Early results of the combined grafting–cementation technique for the treatment of giant cell tumors with a large subchondral bone defect: a case series

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Background
Giant cell tumor (GCT) is a rare, locally aggressive bone tumor. It typically affects young adults close to the joints, mainly the knee joint. The high recurrence rate, along with erosion of the subchondral bone complicates the surgical plan. Current treatment standards involve extended curettage followed by space-filling by cement or graft. We present a detailed technique using a combined technique using both bone graft and cement for reconstructing GCT-related subchondral damage.

Patients and methods
Eighteen patients underwent surgery from January 2018 to December 2021. The surgery involved extended curettage using a high-speed burr, and lavage using hydrogen peroxide. Placement of the graft as a subchondral shelf helps to support the articular cartilage. Bone cement was applied to fill the cavity and support the graft; internal fixation was used in large-sized lesions.

Results
The mean follow-up is 34.5 months. Oncologically, local recurrence was reported in one case, with a distal radius location, and no distant metastasis was reported. Functionally, 86.6% had excellent/good Musculoskeletal Tumor Society score scores. Graft union had occurred in all cases; mean union time was 12 weeks. Rehabilitation included immediate passive range of motion exercises and partial weight bearing. The pain had improved significantly in all cases. Muscle power had been temporarily affected in five cases. One patient had a wound infection, managed with antibiotics.

Conclusion
Treatment of GCTs is challenging. The standard treatment involves curettage and gap filling. The presence of the cement close to the articular cartilage can lead to osteoarthritis due to different modulus of elasticity. We describe this combined technique to provide support, insulation, and stability, and minimize the stresses on the articular cartilage. The results of this technique are promising and yield good functional and oncological outcomes. Further research is needed to evaluate its long-term efficacy in preventing progressive osteoarthritis.

Keywords:
cementation, combined technique, giant cell tumor, grafting, subchondral

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Introduction

Giant cell tumor (GCT) is a rare primary bone tumor, accounting for ∼3–5% of all primary bone tumors. It is classified as a benign tumor but is locally aggressive [1,2].

It mainly affects young adults in the second, third, and fourth decades of life. It affects the epiphysiometaphyseal location, with obvious predilection around the knee joint in more than 50% of cases [3]. Although metastasis is uncommon, GCT exhibits a relatively high recurrence rate, ∼12–27%, which further complicates the surgical management plan [4,5].

The presence of subchondral bone erosion is usually encountered in these cases (84–99%), posing a significant challenge to surgical decision-making, particularly when it involves a weight-bearing joint. Erosion of the articular cartilage may necessitate more extensive surgical procedures, including joint-sparing techniques or en-bloc resection and endoprosthetic replacement to optimize the functional outcomes [6].

The current standard of treatment is extended intralesional curettage and space-filling using either bone cement, graft, or combined techniques. Many authors have reported articular degeneration after cementation, which may jeopardize the durability of this treatment option [7,8].

En-bloc resection and endoprosthetic replacement are resorted to when there is a massive bone and articular cartilage destruction with unreconstructable remaining bone. Its role in lowering the recurrence rate is controversial as the surgical morbidity is higher and the superior functional outcome is lower [9,10].

The combined graft–cement technique has been reported in many studies, but a detailed surgical description of the technique has been scarcely published.

In this study, we report our detailed surgical technique using autogenous bone graft combined with the application of polymethylmethacrylate (PMMA) cement in the reconstruction of massive subchondral affection in cases with GCT of the bones. The study aims to assess the radiological, functional, and oncological outcome of the combined grafting–cementation technique in the treatment of GCT with large subchondral bone defects.

Patients and methods

Eighteen patients who have been operated on using the combined grafting–cementation technique from January 2018 to December 2021 have been included. All patients were treated by the same surgeon (first author) in the same Orthopaedic Department.

The average age was 32.5 ± 12.0 (16–55), and included 11 females. The lesion was in the proximal tibia in 10 patients, in the distal femur in five patients, in the proximal humerus in two patients, and in the distal radius in one patient.

All patients underwent initial evaluation, including local examination and imaging studies, including plain roentgenograms, computed tomography (CT) scans, and MRI, to evaluate the tumor size and stage according to Campanacci, integrity of cortices, an approximate estimation of the subchondral bone thickness, expected volume of the cement, and the graft and planning of the surgical approach [11].

Every case had been discussed in multidisciplinary musculoskeletal tumor' meetings.

The procedures were performed following the ethical standards as stated in the Declaration of Helsinki and following amendments or parallel ethical standards. All cases had an open biopsy before the definitive surgery, and histopathological diagnosis was mandatory before proceeding to the index surgery. Written informed consent was obtained from all participants. The study was conducted after approval of the Institutional Review Board (IRB) of our Faculty of Medicine. IRB registration no is Soh-Med-23-07-08PD.

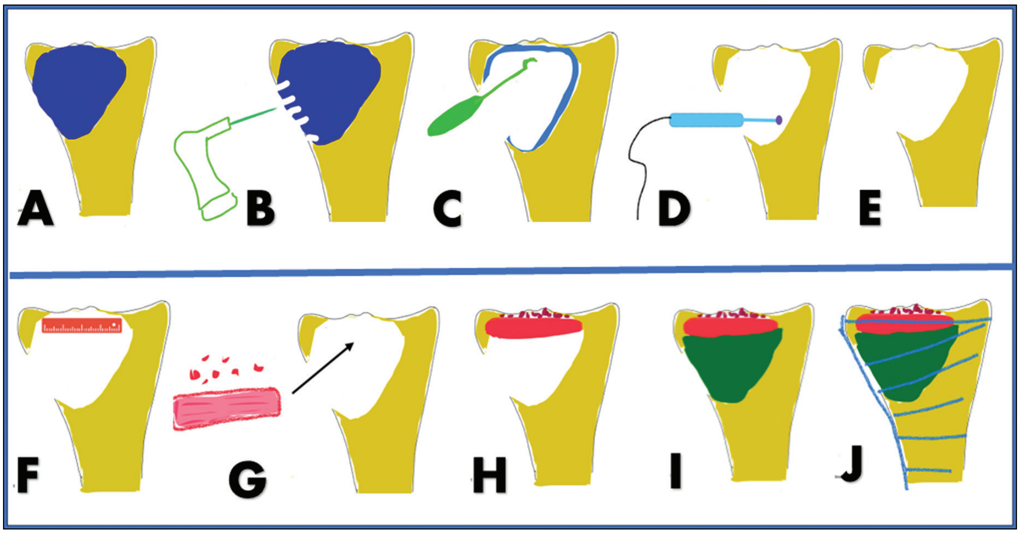
Surgical technique

The patient positioned supine unless the lesion was in the proximal humerus, which mandates a beach chair position. Standard surgical draping was performed with the involvement of the iliac bone graft harvest site. Choosing the graft from ipsilateral or contralateral was decided preoperatively in the preoperative counseling session with the patient. Pre-incision antibiotic prophylaxis, first-generation cephalosporins, is infused with the induction of anesthesia. A tourniquet was used in tibial and radial lesions, while it was not used when the location of the lesion was femoral and humeral. No exsanguination was applied. An incision was planned according to the location, using the shortest possible way to the lesion, approaching the weaker side of the bone to preserve the more sound cortex for mechanical support. These considerations are always applied to the primary surgery of open biopsy, and thus all cases had the same but extended incision of the open biopsy.

Under image intensifier guidance, the cortical window is opened, and with adequate exposure, the tumor tissue is curetted and biopsied again for histopathological examination, then a high-speed burr is used to perform the extended curettage. It is avoided in the subchondral surface in areas where the bone is eroded. However, high-speed burr in areas with thin layers of subchondral bone had led to the extension of exposed cartilage. Surgical lavage using hydrogen peroxide and saline is used to wash out the debris and fine tissues. Additional thermal ablation was applied by electrocautery using a monopolar diathermy probe, avoiding the articular cartilage. Measurement of the surface area of the final cavity is carried out using a sterile ruler. Harvesting the iliac bone graft is then performed with gentle dissection preserving the tricortical structure of the graft. A harvested strut is estimated and cut using an osteotome; furthermore, separate different-sized curettes are used to harvest the largest possible amount of cancellous bone from the donor iliac bone and collected in a wet gauze.

Then the main strut graft is prepared and cleaned from any soft tissue or periosteal attachments, and under the guidance of the C-arm; it is placed

Figure 1



Diagrammatic presentation of the technique. (a) Represents GCT in the proximal tibia. (b) Drilling as the first step to open the window for curettage. (c) Curettage using different-sized curettes. (d) High-speed burr to shave the peripheral margin to destroy any bone trabeculae, which may harbor tumor cells. (e) The cavity as it looks after curettage, high-speed burr, and lavage using hydrogen peroxide; note the subchondral bone is getting thinner and the eroded area is increased after previous steps. (f) Estimation of the surface area to harvest the graft. (g) Harvest the strut iliac and cancellous bone graft. (h) Impaction of the tricortical iliac strut at the trough made at the sides of the wall, and stuffing the space between the articular cartilage and the strut by cancellous graft. (i) Cement filling the majority of the cavity. (j) Represents the fixation added to this reconstruction technique. GCT, giant cell tumor.

parallel to the joint, as close to the exposed articular cartilage as possible. A trough was made on the sides of the cavity to allow proximation of the graft to the cartilage, and support the stability of the graft. The inner and outer tables are placed parallel to the cartilage, while the crest cortex is placed on the bone window, which was opened surgically to access the lesion, to add more mechanical support. Afterward, the cancellous graft is gently and carefully stuffed to firmly fill the minimal space between the articular cartilage and the inner or outer table of the iliac bone. Internal fixation is decided when the lesion's maximum diameter is larger than one-third of the bone; however, it is not sharply demarcated, that is, in cases of young age with good bone quality and reasonable expected stability after cementation, internal fixation is not done. If fixation is decided, usually locked plates are used. The plate is placed, drilling and measurement of the screws is assumed to be applied along the whole plate, then it is removed, this step is to avoid any interruptions or delays while the cement is settled. Now all desired screws are measured, prepared, and ready for application. Intraoperative estimation of the cavity volume is roughly estimated using a 100 ml saline syringe to relatively decide the approximate number of cement packs that are needed. Bone cement is then mixed and applied to the cavity. Application starts after mixing without waiting until settlement of the cement, to provide more time for efficient filling of the cavity. Cement is kept 2–3 mm lower than the surface of the window, first to avoid more prominence as the volume increases with hardening, not to hinder proper application of the plate, and promoting cortical buildup to have new bone formation over the bone window. Saline wash was used for cooling the cement. Image intensification is then used to check the filling of the cavity and proceed to internal fixation, which is now rapidly performed, as all screws were predrilled, premeasured, and prepared on the table.

Deflation of the tourniquet is then requested, followed by gentle hemostasis and closure of the wound with or without surgical drain according to the bleeding. Figure 1 represents a diagrammatic summary of the surgical procedure (Table 1).

Case presentation

A 16-year-old girl presented with right proximal tibial pain of 2 months duration. Clinical examination and imaging studies showed a suspected osteolytic lesion in the proximal tibia, and then an open biopsy was performed and confirmed the diagnosis of GCT. Figure 2 shows the preoperative images of the case.

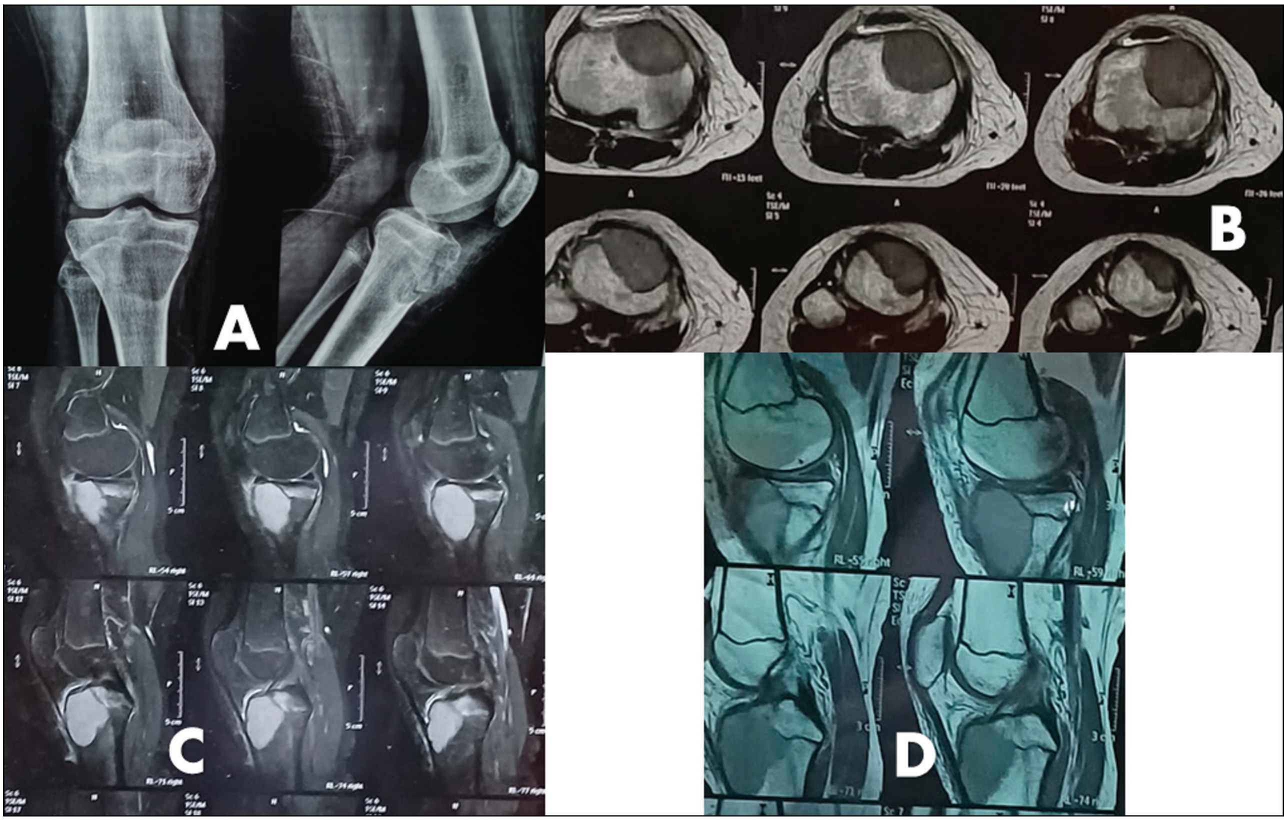
Figure 3 represents the surgical technique we described, starting from curettage and high-speed burr, and then additional electrocautery using monopolar diathermy. Figure 2c shows the complete erosion of the subchondral bone at the central and partially the medial tibial plateau with the only remaining articular

Table 1 Summary of cohort's demographics and outcome

No	Age	Sex	Location	VAS	Age	Follow-up	MSTS score		Complication
1	35	M	PTIB	3	35	60	28	Plate	
2	55	F	PTIB	1	55	37	21	Plate	OA preexisting
3	58	F	PHUM	3	58	48	22	PHILOS	
4	19	M	DFEM	2	19	64	30	No implant	
5	16	F	PTIB	3	16	19	30	No implant	
6	45	F	PTIB	4	45	27	19	Plate	Infected plate
7	26	F	DRAD	1	26	21	29	Plate	
8	22	F	DFEM	3	22	27	28	Plate	
9	39	F	DFEM	2	39	31	29	Plate	
10	42	F	PTIB	2	42	35	26	Plate	
11	40	F	PTIB	2	40	26	25	Plate	
12	31	M	PTIB	3	31	32	29	Plate	
13	27	F	PHUM	1	27	24	24	PHILOS	
14	36	M	PTIB	2	36	29	26	Plate	
15	35	M	DFEM	1	35	38	23	Plate	
16	19	M	PTIB	1	19	25	28	Plate	
17	24	M	DFEM	2	24	29	25	Plate	Lost FU at 29 months
18	26	F	PTIB	1	26	49	26	Plate	

DFEM, distal femur; DRAD, distal radius; F, femail; FU, follow-up; LR, local recurrence; M, male; MSTS, Musculoskeletal Tumor Society score; OA, osteoarthritis; PHILOS, proximal humerus internal locking osteosynthesis system; PHUM, proximal humerus; PTIB, proximal tibia; VAS, visual analog score.

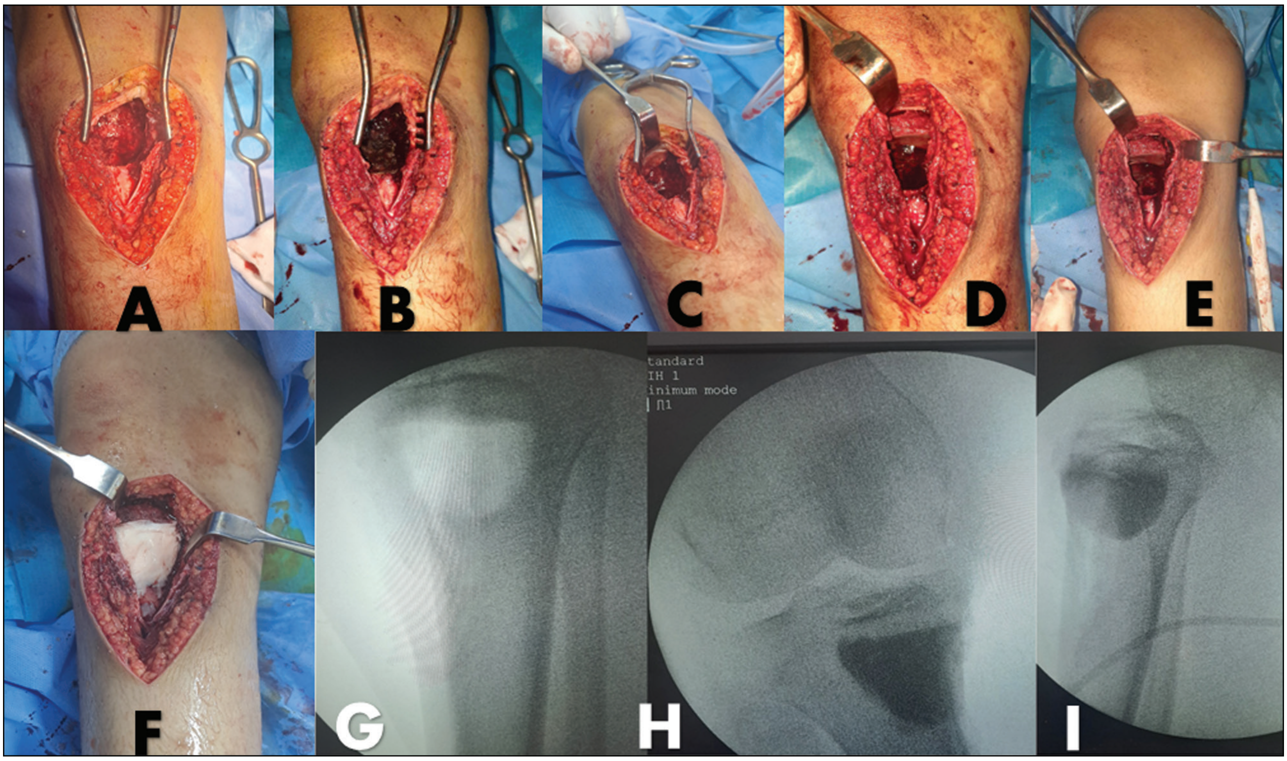
Figure 2



A 16-year-old girl with proximal tibia GCT. (a) Preoperative radiograph. (b) Preoperative axial cuts of T1-weighed MRI images. (c) Preoperative sagittal cuts of STIR-weighted MRI images. (d) Preoperative sagittal cuts of T1-weighted MRI images. GCT, giant cell tumor.

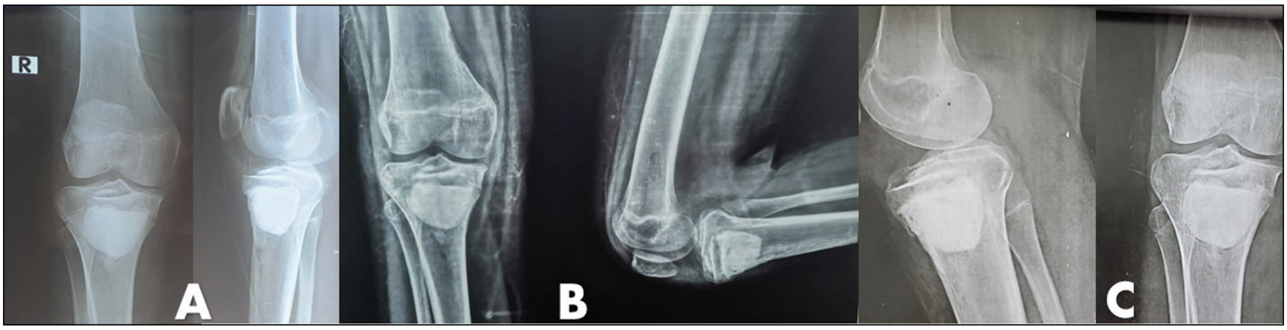
cartilage. Then placement of the graft and stuffing the space with cancellous graft and cementation was performed, in addition to image intensifier shots taken intraoperatively. Figure 4 shows serial follow-up plain roentgenograms till 2 years follow-up with full incorporation of the graft, Fig. 5 shows the clinical pictures of the patient with a full range of motion and full weight bearing.

Figure 3



A 16-year-old girl with proximal tibia GCT. (a) The cavity after curettage. (b) After high-speed burr, lavage, and additional wall electrocautery using monopolar diathermy. (c) This photo shows the articular cartilage with eroded subchondral bone. (d) The strut graft was impacted to the sides just beneath and parallel to the articular cartilage. (e) After stuffing the space immediately under the articular cartilage by the cancellous bone. (f) After cementation, this case did not necessitate internal fixation. (g) intraoperative radiograph after impaction of the graft. (h, i) intraoperative radiograph after cementation. GCT, giant cell tumor.

Figure 4



Postoperative radiograph follow-up. (a) Anteroposterior and lateral views 2 weeks postoperatively. (b) Anteroposterior and lateral views 3 months postoperatively. (c) Anteroposterior and lateral views 1 year postoperatively.

Results

This technique was carried out in 18 patients, with an average follow-up of 34.5 ± 12.8 months (19–64); only one patient was lost to follow-up after 29 months postoperative.

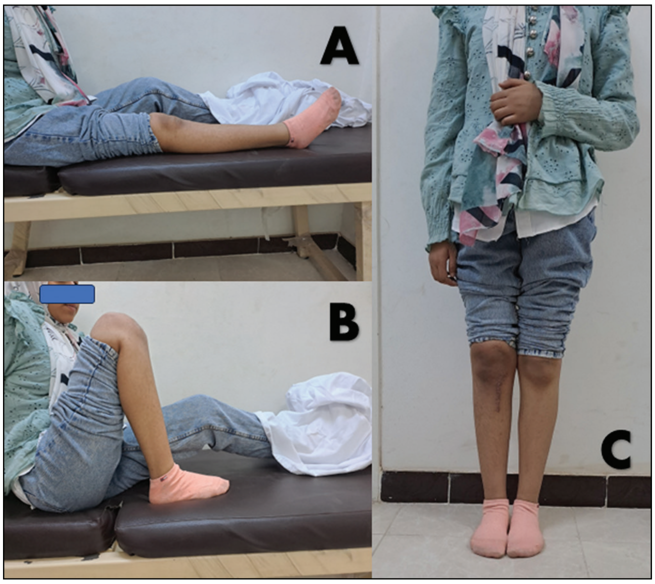
Oncological outcome

No cases had experienced distant metastasis. One (5.5%) patient developed local recurrence after 11 months. The lesion was located in the distal radius. The patient received denosumab and a revision of curettage. He then developed another local recurrence and was treated by resection of the distal radius and fusion of the wrist using an autogenous vascularized fibular bone graft. The second recurrence occurred 7 months after the second curettage, grafting, and cementation.

Nononcological outcome

The average Musculoskeletal Tumor Society score [12] was 26 ± 3.2 (19–30) (86.6%); the function was excellent in 14 (77.8%) cases and good in 22.2%. All cases had graft union; the average union time is approximately

Figure 5



Clinical photographs 8 weeks postoperatively. (a) Full knee extension. (b) Full knee flexion. (c) Full weight bearing.

around the 12th week. The exact time could not be determined, as the graft was firmly impacted into the trough prepared on both sides of the host bone. Even with CT imaging, artifacts from the implant hinder the accurate visualization of the junction site. One patient has preexisting osteoarthritis of the knee osteoarthritis. The pain improved in all cases. VAS had declined from an average of 7 ± 2 to 2 ± 1 in the third week. The pain had returned to the preoperative pattern after 6 weeks and was also comparable to the nonoperated side in cases with preexisting osteoarthritis.

Postoperative rehabilitation program included an immediate passive and active range of motion exercises from postoperative day 1. Partial weight bearing was allowed 2–3 days postoperatively. Full weight bearing was allowed for about 8–10 weeks when pain has totally disappeared.

One patient had a superficial wound infection of the proximal tibia, which was managed by parenteral antibiotics.

Muscle weakening and wasting had been reported in five cases. They were encouraged to undergo a more active exercise and physical therapy course, with subsequent improvement of the muscle power and incomplete improvement of wasting of the muscles.

Follow-up protocol includes local examination, MRI, and plain radiograph every 3 months to look for any sign of recurrence, then every 6 months till the fifth year postoperative, and yearly for future follow-up.

Discussion

GCT is commonly located in proximity to the joints, especially around the knee, in 84–99% within 1 cm from the articular cartilage [6]. This peculiar anatomic predilection in addition to its aggressive local behavior presents obstacles to surgical management.

Preserving the function while performing an adequate oncological removal of the tumor requires a delicate balance. Extended curettage and filling the resultant cavity are currently the standard of care [7,13].

Ebeid *et al.* [3] reported the long-term outcome of 119 patients with a mean follow-up of 13.2 years, following curettage and cementation of GCT around the knee. They concluded that curettage and cementation could be safely used to treat GCT with a possibility of developing a mild degree of osteoarthritis, with no correlation between the development of arthritis and age, sex, pathological fracture, location of the tumor, or presence of recurrence. However, the presence of PMMA cement in close vicinity to the articular cartilage may predispose to several adverse effects, especially osteoarthritis [14,15], which may be attributed to the direct thermal damaging effect of the cement on the articular cartilage, mechanical effect of the articular cartilage, or the toxic effect of some component of the bone cement, that is, MMA which affects the articular cartilage. Furthermore, the difference between the modulus of elasticity of the cement and cartilage is very huge, average of 20 000 MPa for PMMA cement versus 7 Mpa for the articular cartilage [16], which poses a stress riser effect on the articular cartilage and eventually lead to its degeneration and development of osteoarthritis.

However, the study highlighted the concerns regarding the potential adverse effects associated with the proximity of PMMA cement to the articular cartilage. This closeness may predispose individuals to several complications, particularly osteoarthritis.

These findings underscore the importance of understanding the nuances of treatment approaches for GCT around the knee, balancing the benefits of curettage and cementation with the potential risks associated with the presence of PMMA cement near the articular cartilage.

Wechsler *et al.* [2] assumed that removal of the bone cement and autografting may reverse or minimize the effect on the articular cartilage, but they found no statistically significant difference between cases, who had this conversion and those that retain the primary cementation.

Bone grafting alone is still an option, but it is valid only in small-sized lesions, which are not usually the conditions, especially when allografts are unavailable for legal or economic reasons.

Combined autogenous autografts/cement technique has been reported in the literature [17,18]. In this study, we report the surgical technique as well as our results of this technique.

The main advantage of this technique is to benefit from both advantages of bone cement and bone graft while avoiding the hazardous effects of the bone cement on the articular cartilage by applying this technique. Placement of the iliac bone graft as described has many advantages: (a) it provides an insulator to the thermal reaction while the bone cement is settled, because the thickness of the graft prevents the heat transmission to the exposed articular cartilage; (b) fashioning the side trough provides adequate primary stability of the graft to the sides of the lesion which enhances healing; (c) filling the space between the articular cartilage and the strut iliac graft aims to provide support to the articular cartilage using a material with a relatively low modulus of elasticity, which prevent the stress riser effect caused by the significant difference in elasticity between the two materials, namely the cement and the articular cartilage. It is noteworthy that the modulus of elasticity of the cancellous bone is 2.1 MPa, in contrast to cement which exceeds 20 000 Mpa with a very wide gap from that of the articular cartilage 7 Mpa; (d) it allows adequate buildup of the subchondral bone, which would be beneficial in case of recurrence or failure to convert this construct to standard joint replacement instead of tumor endoprosthesis; (e) placement of the crest surface of the graft at the host cortical window made by the surgeon adds more provisional stability and enhance healing of the graft.

Our results are similar to the results published by Wu *et al.* [18,19], who published their records about the combined technique of grafting and cementation in the treatment of GCT around the knee, with a main difference that they split the iliac strut graft, with the utilization of the cancellous portion in a similar technique. We thought that our technique has the advantage of maintaining the mechanical properties of the strut graft and building up thicker subchondral bone with a more efficient heat insulator effect. Their study included 27 patients with an average follow-up of 33 months. They had encountered wound infection in one (3.7%) case and local recurrence in one (3.7%) case. The Musculoskeletal Tumor Society score was 84.6%.

Szalay *et al.* [18] reported the development of degenerative joint changes in seven (19.8%) out of 34 patients after cementation comparable to seven (15.9%) out of 44 patients after grafting at 60 months follow-up. They stated that after 24 months, there was a significant acceleration of degenerative changes in the cemented group.

The strength point of this study is the detailed description of the technique, all procedures were performed by a single surgeon at a single institution, and utilization of the technique in different anatomical locations supports its use in locations other than around the knee, and finally, we included only cases with totally eroded subchondral bones either primarily eroded or that became eroded after curettage and application of a high-speed burr.

Our study has some limitations, first, the relatively small number of cases, second, the heterogenous location with only 16 cases around the knee joint; only one case has a mild osteoarthritis, which is comparable to the other nonoperated knee and osteoarthritis existed preoperatively. Lastly, this study has an intermediate-term follow-up with an average duration of 34.5 ± 12.8 months, while the progression of osteoarthritis probably requires a longer follow-up.

Conclusion

GCT commonly occur close to the joints, particularly the knee, posing challenges to surgical management. The standard approach involves curettage and gap filling; either using bone grafting, cementation, or combined technique. The presence of bone cement close to the articular cartilage can lead to the development of osteoarthritis due to the difference in modulus of elasticity between the cement and the articular cartilage, which fastens the cartilage wear or degeneration. To address this drawback, the combined technique using an autogenous strut iliac bone graft and cement provides support, insulation, and stability, and minimizes the mechanical stress on the cartilage. The early results of this technique are promising and yield good functional and oncological outcomes. Further research is needed to evaluate its long-term efficacy in preventing progressive osteoarthritis.

Author contributions

All authors contributed to the study conceptualization and design. First author: the main surgeon, participate in patient counseling, performed the surgical procedures, followed them up, helped with data collection, and participated with the second author in the primary draft. Second author: supervise surgeries, consult for following the cases up, and participate in the primary draft. Last author was consulted for surgical decision-making, reviewed the manuscript, edited the primary draft, and wrote the final version. All authors read and approved the final manuscript.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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