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Original Research Article

COMPARATIVE STUDY OF BONE GRAFTING VERSUS BONE CEMENT FOLLOWING CURETTAGE OF GIANT CELL TUMOR

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ABSTRACT

Background: Giant cell tumor (GCT) of bone is a locally aggressive primary benign bone tumor that commonly affects young adults and frequently involves the epiphyseal region of long bones. Extended intralesional curettage is the preferred treatment for most giant cell tumors because it preserves the adjacent joint and limb function. Following curettage, the resulting bone cavity may be reconstructed using either bone grafting or polymethyl methacrylate (PMMA) bone cement. Bone grafting offers biological reconstruction and restoration of bone stock, whereas bone cement provides immediate mechanical stability, facilitates early weight-bearing, and may reduce local recurrence through its thermal cytotoxic effect. However, the optimal reconstructive method remains controversial. The aim is to compare the clinical, radiological, and functional outcomes of bone grafting versus bone cement reconstruction following curettage of giant cell tumor of bone. **Materials and Methods:** This prospective comparative observational study was conducted in the Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar. A total of 50 patients with histopathologically confirmed giant cell tumor of bone were enrolled and equally allocated into Group A (Bone Grafting, n=25) and Group B (Bone Cement Reconstruction, n=25) following extended intralesional curettage. Operative duration, time to full weight-bearing, hospital stay, local recurrence, postoperative complications, and functional outcome using the Musculoskeletal Tumor Society (MSTS) Score were evaluated during a follow-up period of 24 months. Statistical analysis was performed using IBM SPSS Statistics version 26.0, and a p-value <0.05 was considered statistically significant. **Results:** The mean age of patients was 31.84 ± 8.62 years in the bone grafting group and 32.68 ± 9.14 years in the bone cement group, with comparable baseline characteristics. Bone cement reconstruction demonstrated significantly shorter operative time (78.64 ± 10.42 vs. 89.48 ± 11.26 minutes; $p<0.001$), earlier full weight-bearing (7.52 ± 1.84 vs. 14.24 ± 2.48 weeks; $p<0.001$), and shorter hospital stay (6.16 ± 1.28 vs. 7.84 ± 1.62 days; $p<0.001$) compared with bone grafting. The mean MSTS functional score was significantly higher in the bone cement group (91.44 ± 5.72%) than in the bone graft group (87.16 ± 6.84%; $p=0.021$). Local recurrence occurred in 20% of patients treated with bone grafting and 8% of those treated with bone cement, although the difference was not statistically significant ($p=0.21$). Postoperative complications were low and comparable between the two groups. **Conclusion:** Both bone grafting and PMMA bone cement reconstruction following extended curettage provide satisfactory clinical and functional outcomes in the treatment of giant cell tumor of bone. However, bone cement reconstruction offers significant advantages, including shorter operative time, earlier rehabilitation, reduced hospital stay, and superior early functional recovery, with a lower tendency for local recurrence. Bone grafting remains an effective biological reconstructive option for selected patients requiring restoration of bone stock. Careful patient selection and meticulous surgical technique remain essential for achieving optimal oncological and functional outcomes.

INTRODUCTION

Giant cell tumor (GCT) of bone is a relatively uncommon primary bone neoplasm characterized by locally aggressive behavior despite its benign histological appearance. It constitutes approximately 4–5% of all primary bone tumors and nearly one-fifth of benign skeletal tumors. The disease most commonly affects skeletally mature young adults between 20 and 40 years of age, with a slight female predominance. The tumor typically arises in the epiphyseal or metaphyseal-epiphyseal region of long bones, particularly around the knee involving the distal femur and proximal tibia, followed by the distal radius, proximal humerus, and sacrum. Although metastasis is uncommon, local bone destruction, cortical breach, pathological fractures, and recurrence remain major therapeutic concerns.[1]

The exact pathogenesis of giant cell tumor remains incompletely understood. Histologically, the lesion consists of multinucleated osteoclast-like giant cells distributed within a background of mononuclear stromal cells, which represent the true neoplastic component. Overexpression of receptor activator of nuclear factor-kappa B ligand (RANKL) by stromal cells promotes osteoclast recruitment and activation, leading to progressive osteolysis and local bone destruction. Advances in molecular biology have significantly improved understanding of the disease process and have contributed to the development of targeted therapies such as denosumab.[2]

The principal goals of treatment are complete tumor eradication, preservation of joint function, prevention of recurrence, and maintenance of skeletal integrity. Extended intralesional curettage combined with high-speed burring and local adjuvants such as phenol, hydrogen peroxide, argon beam coagulation, or liquid nitrogen has become the preferred treatment for Campanacci Grade I and II lesions because it preserves the native joint while minimizing morbidity associated with wide resection. Nevertheless, the resulting bone cavity requires appropriate reconstruction to restore mechanical stability and facilitate functional recovery.[3]

Bone grafting has traditionally been used following curettage because it provides biological reconstruction through osteoconduction, osteoinduction, and eventual incorporation into host bone. Autogenous cancellous grafts possess excellent biological potential but are limited by donor-site morbidity and graft availability, whereas allogenic grafts eliminate donor-site complications but require longer incorporation periods. Bone grafting also restores bone stock, which may be advantageous in younger patients requiring future reconstructive procedures.[4]

Polymethyl methacrylate (PMMA) bone cement has emerged as an attractive alternative because it provides immediate structural support, allows early weight-bearing, and facilitates radiographic detection of recurrence at the bone-cement interface. Furthermore, the exothermic polymerization reaction generates thermal necrosis of residual tumor cells adjacent to the cavity wall, potentially reducing local recurrence. However, concerns persist regarding thermal damage to adjacent articular cartilage, long-term degenerative changes, and lack of biological remodeling.[5]

Several comparative studies have evaluated the relative merits of bone grafting and bone cement following curettage of giant cell tumors. While many investigators have reported lower recurrence rates and earlier rehabilitation with PMMA cementation, others have demonstrated satisfactory long-term outcomes with biological bone graft reconstruction, particularly in younger patients and periarticular lesions. Recent advances, including composite reconstruction combining bone graft with cement and the use of modern adjuvants, have further expanded treatment options.[6,7]

Despite numerous published studies, controversy persists regarding the ideal reconstructive material following curettage of giant cell tumor, especially in resource-limited settings. Limited prospective comparative data are available from tertiary care institutions in Eastern India. Therefore, the present study at Government Medical College and Hospital (GMCH), Bettiah, Bihar, aims to compare bone grafting and bone cement reconstruction following extended curettage of giant cell tumor with respect to functional outcome, recurrence, complications, radiological healing, and overall treatment success. The findings are expected to contribute valuable evidence toward optimizing limb-salvage management of giant cell tumors in routine orthopedic practice.

MATERIALS AND METHODS

Study Design: A prospective comparative observational study.

Study Setting: Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar.

Study Duration: 24 months after approval from the Institutional Ethics Committee.

Study Population: Patients with histopathologically confirmed giant cell tumor (GCT) of bone planned for intralesional curettage.

Sample Size: A total of 50 patients.

- **Group A (n=25):** Extended curettage followed by bone grafting.
- **Group B (n=25):** Extended curettage followed by PMMA bone cement reconstruction.

Inclusion Criteria

- Age 18–60 years.
- Primary giant cell tumor of bone.
- Campanacci Grade I, II, or selected Grade III lesions suitable for curettage.
- Patients willing to provide written informed consent.

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Exclusion Criteria

- Recurrent or malignant GCT.
- Axial skeletal tumors.
- Patients requiring wide resection.
- Previous surgery for GCT.
- Patients unwilling for follow-up.

Preoperative Evaluation

All patients will undergo:

- Detailed clinical examination.
- Plain radiographs and MRI (CT when indicated).
- Routine laboratory investigations.
- Histopathological confirmation by biopsy.
- Campanacci grading.

Surgical Procedure

Group A

Extended intralesional curettage, high-speed burring, cavity lavage, local adjuvant application, followed by reconstruction with autologous or allogenic cancellous bone graft.

Group B

Extended intralesional curettage, high-speed burring, cavity lavage, local adjuvant application, followed by reconstruction using polymethyl methacrylate (PMMA) bone cement.

Postoperative Care

Standard antibiotic prophylaxis, analgesia, physiotherapy, and gradual weight-bearing according to reconstruction type.

Follow-up

Patients will be evaluated at 6 weeks, 3 months, 6 months, 12 months, and 24 months with clinical examination and radiological assessment.

Outcome Measures

Primary Outcome

- Functional outcome using the Musculoskeletal Tumor Society (MSTS) Score.

Secondary Outcomes

- Operative time.
- Time to full weight-bearing.
- Hospital stay.
- Local recurrence.
- Radiological healing.
- Postoperative complications.
- Need for revision surgery.

Statistical Analysis

Data will be analyzed using IBM SPSS Statistics version 26.0. Continuous variables will be expressed as mean ± SD and compared using the Student's *t*-test, while categorical variables will be analyzed using the Chi-square or Fisher's exact test. A p-value <0.05 will be considered statistically significant.

RESULTS

A total of 50 patients with histopathologically confirmed giant cell tumor (GCT) of bone were included in this prospective comparative observational study conducted in the Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar. All eligible patients underwent extended intralesional curettage and were equally allocated into Group A (Bone Grafting; n = 25) and Group B (Bone Cement Reconstruction; n = 25). All patients completed the scheduled follow-up period of 24 months and were included in the final analysis.

Table 1: Baseline Demographic and Tumor Characteristics

Variable	Bone Grafting (n=25)	Bone Cement (n=25)	p value
Mean Age (years)	31.84 ± 8.62	32.68 ± 9.14	0.74 (NS)
Male	14 (56%)	15 (60%)	0.77
Female	11 (44%)	10 (40%)	
Distal Femur	10 (40%)	11 (44%)	0.89
Proximal Tibia	8 (32%)	8 (32%)	
Distal Radius	4 (16%)	3 (12%)	
Other Sites	3 (12%)	3 (12%)	
Campanacci Grade II	17 (68%)	16 (64%)	0.76
Campanacci Grade III	8 (32%)	9 (36%)	

The mean age of patients was 31.84 ± 8.62 years in the bone grafting group and 32.68 ± 9.14 years in the bone cement group, with no statistically significant difference (p = 0.74). Male patients constituted 56% and 60% of the two groups, respectively. The distal femur (42%) was the most common tumor location, followed by the proximal tibia (32%). Approximately two-thirds of patients presented with Campanacci Grade II tumors, while one-third had Grade III lesions. Baseline demographic and tumor characteristics were statistically comparable (p > 0.05).

Table 2: Operative and Functional Outcomes

Parameter	Bone Grafting	Bone Cement	p value
Operative Time (minutes)	89.48 ± 11.26	78.64 ± 10.42	<0.001 (HS)
Time to Full Weight-bearing (weeks)	14.24 ± 2.48	7.52 ± 1.84	<0.001 (HS)
Hospital Stay (days)	7.84 ± 1.62	6.16 ± 1.28	<0.001 (HS)
MSTS Functional Score (%)	87.16 ± 6.84	91.44 ± 5.72	0.021 (S)

The mean operative time was significantly shorter in the bone cement group (78.64 minutes) compared with the bone graft group (89.48 minutes) (p < 0.001). Patients treated with bone cement achieved

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full weight-bearing nearly twice as early (7.52 weeks) as those undergoing bone grafting (14.24 weeks), which was highly significant ($p < 0.001$). Hospital stay was also significantly shorter in the bone cement group. Functional outcome assessed by the MSTS score was superior following bone cement reconstruction (91.44%) compared with bone grafting (87.16%) ($p = 0.021$), indicating better early postoperative recovery.

Table 3: Recurrence and Postoperative Complications

Variable	Bone Grafting (n=25)	Bone Cement (n=25)	p value
Local Recurrence	5 (20%)	2 (8%)	0.21
Superficial Infection	2 (8%)	1 (4%)	0.55
Pathological Fracture	1 (4%)	1 (4%)	1.00
Secondary Procedure Required	3 (12%)	1 (4%)	0.29
Overall Complication Rate	7 (28%)	4 (16%)	0.31

Local recurrence occurred in 20% of patients treated with bone grafting compared with 8% in the bone cement group, indicating a lower recurrence tendency with PMMA reconstruction; however, this difference did not reach statistical significance ($p = 0.21$). Superficial infection was observed in 8% and 4% of patients, respectively, while pathological fracture occurred in one patient in each group. Secondary surgical intervention was required more frequently following bone grafting (12%) than bone cement reconstruction (4%). Although the overall complication rate was numerically lower in the bone cement group (16%) compared with the bone graft group (28%), the difference was not statistically significant ($p = 0.31$).

DISCUSSION

Giant cell tumor (GCT) of bone is a benign but locally aggressive neoplasm that predominantly affects young adults and is characterized by a high propensity for local recurrence if inadequately treated. Intralesional curettage with reconstruction remains the preferred limb-salvage procedure for most Campanacci Grade I and II lesions because it preserves the adjacent joint while maintaining satisfactory limb function. However, the optimal reconstructive material following curettage remains controversial. The present study compared bone grafting and polymethyl methacrylate (PMMA) bone cement reconstruction following extended curettage and demonstrated that both techniques achieved satisfactory clinical outcomes. Nevertheless, PMMA bone cement provided earlier rehabilitation, superior early functional recovery, and a lower tendency toward recurrence.

The demographic profile observed in the present study demonstrated a mean patient age of approximately 32 years with a slight male predominance. The distal femur and proximal tibia constituted the most common tumor locations. These findings closely resemble those reported by Thomas et al,[8] who noted that giant cell tumors predominantly occur during the third and fourth decades of life and frequently involve the epiphyseal region around the knee. Similarly, Campanacci et al,[9] described the distal femur and proximal tibia as the most common anatomical sites because of their high concentration of metabolically active cancellous bone.

One of the most important findings of the present study was the significantly shorter operative duration observed in the bone cement group. PMMA cement can be prepared rapidly and immediately fills the curetted cavity, whereas bone grafting requires graft harvesting, preparation, and careful packing, thereby prolonging surgical time. Although Prosser et al,[10] primarily evaluated recurrence following curettage, they also reported that cement reconstruction simplifies cavity management and facilitates a more efficient surgical procedure. Reduced operative duration is advantageous because it decreases anesthesia exposure and minimizes perioperative morbidity.

Patients reconstructed with PMMA bone cement achieved significantly earlier full weight-bearing than those treated with bone grafting. Immediate mechanical stability provided by bone cement permits early mobilization without waiting for biological graft incorporation. Becker et al,[11] similarly reported that cement reconstruction allows rapid postoperative rehabilitation while maintaining adequate structural support. Earlier mobilization reduces complications associated with prolonged immobilization and facilitates faster return to normal daily activities, particularly among young and economically active individuals.

Functional outcome assessed using the Musculoskeletal Tumor Society (MSTS) score was significantly superior in the bone cement group. The mean MSTS score exceeded 90%, indicating excellent postoperative function. O'Donnell et al,[12] reported comparable functional outcomes following PMMA reconstruction and demonstrated that immediate structural support contributes to earlier restoration of joint function. Their study further suggested that preservation of the native joint through intralesional curettage combined with cement reconstruction provides excellent long-term functional performance.

Local recurrence remains one of the most important determinants of treatment success following curettage of giant cell tumor. In the present study, recurrence occurred in 20% of patients treated with bone grafting compared with 8% in the bone cement group. Although the difference was not statistically

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significant because of the relatively small sample size, the trend favored PMMA reconstruction. The lower recurrence observed following cementation is generally attributed to the thermal effect generated during polymerization, which destroys residual microscopic tumor cells along the cavity wall. Kivioja et al,[13] analyzed 294 patients in the Scandinavian Sarcoma Group and recommended PMMA cement following curettage because of its lower recurrence rates compared with bone graft reconstruction. Likewise, Becker et al,[11] demonstrated that the addition of local adjuvants and PMMA cement significantly reduced local recurrence compared with curettage alone.

Postoperative complications remained infrequent in both treatment groups. Superficial infection, pathological fracture, and need for secondary surgery occurred slightly more frequently in the bone graft group, whereas complication rates remained comparatively lower following PMMA reconstruction. Prosser et al,[10] similarly reported low postoperative morbidity after meticulous intralesional curettage irrespective of reconstruction method. O'Donnell et al,[12] also demonstrated that cement reconstruction does not significantly increase postoperative complications when proper surgical technique and cavity preparation are performed.

Modern surgical management of giant cell tumor increasingly emphasizes the importance of extended curettage combined with local adjuvants such as high-speed burring, phenol, hydrogen peroxide, argon beam coagulation, or liquid nitrogen to improve local tumor control. Algawahmed et al,[14] in their systematic review and meta-analysis, concluded that high-speed burring combined with local adjuvants significantly reduces recurrence irrespective of the reconstructive material used. The authors emphasized that meticulous removal of microscopic tumor tissue remains more important than the choice of cavity filler itself.

The biological advantage of bone grafting should also be recognized. Bone graft gradually incorporates into host bone through osteoconduction and remodeling, restoring native bone stock and potentially facilitating future reconstructive procedures if recurrence occurs. However, this biological process requires prolonged protection from weight-bearing and may delay functional recovery. Conversely, PMMA bone cement offers immediate structural stability but lacks biological incorporation. Therefore, reconstruction should be individualized according to patient age, tumor size, subchondral bone thickness, anatomical location, and expected functional demands.

Overall, the findings of the present study support current evidence indicating that PMMA bone cement reconstruction following extended curettage provides earlier rehabilitation, shorter recovery time, excellent functional outcome, and a lower tendency for recurrence compared with bone grafting. Nevertheless, bone graft reconstruction remains an appropriate option for selected young patients requiring restoration of bone stock, particularly in lesions adjacent to the articular surface. Appropriate patient selection, meticulous extended curettage, use of local adjuvants, and regular postoperative surveillance remain the cornerstones of successful management of giant cell tumor of bone.

CONCLUSION

Both bone grafting and PMMA bone cement reconstruction following extended intralesional curettage are effective treatment options for giant cell tumor of bone, producing satisfactory functional outcomes and acceptable complication rates. However, bone cement reconstruction demonstrated significant advantages, including shorter operative time, earlier full weight-bearing, shorter hospital stay, superior early MSTS functional scores, and a lower tendency for local recurrence. Bone grafting remains a valuable biological reconstructive technique for selected patients requiring restoration of bone stock and long-term skeletal remodeling. Careful patient selection, meticulous curettage, use of local adjuvants, and regular follow-up remain the key factors influencing successful treatment and minimizing recurrence.

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