A Biomechanical Comparison of Repair Techniques for Complete Gluteus Medius Tears
+-1 Dishkin-Paset, J G; 1 Salata, M; 1 Manno, K; 1 Gross, C; 1 Shewman, E F; 1,2 Wang, V M; 1 Bush-Joseph CA; 1 Nho, S J
1 Department of Orthopedic Surgery, Rush University Medical Center, Chicago, IL; 2 University of Illinois, Chicago, IL, USA
snoho@hotmail.com

Introduction
A tear in the gluteus medius tendon has been determined to be a significant source of hip pain in the clinical setting1-3. Pathological development of a medius tear has been found to occur in 10 and 25% of aging men and women respectively4. Partial or complete tears commonly occur at the insertion point on the greater trochanter1-4.

Surgical treatment of a partial gluteus medius tear has been proven to be beneficial5, but current literature does not indicate the most favorable methods of gluteus medius surgical repair. In addition, although surgical intervention is performed, there is no biomechanical data supporting the repair models. The objective of the current study is to biomechanically evaluate two gluteus medius repairs using a human cadaveric model.

Materials and Methods
Ten fresh-frozen human cadaveric hemi-pelvis (5 contralateral pairs, 5 female, mean age of donors 58 ± 3 years) were dissected with removal of skin, muscles and the extensor mechanisms keeping the capsule of the femoral head and gluteus medius muscle-tendon-bone unit intact. Based on CT scans (BrightSpeed, GE Medical Systems, Fairfield, CT) of all hemi-pelvis, the bone mineral density (BMD) was calculated using Mimics (Materialise 13.1, Luven, Belgium). Complete tears of the gluteus medius were created at the insertional footprint. The length and width of the entire anterior and posterior footprint was measured using a caliper. Specimens were randomly divided into two repair groups: (1) Double Row with 2 medial row, double-loaded suture anchors (5.5 TendonFix, Smith & Nephew, Andover, MA) with 4 mattress stitches and 2 lateral row, double-loaded suture anchors with 4 simple stitches and (2) Suture Bridge with 2 medial row, double-loaded suture anchors with 4 mattress stitches and 2 lateral row, Knotless anchors (5.5 Footprint PK, Smith & Nephew, Andover, MA). Five specimens were selected for the Double Row and five for the Suture Bridge, such that a given left-right pair was assigned to the same repair group.

Biomechanical Testing
Within each repair group, preparation methods and testing conditions and were identical for all specimens. After repair, the distal femur was potted in PMMA and then placed in a custom jig such that, the loading vector of the tendon was 20° anterior from the femur. The muscle was placed in a custom cryogenic grip and the construct was tested in a materials testing system (MTS Insight 5, Eden Prairie, MN, USA). The tensile testing protocol consisted of a 10N preload for 2 minutes, followed by cyclic loading for 150 cycles from 10 to 125 N at 90 N/s, followed by a pull to failure test at 1 mm/sec. Throughout testing, digital video was acquired at 48 Hz (synchronized with time, crosshead displacement, and force from the MTS output) for subsequent optical tracking (DMAS, Spica Technology Corporation, Maui, HI) of markers positioned on the bone, muscle, and tendon just above the repair.

Data computed from the failure test included maximum load, yield load, linear stiffness, post yield crosshead extension, normalized yield load, normalized work to yield, and failure mode of the tendon. Yield load was identified by the MTS software as the force at which the slope of the load–displacement curve demonstrated the earliest deviation from the slope of the linear region. Post yield extension was calculated as the net change in crosshead extension from yield to maximum load. Normalized yield load was calculated as the yield load divided by the maximum load. Normalized work to yield was similarly computed. Data computed for the cyclic test included cyclic elongation, elongation amplitude, and stiffness of the final cycle. BMD, footprint dimensions, and mechanical results were compared between repair groups using a two-tailed, unpaired t-test. Statistical significance was assumed for p<0.05.

Results Randomization resulted in no statistical difference in BMD (p=0.97) between the Double Row (470.5 ± 270.7HU) and the Suture Bridge (469.6 ± 226.1HU) groups. Furthermore, there was no statistical difference in footprint length between the Double Row (34.13 ± 1.5mm) and the Suture Bridge (34.20 ± 1.65mm). No difference (p>0.05) in cyclic biomechanical properties were found between groups.

During the pull to failure test, four of the specimens in the Double Row failed on the anterior side by muscle/suture rupture or tendon tear off its insertion, and one specimen failed on the posterior side by tendon tear. For the Suture Bridge, one specimen failed via anchor pullout during cyclic loading (1st cycle). This specimen was removed from the analysis. Three specimens failed on the posterior side by anchor pullout, and one specimen failed on the anterior side by anchor pullout.

A summary of the biomechanical data is provided in Table 1. There was no difference in maximum or yield load between repair techniques. There was a significant difference (p<0.05) in normalized yield load (Figure 1) where the Suture Bridge (70.9 ± 16.8N%) was higher than the Double Row (48.2 ± 7.0N%). Linear stiffness for the Double Row was significantly higher (p<0.05) than that of the Suture Bridge repair. Post yield extension of the Suture Bridge was significantly less than that of the Double Row (p<0.05). Furthermore, normalized work to yield load for the Suture Bridge was significantly higher (p<0.05, Figure 1).

<table>
<thead>
<tr>
<th>Repair</th>
<th>Max Load (N)</th>
<th>Yield Load (N)</th>
<th>Stiff (N/mm)</th>
<th>Post Yield Ext (mm)</th>
<th>Norm Yield Load %</th>
<th>Norm Work to Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Row</td>
<td>402 (98)</td>
<td>188 (18)</td>
<td>54.8*</td>
<td>11.4*</td>
<td>14.8 (7.0)</td>
<td>12.7 (5.7)</td>
</tr>
<tr>
<td>Suture Bridge</td>
<td>405 (163)</td>
<td>278 (121)</td>
<td>39.3</td>
<td>6.0</td>
<td>70.9* (16.8)</td>
<td>34.8* (15.8)</td>
</tr>
</tbody>
</table>

Table 1 - Average (SD) Failure Data. Asterisk denotes significant difference (p<0.05) between repairs.

Discussion
The purpose of the present study was to quantitatively compare cyclic and failure characteristics of the Double Row and Suture Bridge repairs of complete gluteus medius tears. At time zero, while there was no difference in maximum or yield loads between the two repair groups, normalized yield load was higher (p<0.05) for the Suture Bridge (Figure 1). The Suture Bridge exhibited its first signs of failure closer to the point of complete failure of anchor pullout (70.9%), while the Double Row showed initial failure earlier (48.2%). Hence, if clinical failure of repair constructs were to occur, the Suture Bridge would appear to be more robust than the Double Row. Furthermore, due to its comparatively lower stiffness, the Suture Bridge repair-tissue construct may deform more when loaded; this may, in turn, allow greater muscle movement during rehabilitation exercises.

Optical marker displacement data from the construct testing are presently being analyzed to supplement the data presented herein. In pilot tests, mean maximum loads of 1293 ± 723 N for the intact gluteus medius tendon insertion have been noted. Of the four intact specimens tested, the large standard deviation is likely attributable to a specimen with lower BMD which failed by trochanter fracture. To our knowledge, biomechanical data have not been reported for the intact or repaired gluteus medius tendon. Collectively, the current results constitute biomechanical data have not been reported for the intact or repaired gluteus medius tendon. Collectively, the current results constitute

References

Acknowledgements
Project partially funded by Smith & Nephew (Andover, MA).