

## Original Research Article

# Outcome of adult proximal humerus locking plate in the treatment of paediatric subtrochanteric fractures

Naba Pallab Chetia<sup>1</sup>, Himashis Medhi<sup>1\*</sup>, Manasjyoti Das<sup>2</sup>, Aritra Bidyananda<sup>3</sup>

<sup>1</sup>Department of Orthopaedics, Assam Medical College and Hospital, Dibrugarh, Assam, India

<sup>2</sup>Department of Orthopaedics, Guwahati Medical College and Hospital, Guwahati, Assam, India

<sup>3</sup>Department of Orthopaedics, R. G. Kar Medical College and Hospital, Kolkata, West Bengal, India

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### \*Correspondence:

Dr. Himashis Medhi,

E-mail: Himashis007@gmail.com

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## ABSTRACT

**Background:** Subtrochanteric fractures in children are treated by different conservative and operative methods. Patient's age may be the single most important factor deciding treatment. Several studies have documented superior results with internal fixation compared to non-operative treatment. The aim of the study is to evaluate the outcome of proximal humerus locking plate fixation of subtrochanteric femoral fractures in children.

**Methods:** Between October 2015 and December 2017, 13 children with closed subtrochanteric femoral fractures including 3 pathological fractures were treated in our tertiary care teaching institute and the results were retrospectively analysed. Children of both sexes within 5–12½ years of age with isolated subtrochanteric fractures were included. There was no open fracture and fracture associated with neuromuscular disease or any systemic injury. In all cases, ORIF with proximal humerus locking plate was done using lateral approach.

**Results:** Average age at the time of injury was 9.35 years (range 5–12 ½ years). There were four (30.77%) short oblique, four (30.77%) long oblique, three (23.08%) transverse fractures and two (15.38%) comminuted fractures. Average operative time was 88.76 minutes and average intra operative blood loss was 86.23 ml. Average follow-up was 13 months. All fractures showed radiological union at an average of 8 weeks. One case had superficial infection which was controlled by antibiotics. Two patients had limb lengthening (average 0.75 cm) but required no intervention.

**Conclusions:** Internal fixation with adult proximal humerus locking plate appears as a good treatment option for paediatric subtrochanteric femoral fractures.

**Keywords:** Paediatric subtrochanteric femoral fractures, Internal fixation, Adult proximal humerus locking plate, PHILOS

## INTRODUCTION

Difference exists in the literature regarding the definition of sub trochanteric fractures in children. Some authors consider them as the fractures which occur within one to two centimetres distal to the lesser trochanter of the femur whereas others describe them by their location within 10% of the total femur length below the lesser

trochanter.<sup>1,2</sup> This is in contrast to the adult subtrochanteric fractures that occur within 5 cm distal to the lesser trochanter. These bony injuries are rare in children and probably due to their rarity; these fractures have received less attention in the orthopaedic literature.<sup>3,4</sup> Canale has stated that the fractures in children around the hip are of special interest due to the complications associated rather than the frequency of the

injury.<sup>5</sup> Paediatric subtrochanteric fractures may have devastating complications such as malunion, non-union, avascular necrosis, overgrowth and premature physal closure.<sup>6</sup>

There are no specific guidelines for the treatment of these fractures. Various authors have used different treatment options such as skin traction, 90/90 skeletal traction, immediate spica casting, cast bracing, internal fixation and external fixation.<sup>1</sup> Treatment choices are influenced by the child's age and size and whether the femoral fracture is an isolated injury or part of a polytrauma. Economic concerns, the family's ability to care for a child with a spica cast or external fixator and the advantages and disadvantages of any operative procedure are also important factors.<sup>7</sup> Patient's age may be the most important single variable regarding paediatric femoral fracture treatment. The treatment for children between the ages 6-12 years is the most controversial.<sup>1</sup>

Indications for operative treatment include multiple trauma, head injury, open fracture, floating knee, vascular or neurological injuries, failure of conservative treatment, older child or adolescent and social indications.<sup>8-11</sup> Methods of internal fixation include intramedullary nails and compression plating.<sup>12,13</sup>

The aim of the study is to evaluate the outcome of adult proximal humerus locking plate fixation of subtrochanteric femoral fractures in children.

## METHODS

Between October 2015 and December 2017, 13 children with subtrochanteric fractures of femur were treated in our tertiary care teaching institute and the results were retrospectively analysed. Children of both sexes within the age group of five to twelve and half years with isolated closed subtrochanteric fractures including pathological fractures were encompassed in the study. There were no open fractures and fractures associated with neuromuscular disease or any systemic injury. There were three children with pathological fractures, which were diagnosed to be unicameral bone cysts by histopathological examination before going for the definitive fixation. All children were operated by the same surgical team.

The histories of the injured children were taken from them as well as their parents. General, systemic and local examination was done at the time of presentation for clinical diagnosis and exclusion of other injuries. Once they were hemodynamically stabilized, anteroposterior and lateral radiographs from the hip to the knee and anteroposterior radiograph of pelvis with both hips were obtained. The injured limb was splinted in Thomas splint using skin traction till their operation.

Necessary investigations as suggested by the anaesthetist in their pre-operative evaluation were done.

A written informed consent was obtained from parents or legal guardians of all the children to undergo operation under anaesthesia as well as to participate in this study.

Surgery was performed within 3-7 days after injury. One or two units of paediatric packed cell blood were available according to the preoperative haemoglobin percentages. The surgeries were performed under general or spinal anaesthesia according to the decision of the anaesthetist. Third generation cephalosporin was administered at the time of induction of anaesthesia as prophylaxis. The anaesthetized patient was placed supine on a fracture table with the affected limb tied to the traction boot and kept in neutral position and the contralateral limb was supported by a thigh support in abduction in case of older and physically bigger children. Younger and smaller children were operated in radiolucent table in supine position.

In all the cases, a standard lateral approach to the thigh was used. Minimal soft tissue dissection and periosteal elevation were done. In all the cases, a single proximal humerus locking plate was used. Whenever necessary, plate was contoured using plate bender to ensure good bone-plate contact. A minimum of three to four locking cancellous screws were applied to the proximal fragment of the femur. Under C-arm guidance, precautions were taken to avoid penetrating the capital femoral physis and the trochanteric apophysis with drill bit or screws. The distal fragment was fixed with two to three well-spaced bicortical screws. Fibular strut graft was used in two of the pathological fractures. Intra operative blood loss was measured by mop method. Haemostasis was secured and the wound was thoroughly irrigated with normal saline before closing it in layers over a negative suction drain. The operative time was noted beginning from skin incision to closure of the operative wound.

No postoperative external immobilisation using casts, traction or splint was used. Static quadriceps, active knee bending and hip range of motion exercises were encouraged on the second post-operative day as per pain tolerance. The stitches were removed on ten to twelve post-operative day. All the patients were discharged from the hospital after stitch removal and physiotherapy training. Crutch-assisted toe touch weight bearing was started when pain subsided. Full weight bearing was done once union was achieved clinically and radiologically.

Clinical and radiological assessment of the patients included duration of healing, alignment, presence or absence of postoperative infection, hip and knee motion, limb length discrepancy and functional daily activities. The patients were followed in outpatient department at 4 weeks, 6 weeks, 8 weeks and 12 weeks and then at 6 months. Average follow-up was 13 months (range 6 months-21 months).

The results were analysed using computer program, statistical package for social sciences (SPSS for

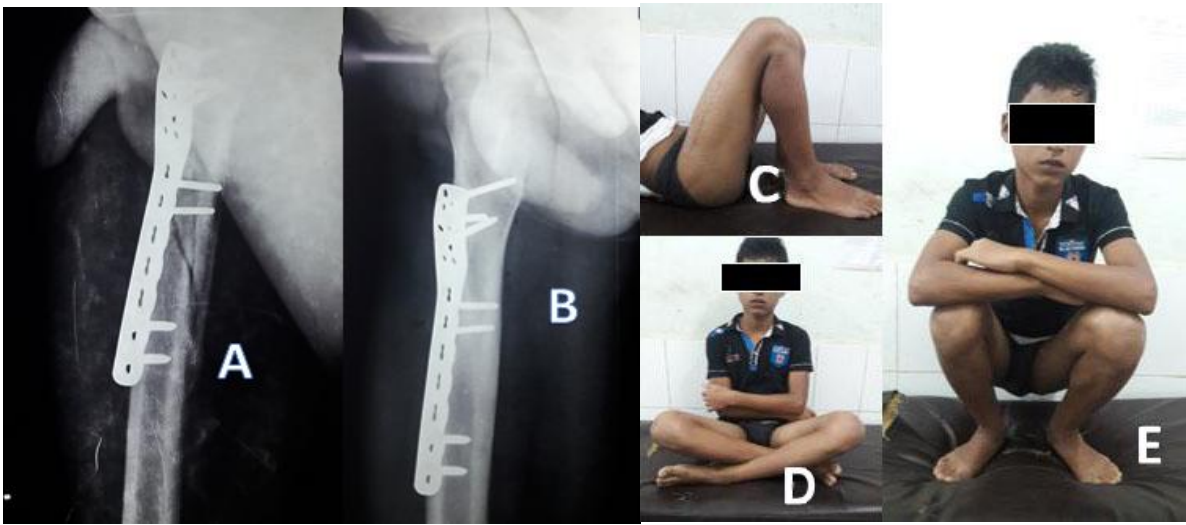
Windows, version 20.0. Chicago, SPSS Inc.) And microsoft excel 2010. Results on continuous measurements are presented as mean±standard deviation.

**RESULTS**

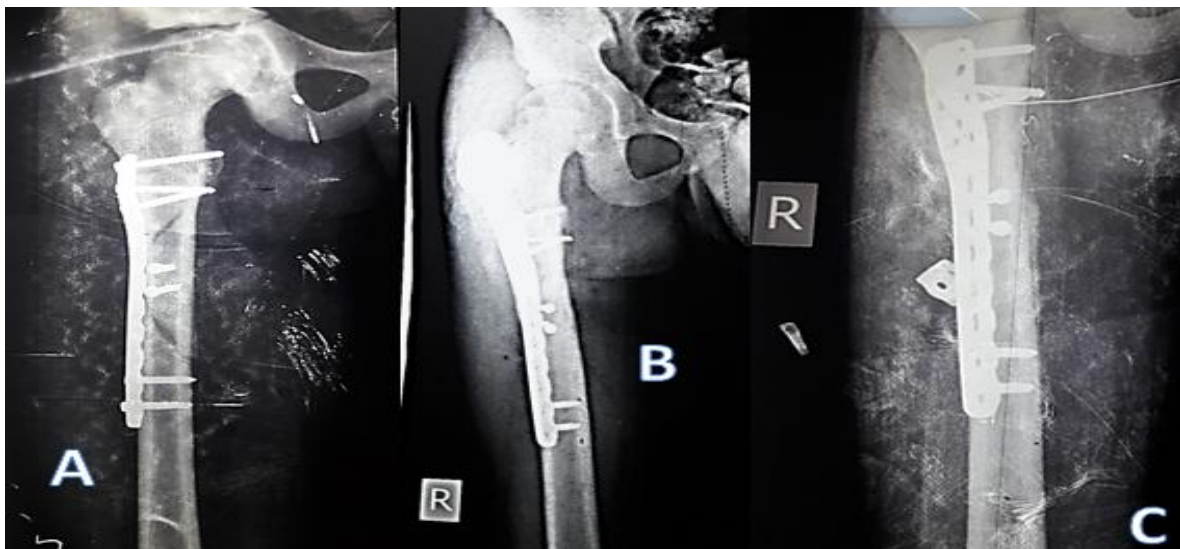
The average age at the time of injury was 9.35 years (9.35±2.31 yrs). There were eleven boys (84.62%) and two girls (15.38%). The mechanism of injury included fall from height in six patients (46.15%), motor vehicle accident in four (30.77%), fall from standing height in two (15.38%) and sports injury in one patient (7.69%). The right femur was affected in eight patients (61.54%) and the left in five (38.46%).

Radiographic evaluation revealed (30.77%) short oblique fractures, (30.77%) long oblique fractures, (23.08%)

transverse fractures and (15.38%) comminuted fractures. Absolute stability was achieved in fractures where there was grade 0 comminution as evaluated by the Winquist and Hausen classification.<sup>14</sup> Absolute stability was provided by open reduction and internal fixation using the principles of compression plating in transverse and short oblique fractures and principle of lag screw and neutralization plate in the long oblique fractures. In all cases of pathological fracture, curettage of the lesion was done. In two cases of pathological fractures with comminution the principles of bridge plating were employed along with strut fibular graft to bridge the bone gap, to provide mechanical support and biological stimulus for healing. Hence, the operative time required in those patients as well as the intra-operative blood loss (Table 1) was higher compared to other cases in our series.



**Figure 1: (A) X-ray of short oblique subtrochanteric fracture fixation with adult proximal humerus locking plate. (B) X-ray showing fracture union. (C) Full range of movement at hip and knee. (D) Comfortable cross-legged sitting position. (E) Comfortable squatting position.**



**Figure 2: (A) X-ray of spiral subtrochanteric fracture fixation with adult proximal humerus locking plate and lag screws. (B and C) X-ray showing fracture union.**





**Figure 3:** (A, B) X-ray of comminuted pathological subtrochanteric fracture, (C, D) immediate post-operative X-rays showing fixation with adult proximal humerus locking plate and strut fibular graft, (E, F) X-ray showing fracture union, (G) comfortable in cross-legged sitting position and (H) comfortable squatting position.

**Table 1:** Epidemiological and peri-operative data.

Parameter	Group A
<b>Mean age (years)</b>	9.35±2.31
<b>Gender</b>	
Male	11
Female	2
<b>Fracture type</b>	
Short oblique	4
Long oblique	4
Transverse	3
Comminuted	2
<b>Mode of injury</b>	
FFH	6
RTA	4
FFSH	2
Sports	1
<b>Average intraoperative blood loss (ml)</b>	86.23±13.82
<b>Mean duration of surgery (min)</b>	88.76±28.48

RTA: road traffic accident; FFH: fall from height; FFSH: fall from standing height.

Average operative time was 88.76 minutes (88.76±28.48 min) and average intra operative blood loss was 86.23 ml (86.23±13.82 ml). There was no malunion, delayed union or non-union. Time to union was eight weeks on an average with a range of six to twelve weeks. There was one superficial infection which was controlled by antibiotics. No deep infection occurred.

All patients regained full hip and knee range of motion. Patients participated fully in sports activities and none had restriction of activities. On the final follow up, there were no patients with implant failure, refracture, heterotopic bone formation or avascular necrosis of the femoral head. It was noted that there was overgrowth of

the injured femur of an average of 0.75 cm ranging from 0.5 to 1 cm in two patients. No patient needed shoe modifications for this limb length discrepancy.

## DISCUSSION

The femoral shaft injuries including the sub trochanter fractures and supracondylar fractures comprise around 1.6% of all the bony injuries in children.<sup>7</sup> Subtrochanteric fractures in children occur in only 4% of all femur fractures.<sup>15</sup> Most injuries occur as a result of high energy trauma and male children are the most affected (Table 2).<sup>15</sup>

**Table 2: Sample size, study period, age and sex distribution and follow up period by various authors.**

Author	Sample Size	Study period (yrs.)	Patient number/year	Age (yrs.)	Avg. age (yrs.)	M:F	F/U (months)	Avg. F/U (months)
Parikh et al <sup>16</sup>	36	2005-11 (6 years)	6	5-12	NA	NA	NA	NA
Li et al <sup>2</sup>	54	2003-10 (7 years)	7.6	5-12	NA	NA	NA	NA
El Sayed et al <sup>1</sup>	18	2000-04 (4 years)	4.5	5.3-11.5	8.2	10:8	12-47	38
Hassan et al <sup>34</sup>	10	2012-14 (2 years)	5	5.5-9.3	7.2	NA	9-18	12
Gogna et al <sup>37</sup>	8	NA	NA	10-16	13	5:3	18-48	32
<b>Our study</b>	9	26 months	4.5	5-12.5	9.35	11:2	6-21	13

Paediatric subtrochanteric femoral fractures present a special unstable type of fracture.<sup>3,4</sup> The proximal fragment tends to flex (ilio-psoas), abduct (abductor group) and rotate externally (short external rotators).<sup>17</sup> The proximal fragment is small and this renders it to be fixed by lesser number of screws in case of internal fixation. The diameter of the neck of femur is small and the presence of capital femoral physis may limit spectrum of internal fixation used in subtrochanteric fractures in children.<sup>6</sup> Various methods of conservative and operative treatment are reported in the literature. Minimally displaced fractures in less than four years of age are commonly treated conservatively with hip spica cast with or without traction.<sup>18</sup> Significantly displaced fractures in the older children are usually treated with operative fixation but there is no fixed consensus regarding the optimal implant.<sup>18</sup> Traction followed by hip spica cast is the method preferred by many surgeons for the treatment of children aged 6-10 years.<sup>11</sup> Aronson et al studied 54 children treated in distal femoral 90/90 traction for an average of 24 days followed by a 1½ hip spica cast.<sup>19</sup> At an average follow-up of 4.3 years, all children were functionally normal and showed a symmetric range of motion of hip and knee. However, this method requires a relatively long hospitalization and accurate control of fracture alignment with frequent radiographs and adjustment in traction as needed. This treatment method is not suitable in children weighing more than 45 kg or in children older than 10 years of age as it is associated with an unacceptable high incidence of femoral shortening and malrotation.<sup>20,21</sup>

Staheli et al popularized immediate spica casting for isolated femoral shaft fractures in children under 6 years of age.<sup>17</sup> Infante et al expanded the indications for spica casts to children up to age 10 and up to 50 kg.<sup>22</sup> Ferguson et al conducted a prospective study of early spica casting in children less than 10 years of age.<sup>23</sup> They found that age greater than 7 years was a variable predictive of a higher risk of failure of this technique to achieve satisfactory alignment. Martinez reported excessive shortening and angular deformity in 26 of 51 patients after immediate spica casting.<sup>24</sup>

It is difficult to maintain isolated paediatric subtrochanteric femoral fractures in an accepted position by non-operative means.<sup>1</sup> Several studies have documented superior results with internal fixation compared to non-operative treatment.<sup>21,25,26</sup> Methods of operative fixation of paediatric subtrochanteric fractures include intramedullary nails, compression plating and external fixators.<sup>8,10,12,13</sup> Awareness of the advantages and disadvantages of intramedullary nails, compression plates and external fixator and the skill to apply each method safely are requisites to the ideal management of such fractures.<sup>17</sup>

Various authors have reported good results with external fixators in paediatric shaft femur fractures but the complications of pin tract infection, pin loosening, refracture, loss of reduction and limb length discrepancy are also constantly observed.<sup>10,27-29</sup> The use of external fixator in the treatment of paediatric subtrochanteric femoral fractures is not preferred as there is no sufficient

room for application of the pins into the short proximal femoral fragment.<sup>1</sup>

Flexible intramedullary nailing is nowadays the treatment of choice in paediatric femoral fractures. Patients are able to partially weight bear early because a rod is a load-sharing device, there is rapid fracture healing and a low incidence of malunion and non-union.<sup>9,12,25,26,30</sup> Disadvantages of intramedullary nailing are lack of rotational control, exposure to irradiation and backing out of implants.<sup>8</sup> Flynn et al reported two deep infections (3%) with titanium elastic nails.<sup>12</sup> Fixation of subtrochanteric fractures in children using intramedullary nails need special experience and may be difficult to achieve.<sup>1</sup>

Parikh et al used elastic nailing for subtrochanteric fractures in children of 5 to 12 years of age or after failed spica cast treatment in younger children in 36 cases between 2005 and 2011.<sup>16</sup> They reported that all fractures healed but 23 of 33 (70%) healed with anterior angulation of about 5°. Other complications included repositioning/removal of nails before radiographic union, malunion, hardware irritation and limb length discrepancy. They concluded that the complication rates are high with elastic nailing for paediatric subtrochanteric fractures (22%) but despite these complications, there were 22 (61%) excellent, 12 (33%) satisfactory and only two (6%) had poor outcomes.

Li et al conducted a retrospective study on 54 children aged 5 to 12 years with subtrochanteric femur fractures treated with titanium elastic nails or plating at two institutions between 2003 and 2010.<sup>2</sup> Outcome scores were significantly better in the plating group ( $p=0.03$ ) but both groups demonstrated high rates of excellent and satisfactory results. The overall complication rate was significantly higher in the titanium elastic nails group (48%; 12 of 25) when compared with the plating group (14%; 4 of 29) ( $p=0.008$ ). Patients in the titanium elastic nails group were advanced to full weight bearing significantly earlier (6.6 vs. 9.9 wks) ( $p=0.005$ ). The major complication rate, length of hospitalization and time to radiographic union were similar for the two groups. They concluded that plate fixation of paediatric subtrochanteric femur fractures is associated with better outcome scores and a lower overall complication rate when compared with titanium elastic nails.

Plate fixation is reported to work well in the paediatric age group.<sup>8,13,21,31-33</sup> Moustafa El-Sayed et al treated eighteen patients with closed subtrochanteric femoral fractures.<sup>1</sup> The average age at the time of injury was 8.2 years (range 5.3 years to 11.5 years). In all cases, a single 4.5 mm contoured reconstruction plate was used and a 6.5 mm cancellous screw was inserted through the plate into the femoral neck. Average follow-up was 38 months. All fractures united with anatomical alignment within an average of 8 weeks. They concluded that open reduction internal fixation (ORIF) with a reconstruction plate

appears as a good treatment option for paediatric subtrochanteric femoral fractures.

Mohamed et al treated 10 patients with closed displaced subtrochanteric femoral fractures between January 2012 and July 2014 using a single 3.5 mm T-plate and two or three 4 mm cancellous screws were inserted through the plate into the femoral neck.<sup>34</sup> The average age at the time of injury was 7.2 years (range: 5.5-9.3 years). Average follow-up was 12 months. All fractures united with anatomical alignment within an average of 8 weeks. There were no complications and no patient had any restriction of activities. This study concluded that internal fixation with a T-plate as a good treatment option for children with subtrochanteric femoral fractures.

Porter et al conducted a study on 'biomechanical analysis comparing titanium elastic nails with locked plating in two simulated paediatric femur fracture models' and concluded that locked plating provides a biomechanically more stable construct than elastic intramedullary nailing.<sup>35</sup> Its use as part of the technique of indirect reduction and sub muscular plating remain a viable alternative in the treatment of length-unstable paediatric femur fracture patterns.

Samuel et al reported successfully using adult precontoured lower extremity peri-articular locking plates for fixation of subtrochanteric femur fractures in two paediatric patients and concluded that it allowed stable fracture construct that precluded post-operative immobilisation.<sup>6</sup>

Cortes et al treated an 11-year-old boy who developed non-union of subtrochanteric fracture after open reduction and internal fixation using a paediatric locked proximal femur plate.<sup>36</sup> The fracture healed and no short- or midterm complications occurred. The authors suggested that adult proximal humerus locking plates may be a safe option for revision surgery of the proximal paediatric femur.

Gogna et al conducted a prospective study to evaluate the outcome of paediatric subtrochanteric fractures managed by adult proximal humerus locking plate (PHLP).<sup>37</sup> Eight children (three females and five males) with mean age of 13 years (range 10-16 years) were treated and the mean follow-up was 32 months. All fractures united at an average of 8.75 weeks. The average final Harris hip score was 80.25. The only complain was prominent hardware in the proximal thigh. The authors concluded that internal fixation of paediatric subtrochanteric fractures using the proximal humeral locking plate of the ipsilateral side appears to be a good treatment option for the age group of 10-16 years.

The average union time in our study was 8 weeks (range 6-12 weeks) with 100% union rate. There was no malunion, delayed union or non-union. These results were similar to various authors who used different plates for fixation of subtrochanteric fracture in children (Table 3).

**Table 3: Implant used, time and rate for union and union related complications by various authors.**

Author	Implant	Union time in weeks		Rate of union (%)	Malunion	Delayed Union	Non Union
		Range	Average				
Parikh et al <sup>16</sup>	TENS*	NA	NA	100	70% (23/33)	Nil	Nil
El Sayed et al <sup>1</sup>	4.5 mm reconstruction plate	6-12	8	100	Nil	Nil	Nil
Hassan et al <sup>34</sup>	T plate	6-12	8	100	Nil	Nil	Nil
Gogna et al. <sup>37</sup>	Adult proximal humerus LCP*	6-14	8.75	100	Nil	Nil	Nil
<b>Our study</b>	Adult proximal humerus LCP*	6-12	8	100	Nil	Nil	Nil

\*TENS= Titanium elastic nailing system; LCP= Locking compression plate.

**Table 4: Post-operative infection and limb lengthening reported by various authors.**

Author	Post-operative infection		Post-operative limb lengthening			
	Superficial	Deep	Range in cm	Average in cm	Number of patients	Any intervention
Li et al <sup>2</sup>	Nil	Nil	NA	NA		
Rang et al <sup>39</sup>	NA	3	NA	NA		
Eren et al <sup>31</sup>	Nil	1 case of Osteomyelitis	0.4-1.8	1.2	40% patient	NA
El Sayed et al <sup>1</sup>	2, controlled by antibiotics, no additional surgery	Nil	0.5-1.2	0.9	12/18 (72.2%)	No
Hassan et al <sup>34</sup>	Nil	Nil	NA	NA		
Gogna et al <sup>37</sup>	Nil	Nil	NA	NA		
Kregor et al <sup>8</sup>	NA	NA	0.3-1.4	0.9	NA	No
Ward et al <sup>33</sup>	NA	NA	NA	2.5	NA	NA
<b>Our study</b>	1, controlled by antibiotics, no additional surgery	Nil	0.5-1.0	0.75	2/13 (15.38%)	No

Patients treated with a plate require less assistance, can walk with crutches within ten days postoperatively and return to school sooner than children treated in 90/90 skeletal traction.<sup>21</sup> The disadvantage of plating are the need for plate removal, poor cosmetic appearance of the scar, blood loss associated with exposure and reduction of the fracture and reported higher degree of overgrowth induced by the plates compared with intramedullary fixation.<sup>38,39</sup>

Moustafa et al encountered no deep infections but two patients (11.1%) had superficial wound infection. Many other reports documented no deep infection with plate fixation.<sup>1,8,13,33</sup> Ziv et al reported three deep infections among five children with head injuries and with femoral shaft fractures treated by plating.<sup>39</sup> Eren et al reported one case of osteomyelitis (2.1%) which occurred in a child with polytrauma.<sup>39</sup> In our study, there was no post-operative deep infection but one patient had superficial infection which was controlled by antibiotics and dressing (Table 4).

Extensive dissection and periosteal stripping during plate application may lead to overgrowth. Kregor et al reported an average increase in length of 0.9 cm.<sup>8</sup> Moustafa et al reported in his series that scanograms revealed

overgrowth of the injured femur with an average of 0.9 cm (0.5 to 1.2 cm) in twelve patients (72.2%).<sup>1</sup> Both authors concluded that overgrowth was not a significant problem in their series and no patient needed a shoe-lift. Ward et al reported several patients with considerable overgrowth (approximately 2.5 cm).<sup>33</sup> Eren et al reported a series of 40 children aged 4 to 10 years with significant lengthening on the operated side in 40% of patients, averaging 1.2 cm.<sup>31</sup> Hansen et al reported overgrowth of 2.5 cm in a 12-year-old boy, suggesting that overgrowth is possible in children over 10 years of age.<sup>32</sup> In our study, two children had postoperative limb lengthening ranging of 0.5 and 1.0 cm (average 0.75 cm) but none of them needed shoe modification for their functional activity (Table 4).

Ward et al and Fyodorov et al had reported hardware failure in their studies. There was no implant failure in our series.<sup>13,33</sup> The need for hardware removal is controversial.<sup>31,33,40</sup> Refracture is rare distal to the plate or through screw holes and whether bone atrophy under the plate is caused by stress shielding or by avascularity of the cortex is unknown.<sup>7,41</sup> Bransby-Zachary recommended plate removal because they had five late fractures 20 to 60 months after internal fixation.<sup>40</sup> In the series of Ward et al, there was a refracture through a screw hole in one of 15 patients who had the plate removed.<sup>33</sup> They do



not recommend plate removal in asymptomatic children. Eren et al also reported a case of refracture 9 years after plate removal.<sup>31</sup> Unlike Gogna et al, we had no hardware prominence in our study.<sup>37</sup>

The limitation of our study is its retrospective design, lack of comparative group and small sample size. A prospective, randomized and comparative study at multiple centres on a larger sample and with longer follow-up period is required to arrive at a definite conclusion.

## CONCLUSION

Internal fixation with an adult proximal humerus locking plate appears as a good treatment option for subtrochanteric femoral fractures in children. This modality of treatment can be done by any orthopaedic surgeon without any special training in a hospital with basic orthopaedic infrastructure.

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