Secondary Reconstruction of the Extensor Mechanism Using Part of the Quadriceps Tendon, Patellar Retinaculum, and Gore-Tex Strips After Proximal Tibial Resection

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Abstract: Competence of the extensor mechanism is the major determinant of functional outcome of patients after proximal tibia resection. A method of secondary reconstruction of the extensor mechanism using the middle third of the quadriceps tendon and the patellar retinaculum augmented with Gore-Tex strips and gastrocnemius flap is described. Between 1981 and 1997, 7 patients with extension lag greater than 20° at least 1 year after the initial surgery underwent secondary reconstruction of the extensor mechanism. All patients were followed up for a minimum of 2 years. Full extension to an extension lag of 10° was achieved in three patients, and an extension lag between 10° and 20° was achieved in 4 patients. All patients had good to excellent functional outcomes and reported no limitations in daily life activities. Key words: extensor mechanism, proximal tibia, quadriceps tendon, Gore-Tex graft, gastrocnemius flap.

The proximal tibia is the second most common site of primary bone sarcomas and giant cell tumors [1,2], and overall it is the second most common site of bone tumors [3]. The treatment of high-grade sarcomas of the proximal tibia is complicated. The difficulty arises from the anatomic features of this region. Extensor disruption precludes normal knee function and ambulation; surgical intervention almost always is necessary.

Eliber [4] reported on 83 patients with malignant skeletal tumors treated by preoperative chemotherapy and limb salvage. He suggested that patients with proximal tibial lesions might require primary amputation because the patellar tendon could not be reattached and the function of the extensor mechanism was severely impaired. Proximal tibia resections with endoprosthetic reconstruction have the least favorable outcome of all limb-sparing procedures [5]. Extensor mechanism fitness is an important determinant of functional outcome after proximal tibia endoprosthetic reconstruction. Compromised active extension of the knee and extension lag is a common problem after proximal tibia endoprosthetic reconstruction [6,7]. Several methods for reconstruction of the extensor mechanism are described in the literature, among them primary direct repair by turndown of the quadriceps tendon or a xenograft [8], reconstruction with autogenous semitendinosus tendon or biceps femoris [9,10],
reconstruction with a medial gastrocnemius muscle transposition flap [11], augmented attachment by synthetic material [12], reconstruction with an extensor mechanism allograft [13], and reconstruction with an Achilles tendon allograft [14]. Other techniques of extensor mechanism reconstruction used in orthopedic oncology include direct suture to the prosthesis or allograft and osteotomy of the fibula with attachment to the lateral collateral ligament [15,16].

Petschnig and Baron et al. [17] compared different techniques for extensor mechanism reconstruction in 17 patients after proximal tibial resection. The 3 methods used were fibular transposition with suturing of the patellar tendon to the biceps tendon and collateral ligament [15], transposition of the gastrocnemius muscle [7], and a combined method of gastrocnemius shift with fibular transposition. The authors [17] favored the combined technique. Higher strength of the extensor muscles at angle positions between 60° and 20° as well as better function results were obtained in patients treated with this method.

All the patients reported in this article underwent primarily reconstruction of the extensor mechanism after proximal tibia endoprosthetic arthroplasty by reattaching the patellar tendon to the prosthesis using Dacron tape (Deknatel, Falls River, MA) and reinforcement with an autologous bone graft and a gastrocnemius flap. Bickels and Witting et al. [18] used this procedure to treat 55 patients. Full extension to an extension lag of 20° was achieved in 44 patients (78%), extension lag of 20° to 30° was found in 10 patients (19%), and extension lag of 40° was found in 1 patient (3%). Functional outcome was measured according to the American Musculoskeletal Tumor Society System [19]. All patients who had extension lag of ≤ 20° had good to excellent functional outcomes and reported no limitations with activities of daily living. Extension lag of >20° was not compatible with activities of daily living; it was found in 11 patients (22%).

Overall functional outcome was good to excellent in 48 patients (87%). Eight of 55 patients required secondary reinforcement of the patellar tendon, one patient underwent simple plication of the tendon, and 7 others underwent reconstruction of the patellar tendon with a part of the quadriceps tendon and the patellar retinaculum reinforced with Gore-Tex (Gore, Flagstaff, AZ) strips. The reason for the failure of the extensor mechanism was a non-specific rupture of the patellar tendon–prosthesis attachment, which was evident in the explorations performed. The reconstructive procedure of the extensor mechanism and the results of its use for 7 patients are described in this article.

Materials and Methods

Between 1981 and 1997, 7 patients with extension lag of more than 20° underwent reconstruction of the extensor mechanism. All patients previously underwent reconstruction of the extensor mechanism after proximal tibia endoprosthetic arthroplasty by reattaching of the patellar tendon to the prosthesis using Dacron tape and reinforcement with an autologous bone graft and a gastrocnemius flap. The time was at least 1 year after the primary surgery for all patients. Patients included 4 women and 3 men with an age range of 17 to 23 years (mean, 20). Five patients had primary bone sarcoma (stage IIB according to the Musculoskeletal Tumor Society [MTST] staging system), 2 had benign-aggressive tumor (giant cell tumor) of the proximal tibia.

Function was evaluated according to the MTST system [19]. This system of functional evaluation assigns numerical values (0–5) for each of 6 categories: pain, function, emotional acceptance, walking and gait ability, use of external supports, and patient satisfaction.

Surgical Technique

A single anterior incision from the distal third of the femur to the proximal third of the tibia is made. The fascia is incised in the same plane as the skin incision. The quadriceps tendon and the gastrocnemius flap covering the endoprosthesis are exposed. The gastrocnemius flap is lifted and separated from its attachment to the failed structure of the patellar tendon and the joint capsule, thus exposing the artificial tibial tubercle (Fig. 1). The failed structure of the patellar tendon is excised. The middle third of the quadriceps tendon is separated from the rest of the tendon. This middle third of the quadriceps tendon together with the patellar retinaculum is harvested and rotated toward the endoprosthesis (Fig. 2). This structure is looped over the artificial tibial tubercle and sutured back to itself, reconstructing the extensor mechanism. The edges of the remaining quadriceps tendon are sutured together to mend the gap in the quadriceps tendon (Fig. 3). The reconstructed patellar tendon structure is augmented on its sides by Gore-Tex strips.

Gore-Tex strips are attached to the patella on one end and looped over the artificial tibial tubercle on the other end (Fig. 4). The Gore-Tex strips are
sutured to the reconstructed extensor mechanism (Fig. 5). The gastrocnemius flap previously lifted is sutured back to the reconstructed patellar tendon and the capsule, providing additional augmentation to the extensor mechanism (Fig. 6).

**Postoperative Management**

The extremity was kept in extension in a knee immobilizer for at least 6 weeks. Partial weightbearing was allowed a few days after the surgery. Gradual active and passive knee motions were initiated after 6 weeks. For the first 6 months, the patients were evaluated on a monthly basis. Thereafter, patients were evaluated every 3 months in the first year. Follow-up evaluation included physical, radiologic, and functional examination. All patients were followed up for more than 2 years.

**Results**

Seven patients with extension lag of more than 20° at least 1 year after resection of the proximal tibia underwent reconstruction of the extensor mechanism. Reconstruction was performed using a part of the quadriceps tendon and the patellar retinaculum augmented by Gore-Tex strips and a gastrocnemius flap. Average surgical time was 1.5 to 2 hours.

All patients were followed up for a minimum of 2 years (range, 29–83 months; mean, 58 months). No postoperative bone or soft tissue infections were seen. One patient experienced a prolonged period of wound healing. The patient was treated conservatively with good end result. An improvement was seen in the range of motion; this improvement depended on the extension value achieved, because the flexion ability was not disrupted or changed compared with the preoperative status.

Markedly increased muscle strength, especially of the hamstrings, was noted after surgery. After surgery, all patients regained active extension; full extension-to-extension lag of less than 20° was seen in all patients. Full extension to an extension...
lag of less than $10^\circ$ was achieved in 3 patients, and an extension lag between $10^\circ$ and less than $20^\circ$ was achieved in 4 patients (Table 1). All patients were ambulatory, and all patients reported no limitations in daily life activities. Overall function was estimated to be good to excellent. The MTST score was 26 to 30, with a median value of 29 (Table 1).

**Discussion**

This article describes a new surgical procedure for reconstruction of the extensor mechanism used after the failure of the primary reconstruction procedure in patients after proximal tibia endoprosthetic reconstruction. Patients with tibial tumors have an overall higher survival rate than those with femoral tumors. The reason is probably because tibial tumors are smaller and are generally detected earlier [20,21,22]. Tibial sarcomas have a smaller extraosseous component than such lesions in other locations. Posterior extension and vascular involvement are rare. When extension does occur, the popliteus muscle often acts as a barrier to involvement of the popliteal and tibioperoneal arteries [23].

Despite the technical difficulty and the need for adequate soft tissue coverage and reconstruction of the extensor mechanism, limb saving procedures for tibial lesions are widely accepted and performed. We use endoprosthesis for reconstruction because of the high rates of complications associated with the use of allograft for reconstruction. With time, these allografts are associated with significant rates
of infection, nonunion, instability; fracture, and subchondral collapse [24–26]. Some authors have suggested that osteoarticular reconstruction should be considered as a temporary measure of reconstruction at best, because of its low survival rate [27]. The gait adaptations needed for walking with an incompetent extensor mechanism, including hyperextension of the knee and abnormal muscle forces, dramatically increase the stresses on a knee arthroplasty [28]. These abnormal forces can lead to failure and loosening of the prosthesis as well as stress fractures [29]. That is why the restoration of the active extension is considered an important determinant of functional outcome.

Looping the harvested part of the quadriceps tendon and the patellar retinaculum over the artificial tibial tubercle on the prosthesis reconstructs the extensor mechanism. The loose end encircling the artificial tibial tubercle is sutured to the harvested part of the quadriceps tendon. Two Gore-Tex strips sutured to the reconstructed patellar tendon reinforce this structure on its sides. The gastrocnemius flap that provides a biologic reinforcement is re-sutured to the patella and the joint capsule.

The gastrocnemius flap is a viable muscle tissue facing the reconstructed patellar tendon-prosthesis construct, and it provides the necessary blood supply for healing. After soft tissue healing is completed, the gastrocnemius flap provides mechanical and biologic reinforcement to the extensor mechanism.

Extensor strength is the functional goal of proximal tibia endoprosthetic reconstruction. This is in contrast to total knee arthroplasty, in which flexion is the main objective of physical rehabilitation. A tension-free environment in which complex healing of bone and soft tissue occurs is provided by keeping the knee joint immobilized for at least 6 weeks. Gradual passive and active flexion is practiced after this period.

Horowitz and Lane et al. [6] reported on a series of 16 patients who underwent extra-articular proximal tibia resection with endoprosthetic reconstruction for a primary bone sarcoma. In an effort to

**Table 1. Extension Lag Before and After Surgery and the Functional Outcome in 7 Patients**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Extension Lag Before Surgery</th>
<th>Extension Lag After Surgery</th>
<th>Functional Outcome</th>
<th>MSTS Score</th>
<th>Histological Diagnosis</th>
<th>Follow Up, m</th>
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</thead>
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<tr>
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<td>17</td>
<td>F</td>
<td>20°–30°</td>
<td>0°–10°</td>
<td>X</td>
<td>29</td>
<td>OS</td>
<td>36</td>
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<tr>
<td>2</td>
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<td>F</td>
<td>20°–30°</td>
<td>10°–20°</td>
<td>X</td>
<td>26</td>
<td>OS</td>
<td>75</td>
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<td>30</td>
<td>OS</td>
<td>76</td>
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<tr>
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<td>20</td>
<td>F</td>
<td>20°–30°</td>
<td>0°–10°</td>
<td>X</td>
<td>28</td>
<td>OS</td>
<td>28</td>
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<td>5</td>
<td>23</td>
<td>M</td>
<td>20°–30°</td>
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<td>30</td>
<td>GCT</td>
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<td>F</td>
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<td>10°–20°</td>
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<td>30</td>
<td>GCT</td>
<td>79</td>
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<td>21</td>
<td>M</td>
<td>&gt;30°</td>
<td>10°–20°</td>
<td>X</td>
<td>28</td>
<td>OS</td>
<td>83</td>
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Abbreviations: MSTS, musculoskeletal tumor society system; OS, osteosarcoma; GCT, giant cell tumor.
maintain part of the extensor mechanism, the patella and quadriceps were divided in a coronal fashion. The resultant quadriceps tendon–patella construct was used to reconstruct the extensor mechanism by attaching the patella with a screw to the porous pad on the anterior surface of the tibial component of the prosthesis. This reconstruction was performed in 10 patients; no reconstruction was performed in the remaining six.

Long-term functional evaluation was feasible in only 11 patients in this series, 6 of whom had an extension lag of $-80^\circ$ to $-90^\circ$ [4]. As previously cited Bickels and Witting et al. [18] used endoprosthetic reconstruction after proximal tibia resection on 55 patients. Reconstruction of the extensor mechanism included reattachment of the patellar tendon to the prosthesis with Dacron tape, reinforcement with autologous bone graft, and attachment of an overlying gastrocnemius flap.

Functional failure of the extensor mechanism (extension lag $>20^\circ$ was not compatible with daily living activities) was found in only 11 patients (22%) after a minimum follow-up period of 2 years. Extension lag correlated with overall functional outcome, which was good to excellent in 48 patients (87%). Eight patient required secondary reinforcement of the patellar tendon. One patient underwent plication of the patellar tendon, and 7 patients underwent reconstruction of the patellar tendon using part of the quadriceps tendon and the patellar retinaculum, which were augmented by Gore-Tex strips. This latter method is described in this article. The technique used for these patients as primary and secondary reconstruction of the extensor mechanism accomplishes a biologic reconstruction of muscle-to-muscle attachment.

Thus, the transferred medial gastrocnemius provides 2 important functions: coverage of the prosthesis, which avoids secondary infection, and a means for reconstruction of the extensor mechanism. The 7 patients treated with this method gained an extension lag of $<20^\circ$. All had good to excellent functional outcomes and reported no limitations with activities of daily living. Secondary reconstruction of the patellar tendon using part of the quadriceps tendon and the patellar retinaculum, augmenting this structure using Gore-Tex strips, and covering it with the gastrocnemius flap, followed by prolonged postoperative immobilization of the knee joint and gradual flexion maneuvers, lowers the extent of extension lag and provides good functional outcome after the primary reconstruction of the extensor mechanism has failed.

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