Semitendinosus Graft for Interspinous Ligament Reinforcement in Adult Spinal Deformity

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Abstract: Proximal junctional kyphosis is an increasingly recognized complication following long-segment posterior spinal fusion for adult spinal deformity. The authors describe a novel technique for interspinous ligament reinforcement at the proximal adjacent levels using a cadaveric semitendinosus tendon graft secured with an Ethibond No. 2 double filament (Ethicon, Somerville, New Jersey) via the Krackow suture weave. A retrospective review identified 4 patients who had received this graft. No proximal junctional kyphosis was seen at a mean short-term follow-up of 5.5 months. Interspinous ligament reinforcement at the proximal adjacent level with a cadaveric semitendinosus tendon graft is a feasible strategy for preventing proximal junctional kyphosis. [Orthopedics. 2017; 40(1):e206-e210.]

Proximal junctional kyphosis is a postsurgical condition seen in the sagittal plane and is an increasingly recognized complication following long-segment correction and fusion for adult spinal deformity.1 Its prevalence has been reported to range from 20% to 39% in the adult spinal deformity population, which highlights the importance of this postoperative phenomenon that can cause significant morbidity and require further operative treatment. It typically occurs in adults through the development of fractures, subluxations, or ligamentous failure.2-13

The authors describe a novel technique of interspinous ligamentous reinforcement at the uppermost instrumented vertebrae with a cadaveric semitendinosus tendon graft. The application of this soft tissue tendon graft serves as a strategy to prevent postoperative proximal junctional kyphosis in long-segment spinal fusions for adult spinal deformity.2

Materials and Methods
Institutional review board approval was obtained to retrospectively review all patients who had undergone long-segment fusion to the upper thoracic spine for correction of adult spinal deformity performed by the senior author (F.L.A.). Those patients who had received additional interspinous ligamentous reinforcement with a cadaveric semitendinosus tendon graft and had at least 3 months of follow-up were further reviewed regarding demographics, surgery, radiographic imaging, clinical follow-up, Oswestry Disability Index (ODI) outcome scores, and postoperative complications.

Surgical Technique
For all patients, the interspinous ligamentous reinforcement was performed as follows (Figure 1). A cadav-
eric semitendinosus tendon graft was obtained and soaked in antibiotic irrigation. A No. 2 Ethibond double filament suture (Ethicon, Somerville, New Jersey) was then obtained as the suture material for the modified locking Krackow weave to be performed at both ends. While an assistant held the semitendinosus tendon taut at both ends, the suture needle was passed through the center of the tendon (Figure 1A). Once the needle was through the center of the tendon, the double filament loop was passed over the top of the tendon and the needle was brought around back to the side of the primary surgeon (Figure 1B). This was the starting anchored position of the weave. The needle was again passed through the center of the tendon (Figure 1C). Once through the center, 1 filament of the loop was passed over the top of the tendon, after which the entire needle was brought back around counterclockwise to the side of the primary surgeon (Figure 1D). The process was repeated (Figure 1E) until the suture weave reached the end of the tendon, where it was tied off and cut. The tendon was then flipped and the process was repeated on the other side of the graft (Figure 2).

This semitendinosus tendon graft was then interwoven between the spinous processes from 1 level above the uppermost instrumented vertebrae to 1 to 2 levels below the uppermost instrumented vertebrae (Figures 3-4). Of note, the interspinous space at the level above the uppermost instrumented vertebrae was carefully identified suprafascially, with great care taken not to disrupt any of the existing soft tissue or ligamentous attachments above the uppermost instrumented vertebrae. Once identified, a small paramedian opening was made in the fascia bilaterally, just large enough to pass the graft through the interspinous space, and then inferiorly down to the interspinous spaces at the uppermost instrumented vertebrae and below. The graft was interwoven between the spinous processes until only the free ends of the Ethibond suture remained. These free suture ends were then tied together so that the entire graft was now firmly interwoven at levels above and below the uppermost instrumented vertebrae (Video).

RESULTS
A total of 4 patients were identified who had received interspinous ligamentous reinforcement with a cadaveric semitendinosus tendon graft (Table 1). All 4 patients were female and had a mean age of 60 years (range, 53-68 years) at the time of surgery. All patients had sagittal imbalance and scoliosis.

The mean postoperative clinical and radiographic follow-up was 5.5 months (range, 4.2-6.6 months). The proximal junctional angle increased postoperatively a mean of 3° (range, 1°-4°). No hardware...
failure, implant loosening, or proximal junctional kyphosis was noted on radiographic follow-up (Figure 5).

Oswestry Disability Index score improved from a mean of 72 (range, 58-88) preoperatively to a mean of 51 (range, 30-80) at last clinical follow-up (Table 2). One complication was identified in this group—a wound infection and dehiscence in one patient 2 weeks after surgery. This required a reoperation for irrigation and debridement as well as postoperative intravenous antibiotic treatment. No other wound infections, reoperations, or cerebrospinal fluid leaks were identified.

**Discussion**

Proximal junctional kyphosis is due to several factors, including progressive deformity from aging, disruption of the posterior ligamentous complex, fractures, instrumentation failure, degenerative disk disease, and facet violation.\(^3\)\(^4\)\(^14\)\(^16\) It has been observed that 66% of proximal junctional kyphosis occurs within 3 months and 80% within 18 months of surgery.\(^2\) Revision rates among patients who develop proximal junctional kyphosis range from 13% to 55%.\(^17\)

The authors sought to develop and implement a technique to address the issue of a soft tissue failure at the level of the uppermost instrumented vertebrae. They hypothesized that re-creating or supplementing a disrupted posterior tension band may help to reduce the incidence of proximal junctional kyphosis by providing a gradual transition zone to a noninstrumented level that is more biomechanically similar to the soft tissues of ligaments, facet capsules, and muscular attachments. Use of a cadaveric semitendinosus tendon was a natural choice in this regard. The Krackow suture technique provided a suture-to-tendon attachment that allowed for a more feasible way to secure the tendon graft around the spinous processes; simply put, tying the 2 opposite ends of suture together in a final knot.

### Table 1

Demographic and Follow-up Data for Patients Who Received a Proximal Interspinous Ligamentous Reinforcement

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Diagnosis</th>
<th>Operation</th>
<th>Clinical Follow-up, mo</th>
<th>Radiographic Follow-up, mo</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/65</td>
<td>Kyphoscoliosis, sagittal imbalance</td>
<td>T4-pelvis PSF, L4 PSO</td>
<td>5.8</td>
<td>5.8</td>
<td>1°</td>
<td>3°</td>
<td>2°</td>
</tr>
<tr>
<td>2/F/53</td>
<td>Scoliosis, sagittal imbalance</td>
<td>T2-pelvis PSF, T12-L5 SPO</td>
<td>5.3</td>
<td>5.3</td>
<td>1°</td>
<td>5°</td>
<td>4°</td>
</tr>
<tr>
<td>3/F/53</td>
<td>Scoliosis, sagittal imbalance</td>
<td>T4-pelvis PSF, T10-L4 SPO</td>
<td>6.6</td>
<td>6.6</td>
<td>5°</td>
<td>6°</td>
<td>1°</td>
</tr>
<tr>
<td>4/F/68</td>
<td>Kyphoscoliosis, sagittal imbalance</td>
<td>T4-pelvis PSF, L4 PSO</td>
<td>4.2</td>
<td>4.2</td>
<td>10°</td>
<td>13°</td>
<td>3°</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; PJA, proximal junctional angle; PSF, posterior spinal fusion; PSO, pedicle subtraction osteotomy; SPO, Smith-Petersen osteotomy.

**Figure 5:** Preoperative (A) and postoperative (B) standing 36-inch radiographs of patient 2 with preservation of the proximal junctional angle at 5.3-month follow-up.
was easier than tying 2 ends of tendon. The originally described suture technique was a double locking loop method using 2 sutures to create 2 sets of 2 to 3 locking loops for a total of 5 to 6 locking loops within a tendon end placed along each side.\textsuperscript{18-20} The current authors used a modified Krackow suture weave to apply just 1 suture for multiple interlocking loops at each tendon end.

The preparation of the graft and its subsequent application into the spine was straightforward, adding only 15 minutes to the operating room time. When in the suprafascial space above the level of the uppermost instrumented vertebrae, great care should be taken not to disrupt or take down any muscular or ligamentous attachments to the spinous processes at those levels. The authors made a single paramedian stab incision just large enough to insert the graft with an instrument and did not disturb any other soft tissues. Complications should also be avoided during routine decortication at the end of the case. Attention should be paid to the tip of the decorticating instrument near the uppermost instrumented vertebrae so as not to inadvertently grab and destroy the tendon graft. Overall, the authors found the technique to be safe. They have not identified any immunologic issues with implantation of the cadaveric semitendinosus tendon, which is otherwise routinely used in many orthopedic applications.

There was 1 complication in this study—a wound infection requiring a reoperation for patient 3. This was likely related to the inherent risks of long-segment fusion for correction of adult spinal deformity, exacerbated in this patient by her history of diabetes, obesity, and prior smoking. Otherwise, no other wound issues, reoperations, cerebrospinal fluid leaks, implant loosening, hardware failure, or proximal junctional kyphosis were identified.

Soft tissue dissection at the uppermost instrumented vertebrae can disrupt facets and ligaments, which in turn can increase the risk of proximal junctional kyphosis. The authors believe that bolstering this soft tissue ligamentous tension band with a semitendinosus tendon graft will support the biomechanical transition zone into the levels above the rigid instrumentation at the uppermost instrumented vertebrae.

**Conclusion**

The authors have described a novel technique for interspinous ligament reinforcement at the proximal adjacent levels using a cadaveric semitendinosus tendon graft secured with an Ethibond No. 2 double filament via the Krackow suture weave. The purpose of this article was to describe this soft tissue graft as a strategy for preventing proximal junctional kyphosis. The authors also reported on 4 patients who underwent this graft technique with a mean radiographic follow-up of 5.5 months. There were no early radiographic signs suggesting proximal junctional kyphosis among these patients at the time of this publication. More clinical data and much longer follow-up are needed to determine if this will be a durable option for preventing proximal kyphosis in the adult spinal deformity population.

**References**


