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SURGICAL TECHNIQUE

Extraarticular Knee Resection for Sarcomas with Preservation of the Extensor Mechanism

Surgical Technique and Review of Cases

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Abstract
Background Sarcomas in or contaminating the knee are rare but extremely challenging to treat. Complete resection of the joint is necessary, and often the entire extensor mechanism is removed as well. Reconstruction of the knee is challenging, and the resulting function may be compromised.
Description of technique We describe a surgical technique of extraarticular resection of the knee while preserving the extensor mechanism combined with prosthetic reconstruction. The medial and lateral retinaculum is prepared such that it allows extraarticular placement of K-wires that are driven through the patella and the proximal tibia, serving as in situ guides for the osteotomies.
Patients and Methods We retrospectively reviewed 11 patients with sarcomas contaminating the knee. The minimum followup was 14 months (mean, 38 months; range, 14–80 months).
Results At last followup patients had a mean flexion of 88° (range, 65°–120°). We observed no complications related to the extensor mechanism, and there was one local recurrence.
Conclusions We believe extraarticular resection of the knee with preservation of the extensor mechanism is a reasonable treatment option for intraarticular sarcomas with functional scores comparable to those for patients having intraarticular resections.
Level of Evidence Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution has approved or waived approval for the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.

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Introduction

Sarcomas around the knee most often are removed using a transarticular resection because the joint rarely is directly involved. Knee contamination occurs infrequently owing to inappropriate biopsy placement, extension of tumor along the intraarticular cruciate ligaments, pathologic fracture, or on rare occasions, direct involvement of the knee [9, 14]. Wide resection of sarcomas with safe margins is the main goal of surgery. When a sarcoma is diagnosed in or is contaminating the knee, extraarticular (instead of intraarticular) resection of the entire knee en bloc should be done. Because such a scenario is infrequent, there is only sparse information in the literature regarding the usefulness of such an approach [1, 5, 6, 8].

Historically, resection arthrodesis is the preferred treatment after complete resection of the knee [10]. However, because of functional limitations, patients prefer keeping the joint whenever possible and therefore prosthetic reconstruction may be preferred over amputation, arthrodesis, or rotationplasty [18]. After complete arthrectomy without amputation, the extensor mechanism must be reconstructed either using muscle transfers or allograft augmentation [4, 15, 16]. Because this requires extensive surgery with considerable failure potential, there is interest in developing a surgical technique that allows performing extraarticular knee resection while preserving the extensor mechanism.

The surgical technique of extraarticular resection of the knee while preserving the extensor mechanism was first mentioned by Dubousset et al. [8] and later by Healey [13], however without describing surgical details. In addition to describing the technique, we specifically asked: (1) what ROM and what complications associated with the preserved extensor mechanism occurred, and (2) whether there were any local recurrences in these 11 patients operated on using the same surgical technique.

Surgical Technique

Indications to perform the proposed procedure (1) include inappropriate biopsy placement, (2) prior curettage of a whoops lesion contaminating the knee, (3) extension of the tumor along the intraarticular cruciate ligaments, (4) a pathologic fracture in or contaminating the joint, (5) direct involvement of the knee, and (6) a sarcoma located at the dorsal aspect of the condyles involving the origin of the gastrocnemius heads. In this latter case, the joint capsule extends above the condyles, and therefore, the condyle covering the head of the gastrocnemius muscle, even when dissected distally during an intraarticular resection, does not provide protection in terms of tumor margin.

The patient is positioned supine. A longitudinal incision is performed, depending on the tumor location and preference of the surgeon, on the lateral aspect of the thigh extending from the midportion of the thigh to the knee and then ventrally over the tibial tuberosity. The skin site with biopsy tract is kept with the tumor. The tensor fascia is split in line to Gerdy's tubercle and retracted posteriorly to find access to the posterior compartment. The biceps femoris muscles are kept intact. The popliteal vessels and peroneal and tibial nerves are dissected and tagged with rubber loops, and both heads of the gastrocnemius muscles are dissected free. Anteriorly, the fascia is dissected off the retinaculum respecting the biopsy site but preserving as much tissue as possible for later soft tissue coverage. This is a critical step because the retinaculum is very thin and because at the level of the superior pole of the patella, there is no clear but rather a virtual anatomic plane between these two layers (Fig. 1). A preoperative MRI allows assessment of the fat layers and the type of tendon arrangement at the distal end of the quadriceps muscles to plan the resection and enhances the chance of a safe dissection while preserving the main tendon of the extensor mechanism [21]. The lateral facet of the patella is

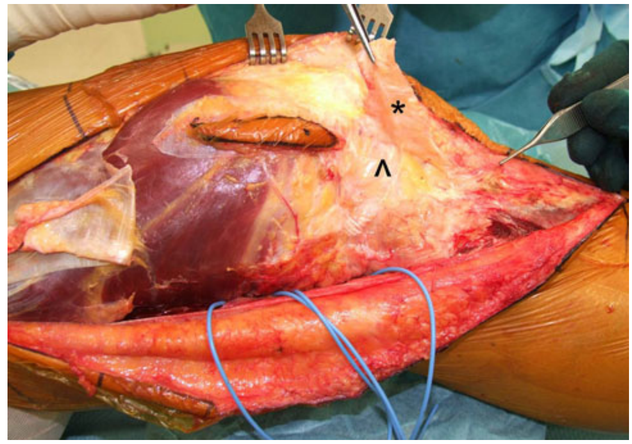

Fig. 1 This lateral view of the knee shows the development of the virtual plane between the retinaculum (*) and the joint capsule (^) at the superior lateral pole of the patella.

prepared to preserve the retinaculum without violating the capsule and the knee. The patellar tendon is dissected by opening the prepatellar bursa. The Hoffa fat pad, which lies extraarticular but partly intracapsular, is left entirely with the specimen (Fig. 2) [2, 3, 11, 17, 19]. The vastus lateralis then is dissected according to the tumor extent, now having access to the femur on all sides. At this step, two Kirschner wires are placed under C-arm fluoroscopy control through the patella in the frontal plane, allowing in situ vertical osteotomy of the patella using an oscillating saw (Fig. 3). The patellar osteotomy is analogous to that used in standard knee replacement, leaving approximately 15 mm thickness. The extensor mechanism then is everted. The femoral osteotomy is performed at the level that was determined before surgery. The specimen is brought anteriorly and dissected free from the posterior compartment structures. The heads of the gastrocnemius muscles are dissected distally to cover the posterior joint capsule to obtain a safe margin. The knee (or specimen) then is extended while the extremity is in flexion, allowing dissection of the fascia from the retinaculum on the medial side and the capsular structures around the tibia. Distal osteotomy of the tibia is made with an oscillating saw over the Kirschner wires (Fig. 2). These Kirschner wires are placed approximately 12 mm below the tibial plateau thereby keeping the joint capsule intact but being proximal to the tibial tubercle to preserve the patellar tendon attachment (Fig. 4). The resected specimen now can be removed after dissection of the retinaculum from the capsule on the medial side (Fig. 5), and a tumor prosthesis including replacement of the patella retrosurface is implanted the usual way. Postoperative management and rehabilitation do not differ from protocols after transarticular resection.

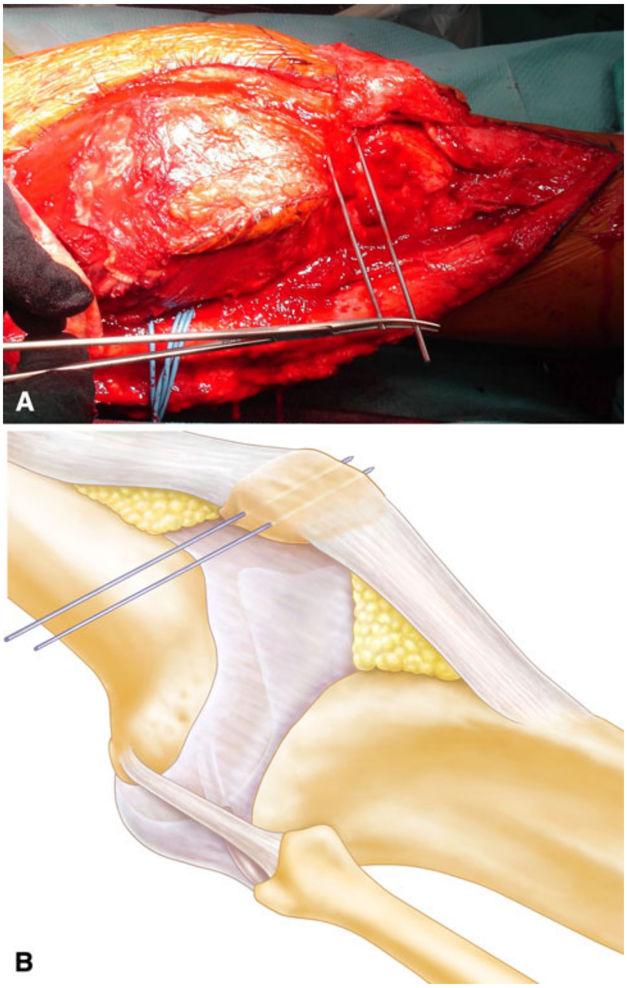

Fig. 2A–B (**A**) After dissection of the distal joint capsule around the tibia, two Kirschner wires are placed laterally to guide the osteotomy at the correct level such that the tibial tubercle with its tendon is preserved. (**B**) A schematic shows the intended resection planes at the tibia and the extent of the synovial and membranous parts of the capsule in relation to the fat pad.

Patients and Methods

We retrospectively reviewed 11 patients (five female and six male patients) who underwent this procedure from 2000 to 2008. The technique was performed as a primary procedure in nine patients and as a secondary procedure in two; these two patients had metastasis to the distal femur, one from an osteosarcoma of the distal tibia and the other from a fibromyxoid sarcoma of the ipsilateral leg extensors. During this period, we treated 411 other patients with tumors about the knee with other approaches. From the medical records we recorded the age, gender, diagnosis, type of surgery, followup, occurrence of metastasis, local recurrence, ROM, and complications. All patients had tumors with intraarticular extension either through direct tumor growth or erosion or pathologic fracture, and two of the tumors extended into the cruciate ligaments. The mean age of the patients was 39.8 years (range, 15–79 years). There were four osteosarcomas, two leiomyosarcomas, two high-grade pleomorphic sarcomas, one chondrosarcoma, one synovial sarcoma, and one low-grade fibromyxoid sarcoma, all located in the distal femur. Patients were followed for a minimum of 14 months (mean, 37.5 months; range, 14–80 months). Six of the 11 patients had metastases develop during the followup time and two died from

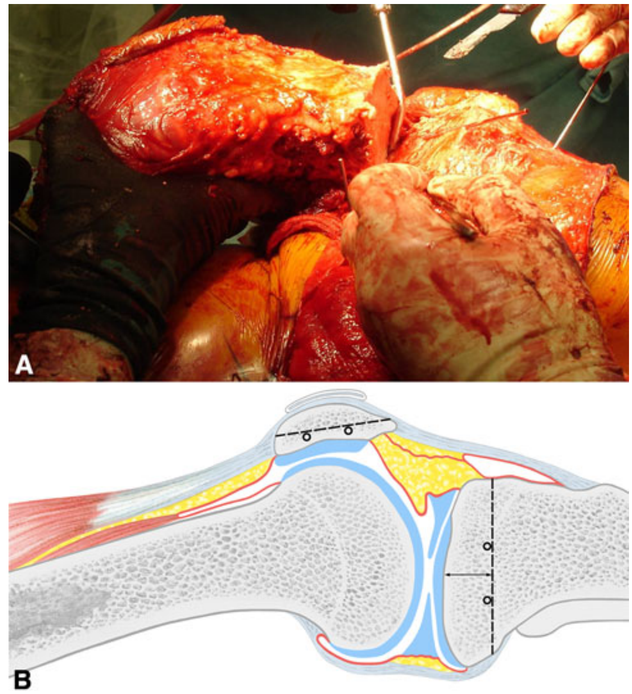

Fig. 3A–B (**A**) Two Kirschner wires were placed through the patella in the frontal plane under fluoroscopy guidance at the level of the planned extracapsular osteotomy. (**B**) A schematic figure shows placement of the wires.

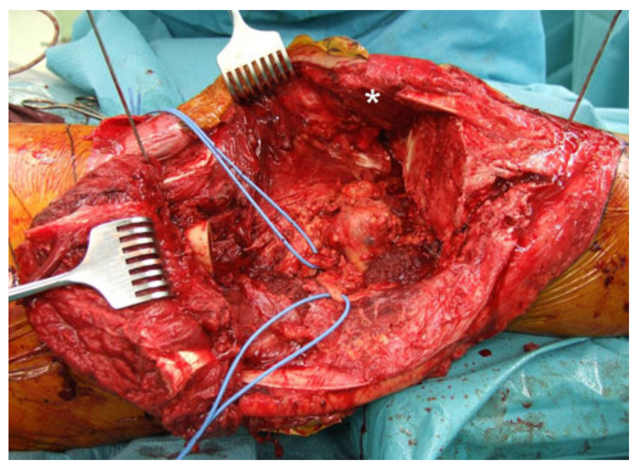

Fig. 4 The intact extensor mechanism with the frontal plane osteotomy through the patella (*) is seen after removal of the tumor specimen.

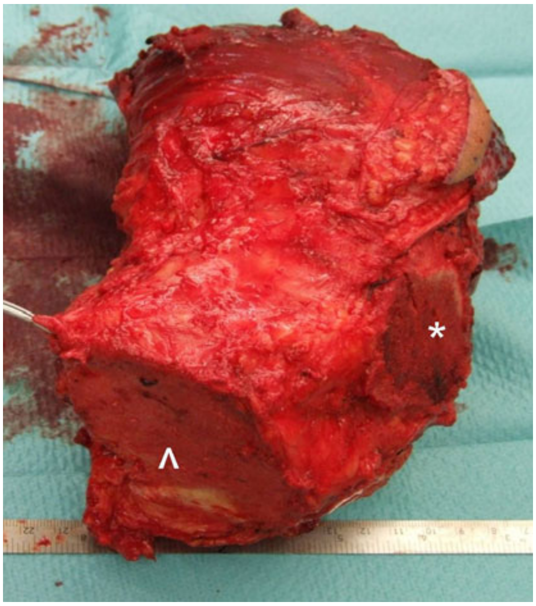

Fig. 5 The entire tumor specimen with the osteotomy planes of the tibia (^) and the articular part of the patella (*) are shown.

widespread metastatic disease. No patients were lost to followup.

Postoperatively, the patients were partial weightbearing of 10 to 15 kg for 6 weeks and then gradually increased to full weightbearing by 3 months postoperatively. Patients had physiotherapy while in the hospital and were taught to climb stairs before they were discharged.

Patients usually were seen at 3-month intervals for 2 to 3 years, and thereafter every 6 months until 5 years. On these occasions, conventional radiographs, MRI of the knee, and CT of the chest usually were performed.

Results

The patients had a mean flexion of 88° (range, 65°–120°); all patients had full extension. There were no complications associated with the extensor mechanism or patella, specifically no patellar fractures (Table 1).

One patient had local recurrence develop 9 months after surgery in the proximal dorsal leg distal to the incision. This patient (Patient 10, Table 1) had presented with a metastatic fibromyxoid sarcoma to the lung. Six months after histologically proven wide resection and reconstruction with a MUTARS tumor endoprosthesis (Implantcast, Buxtehude, Germany) locally and the lung lesion via thoracotomy, metastatic disease again developed in the lung. A second thoracotomy was followed by chemotherapy. The local recurrence 9 months after initial surgery was removed surgically followed by postoperative radiotherapy ($33 \times 2 = 66$ Gy). The patient had no evidence of disease at last followup 4 months after resection of the recurrence.

Discussion

On rare occasions, bone or soft tissue sarcomas may infiltrate or contaminate the knee necessitating resection of the entire joint in toto. Surprisingly, there is only sparse information in the literature regarding the surgical technique of resection and reconstruction in such situations. We describe an extraarticular resection of the knee with preservation of the extensor mechanism. We were interested specifically in the functional ROM of the newly reconstructed knee and the local recurrence rate in these patients.

We recognize some limitations of this study. First, because the indication for extraarticular knee resection is

Table 1. Demographics of patients

Patient number	Age (years)	Gender	Diagnosis	Ind.	Followup (months)	LR (months)	Metastasis (months)	F/E	Adjuvant therapy	Disease status
1	20	F	OS	1°	80	N	Y (23)	110-0	Chemo	ANED
2	15	M	OS	2°	29	N	Y (0)	85-0	Chemo & RT	DOD
3	51	F	CHS	1°	60	N	N	90-0	—	ANED
4	23	M	OS	1°	57	N	N	120-0	Chemo	ANED
5	44	M	LMS	2°	45	N	Y (0)	70-0	Chemo & RT	AWD
6	44	F	LMS	1°	27	N	Y (20)	100-0	Chemo & RT	AWD
7	16	M	SS	1°	39	N	N	110-0	—	ANED
8	68	M	Grade 4 sarcoma	1°	24	N	Y (0)	65-0	RT	ANED
9	79	F	Grade 4 sarcoma	1°	22	N	Y (20)	70-0	—	DOD
10	62	F	MFS	1°	14	Y (9)	Y (0)	85-0	Chemo & RT	ANED
11	16	M	OS	1°	16	N	N	65-0	Chemo	ANED

Chemo = chemotherapy; RT = radiation therapy; LR = local recurrence; F/E = flexion/extension; F = female; M = male; OS = osteosarcoma; CHS = chondrosarcoma; LMS = leiomyosarcoma; SS = synovial sarcoma; MFS = myxofibrosarcoma; N = no; Y = yes; ANED = alive with no evidence of disease; DOD = dead of disease; AWD = alive with evidence of disease; Ind. = Indications.

relatively rare, we can report only on a small group of patients. Second, the sarcomas included in this study are biologically heterogeneous in terms of type, stage, and adjuvant treatment. Third, the indications for performing an extraarticular resection of the knee may vary; for example, when there are signal alterations on MRI in the proximal cruciate ligaments adjacent to a sarcoma in the distal femur, different surgeons may make different decisions. Therefore, we can make no conclusive statements regarding the adequacy of margins of this procedure, particularly with respect to local recurrence. Furthermore, this technique may be contraindicated when the main tumor mass is located in the proximal tibia because obtaining a safe margin while preserving the tibial tubercle may be compromised.

The technique of extraarticular knee resection was described more than 30 years ago by Enneking and Shirley [10]. To obtain a safe margin, they performed an osteotomy distal to the tibial tubercle thereby removing the entire extensor mechanism. Reconstruction was performed using an intramedullary rod with an allograft or vascularized or nonvascularized fibulae [10, 22]. Although resection arthrodesis of the knee still has its place in the armamentarium of orthopaedic oncologists, it is used less frequently because many patients do not want limited ROM of the knee [5, 7, 20]. Complications specifically include fatigue fractures and rod-associated problems, which do not occur when an extraarticular resection with prosthetic reconstruction is used [20, 22] (Table 2). Alternatively, if knee mobility is to be preserved and a tumor megaprosthesis is implanted, reconstruction of the extensor mechanism can be achieved either through muscle transfer or allograft reconstruction to compensate for the loss of the extensor mechanism. Capanna et al. reported an MSTS score of only 50% and loss of extensor strength in 16 patients when they transferred flexors to extensors after arthrectomy [4]. The decreased function was presumed to be the effect of extensive scarring, which led to decreased extensor strength and knee stabilization. They concluded prosthetic replacement with muscle transfer was an experimental alternative to the conventional arthrodesis [4]. In comparison, the patients in our series had normal extensor strength because the extensor mechanism was preserved. Another reconstruction option was reported by Anract et al., who used gastrocnemius and pes anserinus transfer for reconstruction of the extensor mechanism after total knee arthrectomy in nine patients [1]. The overall function in this group was satisfactory with a mean knee flexion of 62° and an extension lag of 12°. They concluded this technique provides excellent tissue coverage, a strong extensor mechanism, and therefore a viable alternative to arthrodesis [1]. Although stronger extension was noticed using this technique, the reconstruction described in our series provides full active extension without lag. Patients having allografts to reconstruct the knee after tumor

Table 2. Overview of literature

Study	Reconstruction type	Cases	Localization	MSTS %	Flexion (mean)	Extension lag (mean)	Followup	Rupture of the extensor mechanism	Local recurrence
Anract et al. [1]	Soft tissue/muscle transfer	9	6 distal femur, 2 proximal tibia, and Hoffa	Average 61%	62°	12°	23 ± 10 months	1	None
Capanna et al. [4]	Soft tissue/muscle transfer	16	Distal femur	50%	> 70°	Poor	2 to 5 years	No information	None
Dubousset et al. [8]		8 children	Distal femur	No information	No information	No information	No information	No information	1
Wunder et al. [23]	Allograft and prosthesis	11 allograft reconstructions	6 distal femur, 5 proximal tibia	57%	—	—	55 months for both groups	None	None
		64 modular tumor prostheses	50 distal femur, 14 proximal tibia	75%	—	—		2 (3%) extensor mechanism repair	None
Wolf et al. [22]	Arthrodesis	40	29 femur; 11 tibia	77%	—	—	17 years	—	2
Wada et al. [20]	Arthrodesis	12	Distal femur	90%	—	—	95 months	—	—
Gebhardt et al. [12]	Allograft	25 distal femur, 10 proximal tibia		—	—	—			
Current study	Prosthesis	11	All distal femur	—	88°	None	37.5 months	None	1

resection have a high complication rate compared with patients with prosthetic reconstruction in general [12, 23], and although used for reconstruction after arthrectomy, to the best of our knowledge, there are no published studies.

When reporting a new surgical technique that accepts closer surgical margins to gain better postoperative function, it is crucial to determine the rate of local recurrence. There are few reports on this issue [1, 8] which set the standard. Dubousset et al. [8] and Healey [13] mentioned the technique but did not report the surgical details. The local recurrence rate in our series compares with that reported in the literature (Table 2). Obviously, larger series need to be analyzed to confirm whether preservation of the extensor mechanism through extraarticular resection offers the same safe margins. Anatomic details are of great importance, and care is taken that the resection be extracapsular. For example, because the Hoffa fat pad lies partly intracapsularly, the patellar tendon does not need to be resected. Care also must be taken to avoid opening the joint around the superior pole of the patella where the retinaculum and the capsule are fused to one layer.

Our patients had no extensor lag, a mean flexion of 88°, and no obviously increased local recurrence rate; these findings may be superior to those for patients with tendon transfer or allograft reconstructions but comparable to those for patients having intraarticular resection and conventional tumor prosthetic reconstruction. When it is doubtful whether the tumor extends into the knee based on preoperative MRI, extraarticular resection is considered. Using the described technique with preservation of the extensor mechanism and reconstruction using a tumor prosthesis, ROM of the knee and local recurrence rate are comparable to those for patients who undergo intraarticular resection for tumors without extension into the knee.

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