Composite ceramic graft in pediatric cavitary benign bone lesions

Ahmad S. Allam

Department of Orthopedic Surgery, Benha University, Benha, Egypt

Correspondence to Ahmad S. Allam, MD, Department of Orthopedic Surgery, Benha University, Benha, Egypt
Tel: +20 111 668 7766/+20 100 868 7733/ +20 122 333 1572;
e-mail: ahmad_allam73@hotmail.com

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Background
In the pediatric age group, filling of some cavitary benign bone lesions (CBBL) may be problematic because of the limited available volume of autogenous iliac bone graft and donor site morbidity. Hence, synthetic materials are becoming an increasingly popular alternative or adjunct to bone graft in such situations.

Patients and methods
A total of 14 CBBL in 13 children (1.5–6.5 years) were managed by local curettage and the application of a composite ceramic bone substitute. The mean size of the cavitary bone lesion was 21.7 cm^2. Patients were followed clinically and radiologically for an average of 39 months (26–51 months).

Results
Patients' function and parents' satisfaction with the procedure were graded as satisfactory end result in all patients. Bone healing (according to Neer *et al.* grading system) was 28.6% type 1, 64.3% type 2, and 7.1% type 3. Graft resorption and incorporation (according to Irwin's staging system) was 35.7% grade II and 64.3% grade III, at the latest follow-up (average 39 months). There were no major early or late postoperative complications.

Conclusion
Composite ceramic bone substitutes are a satisfactory option in the management of pediatric CBBL.

Keywords:
pediatric cavitary benign bone lesions, composite ceramic graft, pediatric, cavitary bone lesions

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Introduction

Autogenous bone graft has the optimal bone healing essential triad: scaffolding for osteoconduction, growth factors for osteoinduction, and osteoprogenitor cells for osteogenesis [1,2]. Interest in avoiding the reported 8% surgical morbidity associated with bone grafting (including the donor site pain, infections, blood loss, nerve injury, and scaring) and the conditions that are associated with massive bone loss (in which the bone graft alone is not suitable for compensation of these defects) has led to the development of many synthetic bone graft substitutes (SBGS) [3,4]. These SBGS are matrices that attempt to simulate the physical and chemical properties of cancellous bone. Realizing that a porous structure is needed to allow extensive invasion by host tissue, porous ceramics composed of hydroxyapatite (HA), tricalcium phosphate (TCP), or both have been most studied extensively. These materials act biologically by the process of osteoconduction [5–7].

Osteogenesis (the process of direct bone formation, which is only present in cells: osteoblasts and osteoblast precursors) follows reabsorption with this class of grafts. The chemical composition and microarchitecture of a synthetic graft profoundly affects its rate of resorption. For example, TCP is resorbed 10–20 times faster than HA [8,9]. Subsequently, it remodels more readily due to its porosity. In contrast, TCP provides significantly less compressive strength than HA. However, after being incorporated and remodeled, the mechanical properties of porous calcium phosphate materials are comparable with cancellous bone. Hence, a combination of TCP and HA may be an ideal choice [10,11]. Composite ceramic graft containing TCP and HA had been used for treatment of many cavitary benign bone lesions (CBBL) with encouraging clinical and radiological results similar to those achieved through autogenous bone grafting [1,2,12,13].

Aim of the study

The aim of the study was to evaluate prospectively the clinical and radiological results of the use of a composite ceramic graft in 13 pediatric cases (14 lesions) with CBBL of various etiologies.

Patients and methods

The material of this prospective study was a random of 13 children who were reviewed and finally diagnosed —

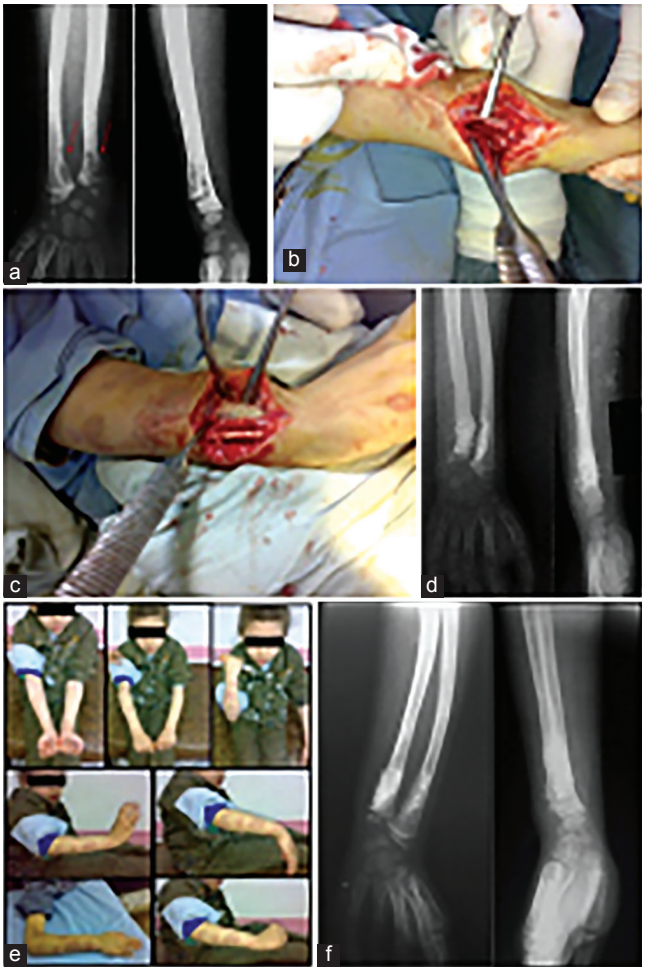
with core-needle bone biopsy — at Benha University Hospitals as having the sum of 14 CBBL. This was carried out during the period between May 2004 and January 2009. The patients' average age was 3.7 years (with a range from 1.5–6.5 years). Only four cases (30.8%) were female patients. All patients were with upper limb affection. All were with monostotic affection except one who had two lesions of ipsilateral distal ends of radius and ulna (Fig. 1a). Dominant side was affected in five patients (38.5%). The different etiology of the CBBL was as shown in Table 1.

Operative decision was decided mainly on the basis of being sizable lesion endangering bone strength (impending fractures) and to a lesser extent because of local pain or swelling. Through the standard surgical approaches and techniques, careful meticulous curettage of the lesions and gentle packing with an appropriate volume of a commercially available FDA-approved composite ceramic graft (which is composed of 65% TCP and 35% HA) was performed. Simple protective bracing was a routine (for 4–6 weeks) depending on lesion's size and location.

Clinical assessment was performed using the musculoskeletal tumor society rating score, MTSR score [14]. Radiological assessment was performed (using the modified Neer *et al.* grading system [15] for union evaluation, Table 2, and Irwin's staging system [16] for graft incorporation, Table 3) at 3, 6, 9, and 12 weeks postoperatively, then every 6 months until the latest follow-up. Patients were followed up for 39 months in average (range: 26–51 months).

A comparison between the above-mentioned results and those of other similar series was made. Statistical comparisons of the data were made using the χ^2 and

Figure 1



(a) Plain radiography for the right wrist in a 4.5-year-old female child with polystotic (total two lesions) fibrous dysplasia of the distal fourth of radius and ulna. (b) Intraoperative photo after curettage. (c) Intraoperative photo after SBGS application. (d) Two months postoperative radiography. (e) Patient's function 2.5 years postoperative (MTSR: excellent). (f) A 2.5 years postoperative radiography (Neer: 2, Irwin: III). SBGS, synthetic bone graft substitutes.

Table 1 Etiology (pathology) of the CBBL in the 13 cases

Diagnosis	Site	*N* (%)
Aneurysmal bone cyst	Proximal humerus	5 (35.7)
Simple bone cyst	Proximal humerus	4 (28.6)
Fibrous dysplasia	Distal end radius	2 (14.4)
	or ulna	1 (7.1)
Eosinophilic granuloma	Midradius	1 (7.1)
Enchondroma	Proximal phalanx, of the index finger	1 (7.1)
Total		14 (100)

CBBL, cavitary benign bone lesions.

Table 2 The modified Neer *et al.* grading system [15]

Grades	Prescriptions
Complete response	The space occupied by the lesion is completely filled with newly formed bone, with remodeling or integration of the bone substitute
Partial response	Small radiolucent areas are seen within the boundaries of the previous lesion, which otherwise demonstrates complete bone filling and remodeling of the graft substitute. With continued radiographic follow-up, no increase in size of the lucencies is recognized over time
Local recurrence	Radiographic lucencies within or adjacent to the prior lesion that enlarge radiologically over time
No response	No radiographic evidence of bony healing after treatment

Table 3 The Irwin's staging system [16]

Stages	Radiolucent zone between the bone cavity and the graft	Intrinsic graft indistinctiveness	Graft margins
I	Present	Distinct	Obvious
II	Indistinct	Indistinct	Hazy
III	Indistinct/ disappearance	Indistinct/ disappearance	Obvious incorporation

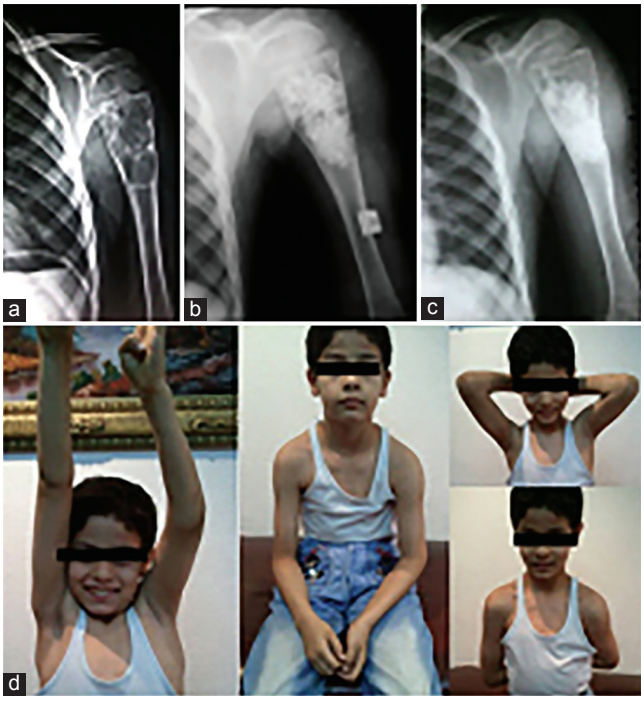
Student's *t* tests. A *P* value of less than 0.05 was considered to be statistically significant.

Results and complications

The initial bone lesions' healing was observed radiologically in 6–11 weeks postoperatively in all cases (100%), as determined by new bone filling and trabiculation across the lesion cavity. This was the primary subjective evaluation, which was supported more by the clinical evaluation regarding disappearance of local pain and tenderness. Subsequent radiography showed progressive increased percentage of graft incorporation (resorption, substitution, and trabiculation) steadily with time. At the latest follow-up, the final evaluation was as follows: clinical assessment (according to the MTSR score) was graded as satisfactory in all patients with 84.6% (11 patients) as excellent and 15.4% (two patients) as good end results. The modified Neer *et al.* grading system for union evaluation showed that four lesions (28.6%) healed as type 1, nine lesions (64.3%) as type 2, and one lesion (7.1%) as type 3. Irwin's staging system for graft incorporation showed nine lesions (64.3%) as type III and five lesions (35.7%) as type II.

Total complications were 14 minor complications (1.07 complication/patient), namely mild temporary limitations of movements of the adjacent joint (four patients: 30.7%, Fig. 2d), which resolved with physiotherapy; low-grade infection with temporary serous wound discharge (three patients: 23%), which resolved quickly with antibiotic therapy; hypertrophic (kelloid) scar in one patient (7.7%); and local recurrence of one aneurysmal bone cyst (7.7%), 4 years postoperative (Fig. 3). Minimal amount of particles of the graft were seen in the soft tissues outside the boundaries of the bone lesion in three cases (23%), with no effect on the final outcome.

Figure 2



A male child, 6.5 years of age, with large aneurysmal bone cyst at the proximal end of his left humerus. (a) Preoperative radiograph. (b) Two weeks postoperative radiography. (c) Fourteen months postoperative radiography. (d) Patient's limited shoulder abduction 2.5 months postoperative. Final MTSR: good, Neer: 1, Irwin: III.

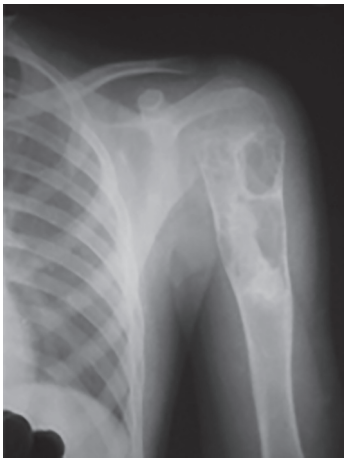
Discussion

In the pediatric age, autograft harvest presents significant comorbidities. In addition, allograft use may be undesirable or refused by the parents. Hence, alternatives to conventional bone graft (CBG) materials are strongly needed. Various materials ranging from coralline, HA, ceramics, growth factors to the trials for using the gene therapy for osteoinduction have been studied as alternatives to autogenous bone graft [17].

Among all types of bone graft substitutes, calcium phosphates have a special position because they are the only materials whose degradation products can be used for new bone formation (Fig. 4). The combination of TCP and HA with its two different resorption rates provides good scaffold for bone formation and remodeling [18].

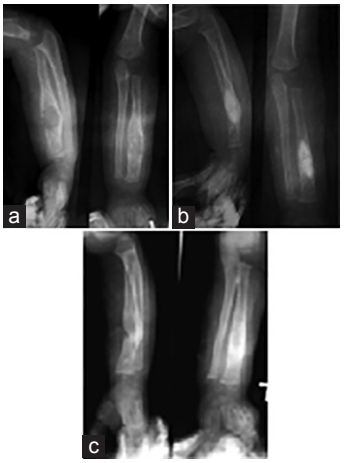
Curettage and bone grafting was considered as the standard treatment for most of the cavitary benign bony lesions with some reported recurrence rates especially for giant cell tumour and aneurysmal bone

Figure 3



Local recurrence 4 years postoperative in an aneurysmal bone cyst (final Neer *et al.* type 3), after complete graft incorporation 3 years postoperative (being at that time: Neer *et al.* type 1 and Irwin type III).

Figure 4



A female child, 1.5 years of age, with large eosinophilic granuloma of her left radius. (a) Preoperative radiography. (b) Three weeks postoperative radiography (a fine powder form of the SBGS was used). (c) Eleven months postoperative radiography (absorption and replacement of most of the graft). SBGS, synthetic bone graft substitutes.

cyst. The results of this study showed no significant difference as compared with those of other similar series treated with conventional bone graft [2,5,17] or those treated with SBGS in combination with bone marrow aspirate [13,18]. In addition, the recurrence rates were comparable. However, the total complication rates were significantly lower in the present series (no donor site morbidity).

The results of the present series showed a significant relationship between the size of the cavitary lesion and the needed time of healing. This opinion is supported by some authors [19] and opposed by others [20].

A final remaining problem is that radiographs comparison is still a matter of interobserver and intraobserver fallacies due to the radio-opaque nature of HA and different rates of its resorption and incorporation according to patient's age, nature and size of lesion, and size of the SBGS particles.

Conclusion

This study (despite being with limited patients' number and intermediate follow-up) has proved that the above-mentioned combination of TCP and HA could be an effective and safe SBGS in most pediatric CBBL with good bone binding capacity, with an accepted minor complication and recurrence rate.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Vaccaro AR. The role of the osteoconductive scaffold in synthetic bone graft. Orthopedics 2002; 25 (Suppl): s571–s578.

2 Schindler OS, Cannon SR, Briggs TW, Blunn GW. Composite ceramic bone graft substitute in the treatment of locally aggressive benign bone tumours. J Orthop Surg (Hong Kong) 2008; 16:66–74.

3 Stevenson S. Biology of bone grafts. Orthop Clin North Am 1999; 30:543–550.

4 Stevenson S, Li XQ, Davy DT. The fate of cancellous and cortical bone after transplantation of fresh and frozen tissueantigen matched and mismatched osteochondral allografts in dogs. J Bone Joint Surg Am 1997; 73:1143–1148.

5 Kelly CM, Wilkins RM, Gitelis S, Hartjen C, Watson JT, Kim PT The use of a surgical grade calcium sulfate as a bone graft substitute: results of a multicenter trial. Clin Orthop Relat Res 2001; 382:42–50.

6 Leunig M, Yuan F, Berk DA. Angiogenesis and growth of isograft bone. Quantitative in vivo assay in nude mice. Lab Invest 1994; 71:300–307.

7 Larry LH. Bioceramics: from concept to clinic. J AM Ceram Soc 1991; 74:1487–1510.

8 Bohner M. Calcium orthophosphates in medicine: from ceramics to calcium phosphate cements. Injury 2000; Suppl 4:37–47.

9 Bohner M, Gbureck U, Barralet JE. Technological issues for the development of more efficient calcium phosphate bone cements: a critical assessment, Biomaterials 2005; 26:6423–6429.

10 Lane JM, Bostrom MP. Bone grafting and new composite biosynthetic graft materials. Instr Course Lect 1998; 47: 525–534.

11 Bauer TW, Muschler GF. Bone graft materials. An overview of the basic science. Clin Orthop Relat Res 2000; 371:10–27.

12 Gazdag AR, Lane JM, Glaser D, Forster RA. Alternatives to autogenous bone graft: efficacy and indications. J Am Acad Orthop Surg 1995; 3:1–8.

13 El-Adl G, Mostafa MF, Enan A, Ashraf M. Biphasic ceramic bone substitute mixed with autogenous bone marrow in the treatment of cavitary benign bone lesions. Acta Orthop Belg 2009; 75:110–8.

14 Enneking, W Modification of the system for functional evaluation in the surgical management of musculoskeletal tumors. *Limb salvage in musculoskeletal oncology.* Enneking W. New York: Churchill Livingston Publishers; 1987; 626–639.

15 Neer CS II, Francis KC, Johnston AO, Kierman HA. Current concepts in treatment of solitary unicameral bone cyst. Clin Orthop 1973; 47:40 –51.

16 Irwin RB, Bernhard M, Biddinger. A. Coralline hydroxyapatite as bone substitute in orthopedic oncology. Am J Orthop (Belle Mead NJ) 2001; 30:544–50.

17 Salyer KE, Hall CD. Porous hydroxyapatite as an only bone graft substitute for maxillofacial surgery. Plast Recons Surg 1998; 84:236–244.

18 Bansal S, Chauhan V, Sharma S, Maheshwari R, Juyal A, Raghuvanshi S. Evaluation of hydroxyapatite and beta-tricalcium phosphate mixed with bone marrow aspirate as a bone graft substitute for posterolateral spinal fusion. Indian J Orthop 2009; 43:234–9.

19 Anker CJ, Holdridge SP, Baird B, Cohen H, Damron TA. Ultraporous beta-tricalcium phosphate is well incorporated in small cavitary defects. Clin Orthop Relat Res 2005; 434:251–7.

20 Siegel HJ, Baird RC 3rd, Hall J, Lopez-Ben R, Lander PH. The outcome of composite bone graft substitute used to treat cavitary bone defects. Orthopedics 2008; 31:754.