



A comparative study of less invasive stabilization system and titanium elastic nailing for subtrochanteric femur fractures in older children

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The objective of this study was to compare prospectively the complications and the radiographic and clinical outcomes of reverse less invasive stabilization system (LISS) and titanium elastic nailing (TEN) for the treatment of subtrochanteric femur fractures in older children. From April 2004 to February 2012, 52 children aged from 10 to 15 years old with subtrochanteric fractures were included in this study. 26 patients were treated with reverse LISS (LISS group) and 26 children treated with titanium elastic nails (TEN group) respectively. Perioperative care was standardized. Surgical time, blood loss, length of hospitalization, hospital costs, fracture union time, full weight-bearing time and complications were analyzed. The radiologic results as well as hip functional outcomes were evaluated.

The average follow-up time of LISS group was 36.5 ± 9.3 months and TEN group was 40.2 ± 10.6 months. No significant difference between these two groups was found in union time, full weight-bearing time and average length of hospitalization. However, the patients of LISS group had longer operation time (60.0 ± 10.6 min vs. 40.5 ± 7.4 min, $p < 0.01$), more blood loss (130.0 ± 45.0 ml vs. 15.5 ± 10.2 ml, $p < 0.01$), and more hospital costs (25000 ± 700 RMB vs. 10800 ± 500 RMB, $p < 0.01$). The overall complication rate was significantly higher in the LISS group than in the TEN group (12/26 vs. 5/26, $p = 0.039$). There was no significant difference between the two groups in terms of early and late radiological results. Using the Sanders score system, there were 13 excellent, 6 good and 7 fair results in the LISS group compared with 22 excellent and 4 good results in the TEN

group. The excellent and good rate was significantly different between the two groups ($p = 0.010$).

Our results indicated that TEN fixation of subtrochanteric femur fractures in older children was associated with better function scores and a lower overall complication rate when compared with reverse LISS.

Keywords : children ; subtrochanteric femur fractures ; less invasive stabilization system ; titanium elastic nails.

INTRODUCTION

Subtrochanteric fractures of the femur are uncommon injuries in children, with incidences reported to be as low as 4% to 10% of pediatric femur fractures (1). However, the fractures continue to remain a difficult subset of fractures to care for, with

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loss of reduction and nonunion being significant complications. In the past, the treatment of pediatric subtrochanteric fractures contains traction, spica casting, and internal or external fixation (1-9). But in the older child or adolescent, conservative treatment methods such as 90°-90° traction followed by delayed hip spica casting may not be tolerated. Additionally, the unique biomechanical forces about the proximal femur and minimal remodeling potential make these conservative measures less amenable in this subgroup of patients. As a result, acceptable alignment of the fracture may not be attained. Operative management of pediatric subtrochanteric fractures is recommended for children with age older than 10 years (1-4,8).

Although previous studies have shown that the use of dynamic compression plate or reconstruction plate or titanium elastic nails (TEN) for subtrochanteric fractures of the femur in older children resulted in good outcomes (2-4,8), there is no consensus regarding the optimal fixation of these injuries. The authors in this study believed that reconstruction plate or compression plate did not fit perfectly with the anatomy of proximal femur. Over-molding of the plate might reduce the biomechanical strength of steel. Therefore in this study we used less invasive stabilization system (LISS) which was more in line with the proximal femoral anatomical characteristics. Furthermore, there have been no studies emphasizing the treatment of children older than 10 years of age who sustain subtrochanteric femoral fractures. The purpose of this study was to compare the complications and the radiographic and clinical outcomes of reverse LISS and TEN for the treatment of subtrochanteric femur fractures in older children. It was also the goal to increase awareness of the two methods of fixation available for the treatment of these fractures in children older than 10 years and, where possible, to make specific recommendations.

MATERIALS AND METHODS

Patients' Data

After approval from Institutional Review Board of our hospital, in accordance with the inclusion criteria and

exclusion criteria, fifty-two consecutive children with subtrochanteric fractures were treated with reverse LISS (LISS group, 26cases) or titanium elastic nails (TEN group, 26 cases) respectively at our hospital between April 2004 and February 2012. The inclusion criteria were : (1) age from 10 to 15 years, (2) fresh closed fractures (within seven days from injury), (3) unilateral femoral fractures, (4) Seinsheimer type II or type III fracture. The following patients were excluded : (1) ipsilateral or contralateral lower limb fractures and/or dislocation, (2) pathological fractures, open fractures, or comminuted fractures, (3) combined with nerve or vascular injury, (4) metabolic bone disease, previous ipsilateral lower limb surgery, or mental illness. At admission, the treatment method was chosen at random by drawing from the box containing an equal number of envelopes with either of the methods. The parents of the children were informed of the study, and an informed consent was obtained from each of them before the operation.

Unlike adults, we defined a subtrochanteric femur fracture as a fracture that was located within 10% of the total femur length below the lesser trochanter (3). The first available postoperative full-length anteroposterior femur radiograph was used to determine the total length of the femur, which was defined as the distance between the top of the femoral head and the medial femoral condyle. Next, the distance between the inferior aspect of the lesser trochanter and the fracture site was measured. If this distance was $\leq 10\%$ of the total length of the femur, the fracture was classified as subtrochanteric. The two groups were comparable in terms of gender, age, body weight, fracture side, fracture type, causes of injury, associated injuries, time from injury to operation and duration of follow-up ($p > 0.05$). The patient demographics and fracture characteristics were shown in Table I.

Surgical procedures

Patients in the LISS group were treated under a direct lateral approach. Minimal soft tissue dissection and periosteal elevation were done. Manual reduction and distraction was attempted for reduction, correction of angulation and restoration of length. A distal femoral LISS reversely was the choice for fixation in all of the patients and some screws of plate proximal end were inserted into the femoral neck. No casts were used postoperatively. If no associated injuries were present, passive rehabilitation and physical therapy were begun 72 hours postoperatively. Ambulation was kept non-weight-bearing until radiographic and clinical evidence of fracture healing were

Table I. — Patient demographics and fracture characteristics between two groups

Characteristics	LISS	TEN	p
Mean Age (yrs)	12.2 (range, 11-15 SDS, 2.5)	11.6 (range, 10-15 SDS, 2.0)	0.344
Gender (male: female, n)	11:15	9:17	0.569
Body weight (kg)	36.2 ± 11.5	35.0 ± 10.2	0.692
Fracture side (left: right, n)	16:10	11:15	0.165
Fracture type (Seinsheimer II: III, n)	20:6	18:8	0.532
Cause of injury (road accident: fall, n)	11:15	17:9	0.095
Associated injury (yes: no, n)	7:19	5:21	0.510
Time from injury to operation (d)	4.0 ± 3.0	4.5 ± 2.5	0.517

present at which time, the patient was allowed to progressively advance their weight bearing.

All of the surgeries in the TEN group were performed on a radiolucent table and two retrograde TENs were used. Nail diameter was measured 40% of the narrowest diameter of the diaphysis. An incision was made 2.5 cm proximal to the distal lateral femoral metaphysis and the subcutaneous tissues were dissected. A starting hole was placed by an awl. A slight bend was placed in the distal end of the nail to facilitate the passage of the nail beyond the far cortex and to facilitate fracture reduction. The appropriately sized nail was placed in the starting hole, and the intramedullary position was verified using fluoroscopy. The lateral nail was advanced across the fracture site and placed into or just distal to the greater trochanteric apophysis depending on an intraoperative assessment of fracture stability. Next, a medial incision was made, and an equally sized nail was placed. The medial nail was advanced into the femoral neck, directed toward the femoral head until it stopped short of the proximal femoral physis (approximately 1 cm). Both nails were trimmed, allowing 1 cm to protrude from the distal lateral cortex. In all cases, one and a half hip spica cast was applied for four weeks. Other rehabilitation process was the same as the LISS group.

Outcome measurement and Data collection

For data collection the operative time was defined as the time from the skin incision to skin closure. Fracture union was defined as the absence of pain and the presence of bridging callus in three of the four cortices seen on the anteroposterior and lateral radiographic views of the femur. Also recorded were the blood loss, length of hospitalization, hospital costs, full weight-bearing time and postoperative complications. Limb-length discrepancy

(LLD) was determined by radiological examination at the last visit. Nails and plates were removed when the fracture line was no longer visible radiographically, which was typically six to nine months after operation. At each postoperative follow-up visit, antero-posterior and lateral radiographs were specifically analyzed by the same two surgeons (SLJ and WZP). The early (the second day after surgery) radiologic outcomes were categorized as satisfactory or unsatisfactory, using the criteria described by Beaty (9). For children 8 years or older, a satisfactory outcome was defined as shortening of ≤ 1.5 cm, no lengthening, coronal angulation of $\leq 5^\circ$, and sagittal angulation of $\leq 10^\circ$. The late (two years after surgery) radiologic outcomes were classified as satisfactory or unsatisfactory according to the criteria described by Theologis (4). A satisfactory outcome included a limb-length discrepancy of ≤ 1 cm, normal clinical alignment, and radiologic angulation of $\leq 10^\circ$. Other outcomes were recorded as unsatisfactory. Hip function was assessed using the Sanders scoring system (10), which evaluated patients on a 60-point scale regarding pain (10 points), walk (10 points), function (10 points), exercise and strength (10 points), daily activities (10 points) and x-ray assessment (10 points). Function of the joint was classified as excellent (55 to 60 points), good (45 to 54 points), fair (35 to 44 points) or poor (< 34 points).

Statistical analysis

Statistical analysis was performed using SPSS software, version 11.0 (SPSS, Inc., Chicago, IL, USA). The patient demographics (sex, injured side, causes of injuries, associated injuries, postoperative complications and radiologic outcomes) and fracture characteristics of the two groups were compared using the Pearson's chi-square test for nonparametric categorical variables.

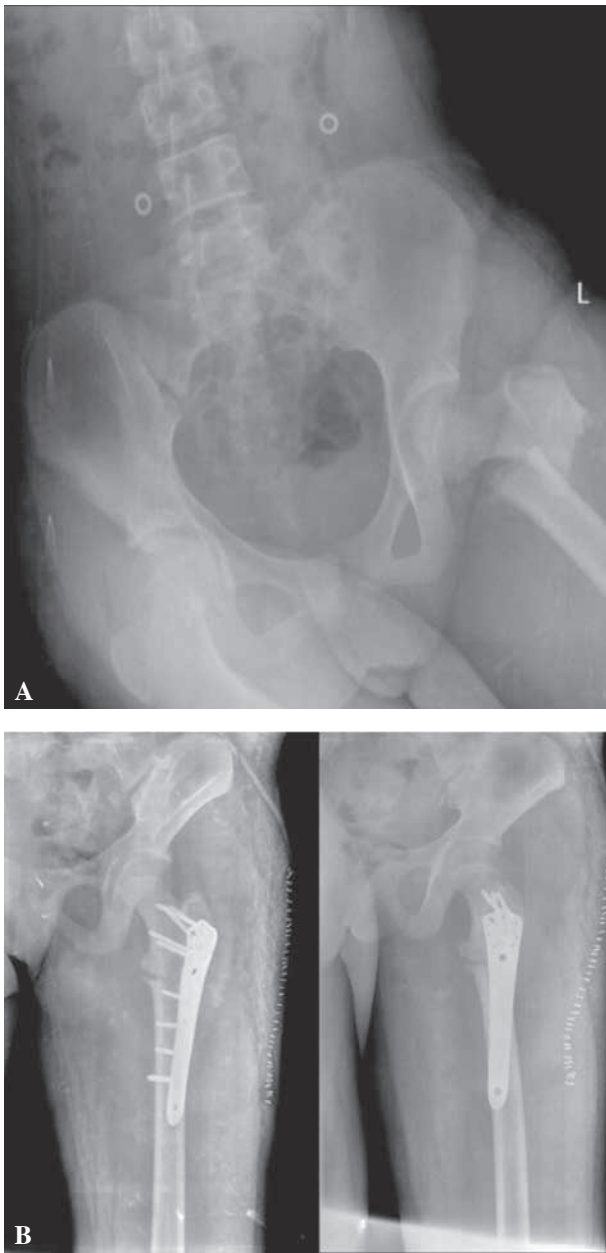
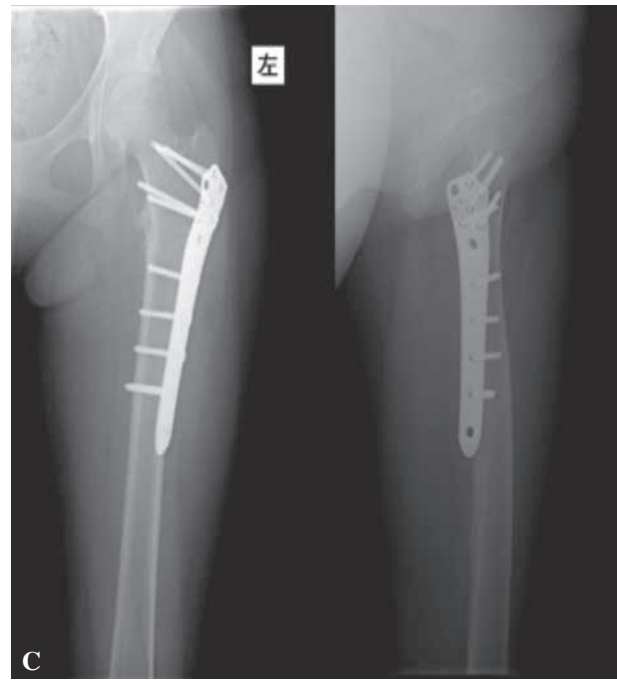


Fig. 1. — (A) A 10-year-old boy with Seinsheimer II subtrochanteric femur fracture. (B) Open reduction and reverse LISS fixation was performed. Three days after operation X-ray film showed a good alignment of the fracture. (C) Four months after operation X-ray film showed a complete healing of the fracture.

Independent sample t test was used to compare the patients' age, body weight, time from injury to operation, operation time, blood loss, length of stay, hospital costs, duration of follow-up, bone healing time, full weight-



bearing time, and score of Sanders. The level of significance was set at $p < 0.05$.

RESULTS

The mean period of follow-up in the LISS group was 36.5 ± 9.3 months (range 26-44), while in the TEN group it was 40.2 ± 10.6 months (range 23-48) ($t = 1.338$, $p = 0.187$). There was no incidence of infection or implant failures in either group. No significant difference between these two groups was found in union time (10.5 ± 3.5 weeks vs. 9.2 ± 3.0 weeks), full weight-bearing time (11.6 ± 2.4 weeks vs. 10.6 ± 2.5 weeks) and average length of hospitalization (6.5 ± 4.4 days vs. 8.2 ± 4.6 days). However, the patients of LISS group had longer operation time (60.0 ± 10.6 min vs. 40.5 ± 7.4 min, $p < 0.01$), more blood loss (130.0 ± 45.0 ml vs. 15.5 ± 10.2 ml, $p < 0.01$), and more hospital costs (25000 ± 700 RMB vs. 10800 ± 500 RMB, $p < 0.01$). The occurrence of persistent pain of incision in the LISS group, 30.8% (8/26), was significantly higher than in the TEN group, 3.8% (1/26). In the LISS group, one patient was overgrowth with a LLD of more than 1.0 cm and four children with a LLD of less than 1.0 cm. In the TEN group, two

Table II. — Comparison of postoperative complications between two groups

	LISS	TEN	p
Infection	0	0	1
Incision pain	8	1	0.028
Implant failure	0	0	1
Angulation	1	4	0.347
Rotational deformity	0	0	1
LLD	5	2	0.416
Delayed union	0	0	1
Nonunion	0	0	1
Total complications	12*	5*	0.039

*Two patients had more than one complication.

patients were overgrowth with a LLD of 1.0 cm or more. The overall complication rate was significantly higher in the LISS group than in the TEN group (12/26 vs. 5/26, $p = 0.039$) (Table II). There was no significant difference between the two groups in terms of early and late radiological results (Table III). Using the Sanders score system, there were 13 excellent, 6 good and 7 fair results in the LISS group compared with 22 excellent and 4 good results in the TEN group. The excellent and good rate was significant difference between the two groups ($p = 0.010$) (Table IV).

DISCUSSION

Few studies in the orthopedic literature are dedicated to the management of subtrochanteric fractures in older children, and there is no consensus regarding the mainstay of treatment. It has been recognized in the literature that femur fractures occurring in the subtrochanteric region present unique problems in fracture management (2,4). This is caused by a limited capacity to compensate for malalignment in this region and the strong deforming muscle forces pulling the proximal fragment into a flexed, abducted, and externally rotated position causing difficulty in maintaining fracture reduction (2,4). Another confounding factor for fractures in this region is the varied fracture patterns, such as long oblique and spiral fractures, that make careful treatment selection important in obtaining a successful outcome.

Table III. — Radiologic outcomes of both groups

	LISS	TEN	p
Early outcomes			
Satisfactory	26	23	0.235
Unsatisfactory	0	3	
Late outcomes			
Satisfactory	25	24	1
Unsatisfactory	1	2	

Surgical fixation offers the advantage of simple nursing care and earlier mobilization, and has become a better alternative for the treatment of subtrochanteric fractures in older children (1-4,8). The advantages of plate fixation include anatomical reduction of fractures and less interference to hip function. In this study, we used LISS which was more in line with the proximal femoral anatomical characteristics. Lateral femoral condyle of older children is similar with the shape of femoral greater trochanter, therefore LISS is also consistent with the anatomical structure of proximal femur. For the physiological femoral bending forward, it can be solved by using the LISS reversely (7,11). Biomechanical study also showed that the strength of LISS constructs could satisfy the biomechanical requirements of proximal femoral fractures fixation (12,13). In the LISS group, no patients showed malalignment and implant failure which further confirmed the effectiveness of LISS.

Neither in the LISS group nor in the TEN group was the blood supply to the fracture site or the environment of the fracture site significantly damaged in any objective way. The minimal iatrogenic damage of LISS did not appear to interfere with callus growth. Therefore, the average union time and full weight-bearing time of the two groups were of no significant difference. Interestingly, the patients of LISS group had longer operation time, less blood loss, and more hospital costs. The reason was that open reduction and screw fixation technique in the LISS group needed more time and caused more bleeding. In addition, elastic nail was less expensive than LISS.

As for complications, the overall incidence of complication in the LISS group was significantly higher than that in the TEN group ($p = 0.039$). We

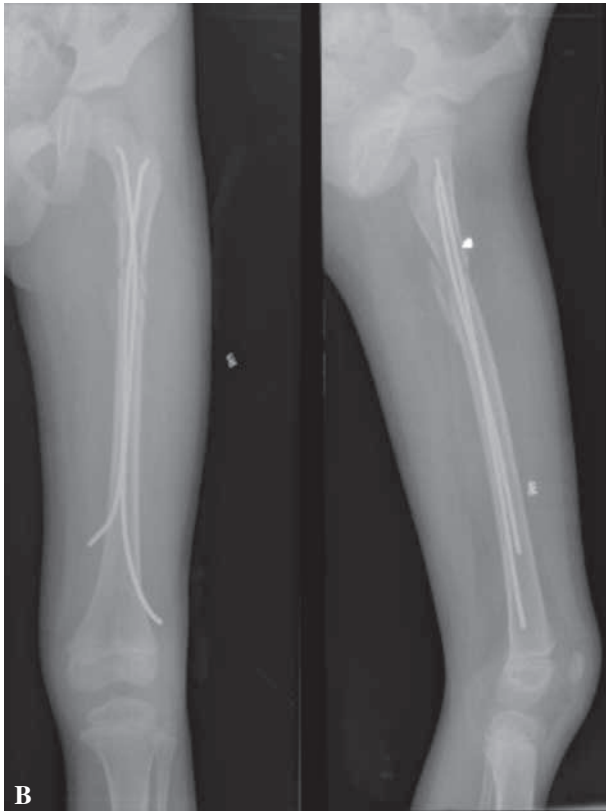
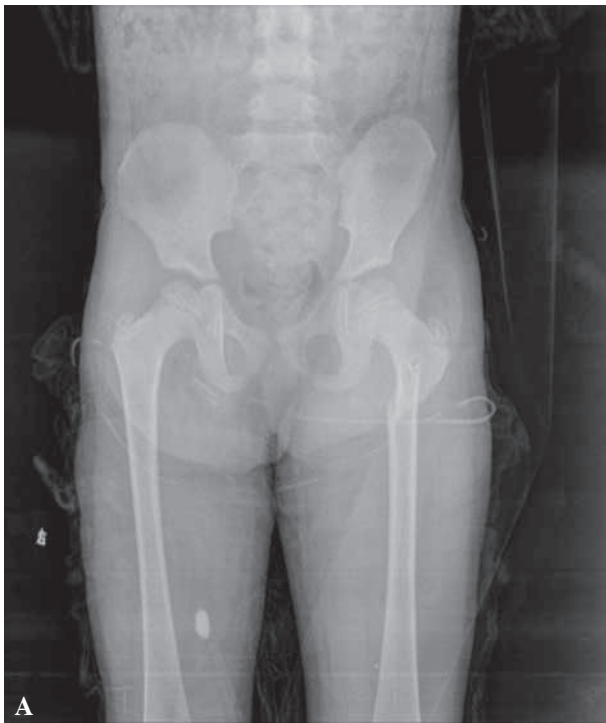


Fig. 2. — (A) A 11-year-old girl with Seinsheimer II subtrochanteric femur fracture. (B) Closed reduction and titanium elastic nails fixation was performed. Three days after operation X-ray film showed a good alignment of the fracture. (C) Four months after operation X-ray film showed a complete healing of the fracture.

Table IV. — Sanders scoring system and results of both groups

Group	Excellent	Good	Fair	Poor
LISS	13	6	7	0
TEN	22	4	0	0

found a higher rate of postoperative incision pain in the LISS group. Other authors also reported persistent pain in the thigh scars of children treated with open reduction and plate fixation, even after removal of the implants (4). However, children treated with closed reduction and intramedullary rod fixation did not complain of such pain. This was also an important factor affecting parents' satisfaction with treatment outcomes. Besides, the fractures fixed by LISS could obtain a more satisfied alignment than those fixed by TEN, though the difference was not

statistically significant. The incidence of angulation in our TEN group was lower than previous studies (2,14). This might be due to our technique modification. The lateral nail in this study was advanced across the fracture site and placed into or just distal to the greater trochanteric apophysis. The medial nail was advanced into the femoral neck, directed toward the femoral head until it stopped short of the proximal femoral physis (approximately 1 cm). Placing the nails more proximally contributes to aiding in the control of rotation and angulation, decreasing the forces at the fracture site and maintaining fracture stability. Additionally, placing one nail up the femoral neck and one nail out of the greater trochanter will also increase the tip-to-tip distance and decrease fracture torsional forces as compared with 2 tips left near the calcar (3). LLD is the most frequent complication of the treatment of femoral shaft fractures in childhood and the incidence of LLD ranges from 8% to 20% (15,16). In this series, seven (13.5%) patients had a LLD and the rate of LLD was consistent with the data previously reported in the literature (15,16). There were no long-term sequelae resulting from the LLD. The incidence of LLD between the two groups was also no significant difference.

Although the satisfaction rate of early radiographic results in the TEN group was lower than that in the LISS group, we found no significant differences in early and late radiographic results between these two groups. This might be due to the stronger remodeling potential of skeleton in children and a certain degree of deformity after operation could rectify itself in the process of growth. We also demonstrated significantly better Sanders scores with TEN. The excellent and good rate was significant difference between the two groups. It seemed that the early radiographic results in the TEN group did not affect the final function of hip. As long as the initial fracture position was maintained within the acceptable limits, as defined by this study, there should be little need to substitute surgical treatment to obtain a satisfactory long-term outcome.

Several limitations existed in our study. First, this was a single center study which enrolled only a small number of patients. To further convince these

results, high quality randomized controlled trials with larger sample size were still needed. Second, although patients were allocated randomly to either surgical group, it was impossible to perform blindness to both the surgeon and patients, which might influence the results. Third, this study included only Seinsheimer II and III fractures and we did not analyze the results of other types of fractures fixed by LISS or TEN. Therefore, further research is needed.

CONCLUSIONS

On the basis of these results, we advocated the use of TEN for the management of subtrochanteric femoral fractures in older children which was associated with better outcome scores and a lower overall complication rate when compared with reverse LISS.

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