


Is elastic stable intramedullary nail a good choice for pathological fractures of the proximal femur due to simple bone cyst in pediatric population?

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Abstract

Pathological fracture of the proximal femur represents a challenging situation for orthopedic surgeons because of the high risk of non-union, varus union, and avascular necrosis (AVN) of the femoral head. This study aims to investigate the efficacy of ESINs for the treatment of proximal femoral fractures caused by simple bone cysts (SBCs).

All the patients with a diagnosis of proximal femoral fracture secondary to SBC treated with ESINs combined with bone grafting between January 2008 and January 2018, were analyzed retrospectively.

In all, 11 patients were included in the Double ESINs group (5.1 ± 0.8 years, 5 male, 6 female) and 27 patients were included in the Triple ESINs group (9.1 ± 2.1 years, 11 male, 16 female). There was no significant difference between the 2 groups concerning the patients demographic parameters, including sex and affected side. However, the age in the Double group was significantly younger than those in the Triple group ($P < .001$). All patients in both groups displayed excellent outcomes according to the Musculoskeletal Tumor Society Score (MSTS), and there was no significant difference between the 2 groups at a 12-month follow-up evaluation ($P = .10$). As for the Capanna classification (1 + 2), there was no significant difference between these 2 groups ($P = .24$). In the Triple ESINs group, 24 (88.9%) patients were categorized in Capanna 1 and 2, whereas all patients in Double ESINs were Capanna 1 and 2. Overall, the success rate was 92%.

ESINs combined with bone grafting is a successful strategy for proximal femoral fractures caused by SBCs in the pediatric population.

Abbreviations: AVN = avascular necrosis, ESIN = elastic stable intramedullary nail, MSTS = Musculoskeletal Tumor Society, SBC = simple bone cyst.

Keywords: simple bone cyst, proximal femoral fracture, pathological fracture

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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1. Introduction

The proximal femur is among the most common locations of simple bone cysts (SBCs).^[1] Moderate and large lesions with impending or actual fractures usually present with pain, limp, or even inability to walk. As a weight-bearing limb, more aggressive procedures are taken to address the lesions in the proximal femur. Surgical interventions should sufficiently eradicate the lesion to preclude local recurrence and restore the anatomic integrity of the pathological fractures.^[2,3] Pathological fracture of the proximal femur represents a challenging situation for orthopedic surgeons because of the high risk of non-union, varus union, and avascular necrosis (AVN) of the femoral head.^[4,5]

The literature on the treatment strategy of proximal femoral SBCs is limited with variable outcomes.^[3-6] Elastic stable intramedullary nails (ESINs) are preferred choices for SBCs in long bones in many studies.^[7-9] This study aims to investigate the efficacy of ESINs for the treatment of proximal femoral fractures caused by SBCs.

2. Methods

All the patients with a diagnosis of proximal femoral fracture secondary to SBC, treated with either double ESINs or triple ESINs combined with bone grafting between January 2008 and

January 2016, were analyzed retrospectively. The pathological fracture was usually evident; however, the fracture displacement might be minimal. In our study, all the patients presented with SBC had a pathological fracture. Institutional Review Board approval was obtained (No: IORG0003571) on June 1st, 2016. Inclusion criteria were as follows: patients under the age of 14 years old at the time of surgery; bone grafting materials were a mixture of the autologous iliac bone and allogeneic bone. All patients were categorized into 2 groups of patients treated with Double ESINs (n=11) and Triple ESINs (n=27). Exclusion criteria: patients with incomplete medical history or radiographs, and follow-up less than 24 months. All the information was collected from the Hospital Database.

2.1. Surgical technique

No open or percutaneous biopsy prior to the surgery was performed. The diagnosis of SBC was strongly suspected based on its typical imaging characteristics, including X-rays, computed tomography (CT) scans, magnetic resonance (MR) imaging, and the diagnosis was confirmed by postoperative pathological examination.

The insertion of the nails were performed in a retrograde fashion from the lateral and medial aspect of the distal femur at 1 to 2 cm proximal of the physal line. Before the placement of the nails, the lesion was located under the fluoroscopy and a curved incision (part of the Smith-Peterson approach) approximately 4 to 6 cm in length was performed. The cyst wall was breached with a small hemostatic clamp, and then the cyst wall was removed partially by a curet, and the nails were advanced to the site of the lesion. Under the image intensifier guidance, the nails were advanced into the proximal femur and provide stability for the pathological fracture. The position of the tip of ESIN was confirmed by the fluoroscopy. Then a mixture of bone graft was used to fill the cavity. After the surgery, in younger children, a spica cast was used for immobilization for 4 to 6 weeks. In older patients, a plaster splint was used for immobilization of the hip joint for 4 to 6 weeks. Partial weight-bearing was not allowed until the cyst showing consolidation on X-rays (see Figs. 1 and 2). We used triple ESINs in older patients with a large diameter of the intramedullary canal in order to provide robust fixation and de-rotation. We did not remove the nails routinely to avoid recurrence of the cyst.

Anteroposterior (AP) and lateral radiographs of the affected leg were performed on the 1st postoperative day, and at 1 month, 3 months, 6 months, 12 months, 18 months, and 24 months after the surgery. Thereafter, annual out-patient visits were scheduled. All the radiographs were evaluated according to the criteria of Capanna.^[10] Functional evaluation was done with Musculoskeletal Tumor Society (MSTS) scoring^[11]; preoperative and postoperative annual follow-up MSTS scores were obtained. The lower limb parameters, including pain, function, emotional acceptance, supports, walking, and gait, were evaluated for each child. The nails were not routinely removed after the consolidation of the lesions.

2.2. Statistical methods

SPSS statistical package program (SPSS 19.0 version; SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The categorical data were analyzed using the Chi-Squared (χ^2) test, and the continuous data were analyzed using Student *t* test. Fisher

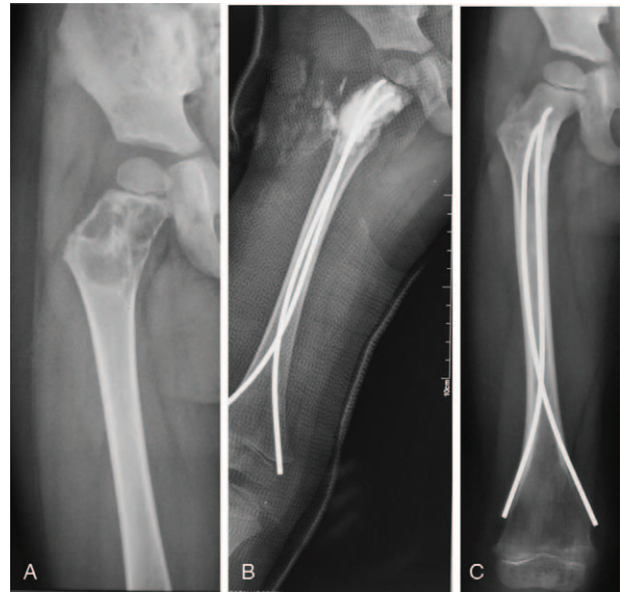


Figure 1. right proximal femoral fracture caused by SBC in a 3-year-old boy is stabilized by Double ESINs A. Preoperative image of right femur B. Postoperative image of right femur treated by double ESINs C. X-ray of the right femur at 24-month follow-up.

exact test was used under those circumstances with fewer subjects in groups of interest. Data were presented as mean \pm SD (range), median (range), or n (%). $P < .05$ was considered significantly different.

3. Results

As shown in Table 1, there were 11 patients in the Double ESINs group (5.1 ± 0.8 years, 5 male, 6 female) and 27 patients in the



Figure 2. Left-sided proximal femoral fracture caused by SBC in a 6-year-old boy is stabilized by Triple ESINs A. Preoperative image B. Postoperative image C. X-ray of the left femur at 13-month follow-up.

Table 1
Demographics of the patients.

Parameters	Double(n=11)	Triple(n=27)	P value
Age(years)	5.1±0.8	9.1±2.1	<.001
Sex			
male	5	11	.77
Female	6	16	
Side			
Left	6	12	.57
Right	5	15	

Double = double ESINs; Triple = triple ESINs.

Triple ESINs group (9.1±2.1 years, 11 male, 16 female). There was no significant difference between the 2 groups concerning sex and affected side. However, the age in the Double ESINs group was significantly younger than those in the Triple ESINs group ($P < .001$).

As shown in Table 2, all patients in both groups displayed excellent outcomes according to MSTs, and there was no significant difference between the 2 groups at the 12-month evaluation ($P = .10$). As for the Capanna classification (1+2), there was no significant difference between these 2 groups ($P = .24$). In the Triple ESINs group, 24 (88.9%) patients were categorized in Capanna 1 and 2, whereas all patients in Double ESINs were Capanna 1 and 2. Overall, the success rate was 92%.

In the Triple ESIN group, 2 patients underwent revision surgery for a varus collapse at 3 months postoperatively. These patients were considerably obese (>50kg), and the reason for failure was early weight-bearing against the surgeons advice. The revision was performed using a pediatric hip plate (PHP). Although the revision surgeries were successful, these 2 cases were still not classified as Capanna 1 and 2 as the result of ESINs. Therefore they were classified as Capanna 3 in this study as a failure. Only one patient in the Triple ESINs group was actually Capanna 3.

As shown in Table 3, all patients in both groups displayed significantly improved clinical outcomes according to MSTs at 6-month and 12-month follow-up even in patients who underwent esins removal, there was no recurrence during the follow-up visits.

4. Discussion

ESINs combined with bone grafting proved to be a successful strategy for proximal femoral pathological fractures caused by SBCs.

Proximal femoral pathological fracture caused by SBC in children represents a challenging problem to orthopedic surgeons because of the high risk of non-union, varus union, and avascular necrosis (AVN) of the femoral head.^[4,5] Effective treatment comprises sufficient curettage and bone grafting of the lesion,

Table 2
Clinical parameters of the patients.

Clinical outcomes	Double(n=11)	Triple(n=27)	P value
Capanna Classification			
1	4 (36.4%)	10 (37.0%)	.94
2	7 (63.6%)	14 (51.9%)	.52
3+4	0 (0%)	3 (11.1%)	.24
1+2	11 (100%)	24 (88.9%)	.24
MSTS Score			
pre-operative	13.9±2.9	15.4±3.3	.19
6th month	64.5±3.1	66.2±3.3	.15
12th month	92.0±1.6	93.0±1.6	.10
Revision	0	2	.34

accurate reduction of the fracture, and adequate and stable fixation with implants.

SBCs occur most commonly in the second decade of life. This group has a heavier body weight, which presents a serious challenge for the implants, especially in the proximal femur. SBCs without fractures or symptoms of impending fractures are usually treated with a less aggressive approach, such as injections of methylprednisolone acetate,^[12] bone marrow aspirate,^[13] and demineralized bone matrix.^[14] Pathological fractures of weight-bearing lower extremities usually require fracture reduction and stabilization by implants.

The etiology and pathogenesis of SBCs are described controversially,^[8] and venous obstruction is the leading cause which is accepted by several authors.^[15,16] Therefore, using ESIN for continuous drainage and continuous decompression of the cyst seems a reasonable choice. Pediatric hip plate (PHP) is a good choice for proximal femoral fractures,^[17] but it usually requires a large incision resulting in longer operative time and increased risk of infection and blood loss. Besides, PHP is not able to provide continuous decompression compared to ESINs. Comparably, ESINs have the advantage of being carried out in minimally invasive fashion and providing relative stability of the fracture after reduction. Moreover, injection of corticosteroids or bone marrow and bone grafting could be performed simultaneously. Many authors have reported using the intramedullary nails without bone grafting for SBCs in long bones, but the healing rate varied in different studies.^[8,16,18,19] Therefore, ESIN combined with bone grafting was adopted at our institute. Only 2 nails could be inserted in the femoral canal in the younger patients, but in combination with the spica cast, the outcome was satisfactory. In older patients, 3 nails were inserted in the femoral canal, but with the protection by a plaster splint instead of spica cast. Varus angulation and non-union are not acceptable in the proximal femoral fracture and must be corrected. Early weight-bearing usually is not allowed in heavier kids in case of varus displacement of the proximal femoral head.

Table 3
Clinical outcomes of the patients.

	pre-operative	6th month	12th month	P1 value	P2 value	P3 value
Double (n=11)	13.9±2.9	64.5±3.1	92.0±1.6	<.001	<.001	<.001
Triple (n=27)	15.4±3.3	66.2±3.3	93.0±1.6	<.001	<.001	<.001

P1 = pre-operative vs 6th month.

P2 = pre-operative vs 12th month.

P3 = 6th month vs 12th month.

The purpose of bone grafting is to provide an osteogenic stimulus to enhance the healing rate of SBCs.^[8] Although autografts deliver a higher rate of complete or partial healing than allografts in the significant defects,^[20] limited sources are frequently encountered in children. Therefore, a mixture of autologous iliac bone graft and allogeneic bone were used as bone grafting material at our institute.

Internal fixation of fracture combined with curettage and bone grafting allows for early mobilization and is associated with a reduced chance of recurrence.^[21] Reports suggest that the internal fixation with curettage delivered better results for pathological fractures than other forms of treatment.^[22,23] Therefore, ESINs combined with bone grafting was used in this study, and the outcomes were satisfactory.

Double nails are standard approach in the application of ESIN for femoral fractures, but in difficult fractures, an additional third or even a fourth nail has been reported.^[24–26] In proximal femoral fracture with the thinned cortex, triple nails pointed at different direction were used to provide better stability. However, its biomechanical analysis remains to be investigated.

There were multiple limitations to our study. Firstly, the sample size was small because we only included the patients with SBCs in the proximal femur; secondly, the follow-up was not long enough; thirdly, indications and treatment selection were based on clinical criteria and physician discretion rather than objective criteria.

5. Conclusion

ESINs combined with bone grafting is a successful strategy for proximal femoral fractures caused by SBCs in the pediatric population.

Author contributions

Conceptualization: Pan Hong.

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Formal analysis: Ruikang Liu.

Software: Ruikang Liu.

Supervision: Pan Hong.

Writing – original draft: Pan Hong.

Writing – review & editing: Jin Li, Saroj Rai, Renhao Ze, Pan Hong.

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