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A novel subchondral bone-grafting procedure for the treatment of giant-cell tumor around the knee

A retrospective study of 27 cases

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Abstract

The vast majority of giant-cell tumors occur around the knee and characteristically affect the subchondral bone. Thermal damage to the articular cartilage arising from the application of polymethylmethacrylate (PMMA) or extensive intralesional curettage presents a challenging problem to orthopedic surgeons and patients due to compliance issues. For this reason, we developed a new subchondral bone-grafting procedure to restore massive bone defects and reduce degenerative changes in the knee.

The aim of this study was to describe the novel subchondral bone-grafting procedure and evaluate clinical outcomes in patients with giant-cell tumors around the knee.

This retrospective single-center study included a total of 27 patients with giant-cell tumors in the distal femur and proximal tibia admitted to our department from January 2012 to December 2015 and treated with aggressive intralesional curettage. Eleven males and 16 females were included. All cases underwent subchondral autograft bone grafting followed by bone cement reconstruction and instrument internal fixation. The Musculoskeletal Tumor Society (MSTS) score and short form-36 (SF-36) were applied to assess the functional outcome of the knee joint and quality of life. Tumor recurrence, Kellgren and Lawrence (KL) grade, and the distance of the cement to the articular surface were assessed throughout the sample.

All cases were followed up after surgery for an average of 32.9 ± 7.1 months (range 25–57 months). At the end of the follow-up period, all patients were alive and free from pulmonary metastasis. Complications associated with this surgery occurred only in 1 patient (3.7%), who presented with an incision infection that resolved with regular dressing and antibiotics. No fractures, instrument breakage, or joint fluid leakage occurred. Local recurrence occurred in 1 case (3.7%) at the distal femur after 23 months and was treated by wide resection followed by prosthesis reconstruction. Twenty-four patients (89%) did not develop radiographic findings of osteoarthritis: at the final follow-up 2 patients (7.4%), had progressed to KL1 and 1 patient had progressed to KL2. According to the MSTS scoring system, the functional score of the affected knee joint at the last follow-up ranged from 80% to 97%, with an average of 87.3%. The quality of life parameters assessed by the SF-36 survey at the last follow-up ranged from 47 to 96, with an average of 77.

For patients with giant-cell tumor of bone near the knee, subchondral bone grafting combined with bone cement reconstruction is recommended as a feasible and effective treatment modality.

Abbreviations: CT = computed tomography, GCTB = giant cell tumor of bone, KL = Kellgren and Lawrence, MRI = magnetic resonance imaging, MSTS = Musculoskeletal Tumor Society, PMMA = polymethylmethacrylate, SF-36 = short form-36.

Keywords: a new bone-grafting procedure, bone cement, giant-cell tumor of bone, knee, osteoarthritis, surgical treatment

1. Introduction

Giant-cell tumor of bone (GCTB), a well-known primary bone tumor with typically benign, locally aggressive, osteolytic lesions, accounts for up to 3% to 8% of all primary bone tumors in Western countries, with an increased incidence in females between the ages of 20 and 50 years.[1–4] However, in some Asian countries (i.e., China), it may account for 20% of all biopsy-analyzed musculoskeletal tumors and has a slight male predominance.[4,5] In general, GCTB can occur in any part of the skeleton; approximately 50% to 65% of GCTBs are located in the area of the knee, predominantly in the metaphyseal-epiphyseal portion of the distal femur and proximal tibia.[6,7] Without immediate treatment, the tumor can result in bone and stability destruction of the knee joint and invasion into surrounding normal soft tissues, eventually leading to loss of function and even amputation.[5]

Although other treatment modalities, such as denosumab, serial arterial embolization, interferon, bisphosphonates, and radiation therapy, are acceptable alternative options, the ideal management of GCTB for extremity-based lesions, especially those around the knee, is surgical treatment.[5–7] Because of the knee joint's involvement in weight bearing and many other activities and the desire of young patients to preserve joint integrity and favorable functional outcomes, extensive intralesional curettage and reconstruction with polymethylmethacrylate (PMMA) bone cement is preferred for GCTBs around the knee.[8,9] This type of surgical procedure commonly includes the

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use of physical or surgical adjuvants following intralesional curettage, such as the employment of high-speed burring and pulse lavage to improve the effectiveness of curettage and extend the surgical margins, filling with PMMA, and the use of chemicals (hydrogen peroxide, phenol, and alcohol), resulting in a relatively low local recurrence of 0% to 12% and disease-free survival rates as high as 85%.[2,4,9–11] Several published medical studies have reported that extensive intralesional curettage and the application of PMMA is recommended for primary and recurrent giant-cell tumors and has the advantages of easier use, cytotoxic effects, necrotic effects on remaining tumor remnants, early detection of local recurrences at follow-up, immediate full weight bearing after surgery and stabilization of the affected joint.[12,13] However, despite these advantages, some scholars are concerned that the application of PMMA directly adjacent to a chondral surface, which is associated with an increased risk of thermal damage to the underlying cancellous and subchondral bone, may increase the healing time in local bone tissues.[1,11,14,15] Additionally, the special mechanical properties of cement may affect the underlying articular cartilage and contribute to nononcologic complications, including degenerative changes in the adjacent joint and fracture.[11,16–18] In a multicenter retrospective Chinese primary bone tumor study, 136 patients with GCTB in the distal femur or proximal tibia were followed for an average of 86 months. The authors found that PMMA had an elasticity modulus higher than that of cortical bone and cancellous bone and well above that of articular cartilage, which may result in cartilage damage, fracture, and arthrosis.[11] Additionally, intra-articular pathological fractures and the extensive curettage itself have been mentioned as possible risk factors for the development of secondary osteoarthritis.[16,19–22] Although the role of PMMA in secondary osteoarthritis development has been cited in several types of literature, it remains to be determined. Van et al[15] believed that the exothermic reaction of PMMA is a risk factor for the development of osteoarthritis. Similar results were reported by Chen et al[23] and Joseph et al.[24] Currently, PMMA is widely used for cavity filling and structural reconstruction in GCTB and some low-grade malignant bone tumors and is believed to be associated with a high rate of osteoarthritis.[1,3,21] However, some remedies might be available to prevent heat necrosis and problems related to the mechanical properties of PMMA. In short, some oncologic orthopedic surgeons have advised bone grafting between the cartilage or subchondral bone layer and the cement in attempt to restore the subchondral osseous anatomy to its normal state, a procedure that may be more beneficial than PMMA alone.[2,20,23] However, due to the limited number of cases, the exact clinical efficacy and functional outcomes of this technique are still lacking.

Hence, we develop a new surgical technique for subchondral bone grafting combined with bone cement reconstruction. To the best of our knowledge, this is the first study to concentrate on bone-grafting procedures for GCTB near the knee. The procedure is different from traditional subchondral cancellous bone grafting or allograft bone graft alone and can more adequately restore the subchondral and cancellous positions of the joint surface with minimum cementation-related harm, such as thermal damage and mechanical problems. The purpose of this manuscript is to describe the novel procedure and assess the clinical outcomes.

2. Materials and methods

2.1. Patients

The institutional review board of the Zhongnan Hospital of Wuhan University approved this retrospective study and waived the requirement for patient informed consent. We performed a retrospective review of clinical and radiographic data that were prospectively collected for 41 patients with GCTB near the knee who were diagnosed and treated at our institution from January 2012 to December 2015. Fourteen patients were initially excluded for the following reasons: 2 patients had missing follow-up data, 1 patient had a follow-up period of <24 months, 7 patients accepted wide resection followed by prosthesis reconstruction, 2 patients had local recurrence, pathologic fractures with intra-articular extension, and 2 had osteoarthritis preoperatively (KL1-2). The inclusion and exclusion criteria were completely applied (Table 1). The remaining 27 cases who accepted extensive curettage followed by subchondral bone grafting combined with bone cement reconstruction were enrolled. The cohort comprised 11 males and 16 females, with an average age of 34 years (range, 19–54 years). The lesion was located in the distal femur in 18 patients and in the proximal tibia in 9 patients. According to the radiographic classification system of Campanacci,[25] there were 5 patients with grade I lesions, 14 patients with grade II lesions, and 8 with grade III lesions in this study. All cases were confirmed as GCTB by imaging studies, including plain radiographs, computed tomography scan and magnetic resonance imaging, as well as needle biopsy or open biopsy before surgery and histopathologic examination after surgery. The clinical data, including gender, age, tumor location, Campanacci radiographical classification system, complications, duration of follow-up in months, Musculoskeletal Tumor Society (MSTS) functional score,[26] the short form-36 (SF-36) score, and postoperative Kellgren and Lawrence (KL) grades[27] at the last follow-up for the distribution of patients with GCTB near the knee were recorded (Tables 2 and 3). At certain levels, higher MSTS and SF-36 scores signify better functional results and quality of life.

2.2. Surgical technique

The initial surgery was performed under combined spinal-epidural anesthesia. All the patients in this study accepted GCTB extensive intralesional curettage followed by subchondral bone

Table 1

Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Treatment by extensive curettage, subchondral bone autograft and cement	Incomplete date or death in the follow-up
Preoperative and postoperative pathologic diagnosis were confirmed as GCTB	Local recurrence
GCTB around the knee (the proximal tibia and distal femur)	Preoperative osteoarthritis or degenerative changes
>24 months of follow-up	Pathologic fractures with intra-articular extension

GCTB = giant cell tumor of bone.

Table 2

The clinical general data and demographics of patients with giant cell of bone around the knee.

Patient no.	Age, y	Sex	Site of the tumor	Follow-up, mo	Campanacci grade	Complications
1	20	M	Proximal tibia	34	Grade III	Incision infection
2	46	M	Distal femur	31	Grade II	None
3	24	F	Distal femur	30	Grade II	None
4	33	M	Distal femur	25	Grade III	None
5	38	F	Proximal tibia	35	Grade I	None
6	22	F	Proximal tibia	35	Grade III	None
7	45	M	Distal femur	23	Grade II	None
8	25	M	Distal femur	26	Grade III	None
9	49	F	Proximal tibia	34	Grade II	None
10	21	F	Distal femur	28	Grade II	None
11	19	F	Distal femur	28	Grade II	None
12	51	M	Distal femur	29	Grade II	None
13	48	M	Proximal tibia	25	Grade I	None
14	31	M	Distal femur	30	Grade III	None
15	54	F	Distal femur	31	Grade I	None
16	22	M	Distal femur	57	Grade II	None
17	20	F	Distal femur	25	Grade II	None
18	27	M	Proximal tibia	32	Grade II	None
19	26	F	Proximal tibia	36	Grade III	None
20	47	M	Distal femur	29	Grade I	None
21	29	M	Distal femur	41	Grade II	Local recurrence
22	21	M	Distal femur	37	Grade III	None
23	39	M	Proximal tibia	45	Grade II	None
24	51	F	Distal femur	41	Grade II	None
25	46	M	Distal femur	33	Grade III	None
26	32	M	Distal femur	29	Grade I	None
27	21	F	Proximal tibia	38	Grade II	None

grafting and bone cement reconstruction. The same group of experienced orthopedic oncology surgeons at our institution completed all surgeries in this study. The following surgical strategies were used by all surgeons: a pneumatic tourniquet was traditionally used during the surgical procedure to control local bleeding. First, a lateral or medial approach was chosen for the more-affected limb. An appropriate cortical window was created to allow access to the entire tumor area and to avoid having to curette under overhanging shelves or ridges of bone. The cortical window was 1 cm larger than the tumor in the longitudinal direction and approximately one-fourth to one-fifth of the perimeter in the cross-section. After intralesional curettage of the tumor using a series of traditional curettes of various sizes and shapes (Figs. 1 and 2), a high-speed burr was applied to the residual cavity. In each case, the high-speed burr was used to enlarge the cavity by 2 mm to remove the residual tumor in the inner reactive bone crest (Fig. 3) After tumor resection and application of the high-speed burr, local adjuvant agents were applied to eliminate small pockets of residual tumor in the cavity. At our institution, anhydrous alcohol is preferred for local control in the treatment of giant-cell tumors; however, when adjuvants are applied, the surrounding normal tissues are protected and shielded by medical gauze. After the application of local adjuvant agents, the curettage cavity was repeatedly rinsed with saline solution using high-speed pulse lavage, which can further achieve the goal of aggressive curettage. After the above procedures were completed, an anterior iliac crest autogenous bone graft was used to restore the subchondral and cancellous positions and repair subchondral bone defects. The defect was measured, and an iliac crest was cut into cancellous bone granules and cortical bone sclerites. Regarding the order of subchondral bone grafting of cancellous bone granules and cortical bone lamellas, the cancellous bone granules were filled under the subchondral bony area first; then, the cortical bone lamellas were placed above the cancellous bone area, with the cancellous surface of the cortical bone toward

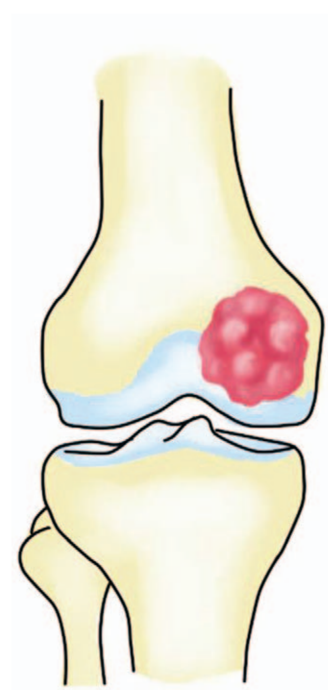

Figure 1. Schematic of the giant cell of bone model near the knee showing that the tumor was located in the distal femur.

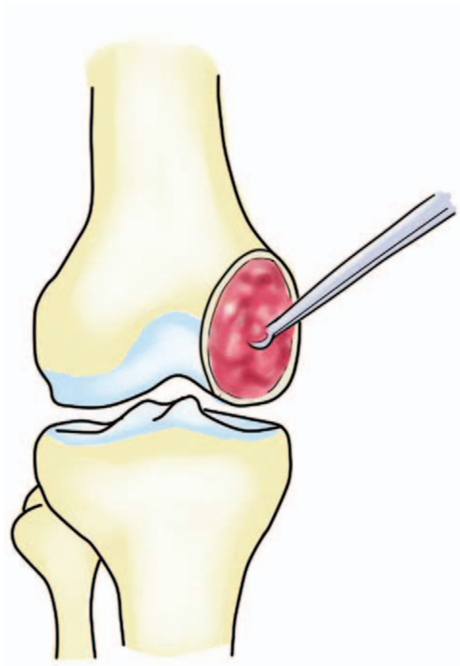

Figure 2. Schematic of giant cell of bone curettage showing that a curette was carried through an appropriate-sized cortical window that allowed the entirety of the tumor to be visualized.

the cancellous bone area. The subchondral bone defect area was packed with autogenous bone grafts approximately 10 mm thick, and the remaining cavity was filled with PMMA cementation (Fig. 4) followed by permanent fixation with locking plates under X-ray. The volume of bone cement depended on the size of the remaining bony cavity, with an average of 20 to 60 mL. At our center, the primary surgeon prefers prophylactic fixation devices such as locking plates for giant-cell tumors near the knee. Finally, all incisions were closed.

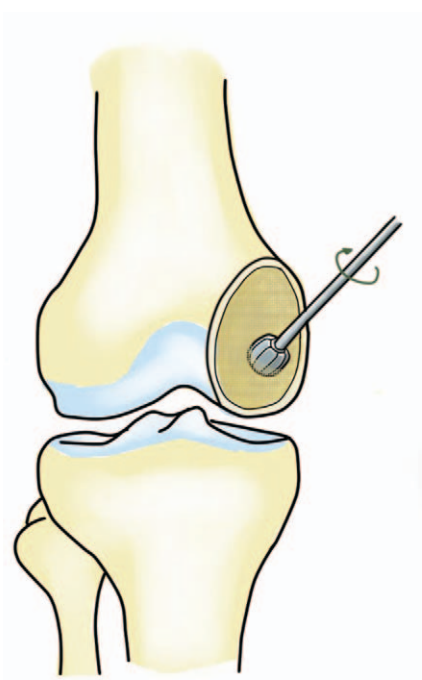

Figure 3. Schematic of extensive intralesional curettage of giant cell of bone showing that a high-speed burr was applied to eliminate the small pockets of residual tumor in the cavity.

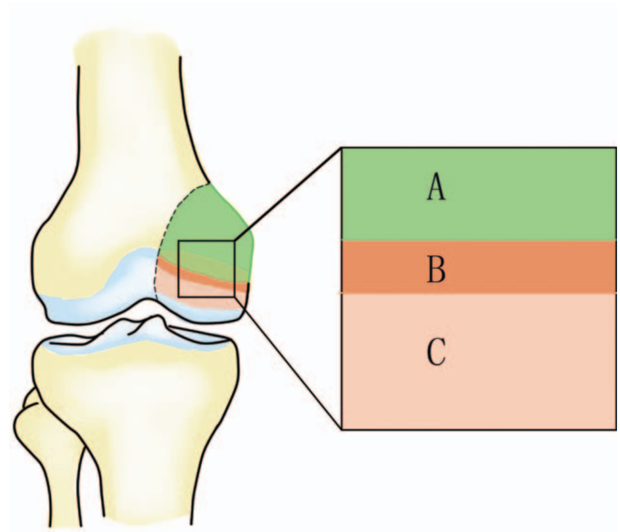

Figure 4. Schematic of subchondral cancellous and cortical bone-grafting procedure after extensive intralesional curettage. (A) Polymethylmethacrylate implant area. (B) Cortical bone grafting area. (C) Subchondral cancellous bone grafting area.

2.3. Postoperative procedure and follow-up

The drainage tube was removed when the drainage flow was <20 mL/24 h. All the patients tolerated partial weight bearing ambulation 2 to 3 weeks postoperation and started functional mobilization, including considerable amounts of strengthening work around the quadriceps femoris and tibialis anterior muscle under the guidance of professional rehabilitation orthopedic doctors until bony fusion was achieved at a mean of 3 months. Generally, the incorporation of the bone graft was assessed using anteroposterior (AP) and lateral radiographs. Postoperative physical examination and radiographs of the knee joint and chest were performed for all the patients every 3 months for the first 2 years after the initial surgery, then every 6 months for the next 3 years, and then every year until the 10th-year post-operation. The follow-up documentation was reviewed in all cases to monitor complications, including incision infection, fractures, joint fluid leakage, local recurrence, pulmonary metastases, and signs of degeneration of the knee joint over time. The MSTS score and the SF-36 questionnaire were used to assess functional results and quality of life, respectively, at the last follow-up visits. The MSTS score evaluates patient activity, including pain, general functional activity, emotional acceptance, and stability of the joint and gait. The distance of the cement to the subchondral bone was measured by plain X-ray and recorded. Degenerative status was defined by KL grades, which is the most universally accepted method of classification for radiographic osteoarthritis.

3. Results

Twenty-seven patients participated in our retrospective study, and none were lost to follow-up. The average follow-up period

Table 3

Preoperative information and final follow-up of surgical efficacy.

Patient no.	Follow-up, mo	Distance of the cement to articular surface, mm	MSTS score	SF-36 score	Arthrosis (Kellgren and Lawrence grade) postoperatively
1	34	11	90%	55%	KL0
2	31	13	93%	88%	KL1
3	30	14	97%	47%	KL0
4	25	15	80%	81%	KL0
5	35	13	83%	76%	KL0
6	35	18	83%	81%	KL0
7	26	13	90%	87%	KL0
8	26	11	83%	93%	KL0
9	34	12	80%	87%	KL2
10	28	13	97%	75%	KL0
11	28	13	93%	90%	KL0
12	29	18	90%	76%	KL0
13	25	13	83%	53%	KL0
14	30	16	83%	68%	KL0
15	31	13	80%	72%	KL0
16	57	15	80%	88%	KL0
17	25	13	90%	74%	KL0
18	32	17	87%	81%	KL0
19	36	15	97%	59%	KL0
20	29	14	83%	94%	KL0
21	41	12	83%	73%	KL1
22	37	10	77%	78%	KL0
23	45	18	93%	67%	KL0
24	41	13	90%	96%	KL0
25	33	15	83%	81%	KL0
26	29	14	83%	82%	KL0
27	38	17	97%	90%	KL0

MSTS = Musculoskeletal Tumor Society, SF-36 = short form-36.

was 33 months (range: 25–57 months). Complications, follow-up time of each patient, the distance from the bone cement to articular cartilage, and the MSTS and SF-36 score results are reported in Table 3. At the end of the follow-up period, all the patients were alive and free from pulmonary metastasis. Complications associated with this surgery occurred only in 1 patient (3.7%), who presented with an incision infection that resolved with regular dressing and antibiotics. No fractures, instrument breakage or joint fluid leakage occurred. Local recurrence occurred in 1 case (3.7%) at the distal femur after 23 months and was treated by wide resection followed by prosthesis reconstruction. According to the KL grade evaluation scale, 24 patients (89%) did not develop radiographic findings of osteoarthritis; at the final follow-up, 2 patients (7.4%) had progressed to KL1, and 1 patient had regressed to KL2 (3.7%). The overall degenerative change rate in the knee joint at the final follow-up was 11.1% (3/27). According to the standardized MSTS score, the functional score of the affected knee joint at the last follow-up ranged from 80% to 97%, with an average of 87.3%. The quality of life scores, assessed by the SF-36 survey at the last follow-up, ranged from 47 to 96, with an average of 77. The mean distance from the cement to the articular cartilage was 14 mm (range: 11–18 mm).

4. Discussion

Currently, management strategies for GCTB include various advanced surgical techniques and other multidisciplinary treatment modalities, such as radiation therapy, cytotoxic chemotherapy, interferon, and bisphosphonates.[5,11,28] For patients with extremity-based lesions, extensive resection curettage with or without physical or surgical adjuvants was almost always performed as a primary treatment according to several articles.[11,29,30] The use of a high-speed burr, PMMA, phenol, hydrogen peroxide, and alcohol after curettage has been well established for the treatment of GCTB, which will contribute to the thoroughness of tumor removal and improved functional outcomes.[2,4,9–11] In a study by Szalay et al,[20] 56% of all GCTB reached the subchondral area (within 3 mm), but 84% subchondral involvement was observed in cases of lower extremity localization. Xu et al[31] also noted that GCTB may frequently compromise the subchondral bone and articular cartilage.

Due to the frequent subchondral involvement and the prevalence of GCTB in young-to-middle-aged adults, most authors suggest extensive intralesional curettage, which preserves joint integrity and maximizes function, as opposed to wide resection followed by prosthesis reconstruction.[5,7,8] At our center, wide resection followed by prosthesis reconstruction was never recommended as the main surgical treatment option for GCTB near the knee, even in the presence of soft-tissue extension and intra-articular pathologic fracture.

We agree with some authors that wide resection is usually associated with almost 100% local control but inevitably impairs functional impairment, reduces activity levels, and has a high risk of limited implant longevity.[5,6,25,26] At our institution, with the application of aggressive curettage technology, a high-speed burr and other adjuvants treatments are widely used in GCTB near the knee, especially for young patients undergoing a first surgery. However, in our study of giant-cell tumors, approximately 66.7% (18/27) of cases occurred in patients between 10 and 40 years of age. Because our institution is a national reference center for bone tumors, these cases are more likely to be referred to our institution.

Of course, after curettage, the bone defect usually should be reconstructed with some type of filler. The most important question is how to fill the cavity after GCTB extensive intralesional curettage. Despite the various biologic and nonbiologic filling materials available, there is no consensus for reconstruction of bone defects after GCTB curettage around the knee.[11,20] In the long term, traditional bone graft materials such as autografts or allografts have the advantage of being able to incorporate into host bone to more adequately restore the subchondral and cancellous positions of the joint surface.[17,22,27] If the graft materials are successfully incorporated, the reconstruction is permanent. However, the disadvantages of using these materials lie in the difficulty of detecting local recurrence, allograft rejection reaction, resorption, and the limits of bone banks, which cannot provide ideal mechanical support for subchondral defects.[11] In addition, the reported recurrence rates following both options are high and vary widely, from 27% to 65%.[25] In this study, however, all of our cases had a strong desire to preserve joint integrity and have favorable functional outcomes.

In theory, the ideal filling material should provide immediate mechanical support and have the capacity to be resorbed and replaced by host bone in the long term without damaging the mechanical integrity of the bone. PMMA is an excellent nonbiologic option because it immediately stabilizes the affected limb for early physical therapy and induces tumor necrosis via the exotherm of in situ polymerization, which is associated with a lower recurrence risk of 12% to 34%.[13,15,26,32] In a recent multicenter survey, Zheng et al[11] concluded that the recurrence rate in the bone grafting group was higher than in the cementation group and the MSTS score was better after curettage than after en-bloc excision and prosthetic reconstruction. Another significant advantage of PMMA cementation is the prevention of cartilage rarefaction and the collapse and fracture of the subchondral bone, along with early detection of local recurrence during follow-up.[12,13,15,32] While the use of PMMA cementation might be beneficial, the normal bordering bone tissue would also be affected. Of concern is thermal damage to the adjacent articular cartilage and even to the underlying cancellous and subchondral bone. Many studies have shown that treatment with PMMA may increase the stiffness of the subchondral bone, leading to degenerative changes in the adjacent joint and increasing the time needed for healing in local tissues.[1,14,20,33] A literature review found that the prevalence of osteoarthritis after curettage and application of PMMA ranges from 4% to 25% in the upper and lower extremities.[1,14,32,34–36] Another concern was a sclerotic rim at the bone–cement interface, first described by Welch et al,[33] which could decrease the shock-absorbing capacity of the subchondral bone layer. The sclerotic rim surrounding bone cement may be caused by thermal damage and the special mechanical properties of cement.[11,33,37] In general, a higher elasticity modulus was confirmed in cement than in bone. Concentrated pressure on the bone-facing cement created a sclerotic rim. This pressure may also result in cartilage damage, fracture, and arthrosis. Van et al[15] retrospectively analyzed a single-center study that included fifty-three patients with giant-cell tumors near the knee and a median duration of follow-up of 86 months. They concluded that 17% of the patients had radiographic findings of osteoarthritis after treatment with curettage and PMMA. To reduce cartilage damage, an alternative possibility is the placement of a bone graft between the cartilage or subchondral bone layer and the cement.

In this study, we described a new bone-grafting procedure that increases the distance between the exothermic reaction of PMMA and the articular cartilage and reduces the pressure on the cartilage and subchondral bone layer. The proposed procedure is applicable for GCTB near the knee. In the case of reconstruction after extensive intralesional procedures with physical and chemical adjuvants, an iliac crest was cut into cancellous bone granules and cortical bone sclerites. First, the cancellous bone granules were used to fill the area under the subchondral plate. Then, the cortical bone lamellas were placed above the cancellous bone area, with the cancellous surface of the cortical bone toward the cancellous bone area. The remaining cavity was filled with PMMA cementation (Fig. 4) followed by permanent fixation with locking plates under X-ray. These procedures increased the distance between the PMMA and the articular cartilage. In our patients, the mean distance between the cement and the articular cartilage was 14 mm (range: 11–18 mm). Baptista et al[38] believed that the distance from the cement to the articular cartilage has prognostic value regarding future arthrosis. After a follow-up of at least 10 years, arthrosis was more frequent in GCTB lesions located $<$10 mm from the subchondral bone when treated with intralesional resection (compared with GCTB lesions $>$10 mm from the articular surface), and the difference was statistically significant. Similar results were reported by Niu et al.[3] Therefore, we chose to restructure the subchondral plate to a thickness of at least 10 mm. Furthermore, to overcome the special mechanical properties of cement, we recommend the use of cancellous bone granules supplemented with cortical bone sclerites. In these cases, PMMA acts as a rigid surface, concentrating pressure on the already thick cortical bone surface and reducing the probability of collapse and fracture of the subchondral bone and of articular cartilage damage. Additionally, this type of procedure could create a cortical bone surface that protects against the thermal effects of PMMA on the cancellous bone layer. Turcotte et al[14] suggested that the use of bone grafts under cartilage may prevent the harm caused by PMMA; however, there are no statistically significant differences in functional outcomes when either cement or bone grafts are used adjacent to the cartilage after curettage. Similarly, Van et al[15] found that the function and quality of life of patients with KL3-4 were comparable with those of patients with KL0-2, suggesting that radiographic findings of osteoarthritis identified at a mid-term follow-up persisted. Joseph et al[24] found that compared with PMMA alone, the use of periarticular bone graft constructions reduces postoperative osteoarthritis without increasing the likelihood of tumor recurrence. However, there remains a lack of consensus concerning the need for fixation when intralesional curettage is performed. At our center, a locking plate is preferred for giant-cell tumors near the knee; this method which will not allow micromotion between the bone and cement, thus improving the stability of the affected limb. In our study, 24 patients (89%) did not develop radiographic findings of osteoarthritis; however, at the final follow-up 2 patients (7.4%) had progressed to KL1, and 1 patient had progressed to KL2. The other patients who underwent subchondral bone grafting combined with bone cement reconstruction showed no evidence of subchondral collapse or degenerative changes. We have routinely used extensive curettage and cementation with subchondral bone grafts to treat giant-cell tumors near the knee. Our goals have been to restore the structural integrity to the bone, reduce local recurrence, and maintain limb function. We report the oncologic and functional results and complications associated with subchondral bone grafting combined with bone cement reconstruction after extensive curettage for GCTB around the knee (Figs. 5–10).

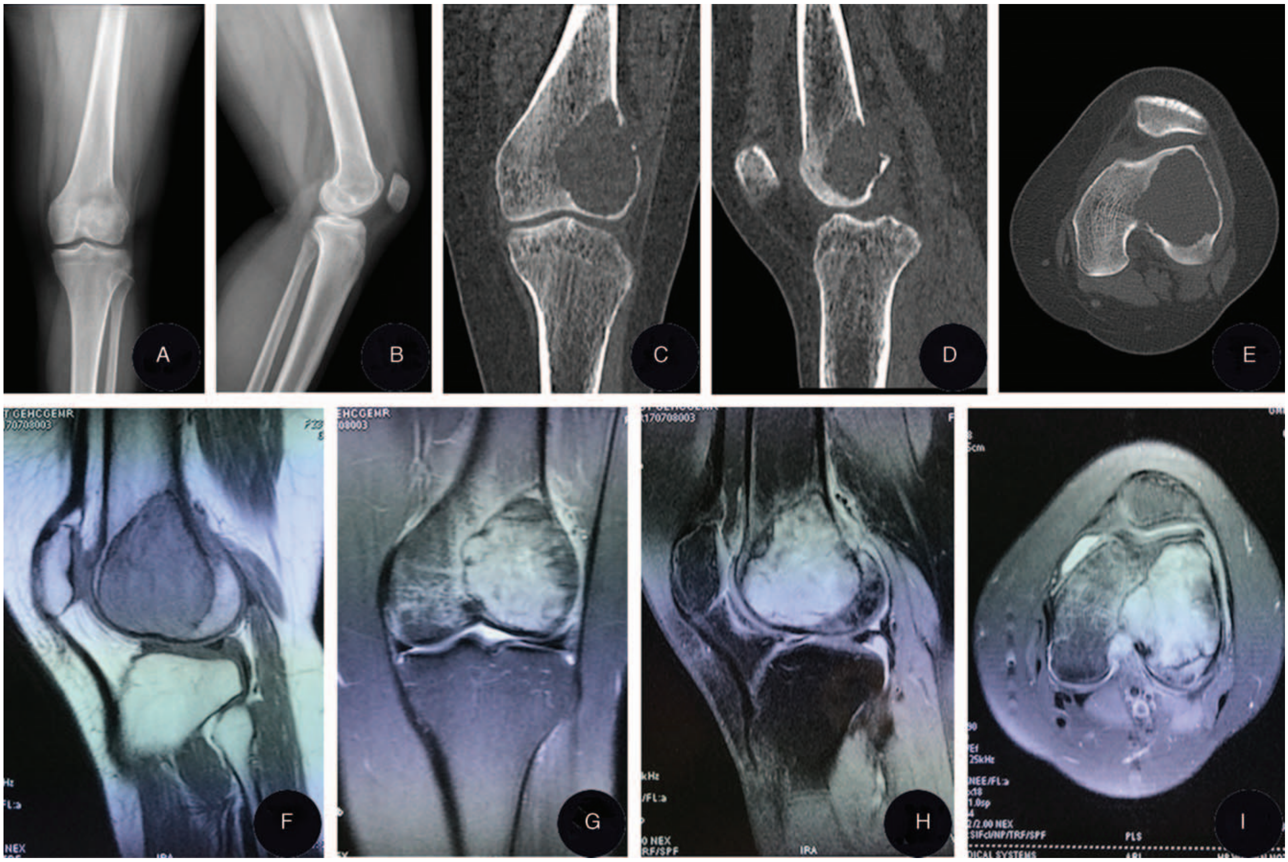

Figure 5. (A, B) Preoperative X-ray of a case of giant cell of bone of the distal femur showing cortical thinning and resorption of the subchondral bone. (C–E) Preoperative computed tomography scan showing a lytic appearance and epiphyseal lesion without sclerotic margin. (F) Preoperative T1-weighted magnetic resonance imaging (MRI) showing the lesion at the distal femur with relatively low-intensity change. (G–I) Preoperative T2-weighted MRI showing a heterogeneous mixed high-intensity change with surrounding soft-tissue edema.

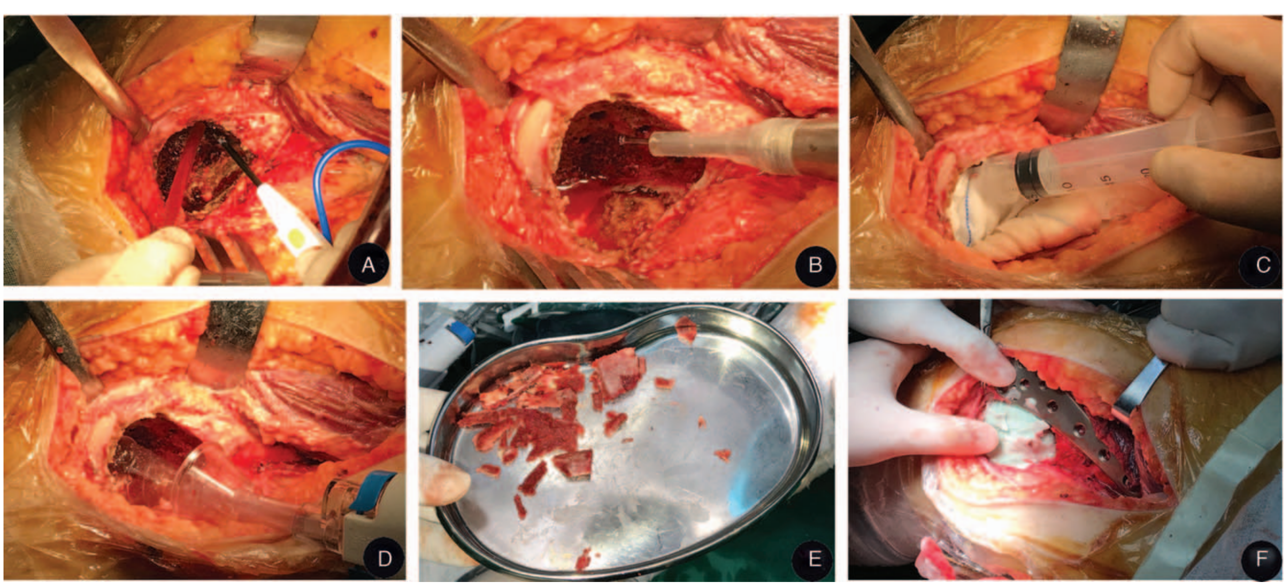

Figure 6. (A–D) Intraoperative photo showing the use of electrocauterization for the cavity wall, a high-speed burr for the remaining cavity, anhydrous alcohol via squirt for local control, and a high-speed pulse lavage with saline solution for the cavity. (E) Intraoperative photo showing the use of iliac crest autogenous bone graft with cancellous bone granules and cortical bone sclerites. (F) Intraoperative photo showing the use of locking plate and polymethylmethacrylate to stabilize the affected limb.

Figure 7. Twenty-five-month follow-up X-ray shows good remodeling of the subchondral bone graft without evidence of joint degeneration.

Figure 8. (A, B) Preoperative X-ray in a case of giant cell of bone of the distal femur showing cortical thinning and "donut sign." (C–E) Preoperative computed tomography scan showing the appearance of a well-defined lytic cystic lesion. (F) Preoperative T1-weighted magnetic resonance imaging showing the lesion at the distal femur with relatively low-intensity change. (G–I) Preoperative T2-weighted image STIR showing a heterogeneous mixed high-intensity change with surrounding soft-tissue edema.

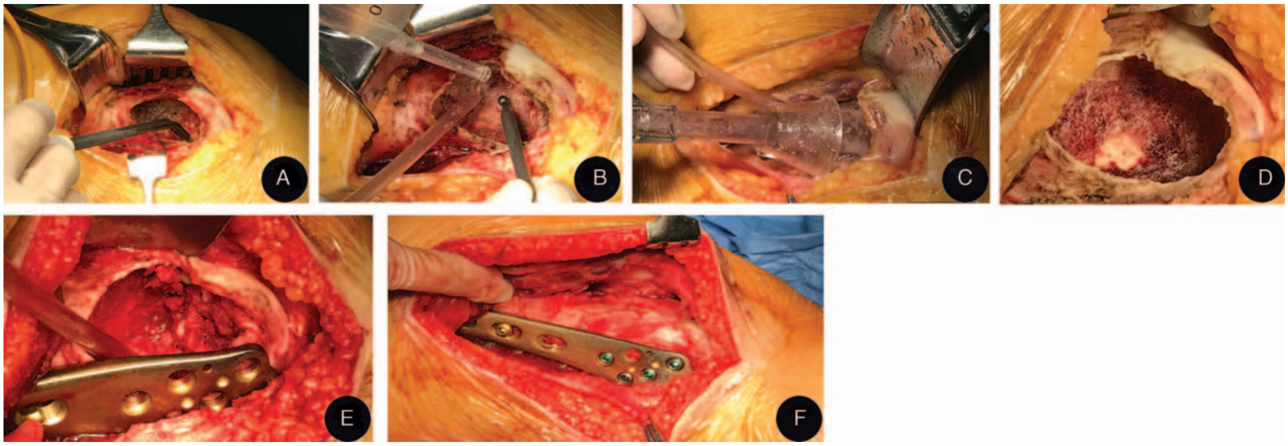

Figure 9. (A–C) Intraoperative photo showing the use of electrocauterization for the cavity wall, a high-speed burr for the remaining cavity and a high-speed pulse lavage with saline solution for the cavity. (D) Intraoperative photo showing the appearance of the remaining cavity after extensive intralesional curettage. (E) Intraoperative photo showing the use of subchondral bone grafting. (F) Intraoperative photo showing the use of locking plate and polymethylmethacrylate to stabilize the affected limb.

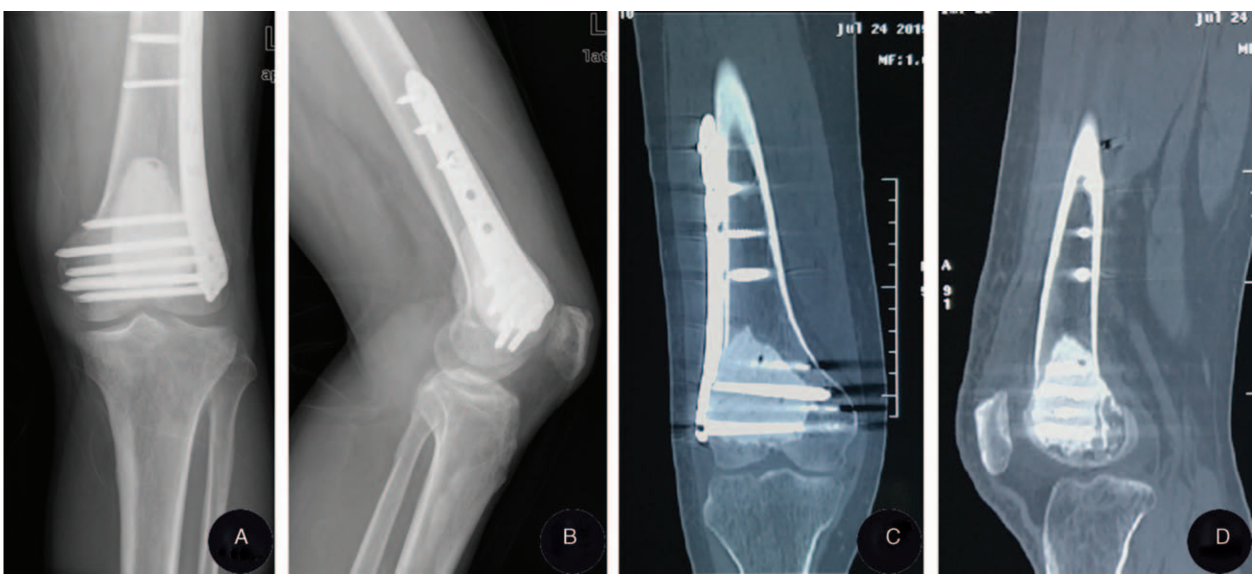

Figure 10. (A–D) 36-month follow-up X-ray and computed tomofraphy scan show good remodeling of the subchondral bone graft without evidence of joint degeneration.

5. Conclusion

In summary, the authors propose a new subchondral bone grafting procedure that could reduce the risk of osteoarthritis, provide structural support, and prevent collapse. This novel, 1-stage procedure is feasible and effective for treating GCTB near the knee. Future studies might include a multicenter, prospective, randomized study to further investigate the role of the subchondral cancellous bone graft with supplemental cortical bone graft in reducing the risk of progression to osteoarthritis.

Author contributions

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