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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 host-donor 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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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

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, adamantinoma in one patient, fibrosarcoma 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 60º 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, well-defined 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 ± 0.05 (± 2 standard error [SE]) (range, 0.9–1.42). At last followup, the mean reconstructed host-donor tendon index was 1.13 ± 0.07 (± 2SE) (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

TABLE 1. Demographic and Clinical Data

Case	Gender/Age (years)	Primary Diagnosis	Type of Proximal Tibia Reconstruction	Followup (months)	Radiographic Insall/Salvati Evaluation		MSTS Functional Score	Range of Motion Examination (degrees)	
					Preop	*Postop*		*Active Extension*	*Active Flexion*
1	F/12	Ewing's sarcoma	Osteoarticular	136	1.06	1.34	27	0	130
2	M/18	Osteosarcoma	Osteoarticular	135	1.32	1.07	28	5	95
3	M/28	GCT	Osteoarticular	130	0.83	0.85	29	0	115
4	F/11	Osteosarcoma	Osteoarticular	120	1.11	1.11	29	0	130
5	F/17	Osteosarcoma	Intercalary	120	1.42	1.90	29	5	130
6	F/20	Ewing's sarcoma	Osteoarticular	98	1.10	1.10	28	0	110
7	F/33	Adamantimoma	Intercalary	96	1.10	1.18	29	0	120
8	M/16	Chondroblastoma	Osteoarticular	82	1.06	1.08	26	0	80
9	F/16	Osteoblastoma	Intercalary	72	1.23	1.19	28	0	125
10	M/13	Osteosarcoma	Osteoarticular	67	1.10	1.10	20	10	90
11	F/24	Fibrosarcoma	Intercalary	60	1.21	1.07	28	0	120
12	M/19	Osteosarcoma	Osteoarticular	59	1.10	1.10	26	0	115
13	F/35	GCT	Osteoarticular	54	1.30	1.27	30	0	130
14	F/14	Osteosarcoma	Osteoarticular	53	1.29	1.29	18	0	80
15	M/13	Osteosarcoma	Osteoarticular	49	1.07	1.32	25	5	95
16	F/12	Ewing's sarcoma	Osteoarticular	46	1.35	1.02	25	0	135
17	F/15	Osteosarcoma	Intercalary	44	1.20	1.00	22	0	115
18	M/18	Osteosarcoma	Osteoarticular	39	0.90	0.98	30	0	110
19	M/16	Osteosarcoma	Osteoarticular	37	1.14	1.12	29	0	120
20	M/25	GCT	Osteoarticular	36	0.98	1.10	28	0	110
21	M/36	GCT	Intercalary	36	1.22	1.24	26	0	120
22	M/35	GCT	Osteoarticular	34	1.26	1.24	29	0	110
23	M/15	Osteosarcoma	Osteoarticular	32	1.39	0.97	22	5	95
24	F/15	Osteosarcoma	Intercalary	30	1.00	0.85	29	0	125
25	M/15	Osteosarcoma	Osteoarticular	29	0.98	1.02	AF	AF	AF
26	F/18	Ewing's sarcoma	Osteoarticular	28	0.93	0.81	26	0	100
27	F/25	Ewing's sarcoma	Osteoarticular	28	1.02	1.00	26	5	95
28	F/26	GCT	Osteoarticular	27	1.06	0.76	27	0	115
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	D
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	1.33	D	D	D
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
36	F/13	Osteosarcoma	Osteoarticular	24	1.42	1.47	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	Osteoarticular	24	1.09	1.07	24	0	110

MSTS = Musculoskeletal Tumor Society; GCT = giant cell tumor; AF = allograft failure after two years of followup; D = deceased after two years of followup; preop = preoperative; postop = postoperative

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°–135°). Ten patients had an average residual extensor lag of 6.5° (range, 5°–10°), 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. Twenty-nine 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.

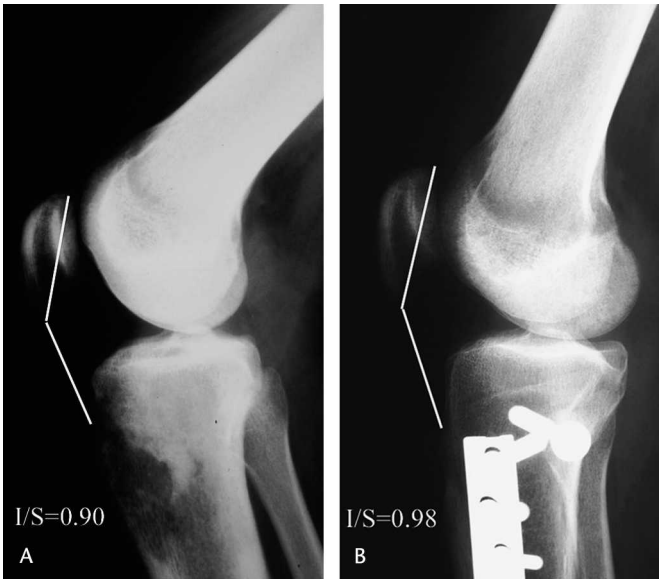

Fig 2 A–B. Radiographs show an 18-year-old male who had a proximal tibia osteoarticular allograft after tumor resection (patient 18). (A) A preoperative lateral radiograph shows the Insall-Salvati index. (B) A postoperative lateral radiograph shows similar Insall-Salvati index 39 months after reconstruction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

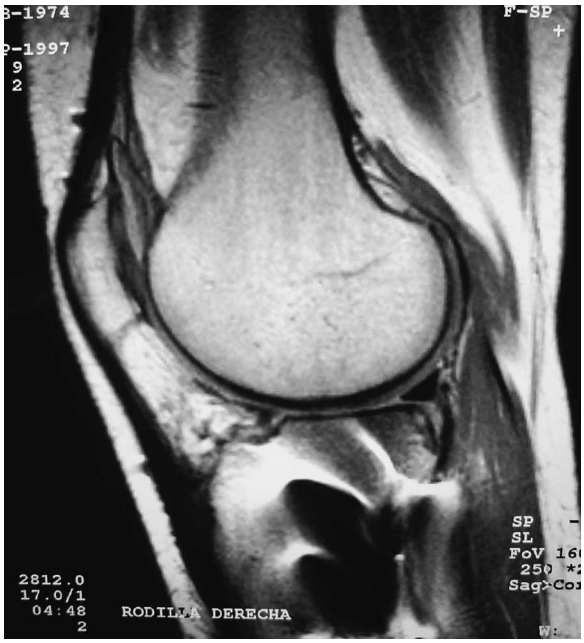

Fig 3. An MR image of a 20-year-old woman with Ewing's sarcoma is shown (patient 6). The sagittal view MR image shows the reconstructed knee 36 months after implantation. It shows a homogeneous, low intensity signal within the entire patellar tendon.

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 host-donor 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°,[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.

References

1. Abboud JA, Patel RV, Donthineni-Rao R, Lackman RD. Proximal tibial segmental prosthetic replacement without the use of muscle flaps. *Clin Orthop Relat Res*. 2003;414:189–196.
2. Barrack RL, Stanley T, Butler RA. Treating extensor mechanism disruption after total knee arthroplasty. *Clin Orthop Relat Res*. 2003;416:98–104.
3. Bickels J. Wittig JC, Kollender Y, Neff RS, Kellar-Graney K, Meller I, Malawer MM. Reconstruction of the extensor mechanism after proximal tibia endoprosthetic replacement. *J Arthroplasty*. 2001;16:856–862.
4. Brien EW, Terek RM, Healey JH, Lane JM. Allograft reconstruction after proximal tibial resection for bone tumors. An analysis of function and outcome comparing allograft and prosthetic reconstructions. *Clin Orthop Relat Res*. 1994;303:116–127.
5. Burnett RSJ, Berger RA, Paprosky WG, Della Valle CJ, Jacobs JJ, Rosenberg AG. Extensor mechanism allograft reconstruction after total knee arthroplasty. A comparison of two techniques. *J Bone Joint Surg Am*. 2004;86:2694–2699.

6. Clohisy DR, Mankin HJ. Osteoarticular allografts for reconstruction after resection of a musculoskeletal tumor in the proximal end of the tibia. *J Bone Joint Surg Am*. 1994;76:549–554.
7. Crossett LS, Sinha RK, Sechriest VF, Rubash HE. Reconstruction of a ruptured patellar tendon with Achilles tendon allograft following total knee arthroplasty. *J Bone Joint Surg Am*. 2002;84: 1354–1361.
8. Emerson RH, Head WC, Malinin TI. Extensor mechanism reconstruction with an allograft after total knee arthroplasty. *Clin Orthop Relat Res*. 1994;303:79–85.
9. Enneking WF, Dunham W, Gebhardt MC, Malawer M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. *Clin Orthop Relat Res*. 1993;286:241–246.
10. Grimer RJ, Carter SR, Tillman RM, Sneath RS, Walker PS, Unwin PS, Shewell PC. Endoprosthetic replacement of the proximal tibia. *J Bone Joint Surg Br*. 1999;81:488–494.
11. Hornicek FJ, Mnaymneh W, Lackman RD, Exner GU, Malinin TI. Limb salvage with osteoarticular allografts after resection of proximal tibia bone tumors. *Clin Orthop Relat Res*. 1998;352:179–186.
12. Horowitz SM, Lane JM, Otis JC, Healey JH. Prosthetic arthroplasty of the knee after resection of a sarcoma of the proximal end of the tibia. A report of sixteen cases. *J Bone Joint Surg Am*. 1991;73: 286–293.
13. Insall JN, Salvati E. Patella position in the normal knee joint. *Radiology*. 1971;101:101–104.
14. Jaureguito JW, Dubois CM, Smith SR, Gottlieb LJ, Finn HA. Medial gastrocnemius flap for the treatment of disruption of the extensor mechanism after total knee arthroplasty. *J Bone Joint Surg Am*. 1997;79:866–873.
15. Jeon DG, Kawai A, Boland P, Healey JH. Algorithm for surgical treatment of malignant lesions of the proximal tibia. *Clin Orthop Relat Res*. 1999;358:15–26.
16. Kollender Y, Bender B, Weinbroum AA, Nirkin A, Meller I, Bickels J. Secondary reconstruction of the extensor mechanism using part of the quadriceps tendon, patellar retinaculum, and gore-tex strips after proximal tibia resection. *J Arthroplasty*. 2004;19: 354–360.
17. Leopold SS, Greidanus N, Paprosky WG, Berger RA, Rosenberg AG. High rate of failure of allograft reconstruction of the extensor mechanism after total knee arthroplasty. *J Bone Joint Surg Am*. 1999;81:1574–1579.
18. Malawer MM, McHale KA. Limb-sparing surgery for high-grade malignant tumors of the proximal tibia. Surgical technique and a method of extensor mechanism reconstruction. *Clin Orthop Relat Res*. 1989;239:231–248.
19. Mariani PP, Margheritini F, Camillieri G, Bellelli A. Serial magnetic resonance imaging evaluation of the patellar tendon after posterior cruciate ligament reconstruction. *Arthroscopy*. 2002;18: 38–45.
20. Nazarian DG, Booth RE. Extensor mechanism allografts in total knee arthroplasty. *Clin Orthop Relat Res*. 1999;367:123–129.
21. Ottolenghi CE, Muscolo DL, Maenza R. Bone defect reconstruction by massive allograft: technique and results of 51 cases followed for 5 to 32 years. In: Straub LR, Wilson PD, eds. Clinical Trends in Orthopaedics. New York: Thieme-Stratton; 1982:171-83.