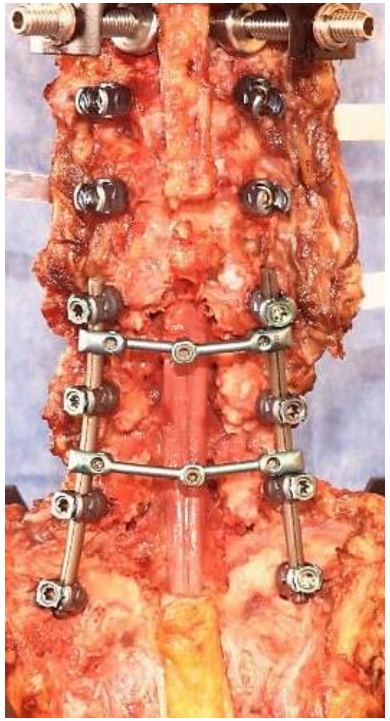
Destabilized Model
L3-S1 Rods



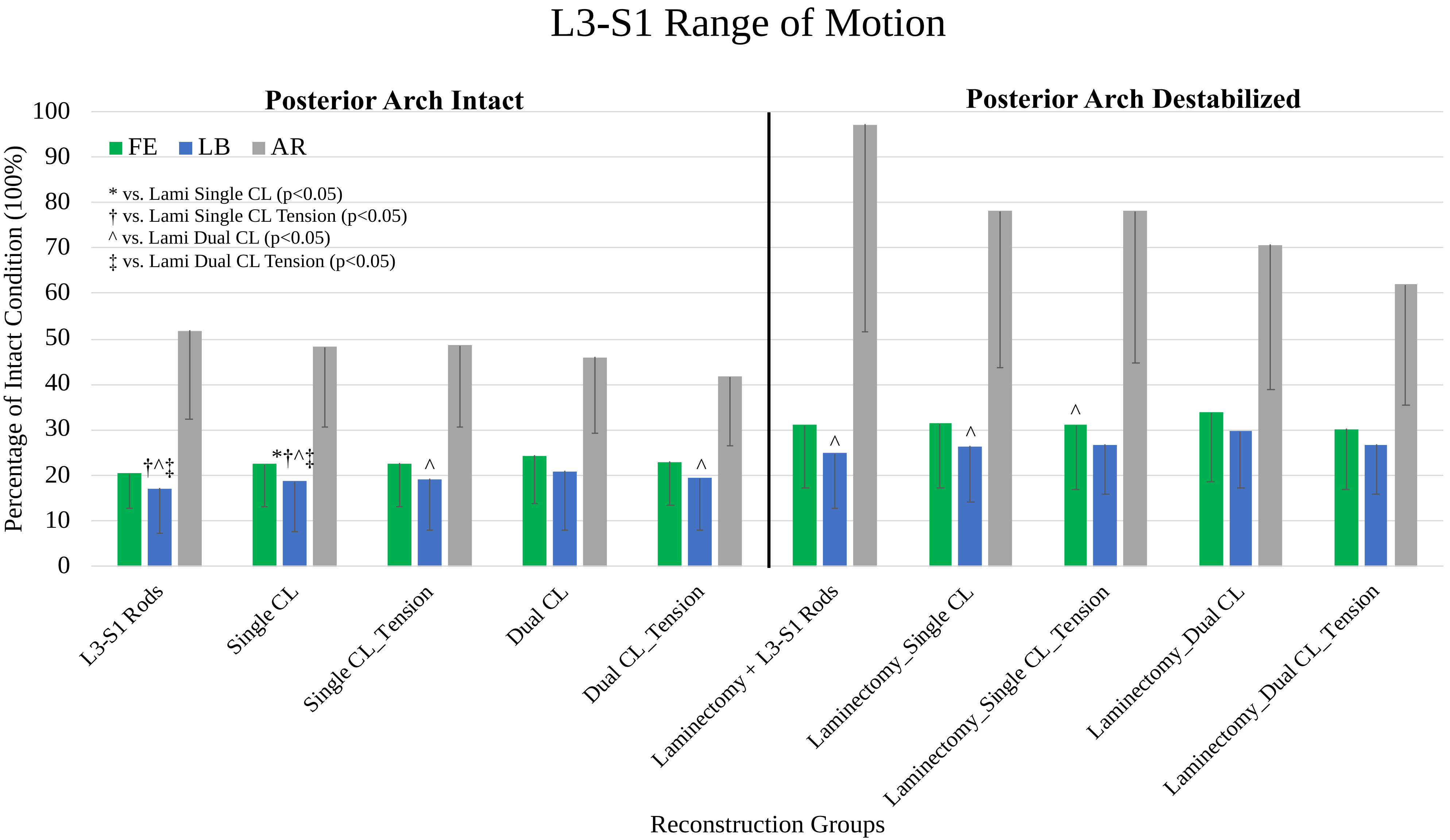
Destabilized Model
Single CL



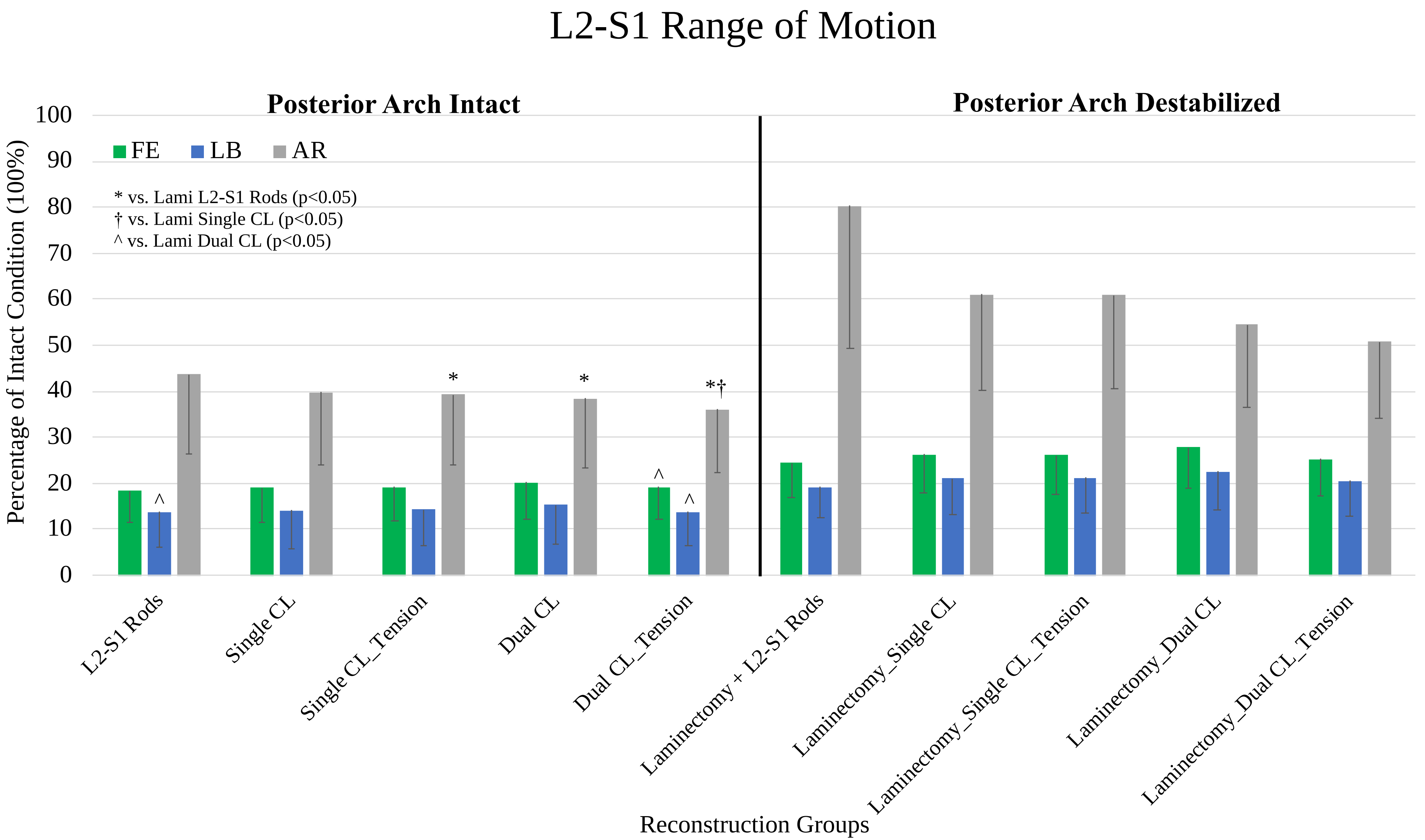
Destabilized Model
Dual CLs



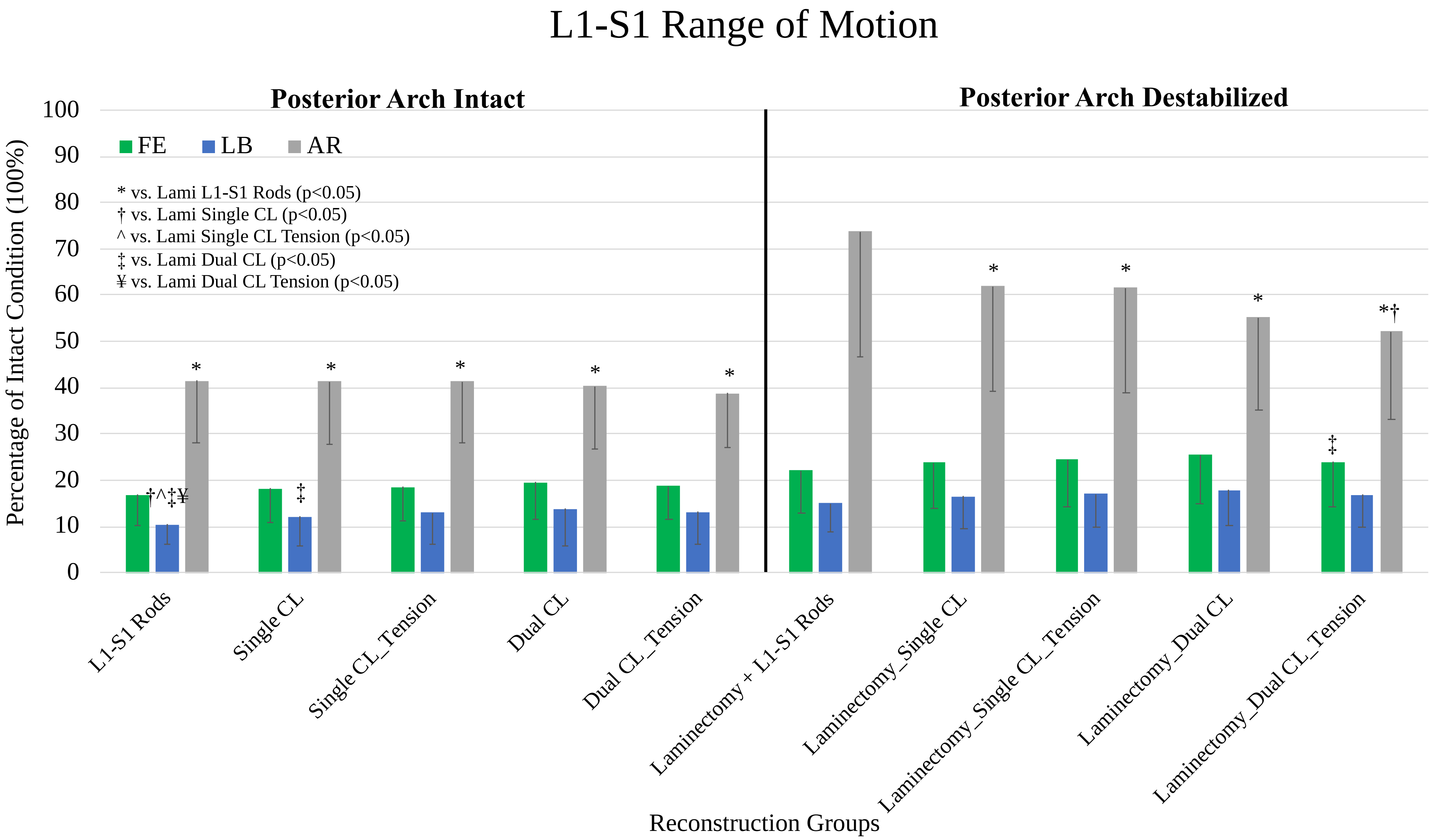
Results: 3-Level Construct



Results: 4-Level Construct



Results: 5-Level Construct



Summary

1. Axial Rotation Stability

- Results of the current study emphasize the biomechanical significance of crosslinks on the overall torsional rigidity of multi-level lumbar reconstructions

2. Single vs. Dual Crosslinks

- Stiffness in axial rotation increased when utilizing dual versus single crosslinks
- The difference between single versus dual constructs was more pronounced at L3-S1 (3-level) compared to L1- S1 (5-level), which suggests that increased crosslink density may provide additional mechanical advantage

3. Medial Compression

- There was a trend of increased resistance to axial rotation with respect to tension
- The effect was smaller than that associated with crosslink number, regardless of levels of destabilization, suggesting that tension alone is an insufficient substitute for additional crosslinks

Summary Continued

4. BMD

- Correlation analysis indicated significance between decreasing BMD and the number of pedicle screws replaced ($p<0.05$)

5. Clinical Implication

- Results suggest that clinical consideration should be given to BMD, as placing crosslinks in tension may be contraindicated in osteoporotic patients

THANK YOU

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Disclosures

None of the authors has any potential conflict of interest.