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ORIGINAL ARTICLE

Percutaneous injection of calcium phosphate composite in pediatric unicameral bone cysts: a minimum 5-year follow-up study

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Abstract

Background Unicameral bone cyst (UBC) is a common lesion in skeletally immature patients. Multiple treatments are proposed as curettage and autologous bone graft, percutaneous local corticoids injections, decompression with internal fixation, and injection of bioresorbable cement. Decompression, curettage, and percutaneous bioresorbable cement injection showed interesting results, but until now, no long-term follow-up was reported in pediatric patients with UBC.

Methods We retrospectively evaluated 13 pediatric patients with UBC treated with curettage, decompression, and injection of a calcium phosphate composite (CPC) at a single institution with an average F-U of 5.46 years (range 5–7 years). Functional outcomes were evaluated according to the Musculoskeletal Tumour Society (MSTS) Score. Radiographic healing was assessed with the modified Neer Outcome Rating System. Complications were recorded.

Results The mean MSTS score was 29.61 (range 28–30). No joint limitation or any pain was recorded. All patients returned to their previous level of activity. Complete healed cysts were observed in 76.9% of patients (10 of 13) and partially healed in 23.1% (3 of 13). Three fractures of the humerus occurred without any further consequence. In two cases, CPC overflow in the surrounding soft tissues was reported on post-operative X-rays, but at last follow-up, no CPC remained in the soft tissues.

Conclusion Our observations suggest that the use of curettage, decompression, and injection of CPC results in a high rate of good clinical outcomes with low recurrence rates and complications in the pediatric population with UBC at a long-term follow-up.

Keywords Unicameral bone cyst · Calcium phosphate cement · Bone substitute · Pediatrics · Percutaneous injection

Introduction

Unicameral bone cyst (UBC) is a common, benign, intraosseous, fluid filled lesion in skeletally immature patients [1]. The incidence is approximately 1:10,000 children each year and the most common sites are the femur and the proximal humerus [1, 2]. These lesions could be asymptomatic and heal spontaneously or could lead to cortical destruction, spontaneous fractures, symptoms. In many cases, the fracture healing process yields to partial or total consolidation of the cyst. The location and the size of the lesion, the symptoms, growth remaining, and the patient characteristic are key factors to chose the adequate treatment [3–6].

Actually, there is no consensus on the best surgical management. The historical treatment was open curettage and bone graft, but a recurrence rate between 27 and 45% and multiple complications are described [2, 7, 8]. Percutaneous local corticoid injections are proposed as treatment for UBC. The lack of primary stabilization, a high recurrence rate, and the necessity of several injections are the principal limits of this technique [9–12]. Injections of autologous bone marrow showed similar or worse results than corticoid injections [13, 14]. Good clinical results are observed with UBC decompression with internal fixation, but a second surgery for hardware removal is often required [15, 16]. In this context, percutaneous injection of bioresorbable cement should

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immediately improve the bone stiffness to prevent fracture and accelerate healing of the cyst in one-step procedure.

Several liquid injectable and bioresorbable cements are currently available [17]. Calcium phosphate composite (CPC) is an osteoconductive, slowly biodegradable injectable cement. It has been used many times in orthopedics in cases of small bone defects or in spine surgery as an alternative to autograft with good results [18, 19]. Their use in pediatrics is more recent, but the previous publications have reported good surgical outcome of bioresorbable cement injection in unicameral bone cysts [2, 20–23]. However, to our knowledge, no study has established the long-term clinical and radiographic results of local injection of CPC in the treatment of bone cysts through a percutaneous approach in pediatrics.

The purpose of this retrospective study was to evaluate clinical, radiographic results and complications after curettage, decompression and injection of calcium decompression, curettage, and percutaneous CPC injection as a minimally invasive technique for the treatment of pediatric unicameral bone with a minimum of 5-year follow-up.

Materials and methods

All pediatric patients with a presumed UBC treated surgically between January 2005 and December 2011 in our department were retrospectively reviewed. For this study, inclusion criteria were: patients aged less than 18 years; a radiological diagnosis of UBC confirmed by histologic examination treated with decompression, curettage, and percutaneous injection of calcium phosphate composite (CPC); a minimum clinical and radiographic follow-up for at least 5 years. The exclusion criteria were: the presence of hardware that limits the radiographic measurement, recurrence of UBC after a previous treatment.

Pre-operatively after clinical evaluation, all of the patients underwent X-rays of the bone involved to evaluate the UBC and plan the surgery.

UBC were classified into latent or active considering the distance between the cyst and the physis according to Jaffe and Lichtenstein [24, 25]. The distance was more or less than 10 mm were classified, respectively, as latent or active.

Surgical technique

Under general anesthesia, first, the configuration of UBC was confirmed under image intensifier and cyst was percutaneously aspirated using a small bore needle reaching the characteristic straw-colored fluid [23].

Then two wide bore needles were inserted in the UBC and a vigorous lavage with sterile saline serum was performed (Fig. 1). The needles were used also to scrape out gently the internal trabecular structure. The CPC was then prepared and injected through the proximal needle under fluoroscopic guidance until the calcium phosphate composite filled the cyst cavity completely. The distal needle was still in place for any liquid evacuation. In our series, we utilized a CPC composed of 61% alpha-tricalcium phosphate (TCP), 26% calcium-hydrogen-phosphate, 10% calcium carbonate, and 3% hydroxylapatite (Calcibon-Biomet, Wehrheim Germany) [17]. Calcibon is a synthetic, biodegradable, and calcium phosphate based, bone substitute. Overlying soft tissues were closed in a standard layered fashion.

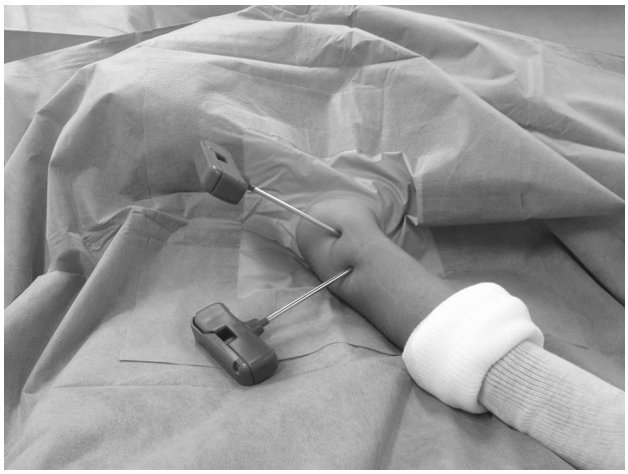

Fig. 1 Per-operative photograph showing the placement of two wide bore needles for a proximal humeral unicameral bone cyst

Upper extremity lesions were protected in a sling, whereas lower extremity lesions were treated with no-weight bearing until structural integrity was sufficient for unprotected activities.

Clinical and radiological assessment

The patients were evaluated by the same examiner with a minimum follow-up of 5 years. Routine evaluation included assessment of ROM, strength, functional status, and X-rays.

Functional outcomes were evaluated according to the Musculoskeletal Tumour Society Score (MSTS score) [26]. In the MSTS system, numerical values (0–5) are assigned to each of the six categories. Categories for lower limbs were pain, function, emotional acceptance of the treatment, walking support, walking ability, and gait. For upper limbs categories were pain, function, emotional acceptance, and hand positioning: dexterity and lifting ability. The maximum total score was 30. The MSTS score was calculated during follow-up examinations.

During the follow-up any complications such as CPC overflow into the soft tissues, fracture, persistence of Cyst,

any abnormal morphological aspect of the bone, wound dehiscence and infection, were recorded.

At the last follow-up, radiological assessment was performed according to the modified Neer Outcome Rating System. Cyst area, cortical thickness, and clinical outcome were considered to rate the cyst as grade I (healed), grade II (partially healed), grade III (persistent), and grade IV (recurrence) [23].

Results

We retrieved 27 patients with UBC, but 12 patients were excluded based on inclusion and exclusion criteria. Of them, three patients were lost to follow-up, ten patients were treated with hardware (8 elastic stable intramedullary nails and 2 plates), and one was excluded a cause of a recurrence of UBC after a previous treatment with another technique. Thirteen patients were included in the study (Fig. 1). The mean age at surgery was 13.46 years (range 9–17), while six were girls and seven boys. The average interval between diagnosis and surgery was 37.9 days. The location of the lesions was the humerus in six cases, the femur in five cases, the calcaneum in one cases, and the tibia in one case. On the pre-operative X-rays, nine cysts were classified as active and three as latent. Calcanear cyst was not classified as active of latent. Two patients presented pathological humeral fractures at the moment of diagnosis. All patients were treated with decompression, curettage, and injection of CPC. The average amount of CPC filled in the bone cyst was 22 ml (range 7–60). The mean hospital stay was 3 days (Fig. 2).

The mean follow-up for all patients was 5.46 years (range 5–7 years). At the last follow-up, the mean MSTS score was 29.61 (range 28–30); in particular, the mean MSTS score for upper limb was 29.33 and 29.87 for the lower limb (Table 1). None of the patient presented joint limitation or any pain. All patients returned to their previous level of activity including sport.

According to modified Neer Outcome Rating System, we observed healed cysts in 76.9% of patients (10 of 13) and partially healed in 23.1% of patients (3 of 13). Partially, healed cysts were observed in three patients that presented a pre-operative diagnosis of active UBC.

Three fractures were reported. Two patients presented pathological fracture of the humeral UBC before surgery. Consolidation and healing of the UBC without other complication was recorded (Fig. 3). Then, a non-displaced fracture of the humerus occurred 2 weeks after surgery and healed with non-operative treatment in 1 month without any further consequence (Fig. 4). In two cases, CPC overflow in the surrounding soft tissues from a cortical breach was observed on post-operative X-rays. No clinical consequence was observed during the follow-up and resorption

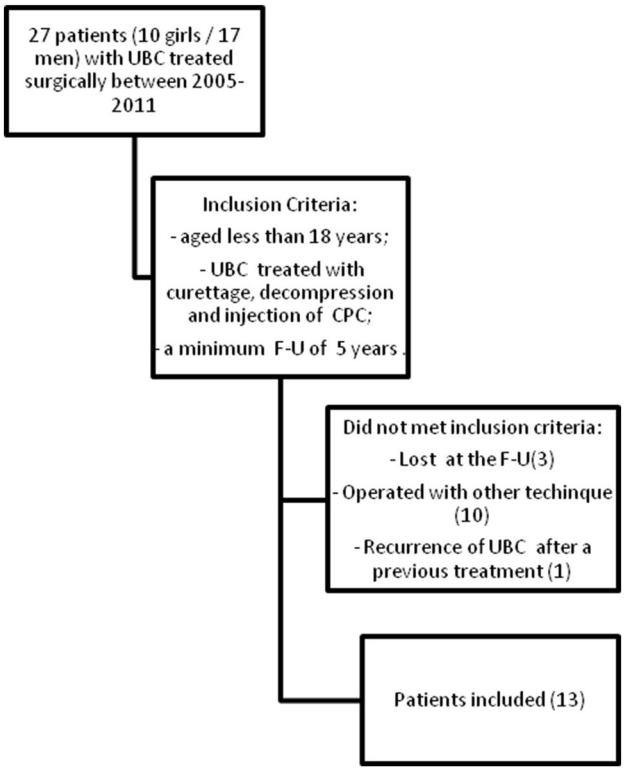

Fig. 2 Flowchart with inclusion and exclusion of study participants. *UBC* unicameral bone cyst, *F-U* follow-up

of CPC outside the bone was faster that in the cyst. At last follow-up, no CPC remained in the soft tissues (Fig. 4). No wound complications or other operative and post-operative complication occurred.

No persistence or recurrence UBC was recorded including active lesions (Table 1).

In all cases, the CPC was partially reabsorbed but still visible on the last X-ray (Figs. 3, 4).

Discussion

UBC is a benign osteolytic cystic lesion that occurs typically in growing children. In 1876, Virchow R described the first case. Historically ‘‘Watchful waiting’’ was considered a valid treatment of UBC based on a good percentage of UBC healing without surgery. It was reported a 14.8% of cyst healed without treatment after cyst fracture [27].

However, Neer et al. observed that 92% of humeral UBC treated conservatively required a secondary surgical treatment. They recommended early surgical treatment to encourage prompt return of normal pediatric activities [8].

The historical gold standard treatment was open curettage and bone graft, but the high recurrence and multiple complications are described. Post-operative pathologic fractures,

Table 1 Patient data

Case	Day diagnosis–surgery	Age at surgery	Sex	Lat.	Cyst site	Active/latent cyst	F-U	MSTS score	Modified Neer Outcome Rating System	Complications
1	91	15	F	L	Humerus	Active	7	30	Healed	Pathological cyst fractured pre-op
2	35	16	M	L	Calcaneum	Not applicable	6	30	Healed	CPC in the soft tissue
3	60	10	M	R	Humerus	Active	6	30	Partially healed	
4	70	12	F	R	Femur	Active	5	30	Partially healed	
5	1	10	M	R	Humerus	Latent	5	30	Healed	
6	45	10	M	R	Humerus	Active	6	28	Healed	CPC in the soft tissue—trauma and post-operative fracture
7	30	14	F	R	Femur	Active	5	30	Healed	
8	35	16	F	L	Humerus	Active	6	29	Healed	
9	20	16	F	R	Femur	Active	5	29	Healed	
10	23	16	M	L	Femur	Latent	5	30	Healed	
11	25	17	F	R	Femur	Active	5	30	Healed	
12	15	9	M	R	Humerus	Active	5	29	Partially healed	Pathological cyst fractured pre-op
13	43	14	M	R	Tiba	Latent	5	30	Healed	

MSTS Musculoskeletal Tumour Society, *CPC* calcium phosphate composite, *F-U* follow-up

growth-plate injuries, morbidity at donor sites, infection, and cyst recurrence were the most important complications described [28].

Percutaneous local corticoids or autologous bone-marrow injections, UBC decompression with internal fixation, curettage, and injection of bone substitute and other surgical treatments of UBC were proposed in literature with widely variable healing rate [9–16].

Good results are described in UBC treated with decompression and elastic stable intramedullary nailing (ESIN). In a prospective long-term study, 47 children with UBC treated with decompression and ESIN were evaluated. 0% recurrence rate was reported. 65.9% UBC were classified as completely healed, and 34.1% UBC were healed with residual radiolucency according to the classification system of Capanna et al. Although ESIN removal was required in 25% of patients [15]. Roposh et al. reported similar clinical results with a 94% success rate (complete healing or partially healed) in 32 patients treated with ESIN and decompression. Recurrence was reported in two patients and a change of ESIN was necessary in nine children (28%) after bone growth [16]. Different studies described treatment of UBC with curettage and injection of bone substitute with good clinical and radiological results. In a clinical study about 24 children with UBCs treated with percutaneous intramedullary decompression, curettage, and grafting with calcium sulfate pellets were revised at a mean follow-up of 21.9 months. They observed a complete healing in 91.7% of patients. One patient (4.2%) demonstrated partial healing and another one (4.2%) no healing. Return to full activities was achieved for all patients [29].

Gentile et al. evaluated 16 children with UBCS treated with curettage, decompression, and injection of a calcium sulfate–calcium phosphate ($CaSO_4$–$CaPO_4$) composite with a mean follow-up of 16 months. UBC healing was described in 93.7% (15 of 16) of patients. Complete and partially healing were observed in 14 and 1 of 16 patients. All 24 patients returned to full activities including sports at the last follow-up [2].

In this report, we show for the first time that the feasibility in terms of clinical and radiographic outcomes after decompression, curettage, and percutaneous CPC injection in pediatric UBC for at least 5 years of follow-up. We observed complete healed cysts in 76.9% of patients and partially healed in 23.1% without recurrence. All patients returned to their previous level of activity. Advantages of this minimally invasive technique are preservation of periosteum and muscle and an efficient decompression and curettage under image intensifier. At the same time having minimal operative risks, almost immediate return to daily activities and good long-term functional and radiographic results.

Several bone graft substitutes are proposed in the literature [30]. The CPC used in our institution was Calcibon in all

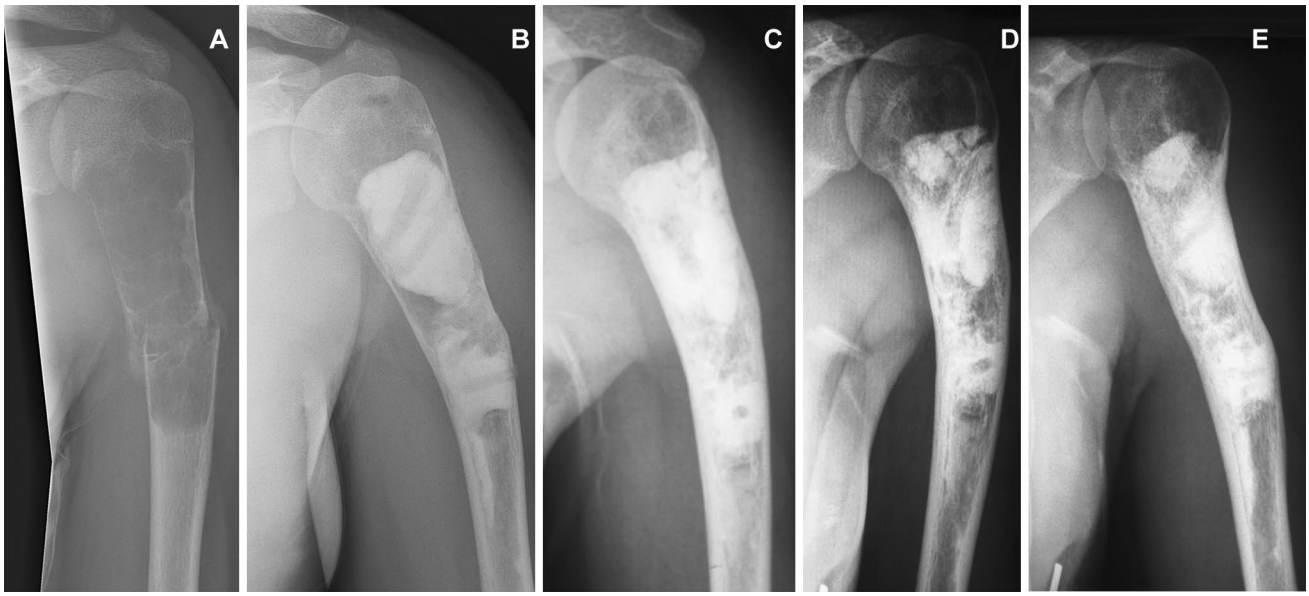

Fig. 3 Pre-operative (**a**), post-operative (**b**), 1-year (**c**), 3-year (**d**), and 5-year (**e**) follow-up X-rays of a humeral UBC with pathological fracture. Cyst healing and partially resorption of calcium phosphate composite were observed

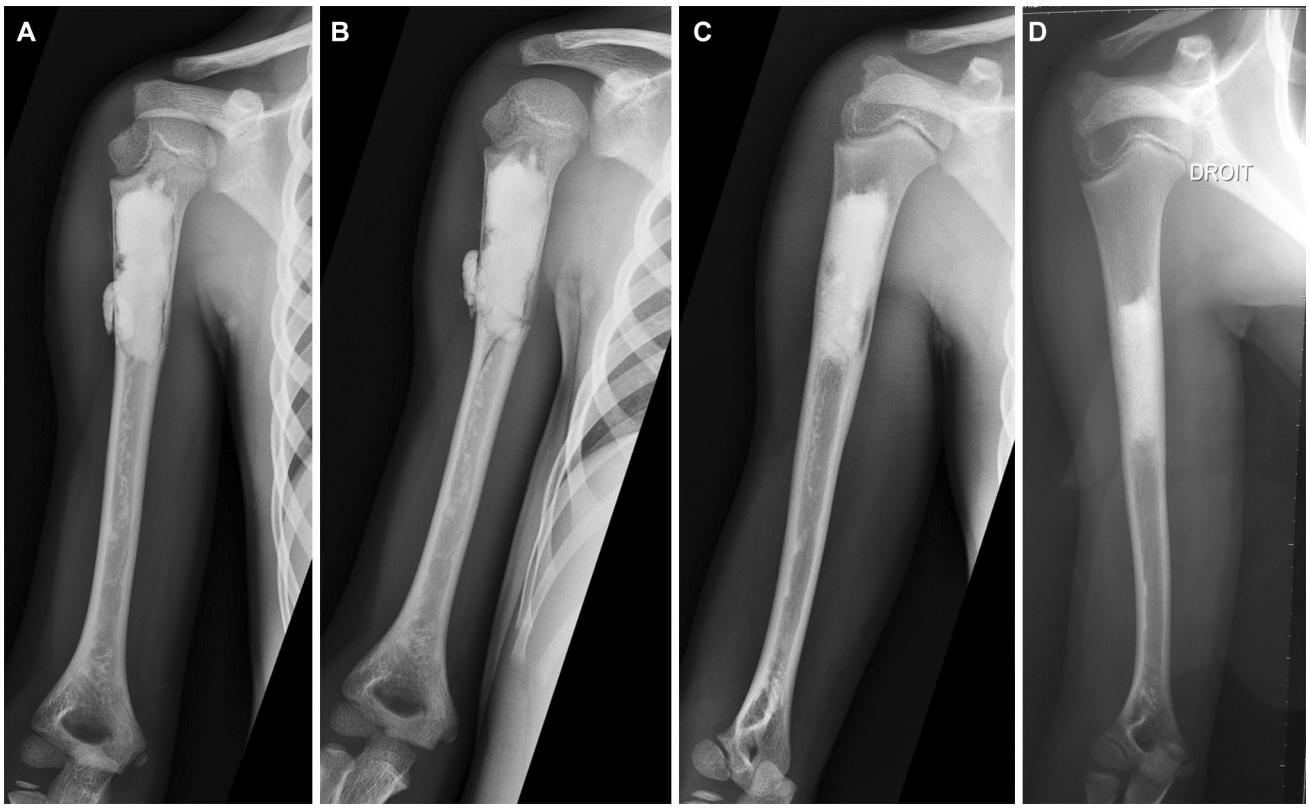

Fig. 4 Post-operative (**a**) X-ray of an UBC of the proximal humerus with CPC overflow in the surrounding soft tissues. After 2 weeks, a non-displaced fracture occurred (**b**). 3-year (**c**) and 5-year (**d**) follow-ups showed complete resorption of CPC in the soft tissue and progressive partial resorption of CPC in the humerus

cases. This is a CPC biodegradable by osteoclastic resorption. Animal studies confirmed an improved osteotransduction capacity without cellular toxicity after 6 months [31–33]. This CPC presents a low porosity, but displays a relatively high compressive strength [17]. CPC allows a direct osseous integration, whereby a slow replacement by normal bone tissue seems possible [31, 34]. For this reason, we observed in all patients the radiographically persistence of CPC at 5-year follow-up. Moreover, no adjacent bone reactions like osteolysis or sclerosis were noticed. The slow reabsorption and the mechanical proprieties of CPC were confirmed also by several studies that utilized this CPC after kyphoplasty of osteoporotic vertebral fractures [18, 19, 34].

This study had limitations. The main limitation is the small size of our series. However, a minimum of 5-year follow-up is long time for a population of children also given the rarity of UBC. Moreover, this study was retrospective without a control group. No biochemical parameters were collected to understand the biological characteristics of UBC [35, 36]. Finally, we did not assess numerically the radiographic incorporation of CPC because of the lack of a defined standardized evaluation of bone graft incorporation radiographically. However, a qualitative evaluation of CPC was performed.

Our 5-year results seem to indicate that decompression, curettage, and percutaneous CPC injection can be used as a potential alternative therapy for UBC in pediatric population. Larger and prospective studies with control groups are needed to confirm our results and to determine which subtypes of UBC are better treated this way.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standard.

Informed consent Informed consent was obtained from all individual participants included in the study.

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