Continuity and Function of Patellar Tendon Host-Donor Suture in Tibial Allograft

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Reconstruction of extensor mechanism after proximal tibia tumor resection is a major concern, especially in young and physically active patients. We evaluated patellar tendon hostdonor reattachments in 42 consecutive proximal tibia allograft reconstructions after bone tumor resection to determine if patellar tendon length and integrity was maintained, and if active knee extension and adequate function was achieved. Patellar tendon length was radiographically measured in all patients by the Insall-Salvati index while magnetic resonance was available in 19 patients to evaluate imaging integrity. Eight patients were not available for functional assessment, leaving 34 patients for clinical evaluation with the Musculoskeletal Tumor Society scoring system. According to the Insall-Salvati index evaluation, the reconstructed patellar tendon remained stable with no elongation between preoperative and postoperative measurements (1.15 versus 1.13). Postoperative magnetic resonance images showed a continuous patellar host-donor tendon in all. Active knee extension was restored in all functionally evaluated patients with an average functional score of 26.6 points. Twenty-four patients had no extensor lag, while ten had an average residual extensor lag of 6.5°. Our findings suggest patellar tendon reconstruction with allogeneic tissue from the proximal tibia allograft sutured to the recipient's remnant patellar tendon can restore and stabilize active knee extension.

Level of Evidence: Therapeutic study, level IV (case series). See the Guidelines for Authors for a complete description of levels of evidence.

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DOI: 10.1097/01.blo.0000229291.21722.b5

Advances in the staging of musculoskeletal sarcomas and improvements in diagnostic imaging, adjuvant therapy, and neoadjuvant therapy have enabled orthopaedic oncologists to offer limb salvage surgery as an alternative to amputation. The durability and long term function of the reconstructions performed after tumor resection is a major concern, especially in young and physically active patients.^{1,4,5,10–12,15,18} Resection of the proximal tibia and reconstruction with either an allograft, endoprosthesis, or a combination (composite biologic implant) are the treatments of choice, although technical problems are still high.¹⁵ However, without appropriate extensor mechanism reattachment to the graft or prosthesis, long-term stability and limb function are inadequate.

Several methods are used for reconstruction, including nonabsorbable tape or suture, transferring the proximal fibula, a medial gastrocnemius transposition flap, or direct reattachment to a prosthetic reconstruction or allograft.^{1,3,4,6,10–12,15,16,18} Increased emphasis has been placed on biologic reconstructive alternatives because of concerns involving the durability of prosthetic materials, and the increasing survivorship of patients with sarcomas.⁴ An advantage of proximal tibia allografts is the ability to reattach host ligaments and tendons to the allograft, accomplishing an anatomical and biological reconstruction of the extensor mechanism.^{4,6,11}

We determined whether patellar tendon length and imaging integrity were maintained, and whether active knee extension was achieved with adequate function with patellar tendon host-donor reattachments in proximal tibia allograft reconstructions.

MATERIALS AND METHODS

We retrospectively reviewed the records of 53 consecutive patients who had a proximal tibia allograft reconstruction in which patellar tendon host-donor reattachments were performed from 1990–2002. We excluded 11 patients: four patients had the allograft removed because of recurrence; four patients had early infections; one patient had a fracture of the allograft; and two

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Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution has approved the reporting of this case report, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

patients died before 2 years followup. This left 42 patients for review, thirty-three osteoarticular and nine intercalary allografts (Table 1). The patients had a mean followup of 52 months (range, 24–136 months), and the mean age at the time of the reconstruction was 21 years (range, 11–54 years). Twenty patients were women and 22 were men. The primary diagnosis was osteosarcoma in 23 patients, Ewing's sarcoma in seven patients, giant cell tumor (GCT) in seven patients, chondrosarcoma in one patient, recurrent chondroblastoma in one patient, and recurrent osteoblastoma in one patient.

The surgical procedure included resection of the proximal tibia with a wide bone and soft tissue margin, and the insertion of a fresh deep frozen nonirradiated allograft segment sized to the articular surface. We harvested and stored proximal tibia allografts according to a previously reported technique.²¹ Allograft selection was based on a comparison of the radiographs of the patient and donor to achieve the closest anatomical match. After being thawed in a warm solution, the donor bone was cut to the proper length. We performed fixation of the diaphyseal host allograft junction with a compression plate or an intramedullary (IM) nail. If an osteoarticular allograft was performed, the posterior capsule, both cruciate ligaments, both meniscuses, and the medial collateral ligament from the host were attached to the corresponding allograft. If an intercalary allograft was performed, the intraepiphyseal osteotomy site was stabilized with cancellous screws. The host patellar tendon was sectioned during tumor removal. The remaining tendon was reattached to the corresponding tissue of the allograft. We opened the allograft tendon longitudinally to obtain two flaps where the host tendon was inserted. Both donor flaps were overlapped and sutured in full extension with enough tension to ensure proper positioning of the patella relative to the joint (Fig 1). We performed a medial gastrocnemius transposition flap only to provide soft tissue coverage to the proximal tibia allograft, making no attempt to reinforce the extensor mechanism. Antibiotics were given intravenously until the drainage tubes were removed, and no routine anticoagulation therapy was used.

After reconstruction, the knee was placed in full extension and secured with a knee immobilizer or locked hinged postoperative brace. Ice or a cryotherapy device was used to help minimize postoperative swelling and discomfort. Postoperatively, a physical therapist instructed patients on brace use, crutched walking, and quadriceps contractions. The goals during the first postoperative week were to minimize swelling and obtain passive complete extension. Passive flexion exercises were started 2 weeks postoperatively with the goal of obtaining at least 60° of flexion. At 4 weeks postoperatively, active assisted knee motion was initiated until full active extension and 90° of flexion were obtained. Most patients were seen at 1 week, 2 weeks, 1 month, 2 months, and 3 months postoperatively. They were seen every 3 months thereafter until 2 years postoperatively, and then annually. Plain radiographs were taken at every visit starting at 1 month postoperatively.

The preoperative and latest followup radiographs were reviewed. The radiographs were measured using the lateral view of the knee with the Insall-Salvati patellar tendon-patella ratio.¹³ The preoperative radiographic ratio was compared with the postoperative ratio at minimum of 24 months postoperatively (average, 52 months).

Magnetic resonance imaging (MRI) of the patellar tendon was performed for 19 patients to evaluate signal intensity and tendon continuity.¹⁹ In Grade I, a homogeneous low intensity signal within the entire tendon is present. In Grade II, at least 50% of normal tendon signal is present. In Grade III, the tendon exhibits less than 50% normal appearing signal, and in Grade IV there is a diffuse increase in signal intensity with abnormal appearing strand of tendon. The continuity of the patellar tendon reconstruction was recorded in three grades: Grade A, welldefined tendon; Grade B, wavy but continuous tendon contour; and Grade C, nondelineated tendon.

The functional evaluation was performed with use of the revised 30-point functional classification system established by the International Society of Limb Salvage and the Musculoskeletal Tumor Society (MSTS).⁹ This functional score measures six parameters: pain, function, emotional acceptance, use of walking supports, walking ability, and gait. Each parameter has a value ranging from 0–5 according to specific criteria. The individual scores are added together to obtain an overall functional score (maximum, 30 points), which then is expressed as a percentage of normal. A score of at least 23 points was considered as an excellent functional result, 15–22 points was a good result, 8–14 points was a fair result, and less than 8 points was a poor result.

We measured postoperative range of motion (ROM) and any extensor lag with a handheld goniometer. An extensor lag was defined as the difference between the greatest passive extension and the greatest active extension of the knee.

The Insall-Salvati ratio, magnetic resonance images, extensor lag, and ROM of the knee were investigated serially by two investigators (LAAT, EA) who were blinded to the results.

We compared groups using a paired t test and correlations using Pearson's correlation coefficient. We defined significance as p < 0.05.

RESULTS

Radiographic evaluations showed no proximal patellar migration. The mean original preoperative patellar tendon index was $1.15 \pm 0.05 \ (\pm 2 \text{ standard error [SE]})$ (range, 0.9-1.42). At last followup, the mean reconstructed hostdonor tendon index was $1.13 \pm 0.07 \ (\pm 2\text{SE})$ (range, 0.76-1.9) (Fig 2).

Magnetic resonance images showed the patellar reattached tendon continuous in all 19 patients (Fig 3). The average time between the reconstruction and the postoperative MRI was 16 months (range, 6–72 months). According the classification for signal intensity there were 11 patients in Grade I, seven patients in Grade II, and one patient in Grade III. The MRI evaluation for fiber continuity showed 13 patients in Grade A and six in Grade B.

Although each allograft survived for at least 2 years, three of the 42 allografts were removed and five patients died of disease 2–5 years after reconstruction (Table 1). At

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17 F/I5 Osteoarroma Intercatary 14 120 100 22 0 0 115 18 W/18 Osteoarroma Deteoarroma Deteoarrom	17 F/15 Osteosarcc 19 M/16 Osteosarcc 20 M/25 GCT 21 M/36 GCT 22 M/35 GCT 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/15 Osteosarcc 27 F/15 Osteosarcc 28 F/16 Osteosarcc 29 M/15 Osteosarcc 33 F/12 Osteosarcc 33 F/12 Osteosarcc 33 F/12 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/16 Osteosarcc 38 M/15 Eving's sar 39 M/16 Osteosarcc 39 M/16 Osteosarcc	arcoma	Osteoarticular	46	1.35	1.02	25	0	135
18 W18 Osteoarticular 39 0.00 0.08 30 0 10 110 21 W26 Osteoarticular 37 1.14 1.12 29 0.0 110 22 W36 GCT Intercatary 36 1.22 1.24 29 0 110 22 W35 GCT Intercatary 36 1.22 1.24 29 0 110 23 W15 Osteoarticular 34 1.26 1.24 29 0 110 24 F/15 Osteoarticular 30 1.00 0.85 0.76 0.76 1.14 1.26 26 F/16 Osteoarticular 27 1.00 0.76 27 0.76 0.76 1.67 27 F/25 Ewing's sarcoma Osteoarticular 27 1.00 27 0.76 7 0.76 1.76 28 F/13 Osteoarticular 27 1.00 27	18 M/18 Osteosarcc 19 M/16 Osteosarcc 20 M/25 GCT 21 M/36 GCT 22 M/15 Osteosarcc 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/16 Osteosarcc 27 F/15 Osteosarcc 28 F/16 Osteosarcc 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 M/21 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 37 M/16 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc	coma	Intercalary	44	1.20	1.00	22	0	115
19 M/16 Osteoarticular 37 114 112 29 0 120 20 M/36 GCT Osteoarticular 37 114 112 29 0 120 21 M/36 GCT Osteoarticular 36 122 124 26 0 110 23 M/15 Osteoarticular 36 126 124 29 0 110 25 M/15 Osteoarticular 32 130 036 27 0 110 26 F/16 Osteoarticular 29 039 1102 27 0 110 27 F/16 Osteoarticular 28 102 0.76 0 126 0 126 28 F/26 GCT Osteoarticular 27 100 0.76 0 126 29 F/18 Ewing's sarcoma Osteoarticular 27 100 0.76 0 116 29	19 M/16 Osteosarcc 20 M/25 GCT 21 M/36 GCT 22 M/35 GCT 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/16 Osteosarcc 27 F/15 Osteosarcc 28 F/16 Osteosarcc 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 M/24 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/16 Osteosarcc 38 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc <tr td=""></tr>	soma	Osteoarticular	39	0.90	0.98	30	0	110
20 M25 GCT Osteoarticular 36 0.08 1.10 28 0 110 21 M/35 GCT Steoarticular 36 1.22 1.24 29 0 120 23 M/15 Osteoarticular 34 1.22 1.24 29 0 120 24 M/15 Osteoarticular 32 1.30 0.37 22 5 95 26 F1/16 Osteoarticular 29 0.39 0.37 22 5 95 27 F25 Ewing's sarcoma Osteoarticular 27 100 0.81 76 7 28 F1/35 Ewing's sarcoma Osteoarticular 27 100 26 7 100 29 M/37 Chordrosarcoma Osteoarticular 27 102 27 10 100 30 F1/35 Ewing's sarcoma Osteoarticular 27 102 27 10 100 1	20 M/25 GCT 21 M/36 GCT 22 M/35 GCT 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/13 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/19 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Osteosarcc 39	soma	Osteoarticular	37	1.14	1.12	29	0	120
21 M(36) GCT Intercatary 36 1.22 1.24 26 0 120 22 M(35) GCT Intercatary 36 1.22 1.24 26 0 10 23 M(15) Osteoanticular 32 1.39 0.127 22 5 9 0 10 25 F/15 Osteoanticular 32 1.00 0.85 22 5 9 05 26 F/16 Osteoanticular 28 0.03 0.081 22 6 0 10 27 F/26 GCT Osteoanticular 28 1.02 0.081 27 0 0 10 28 F/26 GCT Osteoanticular 27 1.06 0.76 27 0 0 115 31 F/12 Osteoanticular 26 1.22 1.26 12 12 12 12 12 12 115 32	21 M/36 GCT 22 M/15 Osteosarcc 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/16 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/14 Osteosarcc 39 M/15 Ewing's sar 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc 39 M/18 Osteosarcc 30 Osteosarcc		Osteoarticular	36	0.98	1.10	28	0	110
22 M/35 GCT Osteoarticular 34 1.26 1.24 29 0 110 23 M/15 Osteoarcoma Osteoarticular 34 1.26 1.24 29 0 0 10 10 24 F/15 Osteoarcoma Osteoarcular 32 1.39 0.97 22 5 9 95 26 F/18 Ewing's sarcoma Osteoarticular 28 0.93 0.01 22 7 7 9 100 105 27 F/25 Ewing's sarcoma Osteoarticular 28 10.20 0.06 27 0 100 30 F/26 Ewing's sarcoma Osteoarticular 27 1.20 1.27 30 0 0 100 31 F/12 Osteoarticular 27 1.20 1.27 30 0 0 100 32 M/37 Osteoarticular 26 1.22 27 10 0 <td< td=""><td>22 M/35 GCT 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/19 Osteosarcc 38 M/15 Ewing's sar 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/19 Osteosarcc 39 M/16 Osteosarcc</td><td></td><td>Intercalary</td><td>36</td><td>1.22</td><td>1.24</td><td>26</td><td>0</td><td>120</td></td<>	22 M/35 GCT 23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/19 Osteosarcc 38 M/15 Ewing's sar 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/19 Osteosarcc 39 M/16 Osteosarcc		Intercalary	36	1.22	1.24	26	0	120
23 M/15 Osteoarticular 32 1.39 0.97 22 5 95 24 F/15 Osteoarticular 30 100 035 29 0 125 26 F/16 Osteoarticular 30 100 035 29 0 125 27 F/25 Ewing's sarcoma Osteoarticular 28 039 0.07 26 7 120 28 F/26 GCT Osteoarticular 28 0.07 26 7 95 95 30 F/35 Ewing's sarcoma Osteoarticular 27 1.00 26 5 95 31 F/12 Osteoarticular 26 1.25 1.02 27 0 115 31 F/12 Osteoarticular 26 1.25 1.25 1.30 31 F/12 Osteoarticular 26 1.25 1.26 27 0 1.15 32 M/13 Osteoartic	23 M/15 Osteosarcc 24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/16 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc 39 M/19 Osteosarcc 39 M/16 Osteosarcc		Osteoarticular	34	1.26	1.24	29	0	110
24 F/15 Osteosarcoma Intercalary 30 1.00 0.85 29 0 125 26 W/15 Osteosarcoma Osteoanticular 29 0.03 1.02 AF	24 F/15 Osteosarcc 25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/35 Ewing's sar 31 F/12 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/16 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	32	1.39	0.97	22	5	95
25 M/15 Osteosarcoma Osteoarticular 29 0.08 1.02 AF AF AF 26 F/18 Ewing's sarcoma Osteoarticular 28 0.03 0.081 26 0 100 27 F/25 Ewing's sarcoma Osteoarticular 28 1.02 1.00 26 0 100 29 M/37 Chondrosarcoma Osteoarticular 27 1.02 1.07 26 5 9 0 31 F/12 Osteoarticular 26 1.02 1.02 0.76 0 110 0 100 31 F/12 Osteoarticular 26 1.25 1.26 1.27 30 0 0 100 33 M/21 Osteoarticular 26 1.26 1.26 1.30 1.31 1.42 27 10 0 100 34 F/13 Osteoarticular 26 1.26 1.30 1.42 27 10	25 M/15 Osteosarcc 26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc 39 M/19 Osteosarcc 39 M/19 Osteosarcc	coma	Intercalary	30	1.00	0.85	29	0	125
26 F/18 Ewing's sarcoma Osteoarticular 28 0.93 0.81 26 0 100 28 F/26 GCT Osteoarticular 28 1.02 1.00 26 5 95 29 M/37 Chondrosarcoma Osteoarticular 27 1.00 0.76 27 0 0 115 30 F/35 Ewing's sarcoma Osteoarticular 27 1.00 0.76 27 0 0 115 31 F/12 Osteosarcoma Osteoarticular 26 1.25 1.02 0.76 0 0 100 32 M/54 Osteosarcoma Osteoarticular 26 1.25 1.02 0.76 0 0 0 0 100 33 M/21 Osteoarcoma Osteoarticular 26 1.26 1.162 27 10 0 0 0 0 0 0 0 0 0 0 0 0	26 F/18 Ewing's sar 27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/12 Osteosarcc 31 F/12 Osteosarcc 32 M/21 Osteosarcc 33 F/12 Osteosarcc 34 F/13 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	29	0.98	1.02	AF	AF	AF
27 F/25 Ewing's sarcoma Osteoarticular 28 1.02 1.00 26 5 96 28 F/26 GCT Osteoarticular 27 1.06 0.76 27 0 115 30 F/35 Ewing's sarcoma Osteoarticular 27 1.06 0.76 0 0 100 31 F/12 Osteoarticular 26 1.25 1.02 0.76 0 0 100 32 M/54 Osteoarticular 26 1.25 1.02 0.76 0	27 F/25 Ewing's sar 28 F/26 GCT 29 M/37 Chondrosa 30 F/35 Ewing's sar 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 F/12 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 40 M/18 Osteosarcc 41 M/19 Osteosarcc	arcoma	Osteoarticular	28	0.93	0.81	26	0	100
28 F/26 GCT Osteoarticular 27 1.06 0.76 27 0 115 30 F/35 Ewing's sarcoma Osteoarticular 27 1.06 0.76 0 100 100 31 F/12 Osteoarticular 26 1.20 1.27 30 0 100 100 31 F/12 Osteoarticular 26 1.25 1.20 1.27 30 0 100 100 32 M/54 Osteoarticular 25 1.28 1.15 26 5 130 33 M/21 Osteoarticular 25 1.28 1.16 0 9 9 34 F/30 GCT Osteoarticular 24 1.37 1.62 27 10 9 9 35 F/13 Osteoarticular 24 1.37 1.62 27 10 9 9 36 F/13 Osteoarticular 24 1.37 <t< td=""><td>28 F/26 GCT 29 M/37 Chondrosa 30 F/35 Ewing's sar 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc 39 M/19 Osteosarcc 39 M/19 Osteosarcc 39 M/19 Osteosarcc 41 M/19 Osteosarcc</td><td>arcoma</td><td>Osteoarticular</td><td>28</td><td>1.02</td><td>1.00</td><td>26</td><td>വ</td><td>95</td></t<>	28 F/26 GCT 29 M/37 Chondrosa 30 F/35 Ewing's sar 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/18 Osteosarcc 39 M/19 Osteosarcc 39 M/19 Osteosarcc 39 M/19 Osteosarcc 41 M/19 Osteosarcc	arcoma	Osteoarticular	28	1.02	1.00	26	വ	95
29 M/37 Chondrosarcoma Osteoarticular 27 1.20 1.27 30 0 100 30 F/35 Ewing's sarcoma Osteoarticular 26 1.02 0.76 D D 100 31 F/12 Osteoarticular 26 1.25 1.26 1.27 30 0 100 32 M/54 Osteoarticular 26 1.25 1.28 1.15 24 10 90 33 M/21 Osteoarticular 25 1.29 1.33 D D 90 34 F/30 Gsteoarticular 25 1.29 1.33 D D 90 35 F/13 Osteoarticular 24 1.30 1.42 27 10 95 36 F/13 Osteoarticular 24 1.32 1.47 AF AF 37 M/20 Osteoarticular 24 1.25 1.10 D D D	29 M/37 Chondrosa 30 F/35 Ewing's sar 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Osteosarcc 39 M/16 Osteosarcc 40 M/18 Osteosarcc 41 M/19 Osteosarcc 42 M/19 Osteosarcc		Osteoarticular	27	1.06	0.76	27	0	115
30 F/35 Ewing's sarcoma Osteoarticular 26 1.02 0.76 D	30 F/35 Ewing's sar 31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/12 Osteosarcc 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Osteosarcc 40 M/18 Osteosarcc 41 M/19 Osteosarcc	arcoma	Osteoarticular	27	1.20	1.27	30	0	100
31 F/12 Osteosarcoma Osteoarticular 26 1.25 1.02 26 5 130 32 M/54 Osteosarcoma Osteoarticular 25 1.28 1.15 24 10 90 33 M/21 Osteosarcoma Osteoarticular 25 1.29 1.15 24 10 90 34 F/30 GCT Osteosarcoma Osteoarticular 25 1.29 1.42 27 10 95 35 F/13 Osteosarcoma Osteoarticular 24 1.37 1.42 27 10 95 36 F/13 Osteosarcoma Osteosarcular 24 1.37 1.47 AF AF 37 M/12 Osteosarcoma Osteosarcular 24 1.22 1.10 D D 38 M/13 Osteosarcoma Osteosarcular 24 1.29 D D D 38 M/14 Osteosarcoma Osteosarcular 24 1.20 1.29 D D D D D D	31 F/12 Osteosarcc 32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/30 GCT 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	arcoma	Osteoarticular	26	1.02	0.76	Ω	Ω	Ω
32 M/54 Osteosarcoma Osteoarticular 25 1.28 1.15 24 10 90 33 M/21 Osteosarcoma Osteoarticular 25 1.29 1.33 D D 95 34 F/30 GCT Osteoarticular 25 1.29 1.33 D D 95 35 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF AF AF AF 36 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF	32 M/54 Osteosarcc 33 M/21 Osteosarcc 34 F/30 GCT 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/16 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	26	1.25	1.02	26	5	130
33 M/21 Osteosarcoma Osteoarticular 25 1.29 1.33 D D 95 34 F/30 GCT Osteosarcoma Osteoarticular 24 1.30 1.42 27 10 95 35 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF AF AF AF 36 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF AF AF AF 37 M/20 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D D 38 M/13 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D D 38 M/15 Ewing's sarcoma Osteoarticular 24 1.20 1.29 D	33 M/21 Osteosarcc 34 F/30 GCT 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/13 Osteosarcc 39 M/16 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	soma	Osteoarticular	25	1.28	1.15	24	10	06
34 F/30 GCT Osteoarticular 24 1.30 1.42 27 10 95 35 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF AF AF AF 36 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF AF AF AF 37 M/20 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D D 38 M/13 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D D D 38 M/13 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D D 39 M/16 Ewing's sarcoma Osteoarticular 24 1.13 1.05 28 0 D D 40 M/18 Osteosarcoma Intercalary 24 1.02 1.12 28 0 0 95 41 M/19 Osteosarcoma Intercalary	34 F/30 GCT 35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/15 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	soma	Osteoarticular	25	1.29	1.33	Ω	Ω	Ω
35 F/13 Osteosarcoma Osteoarticular 24 1.37 1.62 AF 37 M/13 Osteosarcoma Osteosarcular 24 1.22 1.10 D D D D D 38 M/13 Osteosarcoma Osteosarcular 24 1.22 1.109 D D D D D D D AF	35 F/13 Osteosarcc 36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/15 Ewing's sar 40 M/19 Osteosarcc 41 M/19 Osteosarcc		Osteoarticular	24	1.30	1.42	27	10	95
36 F/13 Osteosarcoma Osteosarcular 24 1.42 1.47 AF AF AF AF 37 M/20 Osteosarcoma Osteosarcular 24 1.22 1.10 D D D D D 38 M/13 Osteosarcoma Osteoarticular 24 1.22 1.10 D <	36 F/13 Osteosarcc 37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/15 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	24	1.37	1.62	AF	AF	AF
37 M/20 Osteosarcoma Osteoarticular 24 1.22 1.10 D D D 38 M/13 Osteosarcoma Osteoarticular 24 1.05 1.09 D D D 39 M/15 Ewing's sarcoma Osteoarticular 24 1.20 1.29 D D D 40 M/18 Osteosarcoma Intercalary 24 1.13 1.05 28 0 95 41 M/19 Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteosarcoma Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteosarcoma Osteosarcoma Intercalary 24 1.02 1.12 28 5 130	37 M/20 Osteosarcc 38 M/13 Osteosarcc 39 M/15 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	24	1.42	1.47	AF	AF	AF
38 M/13 Osteosarcoma Osteoarticular 24 1.05 1.09 D	38 M/13 Osteosarcc 39 M/15 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	24	1.22	1.10	Ω	Ω	Ω
39 M/15 Ewing's sarcoma Osteoarticular 24 1.20 1.29 D D 95 40 M/18 Osteosarcoma Intercalary 24 1.13 1.05 28 0 95 41 M/19 Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteosarciular 24 1.09 1.07 24 0 110	39 M/15 Ewing's sar 40 M/18 Osteosarcc 41 M/19 Osteosarcc	coma	Osteoarticular	24	1.05	1.09		Ω	Ω
40 M/18 Osteosarcoma Intercalary 24 1.13 1.05 28 0 95 41 M/19 Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteosarcular 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteosarcular 24 1.09 1.07 24 0 110	40 M/18 Osteosarcc 41 M/19 Osteosarcc	arcoma	Osteoarticular	24	1.20	1.29		Ω	Ω
41 M/19 Osteosarcoma Intercalary 24 1.02 1.12 28 5 130 42 M/17 Osteosarcoma Osteoarticular 24 1.09 1.07 24 0	41 M/19 Osteosarco	coma	Intercalary	24	1.13	1.05	28	0	95
42 M/17 Osteosarcoma Osteoarticular 24 1.09 1.07 24 0 0 110	AO A147 OA	coma	Intercalary	24	1.02	1.12	28	Q	130
		coma	Osteoarticular	24	1.09	1.07	24	0	110



Fig 1 A–C. Intraoperative photographs show the surgical technique for extensor mechanism reconstruction in proximal tibia allograft. (A) The patellar tendon host-donor flaps are shown. (B) The patellar tendon host-donors flaps were overlapped and sutured. (C) The final reconstruction of the extensor mechanism is shown.

final followup the functional condition of the limb was evaluated in 34 patients.

Active knee extension was restored in all functionally evaluated patients. Active ROM was a mean of 110° (range, $80^{\circ}-135^{\circ}$). Ten patients had an average residual extensor lag of 6.5° (range, $5^{\circ}-10^{\circ}$), and 24 patients had no extensor lag.

The average functional score of the 34 available patients was 26.6 points (range, 18–30 points). Function was estimated to be excellent in 29 patients and good in five patients. Twenty-five patients had no functional restrictions, eight patients had restrictions in recreational activities, and one patient had partial disability. Thirty-one patients were enthusiastic about the result and three accepted the result. Thirty-three patients walked without the use of supports and one patient walked with two canes. Twentynine patients could walk an unlimited distance, and five patients had some limitations in walking. Twenty-seven patients had no discernible limp, six patients had a minor cosmetic limp, and one patient had a major cosmetic limp.



Fig 2 A–B. Radiographs show an 18-year-old male who had a proximal tibia osteoarticular allograft after tumor resection (patient 18). (A) A preoperative lateral radiograph shows the Insall-Salvati index. (B) A postoperative lateral radiograph shows similar Insall-Salvati index 39 months after reconstruction with a proximal tibia osteoarticular allograft.



Fig 3. An MR image of a 20-year-old woman with Ewing's sarcoma is shown (patient 6). The sagittal view MR image shows the reconstructed knee 36 months after implantation. It shows a homogeneous, low intensity signal within the entire patellar tendon.

DISCUSSION

Survival rates and limb salvage in patients with malignant or aggressive tumors have greatly improved by earlier diagnosis, accurate preoperative staging, and adjuvant chemotherapy.^{1,4,6,10,11,15,18} Functional longevity of reconstruction at the proximal tibia performed after tumor resection is a major concern because of difficulties obtaining an appropriate extensor mechanism reattachment to the graft or prosthesis. We hypothesized patellar tendon hostdonor reattachments in proximal tibia allografts maintain patellar tendon length and integrity, restoring active extension with adequate function.

We note several limitations related to the retrospective nature of this study in which there is no comparison to other types of reconstructive surgery. However, these are demanding and somewhat individualized surgical procedures for a limited patient population and it would be difficult to compare substantially different techniques at the same institution. In addition, all of the participants were tumor patients, which further diminished the study group due to reasons unrelated to the reconstruction.

Prosthetic replacement is an alternative reconstructive option for patients with tumors about the proximal tibia, but numerous difficulties with extensor mechanism reattachment have been reported.^{1,3,10,12,15,16} Although active extension could be restored, the extensor lag with this type of reconstruction ranged from $7.5-30^{\circ}$,^{1,10} with the probability of a residual extensor lag of more than 20° in 9–33% of the patients with direct reattachment,^{1,12} and between 20–44% in reports using gastrocnemius flap to reinforce direct attachment.^{3,15} Those studies did not report how many patients had no extensor lag at all.

In contrast to prosthetic reconstructions, allografts may provide the possibility to reattach the host patellar tendon to the allograft, accomplishing an anatomical and biological reconstruction of the extensor mechanism of the knee.^{4,6,11} Although good and excellent functional results were described,^{4,6,11} no attempts to evaluate extensor mechanism reconstructions were performed in those previous reports.

Mechanical and physical properties using soft tissue allograft junction have been studied in vivo for extensor mechanism reconstructions after disruptions in total knee arthroplasty (TKA).^{2,5,7,8,20} After this type of reconstruction, active knee extension was found to be restored with a mean extensor lag of 4° ,^{5,7} with a probability of a residual extensor lag of more than 20° in 11 to 33% of the cases.^{2,7,8} However in 66% of the patients no extensor lag was found.^{7,8,20} Tensioning the allograft in full extension yields a higher clinical success rate.^{5,17} A recent study utilizing medial gastrocnemius flap to restore extensor mechanism, with no use of an allograft, found a postoperative mean extensor lag of 24° , with a residual extensor lag greater than 20° in 4 out of 6 patients.¹⁴

In our study, reattachment of patellar tendon host-donor in proximal tibia allograft provided the mechanical support needed for healing without the need of a medial gastrocnemius flap for reinforcement. Radiographic measurements were performed in all patients and showed no proximal patellar migration. The mean original preoperative Insall-Salvati patellar tendon index showed no differences with the mean reconstructed host-donor tendon index. According to MRI studies performed in 19 patients, the patellar reattached tendon was continuous in all patients. At final followup, active knee extension was restored in all 34 evaluated patients with a mean functional MSTS score of 26.6 points. Twenty-four patients had no extensor lag, while the remaining ten patients had an average residual extensor lag of 6.5° (range, 5° – 10°).

Suturing the overlapped donor flaps may provide a higher contact surface between the donor and the host, which probably contributed to healing. As stability obtained by the reconstruction is high, no cast was used to immobilize the limb. The postoperative rehabilitation included passive flexion exercises started 2 weeks postoperatively, and active assisted knee motion started 4 weeks postoperatively. This postoperative regime allows superior knee extension strength.

The treatment of skeletal deficiencies and the reconstruction of the extensor mechanism after resection of the proximal end of the tibia remains controversial to tumor surgeons. Our data provide evidence patellar tendon host donor healing after proximal tibial allograft reconstruction restores active knee extension. It remained continuous and stable at a mean of 52 months post transplantation. The potential clinical relevance of these findings may be applicable when allogeneic extensor mechanism tissues are used to restore grossly disrupted patellar tendons in failed total knee arthroplasty or due to traumatic defects.

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