Austin Journal of Orthopedics & Rheumatology

Open Access

Austin Publishing Group

Case Series

Extensor Mechanism-Sparing Technique for Management of Proximal Tibia Sarcoma Resection: A Case Series Study

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Received: November 23, 2021; **Accepted:** December 15, 2021; **Published:** December 22, 2021

Abstract

The proximal tibia is one of the most challenging anatomic sites for resection of large bone tumors, due to the vicinity of the extensor mechanism. Here, we report outcomes of a novel radical resection technique which preserves the extensor apparatus. 8 patients were operated between 2001 and 2011 for large sarcomas with high-grade tibial localization. Six were giant cell tumor of bone histology (GCTB; defined as severe bone destruction and soft tissue extension) and two chrondrosarcoma at surgical grade G1, but with double localization in tibia and femur. Primary bone tumors and recurrences were treated with novel multiplanar resection technique avoiding removal of the tibial tuberosity and the patella tendon insertion, preserving extensor mechanism. In all cases, curettage and borage were not indicated due to extensive lesion size. Radical resection of the lower extremity (2 femurs and 8 tibias) yielded wide margins (R0) and patients were evaluated at 10 years of follow up. The average post operative Musculoskeletal Tumor Society (MSTS) score was 26.87 points (range: 23-29). All patients reached full passive and active extension and the maximum active flexion was 108.75° (range: 90°-120°). At the last follow-up (mean: 121.8 months), all patients and implants survived; no local infection, recurrence, metastasis, or relevant complications occurred. This surgical technique therefore appears to provide a safe treatment option when wide surgical margins are possible, and preserving the integrity of the extensor mechanism may improve the clinical outcome.

Keywords: Limb Salvage; Bone and Bones; Tibia; Extensor Mechanism

Introduction

Despite numerous surgical options, the reconstruction of the extensor mechanism after en bloc surgery of proximal tibia bone tumor, represents a challenge that significantly influences the clinical and functional outcome [1-5]. Reconstruction of the knee extensor mechanism is among the leading causes of poor function after surgery [1,6,7]. Generally, patients showed extensor lag and insufficient active extension of the knee [2,8,9]. Currently, there are a number of techniques for extensor-mechanism reconstruction. One is the direct attachment of the extensor mechanism to the proximal tibia mega-prosthesis. However, the failure of the patellar tendon–metal junction, and infections are common complications [10-12]. Another method is the reattachment of the extensor mechanism to the tibia allograft. Although the use of the allograft shows better results in the restoration of the extensor mechanism, the osteoarticular allograft reconstruction is not technically easy. The patients have a longer period of immobilization, associated with higher complication rates such as infections, fractures, subchondral collapse, articular cartilage degeneration, and instability [6]. Allograft prosthesis composites (APC) were introduced in order to combine the advantages of a prosthesis, such as better range of motion, load-sharing properties, articular stability, with biologic insertion of soft tissues to reduce subchondral fractures [13-16]. However, many studies reported that these reconstruction techniques of proximal tibia showed an higher index of complications, compared to other anatomic sites, e.g. the distal femur [17-22].

In contrast, the proposal surgical procedure for proximal tibia resection preserves the continuity of the extensor mechanism in order to improve the functional outcome. This procedure is feasible for tumours not localized on the anterior portion of the tibia and when curettage is not possible. Furthermore, precise pre-operative planning is essential to assess whether it is possible to obtain wide resection margins, thereby leaving intact an adequate anterior tibia splint containing the insertion of the patellar tendon, in continuity with the distal portion of the tibia. We here present data from patients undergoing this procedure, and analyze their functional and clinical outcomes.

Methods and Materials

Patients

8 patients with sarcomas localized in the proximal tibia (6 giant cell of bone tumors and 2 chondrosarcoma histologies) who were surgically treated at the orthopedics unit of the Istituto Tumori G. Pascale (Naples, Italy) between January 2001 and January 2011, using a new surgical extensor mechanism-sparing technique. The inclusion criteria were an indication for radical surgery and the possibility to achieve wide surgical margins (in our population, at least 81.6 mm for GCTB recurrence and 220mm for chondrosarcoma longitudinal

Citation: Fazioli F, Ruosi C, Colella G, Gallo M and de Nigris F. Extensor Mechanism-Sparing Technique for Management of Proximal Tibia Sarcoma Resection: A Case Series Study. Austin J Orthopade & Rheumatol. 2021; 8(3): 1105.

length of resection), in order to preserve an adequate anterior tibial cortex splint for our surgical protocol. Patients with less than two years of follow-up were excluded. The follow-up time was calculated from the date of surgical resection to the most recent follow-up visit. The mean follow-up duration in our population was 120 months.

The research was conducted in accordance with the Declaration of Helsinki and Italian and institutional standards. All patients provided written informed consent prior to inclusion in the study.

Surgery plan and protocol

For all patients, we obtained multiplanar and multisequence magnetic resonance images (MRI) to plan resection. No patient underwent neo-adjuvant chemotherapy or radiotherapy. We used an anterior approach to the knee with an anterior incision extended distally on the leg based on the bone resection, and a para-patellar medial arthrotomy. Two longitudinal tibial osteotomies were then performed on two sagittal planes, one medial and one lateral to the insertion of the patellar ligament (Figure 1 and 2). Distally, we performed a circumferential osteotomy parallel to the superior osteotomy, leaving the anterior portion of the tibia intact to allow continuity of the splint bone with the portion of the tibia distal to resection.

We then implanted a modular proximal tibial prosthesis (METS) (Stanmore Implants, Hertfordshire, United Kingdom), coated with hydroxyapatite in the anterior aspect to achieve osseo-integration with the bone splint. In distal femur resection was implanted a METS modular distal femur prosthesis (Stanmore Implants). Surgical margins. were classified according to the R categories defined by the Union for International Cancer Control (UICC): R0-no macroscopic or microscopic residual tumour, R1-microscopic residual, and R2-macroscopic residual. The longitudinal length of the tibial resection was measured.

Teicoplanin was administered to all patients for the first 5 days after surgery, starting from the day of surgery. Physical therapy started one day after surgery with continuous passive motion (C.P.M.), starting from 0°–30°, and increased by 10°/day.

Follow up

Patients were examined 14, 45, and 90 days after surgery. thereafter, patients were seen at 3-month intervals for the first 2 years, and subsequently, every 6 months. At 30 months, we collected the following data: complications; revision surgery; use of walking aids, ability to climb or descend stairs. Furthermore, all implants were analyzed by radiographic imaging at 30 months follow-up, and the functional outcome was evaluated by using the revised 30-point functional classification system established by the International Society of Limb Salvage and the Musculoskeletal Tumor Society (MSTS) [6]. We also recorded the maximum active flexion, maximum active extension, and maximum passive extension of each patient. The difference between the maximum passive and active extensions defined the lag extension. Recurrences and survival were valued considering 10-year Local Recurrence-Free Survival (10y-LRFS), 10 year Distant Metastasis-Free Survival (10y-DMFS), and 10-year Overall Survival (10y-OS).

Statistical analysis

To evaluate qualitative results (which ones), nonparametric statistics were used. Continuous variables were expressed as means with ranges. Categorical variables were expressed as number and percentage. The SPSS software program v.23.0 (IBM corp. Armonk, NY, USA) was used for the database and statistics.

Results

Surgical technique sparing the extensor mechanism

Patients with proximal tibial sarcomas (4 males and 4 females) underwent surgery sparing the extensor mechanism and bone grafting. The mean age at time of surgery was 30.12 years (range: 17-38 years) (Table 1) patients had recurrences of giant cell tumour of bone (GCTB) and two large chondrosarcomas (G1) treated with simultaneous resection of the distal femur and proximal tibia. The mean size of tumor volume was >5cm^3. The mean of tibial resection spanned a longitudinal length of 114.37mm (range: 70-220 mm) and all patients had wide surgical margins (R0) (Table 1). We used an anterior approach to the knee with an anterior incision extended distally on the leg based on the bone resection, and a para-patellar medial arthrotomy. The standard approach was revised in case of excision of previous biopsy sites; alternatively, it was personalized depending on the location of the bone tumour. We performed two longitudinal osteotomies on a sagittal plane, one medial and one lateral to the insertion of the patellar ligament. These bone resections were made at a medio-lateral distance of at least 150mm from each other

Table 1: Clinical pathological characteristics of patients.

Patients	Sex	Tumor site	Diagnosis Surgery Grade	Age at surgery (years)	Longitudinal length of resection (mm)
1	M	Proximal tibia	GCTB (recurrence) G3	33	90
2	F	Distal femur Proximal tibia	Chondrosarcoma (G1)	31	220
3	F	Proximal tibia	GCTB (recurrence) G3	38	85
4	M	Proximal tibia	GCTB (recurrence) G3	27	80
5	F	Proximal tibia	GCTB (recurrence) G3	17	80
6	M	Proximal tibia	GCTB (recurrence) G3	32	85
7	F	Proximal tibia	GCTB (recurrence) G3	29	70
8	M	Distal femur Proximal tibia	Chondrosarcoma (G1)	34	205
Mean				30.12	114.3

GCT: Giant Cell Tumour Recurrence; R categories (Union for International Cancer Control); R0 identifies no macroscopic or microscopic residual tumour; R1: Microscopic residual; R2: Macroscopic residual; MSTS: Musculoskeletal Tumor Society.

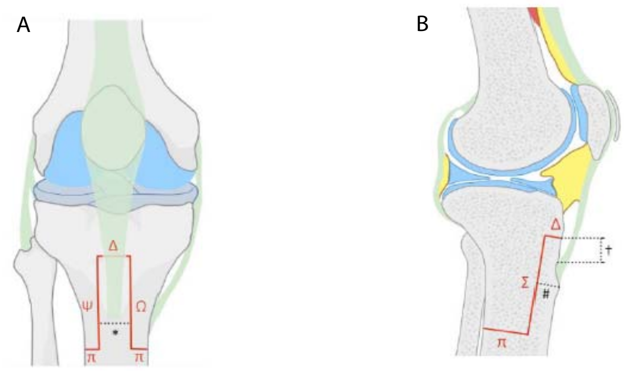

Figure 1: Schematic representation of osteotomies. (A) Osteotomies (continuous red lines): Δ, superior tibial osteotomy; Ψ, antero-lateral osteotomy; Ω, antero-medial osteotomy; π, distal osteotomy; Σ, posterior osteotomy. (B) Measures of the anterior tibial splint (dotted black line): *, medio-lateral length at least 1.5cm; #, antero-posterior thickness, at least 1cm; †, distance between superior osteotomy and patellar tendon insertion at least 1cm.

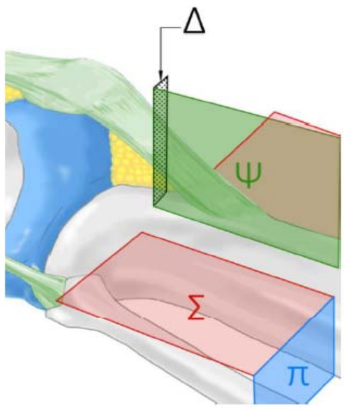

Figure 2: Schematic of osteotomy planes: Antero-lateral osteotomy of the proximal tibia is made on a sagittal plane just lateral to the patellar insertion (green plane - Ψ); antero-medial osteotomy is made parallel to antero-lateral osteotomy at least 1.5cm of distance medially; superior osteotomy is made on an axial plane perpendicular to the longitudinal osteotomies, at least 1cm proximally to patellar tendon insertion (polka dotted plane - Δ); distal osteotomy is a circumferential osteotomy made on an axial plane parallel to the superior osteotomy, leaving intact the anterior portion that connects to the bone splint, containing the insertion of the patellar tendon, to the distal part of tibia (light blue plane - π); posterior osteotomy is made on a coronal plane perpendicular to antero medial and lateral osteotomies, leaving intact at least 1cm of antero-posterior thickness of bone (red plane - Σ).

(Figure 1). Then, we continued with superior osteotomy with a saw blade on an axial plane perpendicular to the longitudinal osteotomies, at least 10mm proximally to the patellar tendon insertion (Figure 2). Distally, we performed a circumferential osteotomy parallel to the superior, leaving the anterior portion of the tibia intact to allow continuity of the splint bone with the portion of the tibia distal to resection.

We implanted a modular proximal tibia prosthesis (METS), coated with hydroxyapatite in the anterior aspect to achieve osseo-integration with the bone splint. The use of an undersized tibia component is essential to render possible its placement in a slightly rear position without altering the correct centre of the tibia stem

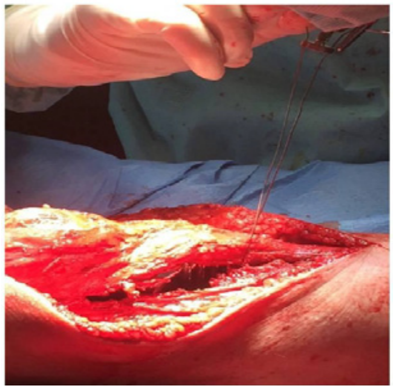

Figure 3: Image from surgery technique. Prothesis insertion.

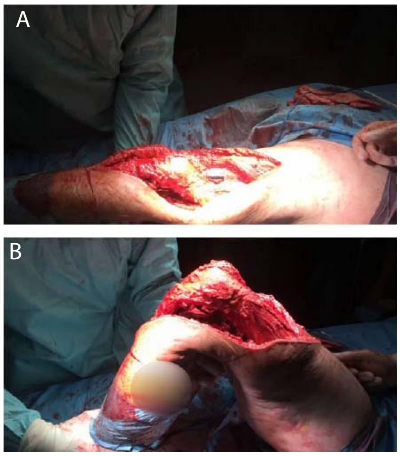

Figure 4: Intra-operative pictures. Patient treated by simultaneous resection of the distal femur and proximal tibia with extensor mechanism-sparing technique: (A) in passive flexion and (B) in passive extension.

(Figure 3).

In patients with tumor in both femur and tibia the intramedullary stem was implanted in distal femur resection) (Figure 4). Teicoplanin was administered to all patients for the first 5 days after surgery, starting from the day of surgery.

Pooled analysis of functional score and outcome

In all patients, the knee was placed in full extension after surgery with the brace for 40 days. Physical therapy started one day after surgery with continuous passive motion (CPM), starting from 0°–30°, and increased by 10°/day. The second day after surgery, all patients began walking with the aid of crutches and partial load. At day 10 post-surgery, was initiated active assisted knee motion. Total weight bearing was achieved after 3 months from surgery. All implants were analyzed by radiographic imaging at the 30 months and last follow-up (Figure 5) and no surgical removal or revision surgery was required. Patients survived, and no cases of local recurrence, metastasis, deep infections, or other relevant complications was reported (Table 2). At the last follow-up examination, all patients reached full passive and active extension, showing no extensor lag (Figure 6). The mean maximum active flexion of the operated knee was 108.75° (range: 90°-120°) (Figure 6 and Table 2). The mean MSTS functional score of our patients was 26.87 points (range: 23-29). All patients could

Table 2: Patients Follow-up and MSTS score.

Patient	Margin (R. categories)	Follow-up (months)	MSTS (R score)	Maximum Active flexion	Lag Local Recurrence or metastasis	Complication
1	R0	162	27	110°	No	No
2	R0	98	26	120°	-	-
3	R0	138	23	90°	-	-
4	R0	110	28	105°	-	-
5	R0	115	27	100°	-	Increase limb
						(8mm)
6	R0	126	28	110°	-	-
7	R0	105	29	105°	-	-
8	R0	121	27	120°	-	-
Mean		121.8	26.87	108.75°		

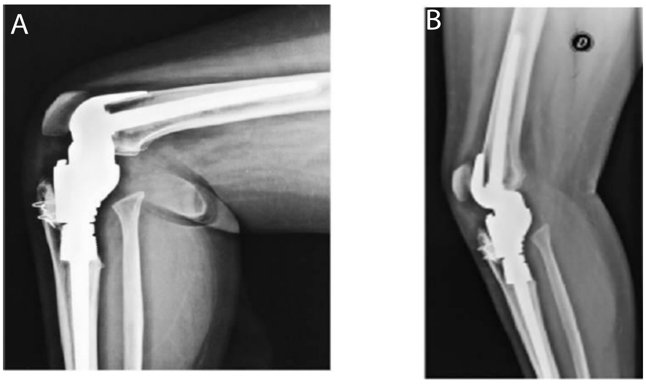

Figure 5: Lateral x-rays of the knee 6 months after surgery. (A) 90 degrees of flexion. (B) 30 degrees of flexion.

Figure 6: Picture illustrating flexion of patient 30 months after surgery with the technique sparing the extensor mechanism. (A) Maximum active flexion in standing position. (B) Maximum active extension in standing position in the same patient.

walk without crutches and were able to climb or descend stairs without support. The Table 2 provides a summary of patient follow up data. No complications connected to the extensor mechanism were highlighted during the follow-up. No fractures of cortical splint, patellar ligament avulsion, or rupture were recorded. In one patient, we recorded an increase of about 8mm of the limb, but additional surgery was not needed.

Discussion

The functional and clinical follow-up of proximal tibia resection are deeply influenced by the techniques used to reconstruct the extensor-mechanism. In present study we propose a novel surgery approach that could be useful in patients with large and high grade tumor localized in proximal tibia, in which curettage and knee sparing approach was not indicated. In our series a marginal multiplanar resection, preserving extensor mechanism, reduced at 24h the patients immobilization, improved the MSTS functional score at 26.87 points (range: 23-29), and clinical final follow up [9,13-16]. The surgery techniques indicated, for large tumor or recurrences treatment is intralesional resection or curettage and intrarticular resections. The preferential reconstruction method is allograft-prosthetic composite reconstruction (APC). However, data reported a graft failure in 27.4% (17/62) of cases; mainly due to infection after chemotherapy, three local recurrence cases, and two aseptic loosening of the implant. In these patients, the average MSTS score was around 76% (22.89 points), the extensor mechanism failed in 14.5% of cases, and the active extension from the sitting position was no greater than 5° [23]. Indicating that this reconstructive technique gives satisfactory functional results but expose patients to high rate of infections in particular whom need post surgery chemotherapy [23]. Nevertheless, APC is a very promising technique, APC to treat patients with tumours of the proximal tibia in which the extensor mechanism cannot be saved. Our proposal method, although is based on a small and rare case series determined that all patients showed a complete active extension and no lag extension after a mean follow-up of 120 months (range: 90-162) improving significantly what was already reported with other techniques. Indeed when the direct attach of the extensor mechanism to the proximal tibia mega-prosthesis, was used the extensor lag ranged from 7.5° to 30°, with a probability of an extensor lag >20° between 9% and 33% [11,24,25]. Better results was obtained with the gastrocnemius flap technique based of synthetic material to improve the fixation of the extensor mechanism to a mega-prosthesis with an extensor lag >20° in 20-44% of cases [1,6]. In a study by Shimose et al., the patellar tendon length and extensor lag of seven patients were serially measured on lateral radiographs after the reconstruction of the extensor mechanism. They reported a mean extensor lag of 37.86 (range: 10–80) and two patients with deep infections required removal of the synthetic material. Concluding that although these procedures decrease the postoperative extensor lag, the patellar tendon stretches over time [26]. In a study by Pilge et al., the reconstruction of the extensor apparatus was made with a polyethylene-terephthalate cord by using the 'patellar-loop technique'. Data from nine of eighteen patients showed an average MSTS score of 20.6 (68.5%) recorded at mean follow-up duration of 11.6 years. Five of the nine patients had undergone revision of their prosthesis. The reason for the revision was aseptic loosening of the tibial component or failure of the hinge mechanism. Three patients had an extensor lag of a mean of 4°, and the overall mean extensor lag in all patients was 1° (0°-5°). The mean maximum active flexion was 91° (30°-110°). The authors reported that the reduction of maximum flexion was not principally dependent on the hinge mechanism itself, but rather was a result of the tension applied to the alloplastic cord. Consequently, full extension was achieved at the cost of full flexion [27]. In our population, we recorded a mean active flexion of 108.75° combined with complete active extension. Although, our mean follow-up time is shorter, we believe that, the salvage of the extensor mechanism, may preserve an higher maximum flexion and maintain good active extension. In a study by Ayerza et al., consecutive patients treated by proximal tibial allograft reconstructions 33 osteoarticular and 9 intercalar were retrospectively reviewed [28]. Eleven patients were previously excluded from their study: four patients had the allograft removed because of recurrence; four patients had early infections; one patient had a fractured allograft; and two patients died before the 2-year follow-up. Three of the 42 allografts were removed because of allograft failure, and five patients died of the disease 2-5 years after reconstruction. Therefore, at final follow-up, the functional outcome and extensor lag were evaluated in 34 patients. They stated that the patellar tendon remained stable with no elongation between pre and postoperative measurements. Ten patients had an average residual extensor lag of 6.5° (range: 5°-10°), and 24 patients had no extensor lag. They reported an average functional score of 26.6 points [29]. Although this average functional score is similar to our study, it is important to mention that we recognized no relevant complications in our population and no patients underwent revision surgery. At the same time, no lag extension was recorded among our patients. On the basis of our results we hypothesized that, in suitable cases, the use of the extensor mechanism-sparing technique can significantly improve the functional outcome in these patients, reducing the rate of complications at the same time.

Conclusion

Few studies consider the possibility of preserving the extensor mechanism in patients with tumours around the knee. Zwolak et al. retrospectively reviewed 11 patients with sarcomas treated by extra-articular resection of the knee to preserve the extensor mechanism. Interestingly, the patients had a mean flexion of 88° (range: 65°–120°), and all patients had full extension. No data about functional scores were reported. Conflicting data were reported when tumour mass is located in the proximal tibia, because attainment of a safe margin while preserving the tibial tubercle may be compromised [23]. Although our experience is based on intra-articular resection, we suggest that in the likelihood of achieving wide surgical margins to preserve an adequate anterior tibial splint, surgeons should explore the chance to save the extensor mechanism even in patients with tumours involving the proximal tibia at the level or just distal to the tibial tuberosity. In conclusion, although further studies are needed to confirm our findings, on the basis of good functional outcome, absence of relevant complications, and, most relevantly, the absence of local recurrence or metastasis, we believe that preserving the extensor mechanism should be favored when possible. Meanwhile, we want to highlight the importance of precise and careful pre-operative planning to establish suitable candidatures for extensor mechanism salvaging, always bearing in mind that the attainment of wide and safe margins is the primary target, and only a complete and radical surgery can offer this chance of care to oncological patients.

Declaration

Author contributions: FF and MG: Performed surgery; CR: Conceptualized the study; GC: Performed clinical follow-up; FdN: Wrote the paper.

Funding: Institutional funds from Italian Minister of Health

Acknowledgements: The manuscript is dedicated to the memory of Dr. Balato.

Institutional review board statement: The research was conducted in accordance with the Declaration of Helsinki and Italian National Institute of Cancer G Pascale standards.

Informed consent statement: All patients provided written informed consent prior to inclusion in the study.

Data availability statement: Data are contained within the article or Supplementary Materials.

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