Cyclic Biomechanical Evaluation of Single-Tunnel Coracoclavicular Reconstruction: Is Augmentation Necessary?

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# Disclosures

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Introduction

AC Injury: common, underestimated
- 9-12% shoulder injuries, 40-50% of athletic shoulder injuries, 6.4/10,000 collegiate athlete-exposures
- Treatment goals: anatomic reduction + restore biomechanics

No conclusively effective surgical technique for coracoclavicular (CC) reconstruction
- >150 described techniques
- Weaver Dunn: biomechanically inadequate, failure rates >30%
- Anatomic double and single-tunnel (DT, ST) techniques = improved biomechanics + lower clinical failure rates
- Anatomic recon complications (fracture, reduction-loss): 27-42%
- 17% 6-month re-operation rate across techniques

Stanford Medicine
CC Reconstruction Clinical Experience

- Augmentation strategies are recommended and commonly used, in an attempt to avoid loss of reduction and mitigate fracture risk
- Little or no empiric data to support this
  - Risks of additional implant irritation, time, cost
  - Allograft risks (bulk, disease, reaction)

Purpose

1. Compare isolated single-tunnel (ST) cortical button CC reconstruction technique to augmentation with high-strength suture (CB+S) or tibialis anterior allograft (CB+G) under anterior-posterior (AP) loads, superior-inferior (SI) cyclic loading and superior load-to-failure conditions
2. Measure and standardize CC reconstruction tensioning (preload) to facilitate comparison across techniques and measure effect on load-displacements
Methods

9 clavicular/scapular segments

Intact Static Testing (-10 to 70 N SI, ±25 N AP)

Instrument with Cortical Button + Suture x2 + destabilize by transecting AC + CC ligaments

Cortical Button

Cortical Button + Tibialis Anterior Graft

Cortical Button + Suture

Cyclic Testing: 5,000 cycles (10 to 70 N Superior) + static testing

Remove prior instrumentation → Inspect
Re-instrument with new Cortical Button + Suture

Superior Load to Failure 2 mm/s

Testing per prior biomechanics studies 7,9,10,15,16
Methods

• Mechanical testing using E10000 materials testing system (Instron Corp)
  • Rigid motion capture setup (Boulder Innovation) to eliminate bending motion artifact and enhance measurement fidelity

• Single tunnel (3mm), double-loaded cortical button technique (Dog Bone™, FiberTape®, Arthrex)

• Each specimen = own control, same tunnels used for 3 sequential reconstruction techniques + cyclic testing
  • Load-to-failure testing on each specimen final recon

• Analysis
  • Paired t-tests: load-displacement intact vs recon groups in AP and SI directions
  • Pearson correlation analysis of preload effect on load-displacements
  • Analysis of variance + Tukey Post-Hoc tests to compare load-displacement, creep, and failure loads
  • Linear mixed effect model to evaluate effect of construct order
Results: Superior load displacement

-10 to 70N SI static load, before & after 5000 cycles
- Instrumented average SI preload: 17.0±7.1N

Across all recon groups:
- Vs intact = Increased stiffness, decreased displacement (by >1/2), p<0.03
- No significant difference between groups, minimal SI creep over 5000 cycles
### Results: Anterior-Posterior load displacement

Intact vs reconstructed: 25N A-P load

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline Net AP Load Displacement (mm)</th>
<th>Post Cyclic Net AP Load Displacement (mm)</th>
<th>Creep (mm)</th>
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<tbody>
<tr>
<td>Intact</td>
<td>5.5±2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CB</td>
<td>7.9±2.1</td>
<td>8.7±2.4</td>
<td>0.7±0.5</td>
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<tr>
<td>CB + S</td>
<td>6.4±2.2</td>
<td>6.9±2.4</td>
<td>0.5±0.5</td>
</tr>
<tr>
<td>CB + G</td>
<td>6.9±2.2</td>
<td>7.6±2.5</td>
<td>0.8±0.4</td>
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- Increased AP laxity in CB group vs intact (p<0.05) post 5000 cycles
- CB + S = decreased AP displacement vs CB, pre & post 5000 cycles (p<0.009)
Results: Load to failure

2mm/s superior load

- Reported native superior failure loads: $550N \pm 200N^{9,16,17}$

- No significant difference between groups
- 3 fractures at coracoid (2 in CB group)
  ‣ All other failures at clavicle-potting interface (underestimates true failure load)
- All augment groups failed >700N

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<th>Group</th>
<th>Ultimate Load (N)</th>
<th>Disp. at Failure (mm)</th>
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<tr>
<td>CB</td>
<td>651±304</td>
<td>5.3±2.4</td>
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<tr>
<td>CB + S</td>
<td>1008±194</td>
<td>6.4±4.8</td>
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<tr>
<td>CB + G</td>
<td>817±79</td>
<td>6.6±2.9</td>
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Results: Recon order and preload effects

- Order of recon = NO effect (type III test for fixed effects)
- Preload tension = strongly inversely correlated with load-displacement (pre + post cyclic testing); independent of construct
Discussion:

Improved method to study & compare AC recon techniques

- Motion capture = improved measurement fidelity vs actuator
- Measurement and consideration of construct tension (preload) relevant for biomechanical comparisons, impacts construct performance
  - Preload significantly inversely correlates with construct load displacements

ST Technique

- ST with CB (double-loaded suture) = significantly stiffer (2x in SI) vs native
  - Minimal superior creep over 5000 cycles (unlikely failure mode)
  - Good for acute healing ≠ native biomechanics
Conclusions:

Augment Role: Suture loop or graft = no superior stiffness benefit

- Augments (CB +S) = improved AP performance over cyclic loading
  - Trend toward increased ultimate load (failure >700N)
  - Ultimate loads ≥ native, role to prevent catastrophic failure?

Ideal Construct:

- Single-loaded CB (reduce stiffness by \( \frac{1}{2} \)) + suture loop to improve AP stiffness + prevent catastrophic failure
  - Allograft = no mechanical benefit, healing response?, cost

Limitations: Controlled laboratory experiment

- Sample size limits ultimate load comparisons
- Long-term clinical significance of increased superior stiffness, reduced AP laxity?
- Translation to intra-op surgical tensioning + effect on clinical outcomes
References


18. www.Meditek.com