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Clinical Study on Decalcified Tooth Matrix Combined with Artificial Bone for Repairing Lacunar Bone Defects After Tumor Curettage

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Abstract

Background

Repairing lacunar bone defects following bone tumor curettage presents a common clinical challenge. This study aims to evaluate the clinical efficacy of combining decalcified tooth matrix (DTM) with artificial bone in the repair of these bone defects.

Methods

We analyzed data from 30 patients who underwent tumor curettage and bone grafting with DTM and artificial bone within the past year. Outcomes were assessed based on general health status, surgical complications, local disease control, and bone healing, which was measured using the Extended Lane and Sandu Score (eLSS) scoring system.

Results

The study included 30 patients, comprising 19 males and 11 females, with a median age of 21 years (range: 5–54 years). Tumor locations were as follows: 12 cases in the femur, 7 in the tibia, 3 in the humerus, 4 in the phalanges, 3 in the fibula, and 1 in the ulna. Pathological types included 8 non-ossifying fibromas, 6 bone cysts, 6 enchondromas, 4 fibrous dysplasia cases, 2 chondroblastomas, 2 aneurysmal bone cysts, and 1 each of intraosseous lipoma and hamartoma. The median maximum diameter of the tumors was 4.7 cm (range: 1.2–13.5 cm), with a median follow-up duration of 7 months (range: 3–14 months). No patients required blood transfusions or experienced perioperative complications. There were no observed tumor recurrences during the postoperative follow-up, and limb function remained largely unaffected. Notably, following treatment with DTM and artificial bone, similar healing rates were observed in both the cortical bone area and the bone marrow cavity. The median eLSS score for this patient cohort was 8 points, with scores ranging from 6 to 10 points.

Conclusions

The combination of artificial bone and DTM transplantation represents an effective clinical approach for the repair and reconstruction of bone defects resulting from benign bone tumor resection surgery.

Background

Repairing and reconstructing bone defects is a prevalent issue faced by orthopedic surgeons. Autologous bone transplantation has long been considered the gold standard for bone graft selection due to its superior osteoinductivity, osteoconductivity, and osteogenic potential[1–3]. However, autogenous bone grafting presents several limitations, including increased trauma at the donor site and restricted volume availability[1]. While numerous alternative bone graft materials exist—such as true bone ceramics,

decalcified bone matrix, freeze-dried bone, demineralized freeze-dried bone, bioactive glass, bone marrow aspirate concentrates, and polymer nanocomposites—these materials exhibit varying characteristics concerning osteogenesis, osteoconductivity, osteoinductivity, biocompatibility, mechanical properties, and resorption[2–7]. Moreover, tissue engineering technology holds promise for addressing these limitations in the future[4–6, 8]. However, an ideal bone graft material that meets all clinical requirements has yet to be identified.

Given that no single bone graft material can fulfill all clinical needs, one may question whether the ideal properties can be achieved through a combination of materials. In light of this inquiry, we reviewed existing bone graft options and conducted clinical trials using commercially available materials. Artificial bone produced through inorganic processing is abundant, economical, and readily accessible but lacks bone inductive capability and exhibits limited osteogenic properties[6]. Thus, there is an urgent need to address the challenges associated with artificial bone grafting. Bone Morphogenetic Proteins (BMPs) are well-known for their osteogenic induction capabilities, suggesting that a combination of BMP and artificial bone could yield satisfactory therapeutic outcomes[9]. Demineralized bone matrix is the sole allograft with osteoinductive capacity, enriched with bone morphogenetic proteins (BMPs). Typically, demineralized bone is combined with various substances, including calcium sulfate, bovine or porcine collagen, and bioglass[6]. Decalcified tooth matrix (DTM) is a bone graft material enriched with BMP, making it a theoretically ideal partner for artificial bone.

In this clinical study, we explored the effectiveness of combining DTM with artificial bone (a collagen and hydroxyapatite composite, specifically Gulifang) for filling tumor cavities following benign bone tumor resections. Our retrospective analysis confirms the clinical efficacy of this innovative approach.

Patients and Methods

This study involved the application of combined bone grafting to repair lacunar bone defects in 30 patients treated at the 960th Hospital of the PLA Joint Logistics Support Force between July 2025 and June 2026. Data were collected from patient records, including surgical protocols and postoperative complications. All patients received regular follow-up evaluations to monitor tumor control and assess bone healing. These assessments included evaluations of each patient's clinical condition, proprioception, imaging reexaminations, and bone healing as measured by the Extended Lane and Sandu Score (eLSS) scoring system[10].

Inclusion criteria: (i) Patients diagnosed with benign bone tumors in the extremities. (ii) Patients who underwent tumor curettage and bone grafting surgery. (iii) Bone graft materials utilized included artificial bone (Gulifang) and decalcified tooth matrix (DTM) (Guyousheng). Exclusion criteria: (i) Patients who died from unrelated diseases. (ii) Incomplete clinical, radiographic, and pathological records. (iii) Absence of standardized follow-up data.

Not all benign bone tumors necessitate surgical intervention. In our clinical practice, we consider surgical treatment for benign bone tumors when the maximum diameter of tumor invasion and destruction exceeds

50% of the diameter of the long bones, or if benign tumors have caused pathological fractures. This frequently pertains to enchondromas in the finger and foot bones, as well as bone cysts in the long bones of the limbs. In such cases, we performed tumor curettage followed by bone grafting, sometimes incorporating internal fixation to facilitate fracture healing.

For patients diagnosed with benign bone tumors based on imaging, and where the diagnosis is unequivocal, we do not perform preoperative biopsies. The surgical technique for benign bone tumors is relatively straightforward. During surgery, we determine the extent of the tumor invasion, isolate the soft tissue to expose the bone tumor, and, at times, create a cortical window to access the lesion. Following exposure of the bone tumor, thorough debridement of the tumor is essential; failure to completely remove the tumor may result in recurrence, even for benign tumors. After extensive curettage, we examine the remaining tumor site to ensure no residual lesions are present, and perform pulse pressure irrigation of the tumor cavity. Following treatment of the tumor cavity, we proceed with bone grafting, using artificial bone in strip form and DTM in small particles stored in 75% alcohol. Prior to mixing the two materials, the DTM is rinsed multiple times (typically three or more). The DTM particles are then combined with the strip artificial bone to create a graft that resembles "French fries with white sugar" (Fig. 1). The prepared bone graft material is implanted into the tumor cavity, with slight compression applied to enhance filling. Excessive compression should be avoided to preserve the porous structure of the artificial bone, facilitating effective bone tissue repair. If applicable, replantation of the fenestrated cortex is performed, with the use of internal fixation determined based on tumor location and the patient's bone strength.

All patients underwent X-ray and CT examinations one week postoperatively to assess bone grafting efficacy, as well as to monitor for tumor recurrence and evaluate bone graft healing during subsequent follow-ups. Follow-ups were conducted every three months and included evaluations of wound healing, limb function, and imaging of the surgical site, typically utilizing X-rays. In cases where tumor recurrence was suspected, CT scans were performed for comprehensive assessment. Once bone graft healing was confirmed, asymptomatic patients were advised to have annual follow-up examinations, while any discomfort prompted immediate follow-up. The Extended Lane and Sandu Score (eLSS) was employed to evaluate bone graft healing.

Results

The cohort consisted of 19 males and 11 females, with a median age of 21 years (range: 5–54 years). Tumors were anatomically located as follows: 12 cases in the femur, 7 in the tibia, 3 in the humerus, 4 in the tubular bones of the hands or feet, 3 in the fibula, and 1 in the ulna. Pathologically, the cohort included 8 patients with non-ossifying fibromas, 6 with bone cysts, 6 with enchondromas, 4 with fibrous dysplasia, 2 with chondroblastomas, 2 with aneurysmal bone cysts, 1 with an intraosseous lipoma, and 1 with a hamartoma. All tumors occurred in long bones and grew along the long axis of these bones. Imaging measurements revealed a maximum tumor diameter of 13.5 cm, a minimum of 1.2 cm, and a median of 4.7 cm. The median follow-up duration was 7 months, with a range of 3 to 14 months (Table 1).

Table 1
Demographic data of the patients in the study.

No.	Tumor location	Maximum tumor diameter (mm)	Pathological diagnosis	Pathological fracture	Fixation	Follow-up (months)	eLSS*
1	Humerus	52	Bone cyst	No	No	14	10
2	Tibia	50	NOF	No	No	13	10
3	Fibula	44	Bone cyst	No	No	12	10
4	Ulna	42	Bone cyst	Yes	Yes	10	10
5	Femur	65	NOF	No	No	10	9
6	Tibia	56	Intraosseous lipoma	No	No	10	9
7	Femur	45	Enchondroma	No	No	9	8
8	Humerus	48	Chondroblastomas	No	Yes	9	8
9	Phalanges	32	Enchondroma	No	Yes	9	8
10	Phalanges	12	Enchondroma	Yes	Yes	9	8
11	Tibia	44	NOF	No	No	9	9
12	Femur	56	NOF	No	No	9	8
13	Femur	58	Fibrous dysplasia	No	Yes	9	9
14	Tibia	45	Hamartoma	Yes	Yes	8	7
15	Tibia	51	NOF	No	No	7	9
16	Femur	65	ABC	No	Yes	7	7
17	Tibia	100	Fibrous dysplasia	No	Yes	7	8
18	Femur	30	Chondroblastomas	No	No	7	7
19	Femur	46	NOF	No	Yes	6	8
20	Femur	135	Bone cyst	Yes	Yes	6	7
21	Humerus	64	Bone cyst	Yes	Yes	6	8
22	Femur	120	Bone cyst	Yes	Yes	5	7
23	Tibia	35	ABC	No	No	5	8
24	Phalanges	18	Enchondroma	No	No	5	8

* According to Extended Lane and Sandu Score (eLSS); NOF: non-ossifying fibromas, ABC: aneurysmal bone cysts.

No.	Tumor location	Maximum tumor diameter (mm)	Pathological diagnosis	Pathological fracture	Fixation	Follow-up (months)	eLSS*
25	Fibula	40	Enchondroma	No	No	5	7
26	Femur	36	NOF	No	No	5	8
27	Fibula	24	Fibrous dysplasia	No	No	5	6
28	Femur	54	Fibrous dysplasia	No	Yes	4	6
29	Phalanges	28	Enchondroma	Yes	Yes	3	8
30	Femur	76	NOF	No	Yes	3	6

* According to Extended Lane and Sandu Score (eLSS); NOF: non-ossifying fibromas, ABC: aneurysmal bone cysts.

Seven patients experienced pathological fractures as a result of tumor invasion and bone destruction. Following the curettage of the bone tumors to repair bone defects and address the fractures, internal fixation was employed. Eight patients underwent bone tumor curettage and bone grafting for defect repair; due to severely compromised bone strength, plate fixation was also implemented. Fifteen patients received simple bone tumor resection and subsequent bone grafting. Notably, all patients required no blood transfusions during surgery and experienced no perioperative complications. The median surgical duration was 60 minutes (range: 30–120 minutes), and the average hospital stay was 6.2 days (range: 5–12 days). Postoperative follow-up indicated that there were no instances of local tumor recurrence.

All patients were advised to engage in partial weight-bearing within 3 months postoperatively. Reexaminations conducted in March demonstrated bone graft healing and gradually increased weight-bearing capacity. By 6 months postoperative, all patients were able to bear full weight. During follow-up, imaging assessments were utilized to evaluate the healing of pathological fractures and bone defects treated with grafting. All patients experienced varying degrees of bone graft healing. Postoperative follow-up images for all 30 patients were evaluated by two bone oncologists, who quantified bone healing using the Extended Lane and Sandu Score (eLSS). In cases of score discrepancies, a consensus was reached. The median eLSS for the cohort was 8 points, with a score range of 6 to 10 points.

Notably, we observed that after employing the combined grafting approach with artificial bone and DTM, the healing rates of cortical bone and the bone marrow cavity were similar. Cortical bone demonstrated rapid repair; however, artificial bone without DTM wrapping exhibited slower healing (Fig. 2). This combined bone grafting technique facilitates rapid bone healing in younger patients and proves effective for older individuals, particularly in challenging areas such as the femoral neck (Fig. 3). Additionally, there were no noticeable negative impacts on limb function during follow-up evaluations.

Discussion

As is widely recognized, not all benign bone tumors necessitate surgical treatment. The decision for surgery is primarily influenced by the pathological type of the tumor, its maximum diameter, and the extent of cortical bone damage. For instance, non-ossifying fibromas with smaller lesions typically do not require surgical intervention, as most patients exhibit self-repair of the lesions during follow-up[11]. However, when a non-ossifying fibroma presents with a significant extent of involvement, specifically measuring more than half of the transverse diameter of the affected long bone, the risk of fracture increases substantially, warranting surgical intervention. The standard surgical approach generally involves tumor curettage and bone grafting, with the need for internal fixation assessed on a case-by-case basis. The healing rate following tumor cavity curettage and bone grafting is a critical factor in determining the necessity for internal fixation. In instances where artificial bone is utilized alone, healing tends to be slower, thus indicating that the implementation of internal fixation can be a prudent choice. In our cohort, after combining DTM with artificial bone, we observed faster bone healing; consequently, only 2 out of 7 patients with non-ossifying fibromas required internal fixation plates. Overall, while 7 patients with pathological fractures utilized internal fixation, only one-third of the cohort required it, suggesting that the combination of bone grafting techniques may help reduce the need for internal fixation.

While some studies propose that bone defects following the resection of benign bone tumors can be managed without bone repair[12], many surgeons continue to advocate for the repair and reconstruction of these defects as the preferred treatment option[13–15]. During the tumor curettage and the subsequent reconstruction of bone defects, clinical considerations are of utmost importance. Despite individual surgeon preferences, autogenous bone grafting continues to be regarded as the gold standard due to its significant advantages. Nevertheless, the drawbacks associated with harvesting autogenous bone are considerable. However, the disadvantages associated with harvesting autogenous bone are notable[1, 3]. Researchers have long sought an ideal bone graft material that possesses osteoinductive and osteogenic properties, yet no clinically available artificial or allogeneic bone materials have met these criteria effectively[5, 6]. Calcium phosphate artificial bone has shown a longstanding clinical presence, but its poor bioactivity typically necessitates extended periods for effective bone repair[16]. There are instances where artificial bone fails to achieve healing long after implantation, as evidenced by imaging follow-up revealing the continued presence of artificial bone blocks, emphasizing the limitations of relying solely on such materials for bone grafting (Fig. 4). Decalcified tooth matrix (DTM), derived from discarded human dental structures, presents a viable alternative. Prepared through a unique method of inactivation, it is rich in bone morphogenetic proteins (BMPs), which promote bone growth and facilitate tissue formation, making it a bioactive ceramic with established benefits in alveolar bone repair[9, 17]. In this study, we introduced the combined use of DTM and artificial bone grafting for tumor cavity repair, capitalizing on the strengths of both materials to achieve synergistic osteoinductive and osteogenic effects. Clinical results demonstrated that this grafting approach facilitated rapid healing in both large long bones and short tubular bones, while also minimizing concerns about rejection or disease transmission.

Despite the promise of tumor curettage and bone grafting, objectively evaluating bone healing remains a prevalent clinical challenge. In our study, we employed the Extended Lane and Sandu Score (eLSS) to assess bone repair from multiple dimensions. With a median follow-up duration of 7 months, the median

eLSS score for our cohort was 8 points, indicating both the scientific rigor of our evaluation methodology and the effectiveness of our bone grafting approach in promoting faster healing.

Yet, this study has several limitations that need to be acknowledged. Firstly, the small patient sample size and lack of a control group limit the ability to convincingly compare the results against those obtained from artificial bone grafting alone. Secondly, although varying degrees of bone healing were observed during the median follow-up period, many patients have yet to achieve complete bone regeneration. While complete repair is not the principal focus of this research, the emphasis remains on early, rapid healing. Thirdly, although the combined bone grafting technique offers substantial advantages, the optimal ratio of DTM to artificial bone remains uncertain. Future studies should aim to determine this optimal ratio for improved clinical efficacy and economic benefits. Lastly, it is important to recognize that the favorable bone healing outcomes observed in this cohort result from a combination of benign bone tumor types, thorough tumor curettage, the application of the combined bone grafting method, and, in some cases, the use of internal fixation. Therefore, attributing success to any single factor would be an oversimplification.

Conclusion

In conclusion, the combination of DTM and artificial bone for the repair of lacunar bone defects following benign bone tumor resection is a safe and effective treatment option.

Abbreviations

DTM decalcified tooth matrix

eLSS Extended Lane and Sandu Score

CT computerized tomography

Declarations

Acknowledgements

Not applicable.

Authors' contributions

KZ and WX designed the study. KZ drafted the manuscript. KZ, HC, WX and MX accumulated the data. KZ and QC analyzed the data. All authors read and approved the final manuscript.

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Availability of data and materials

The dataset supporting the conclusions of this article is available on request-please contact the corresponding author.

Ethics approval and consent to participate

We had prior ethics approval from Institutional Ethical Committee of The 960th Hospital of the PLA Joint Logistice Support Force (NO: 2023016) and adult patient consent or child guardian consent (under 16-year old) was obtained for this study. The written informed consent was obtained from all subjects or their legal guardian. The research was carried out according to the principles set out in the Declaration of Helsinki 1964 and all subsequent revisions.

Clinical trial number

Not applicable.

Consent for publication

Each patient or their legal guardian provided informed consent to publish relevant identifying information and images in an online, open-access publication.

Competing interests

The authors declare no competing interests.

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Figures

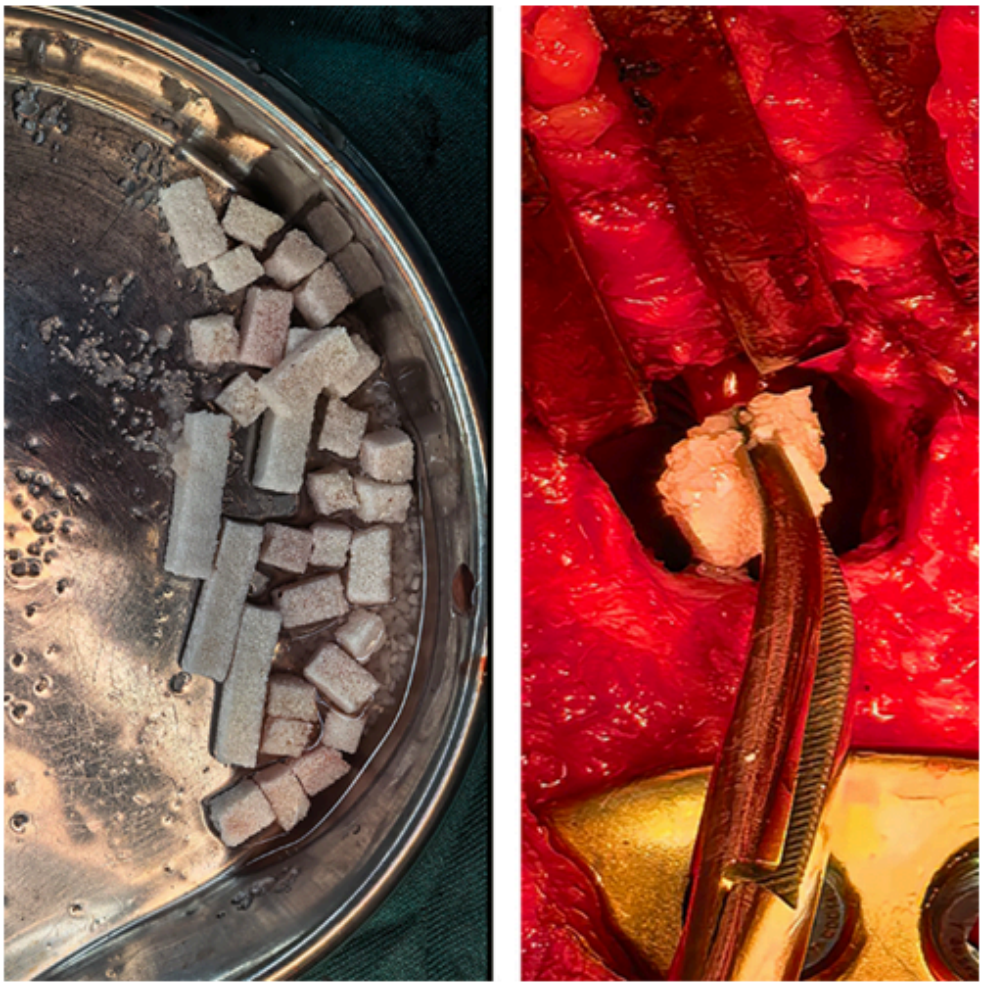


Figure 1

This figure illustrates the combined application of decalcified tooth matrix (DTM) particles and artificial bone strips. The DTM particles are incorporated with the artificial bone strips to form a graft that resembles "French fries sprinkled with powdered sugar."

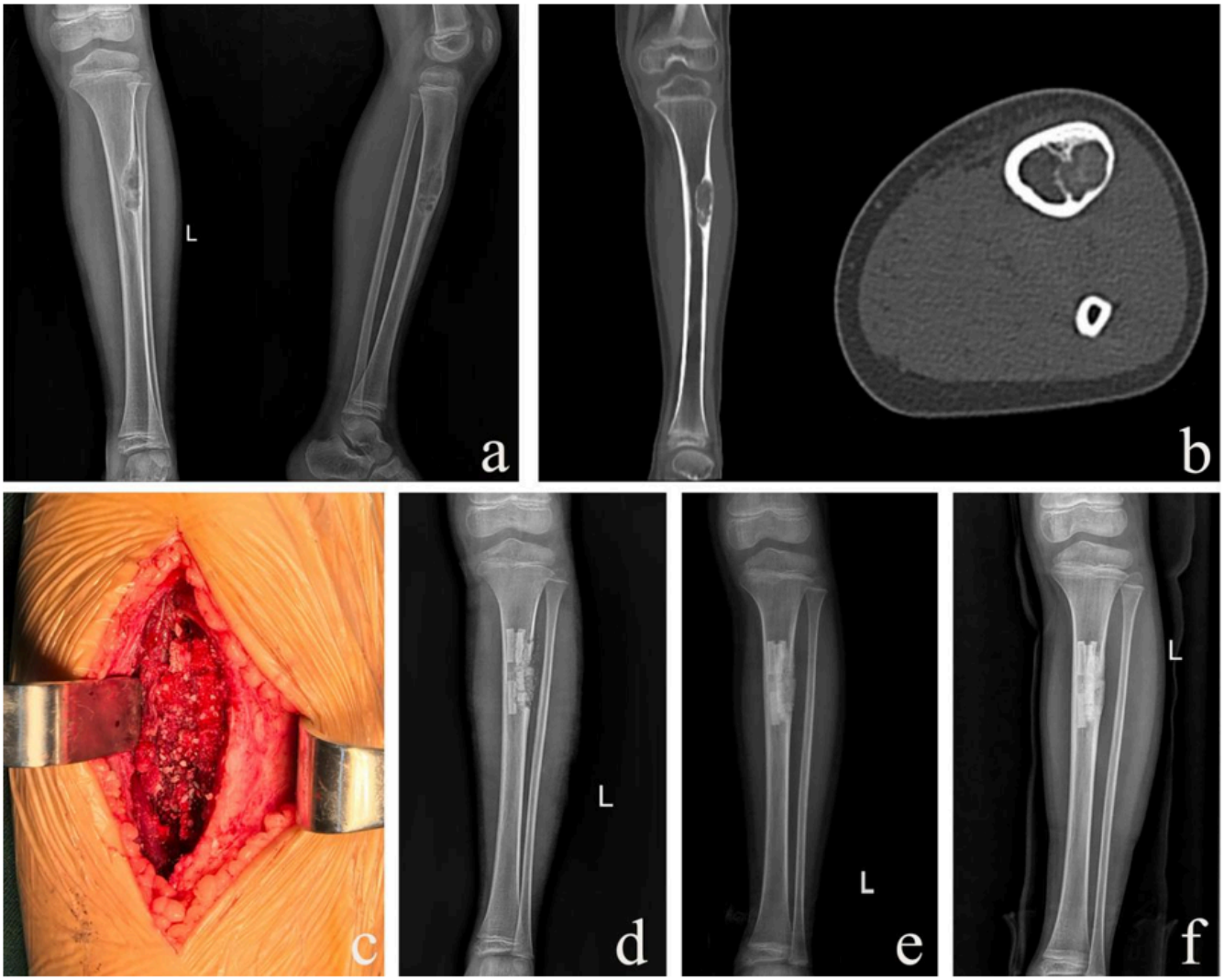


Figure 2

A young girl presented to the hospital with right calf pain persisting for one week. Imaging studies diagnosed her with a non-ossifying fibroma of the right tibia. Due to the tumor's extensive invasion and the presence of pain, the patient underwent tumor resection followed by bone grafting. Postoperative evaluations were conducted. (a) Preoperative imaging revealed clear-margin osteolytic bone destruction in the upper middle segment of the right tibia, accompanied by surrounding sclerosis, consistent with typical findings of non-ossifying fibroma. (b) Computed tomography further clarified the tumor's extent, indicating cortical damage on one side, with a cortical thickness of less than 2 mm, and a tumor volume that exceeded 50% of the normal bone's transverse diameter. (c) Following the tumor resection, the resulting cavity was treated with a combination of DTM and artificial bone grafting. (d) One week post-surgery, imaging indicated the presence of the artificial bone, characterized by small elongated structures, alongside DTM exhibiting granular structures. (e) Three months postoperatively, follow-up X-rays showed that the bone graft had healed well, with the graft area becoming less defined. (f) Six months post-surgery,

X-rays indicated further completion of bone graft repair and the emergence of new cortical bone structures.

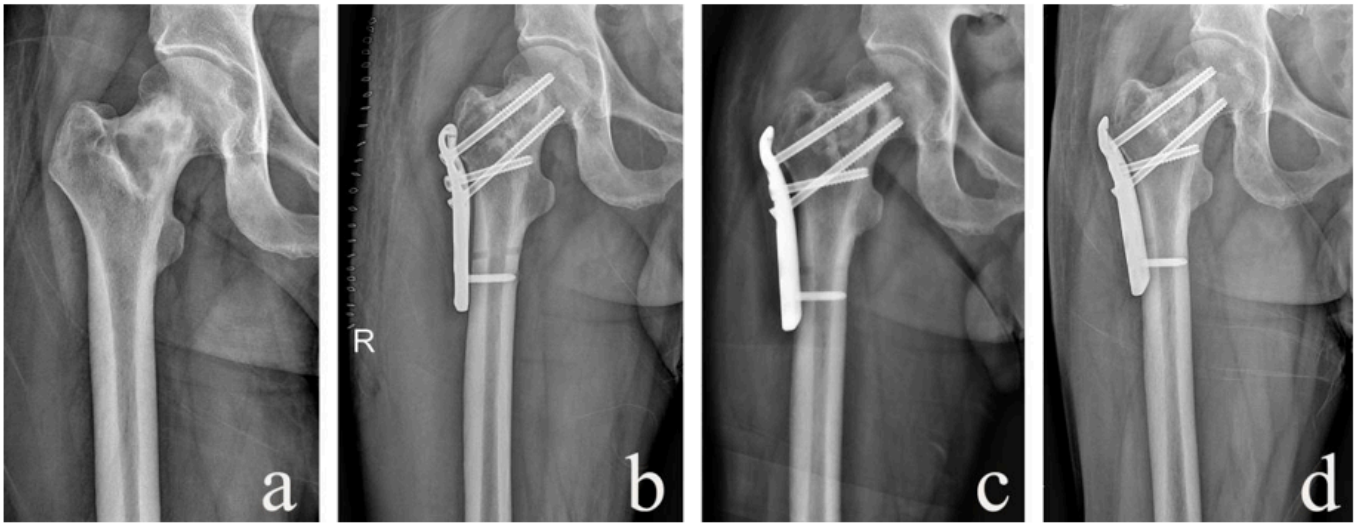


Figure 3

A middle-aged man underwent tumor resection, bone grafting, and internal fixation due to fibrous dysplasia in the right femoral neck. The lacunar bone defect was repaired using a combination of DTM and artificial bone grafting. (a) Preoperative imaging revealed osteolytic bone destruction in the right femoral neck, accompanied by surrounding sclerosis and typical fibrous structural abnormalities. (b) One week post-surgery, imaging demonstrated adequate filling of the bone defect and effective internal fixation. (c) Follow-up X-rays taken three months postoperatively indicated that the bone graft had healed well, with the graft area becoming less distinct. (d) Six months post-surgery, follow-up X-rays showed further completion of bone graft repair..



Figure 4

A young womanunderwent tumor curettage, bone grafting, and internal fixation for fibrous dysplasia of the right tibia. The bone defect was repaired using artificial bone. (a) One week post-surgery, X-ray imaging revealed adequate filling of the bone defect with artificial bone, and the internal fixation was observed to be intact. (b) Three months postoperatively, follow-up X-rays indicated no significant evidence of bone repair. (c) After one year, X-rays showed that the artificial bone had not undergone reconstruction. (d) Two years following surgery, X-ray images still exhibited clear visibility of the artificial bone fragments; however, there was no significant bone repair noted.