Knee Reconstruction with Preservation of the Meniscus in Tibial Giant Cell Tumor

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Abstract Giant cell tumor of bone sometimes is an aggressive benign skeletal tumor. Historically, curettage and bone grafting have a high recurrence with satisfactory function whereas wide resection has a reduced recurrence rate with compromise of limb function. Thus, maintaining joint function and achieving adequately wide resection introduces contradictory surgical goals. We developed a method for achieving both goals for giant cell tumors located in only one lateral plateau of the proximal tibia. We reconstructed 13 knees preserving the meniscus and reconstructing the tibial plateau with an iliac plate autograft after resection of a giant cell tumor involving one tibial plateau. Four patients had primary tumors and nine had recurrences after curettage. The minimum followup was 5 years (mean, 9.1 years; range, 5–12.75 years). We used the system of Enneking et al. to evaluate function. One patient had recurrence and underwent prosthesis replacement. No patient experienced collapse, instability, or pain, and knee function was restored to near normal. The

mean functional score was 95%. While resecting the tumor, the normal anatomic structures of the knee can be preserved or restored in many patients. This method can be used in selected patients to reconstruct the knee after resection of tumors involving one tibial plateau.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Giant cell tumor (GCT) of bone is considered a more aggressive benign skeletal tumor with a high recurrence rate. Historically, curettage and bone grafting have been the preferred treatment for GCT of bone with a recurrence rate of 25% to 50% [6, 8, 10, 14]. Wide resection apparently reduces the recurrence rate to approximately 7% [8]; however, this treatment often causes considerable compromise of limb function. Adjunctive treatments such as high-speed burr, liquid nitrogen, sterile water, and electrocautery have been used to improve local control [9, 10, 16, 17] and extend surgical margins without wide resection to maintain limb function and limit recurrence.

However, numerous studies suggest the recurrence rate is related only to how completely the tumor is removed [1, 2, 7, 9, 10, 15]. Although less wide resections provide better joint function, it is at the risk of a higher recurrence rate. When the lesion is in the lateral plateau of the tibia involving the superior tibiofibular joint, the operation is more difficult. GCT in the proximal tibia typically extends to subchondral bone, so improved local control frequently compromises preserving joint function because the remaining quantity of bone and the type of reconstruction are closely associated with postoperative limb function.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Fig. 1A–C The line drawings of the procedure show (A) the preoperative knee with a tumor, (B) resection of the proximal tibia, and (C) functional reconstruction of the tibial plateau with the patient's fibula and iliac plate.

The question is how we can resolve the seemingly contradictory goals of maintaining joint function and achieving adequately wide resection. We developed a method for achieving these goals for GCT located in only one lateral plateau of the proximal tibia. While completely resecting the tumor, we preserve the meniscus, reconstruct the tibial plateau with the iliac plate concave upward, and strut graft with the fibula (Fig. 1).

We asked whether this method would achieve satisfactory control of the tumor with low recurrence rates and with satisfactory function.

Materials and Methods

We retrospectively reviewed 13 selected patients with GCT of the proximal tibia between January 1995 and March 2002. The lytic lesions of these patients were located

Fig. 3 A CT scan of Patient 1 shows a GCT on the lateral tibial side.

primarily in either the medial or lateral tibial plateau and tumor had already extended to the articular cartilage with some subchondral bone left and sometimes included a large soft tissue mass (Figs. 2, 3). Therefore, these tumors could not be removed completely through curettage, and we resorted to wide resection and joint reconstruction to achieve a wide surgical margin. The diagnosis was confirmed by preoperative fine-needle percutaneous biopsy. There were eight men and five women, ranging in age from 21 to 48 years (median, 30 years) (Table 1). The location of the tumors included nine lateral plateaus and four medial plateaus. Four were primary tumors and nine were recurrences after curettage (seven lateral and two medial, respectively). Among the patients with recurrence, seven had their lesions packed with free autogenous bone, one with bone cement, and one with bone substitute. The minimum duration of followup was 5 years (mean, 9.1 years; range, 5–12.75 years).

Fig. 2A–B (A) Lateral and (B) anteroposterior radiographs of Patient 1 show a GCT on the lateral tibial side.

Table 1. Patient characteristics

Patient number	Gender	Age (years)	Site	Preoperative diagnosis	Followup (years)	Recurrence
1	Male	24	LC, L	Recurrent*	12.75	—
2	Female	29	LC, L	Recurrent [†]	11.7	+
3	Male	27	LC, L	Recurrent*	10.75	—
4	Female	25	MC, R	Recurrent*	10.7	—
5	Female	21	LC, R	Recurrent*	10.25	—
6	Male	39	LC, L	Primary, malignant	10.25	—
7	Male	26	LC, L	Recurrent*	9.5	—
8	Female	28	LC, L	Recurrent [‡]	9.42	—
9	Male	31	LC, R	Recurrent*	9	—
10	Male	25	MC, R	Primary	7.25	—
11	Female	30	MC, R	Primary	6	—
12	Male	32	LC, L	Primary	5.5	—
13	Male	48	MC, L	Recurrent*	5	—

* Previous operation was curettage and bone grafting; [†]previous operation was curettage and artificial bone filling; [‡]previous operation was curettage and cement filling; LC = lateral condyle; L = left; MC = medial condyle; R = right; + = recurrent; — = not recurrent.

All patients underwent staging studies that included plain radiography, computed tomography (CT), and chest radiograph. According to the grading system of Campanacci et al. [2] for GCT of bone, one tumor was classified as Grade I, five as Grade II, and seven as Grade III. We determined the grade from conventional radiographs and operative findings in conjunction with the results of CT and MRI. Surgical planning was based on the preoperative plain radiography, CT, and MRI to obtain en bloc resection of the medial or lateral plateaus including the entire lesion. We resected the proximal fibula in eight of nine lateral plateau tumors.

We performed anterolateral or anteromedial incision of the knee according to the tumor location. We first excised the proximal fibula (in resection of the lateral plateau) or middle fibula (in resection of the medial plateau) for the later strut grafting. Only one incision was needed with lateral condylar resection, but an additional incision was needed for medial condylar resection. We incised the joint capsule semicircularly along the attachment at the edge of the proximal tibia. The joint capsule, ipsilateral meniscus, and collateral ligament were retracted upward, ensuring preservation of the blood supply of the articular capsule and synovial lining and an intact meniscus. We specifically avoided damage to the meniscus to minimize the risk of subsequent degeneration or necrosis. We circumferentially excised the tumor in normal tissue extending to the tibial tubercle anteriorly and the midline of the tibial plateau posteriorly (Fig. 4).

The amount of tibial plateau and lesion removed was based on the extent seen on CT and MRI while preserving the tibial tubercle (the attachment point of patellar tendon) and the attachments of the anterior and posterior cruciate

Fig. 4 An intraoperative photograph shows the preserved meniscus and resected lateral plateau.

ligaments at the spinous process of the tibia. If the tumor had reached the midline of the tibia transversely, we performed an osteotomy deep into normal bone tissue under the tibial tubercle and spinous process of the tibia, achieving complete resection while preserving the ligamentous structures.

We obtained an iliac bone crest graft through an osteotomy in the anterior iliac wing, using separate instruments, and trimmed it to match the remaining plateau. With the iliac inner plate's concavity upward and in contact with the remaining tibial plateau, the iliac graft was placed to best conform to the radius of the femoral condyle (Fig. 1). We fixed the iliac plate to the contralateral plateau with a bolt, long cancellous screw, or steel plate, ensuring it was at the same elevation as the remaining plateau. We divided the segmental fibulae into several portions and inserted them longitudinally under the reconstructed tibial

plateau (iliac crest) for strut bone graft and fixed them to the tibia with screws. The remaining bone defect was packed with small iliac pieces (Fig. 1). No reconstruction at the donor site was performed.

We drilled two holes at the border of the reconstructed plateau and the free margin of the opened articular capsule with the meniscus was sutured through these holes carefully using absorbable sutures. Then the sectioned lateral or medial collateral ligament was sutured. If a soft tissue defect resulted from wide resection and was difficult to cover the bone and internal fixation devices with deep fascia, we created a gastrocnemius muscle flap to cover the bone and internal fixation devices (Fig. 5).

Patients were nonweightbearing with crutches after surgery. They began isometric muscle contraction 2 days after surgery and passive functional exercises 14 days after

surgery. Supervised exercise began with 30° flexion for 30 minutes twice a day. We attempted to achieve an additional 5° a day until 80° was achieved. We anticipated 90° or more range of motion 3 to 4 weeks after surgery. Thereafter, patients began active functional exercises without supervision. Partial weightbearing was allowed at 12 to 16 weeks with a gradual increase in weightbearing. Full weightbearing without walking assists was permitted at 16 to 20 weeks.

We (ZFL, XL) performed clinical and radiographic evaluations on the patients at semiannual followups. For the clinical evaluation, we measured range of motion, assessed stability with the drawer test and the manual varus and valgus stress tests, and evaluated meniscus strength. We assessed function using the Functional Evaluation System of Enneking et al. [4], in which patients assess their pain, function, emotional acceptance, supports, walking, and gait each on a scale of 0 (worst) to 5 (best) points for a maximum of 30 points (Table 2).

We judged union of the grafts on anteroposterior and lateral radiographs at approximately 6 months. Union was judged to have occurred when there was no space in the fracture and there was a continuous scar. All radiographs were viewed by two individuals (ZFL, XL) who were blinded to the results. Differences of opinion were settled by a third individual (JML).

Results

Primary wound healing occurred in 12 patients and subcutaneous fat liquefaction developed in one patient that resolved after dressing changes and secondary suture.

Fig. 5A–B Postoperative (A) lateral and (B) anteroposterior radiographs show the reconstructed plateau.

Table 2. Postoperative functional evaluation of the patients[†]

Patient number*	Pain	Function	Emotional acceptance	Supports	Walking	Gait	Total
1	5	5	5	5	5	5	30 (100%)
3	5	5	5	5	5	5	30 (100%)
4	4	3	4	5	4	4	24 (80%)
5	5	5	5	5	5	5	30 (100%)
6	5	5	5	5	5	5	30 (100%)
7	5	5	5	5	5	5	30 (100%)
8	4	4	4	5	4	4	25 (83%)
9	5	5	5	5	5	5	30 (100%)
10	5	5	5	5	5	5	30 (100%)
11	5	5	5	5	5	5	30 (100%)
12	5	5	5	5	5	5	30 (100%)
13	4	3	4	5	4	4	24 (80%)
Average	4.8	4.6	4.8	5	4.8	4.8	28.8 (95%)

* Patient 2, who had a recurrence and a subsequent arthroplasty, was excluded from this evaluation; [†]based on evaluation system of Enneking et al. [4].

Fig. 6A–B (A) Lateral and (B) anteroposterior radiographs taken 12.5 years after surgery show the bone has united and the internal fixation has been removed.

One patient had a recurrence and none had metastases. The recurrence was in a patient with a lesion in the lateral plateau initially treated elsewhere with curettage and artificial bone filling. When we saw the patient, greater than $\frac{1}{2}$ of the tibial plateau was involved with the recurrence. We did not remove the proximal fibula and had inadequate exposure of the lesion. When we were resecting the lesion, there was unexpected contamination as the osteotome entered the lesion. Eighteen months later, the lesion recurred and arthroplasty was performed. At the latest followup at 6 years, no additional recurrence was noted.

All grafts united to host bone. Followup radiographs revealed blurred gaps between the reconstructed plateau and the contralateral plateau, and callus formation appeared among the reconstructed plateau, and the segmental fibular and iliac bone 3 months postoperatively. At 6 months, the gaps between the reconstructed plateau and the contralateral plateau disappeared, the bone defects were full of adequate bone callus, and there was gradually increasing bone density in the tibia and the autograft (Fig. 6). We saw no collapse or resorption of the reconstructed tibial plateau. A slight step appeared between the spinous process of the tibia and the reconstructed tibial plateau in three patients treated early in the series. However, the steps did not alter the motion of the femorotibial joints because they were located in the center of the tibial plateau.

No patient reported pain when walking or weightbearing in followup. Excluding the patient with arthroplasty, the average functional rating for the remaining 12 patients was 95% (range, 83%–100%) (Table 2). Three patients had a range of motion of only 0° to 110°; these patients had discontinued their exercises at 3 to 4 weeks because of postoperative pain. The remaining nine patients approached normal range of motion with 0° to 140° (Fig. 7).

Fig. 7A–B Photographs taken 12.5 years after surgery show the range of motion of the knee in (A) extension and (B) flexion.

We observed no instability on the drawer test and manual varus and valgus stress tests. All patients have normal gaits except one who walks with a limp. Followup physical examination showed no weakness or signs of meniscal injury of the surgically treated knees in all patients. Postoperative MRI showed the signal and thickness of the retained meniscus were the same as those of the contralateral meniscus (Fig. 8).

Discussion

Historically, the local recurrence rate after GCT of bone curettage has been reported to range from 25% to 50% [3, 7, 8, 12, 15]. Higher recurrence rates occur in patients with soft tissue invasion or recurrence [13]. To decrease the local recurrence rate, surgeons enhanced their surgical technique of curettage to a typical modality [6] that was intralesional curettage, high-speed burring, adjunctive agents (liquid nitrogen), curettage and bone grafting, and cryosurgery [1, 9]. The rate of local recurrence was low with wide resection [5, 10, 11], but the reported results ranged from 0% to 32% [2, 7, 10, 15]. Only wide en bloc resection can obtain negative margins to make the recurrence rate decrease to 0%. The main factor limiting wide resection is loss of integrity of involved joints after en bloc resection. In addition, wider resection typically is associated with a higher rate of early- and late-stage complications and worse function of joints than curettage [5]. To achieve local control of wide resection and satisfactory function of reconstructed joints, we developed a technique for GCT located below one plateau of the proximal tibia, in which we en bloc resect the tumor but retain the meniscus and reconstruct the plateau with the patient's iliac bone.

Fig. 8A–D MR images obtained 12.5 years after surgery show (A) the body of the medial meniscus, (B) the body of the lateral meniscus, (C) the posterior horn of the medial meniscus, and (D) the posterior horn of the lateral meniscus. No degenerative changes or tears are observed in the surgically treated knee (A, C) in comparison with the contralateral knee (B, D).

The main limitations of our study are the small number of cases and relatively short followup. The occurrences of tumors for which the technique would be suitable are uncommon and therefore it would be difficult to accumulate a large number of cases. The followup was too short to assess the development of secondary osteoarthritis given the absence of articular cartilage, although it was likely sufficient to detect most graft failures. We cannot ensure these patients will not require later reconstruction for joint degeneration.

Osteochondral allografts with preservation of the meniscus can preserve the articular cartilage, but the bone can unite to the host bone with difficulty and the graft can develop degenerative changes quickly with articular cartilage. En bloc resection with metallic endoprosthesis reconstruction is associated with many problems, including higher infection rate, transplantation rejection, loosening, and breaking [5]. The main limitation of our technique is the loss of articular cartilage. However, the meniscus is preserved, and autologous bone easily unites to host bone

and is vascularized. Followup radiographs revealed blurred gaps between the reconstructed plateau and the contralateral plateau, and callus formation between the reconstructed plateau and the underlying struts 3 months postoperatively.

With proximal tibial GCT of one plateau and the following conditions, we recommend wide resection: (1) the tumor approaches articular cartilage and the cartilage cannot be preserved; (2) the tumor has destroyed cortical bone and there is a large soft tissue mass, especially when the lateral plateau tumor invades the superior tibiofibular joints; and (3) an intralesional procedure cannot provide a negative margin and ensure absence of tumor cell contamination in soft tissue. The major factor influencing the surgical outcome is collapse of the articular surface. Despite internal fixation with a steel plate and screws or with a bolt and screws, collapse of the articular surface will inevitably occur once one of following conditions appears: (1) translation or rotation of the graft; (2) necrosis and resorption of either end of the supporting segmental

fibulae; or (3) weightbearing or walking without support too soon. Although functional exercise should be emphasized, we do not recommend walking until 12 to 16 weeks postoperatively, because the defect in the proximal tibia after resection often is so large that cancellous or corticocancellous bone grafting and repair cannot be expected to sufficiently heal to allow full weightbearing within 3 months [16]. The outline form of the iliac plate (concave surface upward) is similar to the normal tibial plateau. Although there are some differences between the transplanted iliac plate and the normal tibial plateau, the meniscus can absorb shock, buffer stress, and transform in outline form to make up the discrepancy between the femoral condyle and the iliac plate. MRI showed the signal and thickness of the preserved meniscus were similar to those of the contralateral one, and no degenerative changes or tears occurred. We believe the transplanted menisci played an important role in the outcomes, allowing stress transfer between the femoral condyle and the reconstructed plateau transfer. Perhaps because of preserved cruciate ligaments, meniscus, and reattachment of the articular capsule and collateral ligaments, we observed no patients with instability and most patients had normal range of motion and function.

This technique can preserve and restore the normal structure on the premise of complete resection of tumor with a low recurrence rate, few complications, good bone healing, and satisfactory joint function. However, this operation can be used only in cases where the tumor invades a unilateral plateau and ligaments are not affected. It is a new method for knee reconstruction after resection of GCT involving one tibial plateau.

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References

1. Blackley HR, Wunder JS, Davis AM, White LM, Kandel R, Bell RS. Treatment of giant-cell tumors of long bones with curettage and bone-grafting. *J Bone Joint Surg Am.* 1999;81:811–820.
2. Campanacci M, Baldini N, Boriani S, Sudanese A. Giant-cell tumor of bone. *J Bone Joint Surg Am.* 1987;69:106–114.
3. Eckardt JJ, Grogan TJ. Giant cell tumor of bone. *Clin Orthop Relat Res.* 1986;204:45–58.
4. Enneking WF, Dunham W, Gebhardt MC, Malawar 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.
5. Gitelis S, Mallin BA, Piasecki P, Turner F. Intralesional excision compared with en bloc resection for giant-cell tumor of bone. *J Bone Joint Surg Am.* 1993;75:1648–1655.
6. Goldenberg RR, Campbell CJ, Bonfiglio M. Giant-cell tumor of bone: an analysis of two hundred and eighteen cases. *J Bone Joint Surg Am.* 1970;52:619–664.
7. Larsson SE, Lorentzon R, Boquist L. Giant-cell tumor of bone: a demographic, clinical, and histopathological study of all cases recorded in the Swedish Cancer Registry for the years 1958 through 1968. *J Bone Joint Surg Am.* 1975;57:167–173.
8. Liu HS, Wang JW. Treatment of giant cell tumor of bone: a comparison of local curettage and wide resection. *Changgeng Yi Xue Za Zhi.* 1998;21:37–43.
9. Malawar MM, Bickels J, Meller I, Buch RG, Henshaw RM, Kollender Y. Cryosurgery in the treatment of giant cell tumor: a long-term followup study. *Clin Orthop Relat Res.* 1999;359:176–188.
10. McDonald DJ, Sim FH, McLeod RA, Dahlin DC. Giant-cell tumor of bone. *J Bone Joint Surg Am.* 1986;68:235–242.
11. Muscolo DL, Ayerza MA, Calabrese ME, Gruenberg M. The use of a bone allograft for reconstruction after resection of giant-cell tumor close to the knee. *J Bone Joint Surg Am.* 1993;75:1656–1662.
12. Persson BM, Ekelund L, Lövdahl R, Gunterberg B. Favourable results of acrylic cementation for giant cell tumors. *Acta Orthop Scand.* 1984;55:209–214.
13. Prosser GH, Baloch KG, Tillman RM, Carter SR, Grimer RJ. Does curettage without adjuvant therapy provide low recurrence rates in giant-cell tumors of bone? *Clin Orthop Relat Res.* 2005;435:211–218.
14. Sung HW, Kuo DP, Shu WP, Chai YB, Liu CC, Li SM. Giant cell tumor of bone: analysis of two hundred and eight cases in Chinese patients. *J Bone Joint Surg Am.* 1982;64:755–761.
15. Turcotte RE, Wunder JS, Isler MH, Bell RS, Schachar N, Masri BA, Moreau G, Davis AM, Canadian Sarcoma Group. Giant cell tumor of long bone: a Canadian Sarcoma Group study. *Clin Orthop Relat Res.* 2002;397:248–258.
16. Ward WG Sr, Li G 3rd. Customized treatment algorithm for giant cell tumor of bone: report of a series. *Clin Orthop Relat Res.* 2002;397:259–270.
17. Zhen W, Yaotian H, Songjian L, Ge L, Qingliang W. Giant-cell tumour of bone: the long-term results of treatment by curettage and bone graft. *J Bone Joint Surg Br.* 2004;86:212–216.