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Reconstruction of the Extensor Mechanism After Proximal Tibia Endoprosthetic Replacement

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Abstract: The proximal tibia is a difficult area in which to perform a wide resection of a bone tumor. This difficulty is due to the intimate relationship of tumor in this location to the nerves and blood vessels of the leg, inadequate soft tissue coverage after endoprosthetic reconstruction, and the need to reconstruct the extensor mechanism. Competence of the extensor mechanism is the major determinant of functional outcome of these patients. Between 1980 and 1997, 55 patients underwent proximal tibia resection with endoprosthetic reconstruction for a variety of malignant and benign-aggressive tumors. Reconstruction of the extensor mechanism included reattachment of the patellar tendon to the prosthesis with a Dacron tape, reinforcement with autologous bone–graft, and attachment of an overlying gastrocnemius flap. All patients were followed for a minimum of 2 years; 6 patients (11%) had a transient peroneal nerve palsy, 4 patients (7.2%) had a fasciocutaneous flap necrosis, and 2 patients (3.6%) had a deep wound infection. Full extension to extension lag of 20° was achieved in 44 patients, and 8 patients required secondary reinforcement of the patellar tendon. Function was estimated to be good to excellent in 48 patients (87%). Reattachment of the patellar tendon to the prosthesis and reinforcement with an autologous bone–graft and a gastrocnemius flap are reliable means to restore extension after proximal tibia endoprosthetic reconstruction. **Key words:** extensor mechanism, proximal tibia, endoprosthesis.

The proximal tibia is the second most common site of primary bone sarcomas [1]. Despite advances in limb-sparing techniques, it remains a difficult area in which to perform a wide resection of a high-grade malignant bone tumor with endoprosthetic reconstruction. The difficulty is due to several unique anatomic features, including the intimate relationship of the proximal tibia to the tibial and peroneal nerves and blood vessels of the leg, inadequate soft tissue coverage after endoprosthetic reconstruction, and the need to reconstruct the extensor mechanism after en bloc resection of its insertion site (ie, the tibial tuberosity) with the surgical specimen. As a result, until the early 1980s, limb-sparing surgeries for high-grade sarcomas involving the proximal tibia were infrequent, and resection-arthrodesis and above-knee amputation were considered as he surgical treatments of choice for large lesions at this site [2–9]. Better understanding of the biology of the tumor, use of effective

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neoadjuvant chemotherapy that reduces tumor size, and refinements in surgical technique allow execution of these highly demanding procedures. Even with the current chemotherapeutic regimens and prosthetic design, however, proximal tibia resections with endoprosthetic reconstruction have the least favorable outcome of all limb-sparing procedures. Unwin et al [10] reported a retrospective analysis of 1001 custom-made prostheses used for reconstruction after tumor surgery. The highest rate of complications requiring revision or amputation occurred in the proximal tibia group, followed by the distal femur and proximal femur.

Competence of the extensor mechanism is considered to be an important determinant of functional outcome after proximal tibia endoprosthetic reconstruction. A common problem after these procedures is a compromised active extension of the knee and an extension lag [6,11]. This long-term follow-up study, based on experience with 55 patients who underwent proximal tibia resection with endoprosthetic reconstruction, focuses on the surgical reconstruction of the extensor mechanism and postoperative rehabilitation. Reattachment of the patellar tendon to the prosthesis with a Dacron tape and reinforcement of this complex with autologous bone–graft and a gastrocnemius flap are emphasized. Rehabilitation included prolonged knee immobilization and gradual passive and active flexion of the knee joint. As a result, a range of motion around the knee joint that was compatible with activities of daily living was achieved in 78% of these patients.

Materials and Methods

Between 1980 and 1997, 55 patients underwent proximal tibia resection with endoprosthetic reconstruction. There were 34 male patients and 21 female patients who ranged in age from 8 to 56 years (median, 27 years). Four patients were <12 years old. Forty eight patients had primary bone sarcomas, 6 had benign-aggressive tumor of the proximal tibia, and 1 had a failure of an allograft after proximal tibia resection for a low-grade chondrosarcoma. Table 1 summarizes the histopathologic diagnoses and surgical classification of the patients in this series [12]. Complete staging studies were performed before surgery for all patients with a primary bone sarcoma. The imaging studies included plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) of the distal femur, knee joint, and whole tibia. Particular attention was directed to the anatomic relationship of the tumor to the nerves and blood vessels; angiography was used to assess the anatomic relationship of the blood vessels to the tumor, the presence of vascular anomalies, and vascular patency.

Surgical Technique

The surgical technique of proximal tibia endoprosthetic reconstruction after resection of a high-grade bone sarcoma has been described elsewhere [6,8,13–15]. Briefly, a single anteromedial incision was made, beginning proximally at the distal one third of the femur and continuing to the distal one third of the tibia. Medial and lateral fasciocutaneous

Table 1. Histopathologic Diagnoses and Surgical Staging of 55 Patients Treated With Proximal Tibia Resection

		Enneking's Surgical Classification [12]				
Histologic Diagnoses	No. Patients	IA	IB	IIA	IIB	IIIB
Primary bone sarcomas						
Osteosarcoma	32	—	—	1	31	—
Chondrosarcoma	6	1	—	1	4	—
Ewing's sarcoma	5	—	—	1	4	—
Malignant fibrous histiocytoma	3	—	—	—	3	—
Fibrosarcoma	1	—	1	—	—	—
Leiomyosarcoma of bone	1	—	—	—	1	—
Benign-aggressive tumors						
Giant cell tumor	5	NA	NA	NA	NA	NA
Chondromyxoid fibroma	1	NA	NA	NA	NA	NA
Other						
Allograft failure after resection of a low-grade chondrosarcoma	1	NA	NA	NA	NA	NA
Total	55	1	1	3	43	—

NA, nonapplicable.

flaps were raised. The medial hamstrings were released at 2 to 3 cm proximal to their insertion to expose the popliteal fossa, popliteal vessels, and tibial and peroneal nerves. The medial gastrocnemius was mobilized partially, and the soleus was split to expose the neurovascular structures further. Care was taken to preserve the medial sural artery, which is the main pedicle to the medial gastrocnemius muscle. The anterior tibial vessels were ligated, and the entire neurovascular bundle fell away from the posterior aspect of the tibia. Occasionally the peroneal artery must be ligated because of its proximity to the tumor. The knee joint was then explored through a small arthrotomy; if there was no evidence of intra-articular tumor extension, an intra-articular resection was performed. The patellar tendon was sectioned 1 to 2 cm proximal to the tibial tubercle, the cruciate ligaments were sectioned close to their femoral attachments, and the posterior capsule was dissected. The proximal tibia was osteotomized 3 to 4 cm distal to the lesion, as determined by the staging studies, and resected en bloc with the fibular head and a portion of the tibialis anterior muscle.

After femoral and tibial components of the prosthesis were cemented, reconstruction of the extensor mechanism was performed. First, the patellar tendon was advanced distally and secured tightly to the prosthesis with a 3-mm Dacron tape (Deknatel, Falls River, MA) that provided immediate mechanical fixation (Fig. 1A). Dacron is a nonabsorbable synthetic polyester (polyethylene terephthalate) that has a minimum pull-out tensile strength of 36.1N and allows approximation of the patellar tendon to the prosthesis under significant tension. An autologous bone–graft, taken from the cut femoral condyles, was packed between the prosthesis and sutured patellar tendon, facing both surfaces (Fig. 1A). The medial gastrocnemius flap was sectioned through its tendinous insertion, separated from the lateral gastrocnemius, and rotated to cover the proximal tibia and knee joint (Fig. 1B). The gastrocnemius muscle was sutured to the underlying patellar tendon, the remaining joint capsule, and the quadriceps muscle [16]. Fig. 2 summarizes the 3 steps involved in reconstruction of the extensor mechanism: i) attachment of the patellar tendon to the prosthesis, ii) reinforcement with a bone–graft, and iii) attachment of a gastrocnemius flap.

Postoperative Management

The extremity was kept elevated for at least 5 days. Continuous suction was required for 3 to 5 days, and perioperative intravenous antibiotics were continued until the drainage tubes were removed. If there was no evidence of significant swelling by the end of the 5th day, the patient was allowed to walk with weight bearing as tolerated for 10 to 15 minutes in each session. If the extremity still did not become swollen, a gradual increment in exercise was allowed. The knee was kept immobilized in a knee immobilizer for 6 weeks, by the end of which passive and active flexion of the knee joint were allowed gradually.

For the first 2 years after surgery, patients were evaluated every 3 months. On each visit, physical examination, plain radiography, and chest CT were performed. Patients were evaluated semiannually for an additional 3 years and annually thereafter. Functional evaluation was done according to the American Musculoskeletal Tumor Society System [17]. Fisher's exact test was used to evaluate statistical significance of functional outcome; $P<.05$ was considered significant. An orthopaedic oncologist analyzed the clinical records and operative reports. The histopathologic diagnoses, results of staging studies, prostheses used for reconstruction, technique of reconstruction, complications, and rates of local tumor recurrence and revisions were determined. The results presented here as well as the range of motion of the knee joint are based on each patient's most recent follow-up.

Results

Fifty-four patients with tumors of the proximal tibia and 1 patient with a failed allograft underwent intra-articular proximal tibia resection. Reconstruction devices included 39 modular, 12 custom-made, and 4 expandable prostheses. The latter were used in patients <12 years old, who were skeletally immature at the time of surgery. Reconstruction of the extensor mechanism was performed by reattaching the patellar tendon to the prosthesis with a Dacron tape, autologous bone grafting of the tendon–prosthesis interface, and covering the area with a gastrocnemius flap. A medial or lateral gastrocnemius flap was used in 50 patients, a bilateral flap was used in 1 patient, and no flap was used in 4 patients.

All patients were followed up for a minimum of 2 years (median, 75.5 months). Six patients (11%) had peroneal nerve palsy; all recovered spontaneously within 4 months of surgery. Four patients (7.2%) had flap necrosis; 2 were managed satisfactorily with nonsurgical treatment, and 2 required débridement and skin grafting. Deep wound infection necessitating surgical intervention occurred in

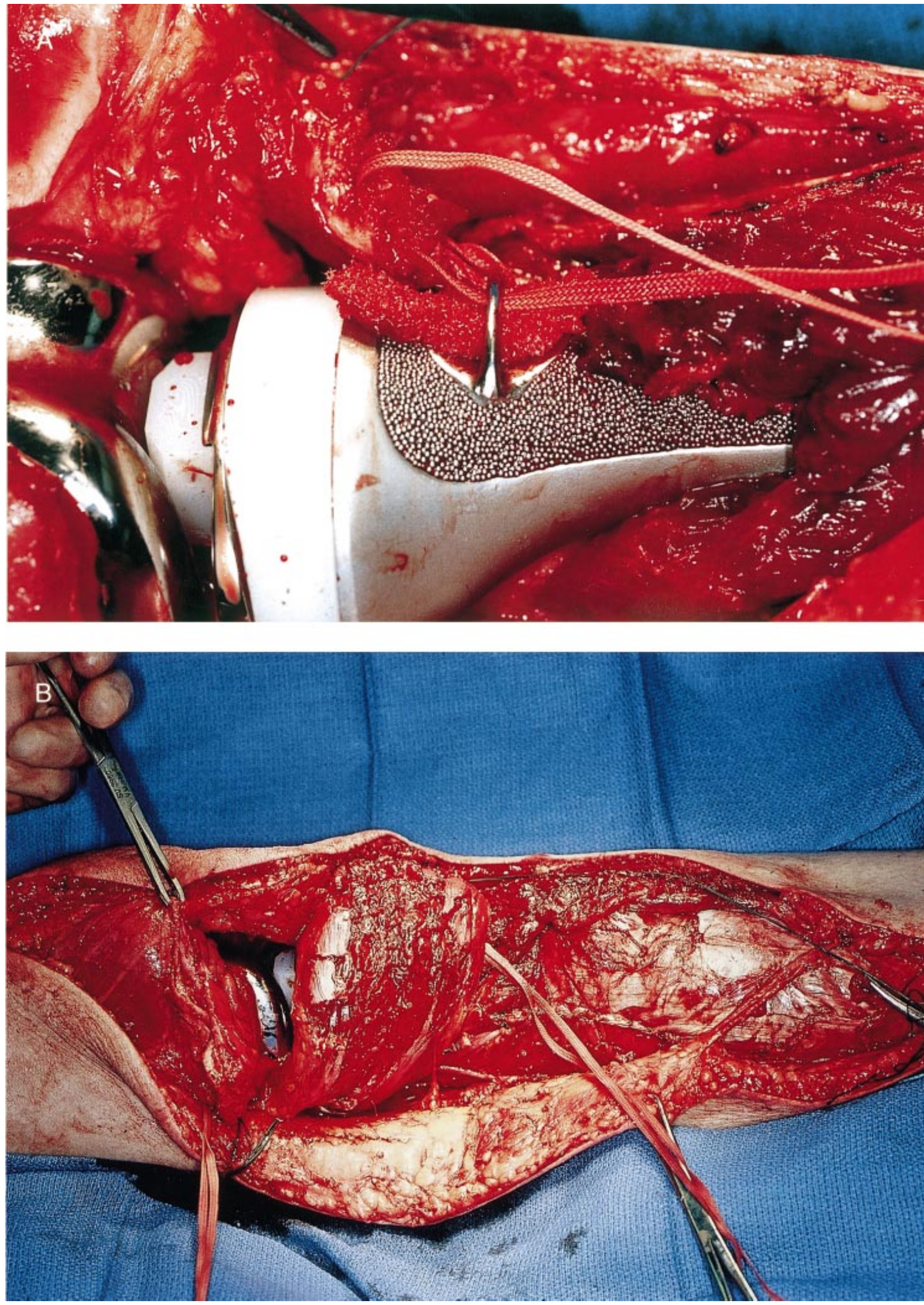

Fig. 1. (A) The patellar tendon is advanced to the prosthesis and reattached with a Dacron tape over an autologous bone–graft. Note the porous coating around the patellar tendon insertion site. (B) A medial gastrocnemius flap is rotated over the proximal tibia and knee joint and sutured to the patellar tendon and ipsilateral quadriceps muscle.

2 patients (3.6%). Both were treated with repeated wound débridement and irrigations, delayed primary closure, and a 12-week regimen of intravenous antibiotics. None of the patients had thromboembolic complications.

Full extension to an extension lag of 20° was achieved in 44 patients (78%), an extension lag of 20° to 30° was found in 10 patients (19%), and extension lag of 40° was found in 1 patient (3%). All patients were ambulatory; 48 required no braces or external support. Overall, function was estimated to be good to excellent in 48 patients, fair in 6 patients, and poor in 1 patient. All patients who had an extension lag of ≤20° had a good-to-excellent functional outcome and reported no limitations with activities of daily living. This difference in function was statistically significant ($P<.0001$). Table 2 summarizes the extension lag, flexion, and functional outcomes of the patients in this series. Eight patients required secondary reinforcement of

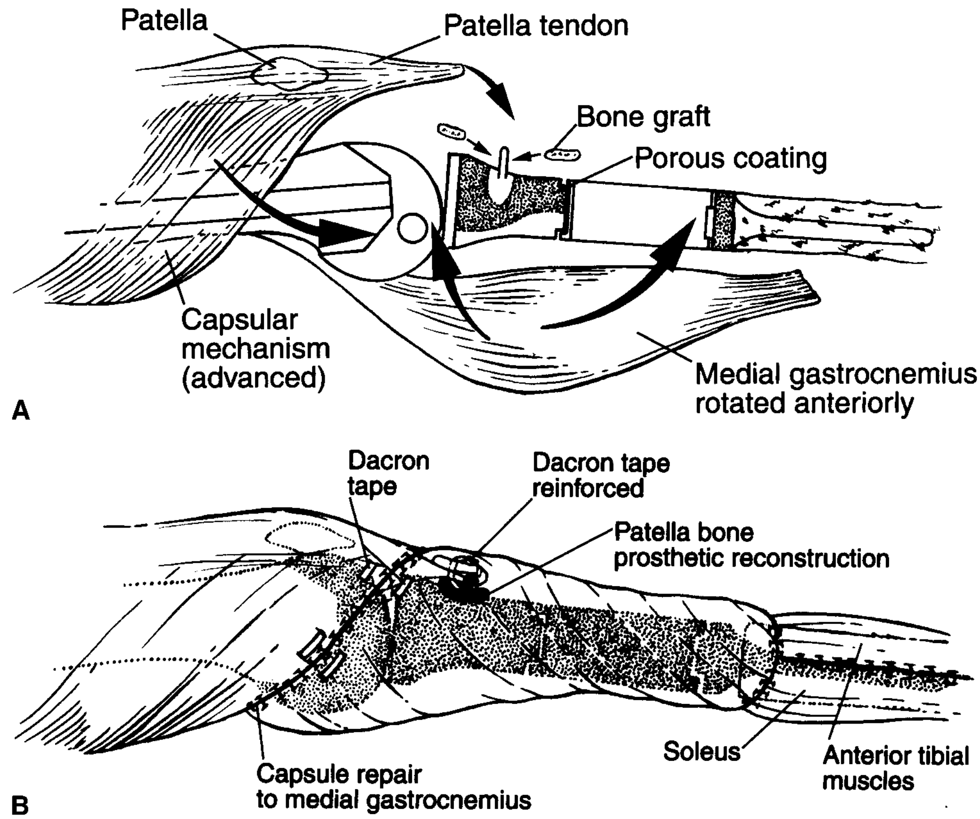

Fig. 2. (A and B) A scheme of the 3 components of extensor mechanism reconstruction: i) attachment of the patellar tendon to the prosthesis, ii) reinforcement with a bone–graft, and iii) coverage with a gastrocnemius flap.

the patellar tendon with either a combined quadriceps tendon and Gore-Tex graft (Gore, Flagstaff, AZ) construct (7 patients) or simple plication of the tendon (1 patient). Seven of these patients gained an extension lag of <20°.

Revision surgery for prosthetic failure was performed in 3 patients (5.4%). Two patients had a broken prosthetic stem, and 1 patient had a loosened prosthetic stem. Both breakages occurred in custom-made prostheses. The stem diameter in these devices was relatively small, and there was no widening at the stem–prosthetic body interface. Local recurrence developed in 3 of the 48 patients with primary bone sarcomas (6.2%), all of whom had a stage IIB (ie, high-grade and extracompartmental) tumor at presentation. All recurrences occurred in the soft tissues. One patient was treated with wide local excision with preservation of the prosthesis and adjuvant radiation therapy, and amputation was performed in the other 2 patients. The limb salvage rate in the 48 patients with primary bone sarcomas was 96%.

Table 2. Extension Lag, Flexion, and Functional Outcome of 55 Patients Treated With Proximal Tibia Endoprosthetic Reconstruction

					Functional Outcome [17]		
Extension Lag	No. Patients	Flexion			Good-to-Excellent	Fair	Poor
—	32	2	3	27	32	—	—
—	12	1	2	9	11	1	—
—	10	3	2	5	5	5	—
—	1	—	1	—	—	—	1
Total	55	6	8	41	48	6	1

Discussion

The purpose of this study was to describe the surgical technique and long-term functional outcome in 55 consecutive patients who underwent reconstruction of the extensor mechanism after proximal tibia endoprosthetic reconstruction. This is the largest report to date of a series of patients who underwent proximal tibia endoprosthetic reconstruction using a single technique. We used endoprostheses for reconstruction because of the high rates of complications associated with the use of allografts for reconstruction. With time, these allografts are associated with significant rates of infection, nonunion, instability, fracture, and subchondral collapse [18–20]. Rodl et al [21] reported their experience with 17 patients who underwent osteoarticular allograft reconstruction after resection of high-grade sarcoma of bone. Seven of these tumors were located at the proximal tibia. At 5 years after surgery, 5 of these proximal tibia allografts fractured. Overall, 8 of 15 allografts (53%) failed as a result of either a fracture or a deep infection. Only 4 patients did not require additional surgery after the primary repair. Rodl et al [21] concluded that osteoarticular reconstruction, owing to its low survival rate, should be considered as a temporary measure of reconstruction, at best. Reattachment of the patellar tendon to the prosthesis with a nonabsorbable suture provides the initial mechanical support needed for healing and scarring, which is reinforced further by 2 forms of biologic fixation: autologous bone–graft, which reinforces the patellar tendon–endoprosthesis interface, and an overlying muscle flap. The gastrocnemius flap is stripped from its covering aponeurosis, and a wide surface of viable muscle tissue is facing the patellar tendon–prosthesis–bone graft construct and 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.

Bone ingrowth into the porous-coated surface of cementless endoprosthetic components is well documented [22,23]. When the porous-coated surface of the endoprosthesis is extramedullary (ie, facing the surrounding soft tissues), however, fibrous tissue rather than bone grows into it [24]. Malawer et al [25] described a technique of extracortical bone fixation, in which a bone–graft is laid and secured over the extramedullary porous-coated surface of the prosthesis. In their preliminary report of 20 patients, incorporation of the bone–graft was established radiologically in 60% [25]. Based on these reports, we expected that attaching the patellar tendon to the extramedullary porous-coated surface of the prosthesis and reinforcing it with an autologous bone–graft would result in a fibrous–bone bridge. Because the bone–grafts used for this purpose were relatively small and located within a prosthetic groove (Fig. 1A), it was difficult to assess their incorporation by means of imaging studies.

In contrast to total knee arthroplasty, in which flexion is the main objective of physical rehabilitation, extensor strength is the functional goal of proximal tibia endoprosthetic reconstruction. To provide a tension-free environment in which complex healing of bone and soft tissues can occur, the knee joint should be kept immobilized for at least 6 weeks; after this, a gradual passive and active flexion are practiced. Horowitz et al [11] reported a series of 16 patients who underwent extra-articular proximal tibia resection with endoprosthetic reconstruction for a primary bone sarcoma. In an effort to 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 6. Long-term functional evaluation was feasible in only 11 patients in this series, 6 of whom had an extension lag of −80° to −90° [11]. In the present study, a functional failure of the extensor mechanism (ie, an extension lag that was not compatible with activities of daily living) was found in only 22% of the patients after a minimum follow-up of 2 years. Extension lag correlated with overall functional outcome, which was good to excellent in 87% of the patients.

The bone tumors in the present series represent a large spectrum of biologic behaviors and prognoses. Presenting detailed information on neoadjuvant and adjuvant treatment modalities and oncologic outcome is beyond the scope of this article, which focuses on surgical technique and the concept of extensor mechanism repair. Reconstruction of the extensor mechanism by reattaching the patellar tendon to the prosthesis, reinforcing it with bone–graft, and covering it with a 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 proximal tibia endoprosthetic reconstruction.

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