Long-Term Followup of Muscle and Tendon Morphology after Reconstruction of the Anterior Cruciate Ligament with Autologous Semitendinosus-Gracilis Graft

ABSTRACT INTRODUCTION:
Approximately 250,000 anterior cruciate ligament (ACL) injuries occur in the United States, costing over $1.5 billion (Boden, 2000). The semitendinosus-gracilis (STG) tendon autograft is commonly used to reconstruct the ACL. The changes in donor tendon and muscle morphology provide insight into how we recover from tendon harvest after ACL reconstruction. Long-term studies have not been done on the mechanisms involved with tendon growth. Therefore, the objective of this study was to evaluate the effects of ACL reconstruction using an STG tendon autograft on long-term muscle and tendon morphology of the donor tendon/muscle complex and synergistic muscles.

METHODS:
Three males from a prior morphological study (Williams, 2004) were studied 7 years after ACL reconstruction. All subjects signed written informed consent forms approved by the University of Delaware Human Subjects Review Board. All were regular participants (>50 hrs / yr) in sports requiring cutting, pivoting, and jumping at the time of injury. Subject 1 injured his left ACL and had tendon stripped and fixed with a Washer-loc and Bone mulch screw, while subjects 2 and 3 injured their right ACLs, and had tendons stripped one cm proximal to the insertion and the tendon sheaths were preserved in situ and the graft fixed with interference fixation.

Axial spin-echo T1-weighted images were acquired with a 1.5T GE Signa LX scanner from the base of the calcaneus to the iliac crest as subjects lay supine. Images were acquired in 4 sequences including the lower-leg, knee, thigh, and pelvis. Repetition time was 350 ms, echo time was 9 ms, slice thickness was 11.5 mm (6 mm over the knee for more detailed tendon data), interslice gap was 1.5 mm (1.0 mm over the knee), matrix was 256x160 pixels, and field of view varied with subjects’ pelvis size.

Image processing required three steps. First, the muscle contours were manually traced in each slice they appeared using IMOD (University of Colorado) and a digital palette. Muscle and tendon were traced as separate objects to differentiate tissue effects. Second, the contours of each muscle from the 4 sequences were grouped. Third, 3D reconstructions were generated in a custom written Matlab program (The MathWorks Inc., Natick, Massachusetts, USA). Muscle and tendon volume (cm³), peak cross-sectional area (PCSA) (cm²), and length (cm) were calculated. The 13 muscles traced were the semimembranosus (SM), semitendinosus (ST), gracilis (GRA), biceps femoris – long head (BFL), biceps femoris – short head (BFS), sartorius (SAR), rectus femoris (RF), vastus medialis (VM) and lateralis (VL), vastus intermedius (VI), tensor fascia lata (TFL), medial (MG) and lateral gastrocnemius (LG).

RESULTS:
The three subjects differed in their ST and GRA distal tendon (figure) and muscle volume (table) regeneration in response to graft harvest. Subject 1 had no tendon regeneration and demonstrated ST and GRA atrophy from the 6-month test, and the muscles appeared to have fatty infiltrates. Subject 2 had complete regeneration of both tendons to the tibial insertion site with normal GRA and ST size, 99.11% and 86.58% respectively of pre-op. Subject 3 had complete regeneration of the GRA tendon and incomplete regeneration of the ST tendon, with significant hypertrophy and ST atrophy. SM, BFL, BFS, and SAR hypertrophied for all three subjects.

DISCUSSION:
MRIs of three subjects approximately 7 years after autologous STG ACL reconstruction were obtained. Subject 1 had no tendon regeneration, significant atrophy, and fatty infiltration of the GRA and ST muscles. Subject 2 had complete tendon regeneration and near normal muscle size of GRA and ST. Subject 3 had complete generation of the GRA tendon accompanied by significant GRA hypertrophy, and incomplete tendon regeneration and atrophy of the ST. All three subjects had hypertrophy of the other hamstrings. The difference in STG muscle and tendon morphology may be related to graft harvest differences. Subject 1 was the only subject who demonstrated no tendon regeneration in the first study (1 of 8) and continued to have no regeneration at 7 years. He had a different graft harvest technique from all the other subjects. This follow up expanded on the results of a previous study (Williams, 2004) in that BFS, BFL, and SM muscle volumes hypertrophied in all subjects suggesting that atrophy of synergists may be a compensatory strategy after hamstring graft harvest.

There are limitations of the current study. The sample size was small and further, we are unable to make conclusions about the functional status of muscles or tendons based upon their MRIs.

The differential morphological response gives insight into how regeneration may be enhanced or retarded. Graft harvest technique may play a role in muscle and tendon response. These findings warrant further study.

Figure: Frontal plane MRI reconstruction of semitendinosus (far left and far right) and gracilis (center left and center right) morphology of three subjects’ injured (left) and uninjured (right) limbs demonstrate a variety of responses to autologous ACL reconstruction using a hamstring graft at long-term followup.

REFERENCES:

ACKNOWLEDGEMENTS:
Supported by NIH R01-AR046386

<table>
<thead>
<tr>
<th>Subject</th>
<th>ST % 6 month</th>
<th>ST % 6 year</th>
<th>SM % 6 month</th>
<th>SM % 6 year</th>
<th>GRA % 6 month</th>
<th>GRA % 6 year</th>
<th>BFL % 6 month</th>
<th>BFL % 6 year</th>
<th>BFS % 6 month</th>
<th>BFS % 6 year</th>
<th>SAR % 6 month</th>
<th>SAR % 6 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42.58%</td>
<td>20.63%</td>
<td>95.52%</td>
<td>124.19%</td>
<td>51.74%</td>
<td>45.42%</td>
<td>105.83%</td>
<td>124.93%</td>
<td>110.71%</td>
<td>135.64%</td>
<td>100.33%</td>
<td>137.09%</td>
</tr>
<tr>
<td>2</td>
<td>78.01%</td>
<td>86.58%</td>
<td>104.97%</td>
<td>107.51%</td>
<td>72.73%</td>
<td>99.11%</td>
<td>105.69%</td>
<td>132.39%</td>
<td>99.77%</td>
<td>112.90%</td>
<td>101.74%</td>
<td>132.21%</td>
</tr>
<tr>
<td>3</td>
<td>69.04%</td>
<td>48.01%</td>
<td>108.82%</td>
<td>149.32%</td>
<td>81.31%</td>
<td>148.72%</td>
<td>106.97%</td>
<td>139.30%</td>
<td>108.83%</td>
<td>144.36%</td>
<td>108.33%</td>
<td>190.60%</td>
</tr>
</tbody>
</table>