

DISCUSSION

Many authors have reported compression plating of femoral fractures in children and adolescents.

Hanson⁽¹³⁾ used AO compression plates for fixation of femoral shaft fractures in children with an average age of 11 years. All fractures healed without angulation or rotation and with a mean overgrowth of 7 mm. All patients had unrestricted ranges of motion of the hip and knee.

Ward et al⁽¹⁴⁾ reported good fracture healing without leg length discrepancy after compression plating of femoral fractures in children aged 6 to 16 years. They recommended compression plate fixation for patients with severe head injury or multiple traumas. Average healing time was 11 weeks. Limb length discrepancy was reported in 25%.

The disadvantage of plating include the need for plate removal, poor cosmetic appearance of the scar, reported higher degrees of overgrowth induced by plates compared with intramedullary fixation.⁽¹⁵⁾

Although rare, stress fracture may occur through the screw holes during the first few months after plate removal.

Replating was done in one of our patients due to metal failure. Infection was reported in 20% of patients.

ESIN functions as an internal splint, maintains the fracture hematoma and provides biological fixation. It is usually performed through a closed technique. Even when open reduction is required, a minimal approach is usually adequate to facilitate reduction, with minimal periosteal stripping. Furthermore, fixation fulfils the three-point principle since the nails are medially and laterally placed. Both elasticity and stress distribution of the titanium elastic nails facilitate callus formation.⁽¹²⁾

Good results using flexible (Ender) or elastic stable (Nancy) intramedullary rods have been reported by several authors.⁽²⁰⁻²⁵⁾

In 1988, the original series from Nancy reported by Ligier et al⁽²⁶⁾ included 123 fractures managed by ESIN with no surgical failures with excellent results.

Most reports^(12,28,29) recommend this technique for children ages 6 to 10 years in whom traction or external fixation has not been selected as an option and in whom both the proximal and distal femoral physis need to be avoided.

Oh et al⁽²⁸⁾ found that femoral fractures in patients aged 5-10 years could be safely treated with retrograde flexible intramedullary nailing with minimal risk of surgical complications.

Greis-berg⁽²⁹⁾ stated that the use of flexible intramedullary nails allowed patients and their families to achieve independence months earlier than the spica cast patients. Earlier return to school, independent ambulation, and independent bathroom use are advantages of this treatment modality.

Buech-senschuetz⁽¹²⁾ concluded that less cost and comparable clinical outcome make elastic rods a better option than traditional conservative treatment for femoral fracture care in the skeletally immature patient.

In 2004, Houshian et al ⁽⁵⁵⁾ reported excellent results in thirty-one (100%) patients.

In 2007, Bassiooni et al ⁽⁵⁶⁾ reported their results were excellent in thirty-seven (100%) patients.

The flexible intramedullary elastic rod does not lead to overgrowth, as there is no periosteal stripping. Only reported in one case, overgrowth was 1.5 cm in our study. The implant is easily applied, removed, with no exposure to the fracture site. There is an elastic mobility; it applies internal elastic support that prevents excessive displacement. The use of double ascending nails increases the stability of fixation. However, there is no control of rotational stability. Hip spica may be recommended in many cases. It was applied to all patients in our study. The presence of image intensifier is mandatory. Special expertise is needed to stabilize subtrochanteric fractures and fractures of the distal third of the femur; antegrade insertion commonly is used for the latter.

Flynn et al ⁽²³⁾ found that the most common problem encountered has been irritation at the nail insertion site (18% of cases). In this study (20%) of cases complained of bursitis at the insertion site.

In 2006, Caglar et al ⁽⁵⁹⁾ compared compression plating to ESIN in paediatric femoral shaft fractures. They reported that their results were similar in both groups with no statistically significant differences in outcome. However, the average operation time and the average healing time were statistically shorter in the ESIN group.

According to the criteria of evaluation mentioned before ^(50,51), the results obtained in group (I) were excellent in eleven patients (73.3%), good in one patients (6.7%), fair in one (6.7%), and poor in two (13.3%). So satisfactory results were obtained in twelve patients (80%) and unsatisfactory in three patients (20%). In group (II), the results were excellent in fifteen patients (100%), as, there was a continuous significant improvement of the total score throughout the follow up period. Therefore, satisfactory results were obtained in fifteen patients (100%) and unsatisfactory in no patients at the end of follow up.

Factors that might affect the results

Age

The age was not an influencing factor on the results. This coincides with several reports on the same subject. ^(12,38,54)

Shape, level and type of the fracture

Fracture geometry and location are important determinants for selection of surgical techniques. ⁽¹²⁾ Transverse, short oblique and minimally comminuted fractures are suitable for ESIN. ⁽⁵³⁾

In the present study; shape, level and type of the fracture had no significant impact on the final score. However, Narayanan et al ⁽¹²⁾ reported that fractures with more than 25% cortical comminution fixed by ESIN were over four times more likely to get loss of reduction requiring reoperation or malunion. They stated that ESIN does not provide adequate stability in comminuted, long oblique or spiral fractures.

Bar-on et al (1997)⁽⁵⁷⁾ compared the results of external fixation to ESIN in paediatric femoral shaft fractures and recommended the use of external fixation for open or severely comminuted fractures.

Average hospitalization time

In the present series, the average hospitalization time was 6.13 days in group I and 4.13 in group II. The decreased hospitalization time has resulted in the decrease in the hospital bed occupancy and early return of patients to their home environment. In addition, it is also a cost effective treatment modality, as the parents can get back to their work earlier.

In 2002, Griesberg et al⁽⁶²⁾ observed fifteen children with femoral shaft fractures treated by ESIN. They reported that hospitalization averaged 15 days and school absence averaged 29 days.

Flynn et al⁽⁵⁸⁾ reported that compared with children treated with traction and cast, those treated with ESIN had shorter hospitalization and returned to school earlier. These differences were significant.

Time to radiological union

In this series, the mean time to radiological union in group I was 7.9 weeks (range from six to ten weeks) and group II was 8.2 (range from seven to eleven weeks), which was comparable to other studies. The mean time to radiological union in Heybeli's et al⁽⁵⁴⁾ work was 7.4 weeks (range from five to twelve weeks) and in Bassiooni's et al⁽⁵⁶⁾ work was 8.9 weeks (range from five to ten weeks).

Time to weight bearing

In group I, the mean healing time was six to nine months, and group II was four to five months. Caglar et al⁽⁵⁹⁾ reported that the mean healing time in the ESIN group was four months, while in the compression plating group it was 7.7 months. Flynn et al⁽⁵⁸⁾ reported that the ESIN group started to walk with aids and walk independently after two weeks and nine weeks, respectively. Bar-on et al⁽⁵⁷⁾ reported that the ESIN group was fully weight bearing in seven weeks and the external fixation group achieved full weight bearing in an average of ten weeks.

Skin irritation due to prominent nail ends

In this study, skin irritation due to prominent nail ends was a common problem encountered in our first three (20%) patients. They also had restriction of knee motion. Review of these cases showed that in three cases nails were left too long. Nails that are left too long in the distal femur can block the iliotibial tract movement, thus inhibiting knee flexion. The problem resolved in all our patients once the nails were removed.

Ligier et al⁽³⁸⁾ reported that this was the most common complication they encountered. There were thirteen cases (10.5%) of skin inflammation due to nail protrusion. Three of these required reintroduction of the nail, while in the remaining ten the nails were trimmed under local anaesthesia.

Narayanan et al⁽¹²⁾ encountered this problem in 51% of their patients. Initially in their series, nail ends were bent outward at the entry site to facilitate subsequent removal of the nails. The frequency of symptoms prompted them to abandon this

practice in subsequent patients. This change in practice was associated with a significantly reduced rate of symptoms, and also with a significantly earlier return to functional range of motion of the knee.

Infection

In group I, three cases of deep infection was encountered needing removal of plate and culture and sensitivity test was done, one case had external fixator, but the other two cases treated by intravenous antibiotics and debridement, In group II, only superficial infection controlled by medical treatment.

In Ligier's et al⁽³⁸⁾ series, one paraplegic child with urinary tract infection encountered deep wound infection six weeks postoperatively. Removal of the nail and drainage of the fracture site was done and the fracture healed after immobilization in plaster. Narayanan et al⁽¹²⁾ reported superficial wound infection in two patients.

Bar-on et al⁽⁵⁷⁾ reported two cases (20%) of deep pin-track infections (in the external fixation group) which were initially treated with antibiotics, however both failed to settle and the fixators were removed and the patients were placed in casts.

Nonunion

In group I, three cases had nonunion but in group II, all fractures united.

This was comparable to results reported in other studies using ESIN.^(54,55,56) However, Caglar et al⁽⁵⁹⁾ reported that in the compression plating group, four femoral non-unions and implant failures occurred in six to ten months.

Neurological injury

In our series, there were no neurological complications. However, Narayanan et al⁽¹²⁾ reported two neurological complications. Sciatic neuropraxia occurred in one boy due to perforation of the posterior femoral neck by the proximal end of one nail. Paraesthesia in the dorsum and lateral aspect of his foot resolved shortly after withdrawal and trimming of the nail. Transient pudendal nerve palsy occurred in another boy whose fracture was fixed on a fracture table with the leg held in traction.

Avascular necrosis of the femoral head

In our series, there were no cases of avascular necrosis of the femoral head, which was comparable to other studies.^(54,55,56)

However, several case reports^(64,65,66) demonstrated the risk of deformity in the proximal femur and the development of avascular necrosis in the femoral head with antegrade locked nailing. They reported damage to greater trochanter apophysis and engraving in the medulla by Küntscher intramedullary nails in adolescence.

Carey et al⁽⁶⁷⁾ performed antegrade ESIN in twenty-five cases; they did not observe disturbance in the proximal femur.

Rotational Alignment

In group I, there is no reported case of rotational malalignment but in group II, no in-toeing or out-toeing was seen in any of the patients initially. We checked the anatomical position of the patella and greater trochanter during the fixation in our patients. However, in our clinical examination during follow up two patients developed 10° external rotation deformity. The diameter of the nails used in these patients was less than 40% of the minimum canal diameter suggesting that fixation was inefficient in terms of rotational stability.

Heybeli et al⁽⁵⁴⁾ analysed the rotational alignment of the femur using computed tomography (CT) to measure the femoral anteversion angle (FAA) (the angle between the femoral neck and composite lines, which are tangent above, and below both condyles) in fourteen patients. Ten patients had retroversion over 10° and one patient had 9° retroversion. In comparison to the normal side, they were statistically significant; however, it did not result in any complaint concerning functional or cosmetic deformity. They have stated that to avoid these malalignments appropriate nail diameters should be used and in unstable fractures, additional postoperative plaster immobilization for three weeks is recommended.

In 2008, Mehdiinasab et al⁽⁶⁸⁾ compared traction and casting (in thirty patients) to ESIN (in thirty-six patients) in paediatric femoral shaft fractures. They reported external rotation of the leg (average 15 °) in three patients in the first group.

Angulation

There was no case of angulation in group I, but in group II, one patient had varus angulation average 10° , one patients had valgus angulation ranging from 10° to 20° , one patient had average 10° anterior angulation and one patient had 10° posterior angulation.

Narayanan et al ⁽¹²⁾ reported that the use of nails of two different diameters produces asymmetric forces resulting in angulation in the direction determined by the larger nail. This occurred early in their series. They proposed theoretical risk factors for angulation including; failure to match the apex of curvature in both nails, the use of smaller-than-optimal diameter and abnormal twists in the nails during insertion. However, they were unable to make any valid conclusions about the effect of these on malunion.

Flynn et al ⁽⁵⁸⁾ reported five patients (14.3%) in the traction and casting group developed substantial angulation that were treated with remanipulation and casting or by ESIN. However, no malalignment occurred in the ESIN group. Bar-on et al ⁽⁵⁷⁾ reported three malalignments in varus and one in recurvatum in the external fixation group, while no malalignment greater than five degrees occurred in the ESIN group.

Limb-length inequality

In group I, there is no reported case of limb-length inequality but in group II, two patients (13.3 %) had lengthening (range from one to two centimetres). these patients had distraction at the fracture site. two patient (13.3%) had shortening (1.5 cm). The limb length discrepancy was not described as a complaint by the patients or their relatives.

Heybeli et al ⁽⁵⁴⁾ reported seven patients (20.6%) developed limb-length inequality less than 2 cm. The discrepancy was associated with lengthening in three patients and shortening in three patients. 18mm discrepancy was found in a patient who underwent ESIN in bilateral femoral shaft fracture. Houshian et al ⁽⁵⁵⁾ reported 1cm lengthening in five patients (16%)

In comparison to traction and casting, Flynn et al ⁽⁵⁸⁾ and Mehdinasab et al ⁽⁶⁸⁾ reported shortening (more than 1 cm) in three children (8.6%) and in four children (13%), respectively. They reported that no child treated with ESIN had more than 1 cm limb-length inequality.

In Bar-on's et al ⁽⁵⁷⁾ series two patients developed 1cm limb-length discrepancy in the external fixation group, however none of the ESIN group developed discrepancies.

SUMMARY

Femoral shaft fracture is an incapacitating paediatric injury. The treatment has traditionally been age-related, influenced by the type of injury, associated injuries and the location and type of the fracture.

To a great extent, treatment options vary according to the surgeon's preference. There is little disagreement regarding the treatment of younger children (usually less than six years of age) with immediate spica casting.

These young children tolerate the cast well, are easily managed at home and mild to moderate fracture displacement and angulation correct well by growth and remodelling.

Above six years of age, nonoperative treatment could lead to; loss of reduction, malunion, intolerance and complications associated with plaster. Near the end of skeletal maturity, accurate reduction is necessary as angular deformity is no longer correctable by growth. Availability of locked intramedullary nail has made the treatment of femoral shaft fractures in skeletally mature children well established.

For children that occupy the middle age group between six and fourteen years, there are a wide variety of surgical and nonsurgical treatment options available, such as, early spica casting, traction followed by casting, external fixation, plate fixation, reamed intramedullary rods and flexible intramedullary nails with no clear consensus as to the preferred treatment.

The aim of this work is to evaluate the outcome of result of femoral shaft fracture treatment by DCP versus Nancy nails in 30 adolescents.

Thirty patients were included in the study; they were admitted to El-Hadara University Hospital suffering from femoral shaft fractures. On admission, all patients were assessed by history taking, clinical examination and radiological evaluation.

Group I: The surgery was performed under general anaesthesia. Open reduction and internal fixation through lateral femoral approach by single 4.5 AO narrow DCP applying the same AO fixation principles, closure of the wound in layers after insertion of suction system that was removed within 24 hours, skin stitches was removed after ten days.

Group II: The surgery was performed under general anaesthesia. Two titanium elastic nails of identical diameter were used. The diameter of the individual nail was chosen by calculation (nail diameter = minimum canal diameter x 0.4). Fractures were reduced using fluoroscopic guidance. Nails were inserted in retrograde fashion with medial and lateral incisions two centimetres above the physis. The nails were prebent sufficiently so that apex of the bowed nails rested at the same level of the fracture site to ensure a good equal recoil force. The nails were driven proximally so that both were divergent and the tips were anchored about one centimetre distal to the physis. Hip spica applied to most of cases for two weeks.

Patients were moved with partial weight bearing as soon as the fracture was pain-free. Partial weight bearing commenced when a bridging callus was evident radiologically. Full weight bearing was allowed according to fracture healing and as soon as the patient felt ready.

The mean age in **group I** was 11.5 years, three patients were girls (20%), while twelve patients were boys (80%). nine patients had right side affection (60%), while six had left side affection (40%). The mechanism of trauma in the patients was road traffic accidents in ten patients (66.7%) and falling from height in five patients (33.3%). all fractures were closed, the level of the fractures was in the middle third in ten patients (66.7%), proximal third in three patients (20%) and distal third in two patient (13.3%). eight fractures (53.3%) were transverse, three (20%) were oblique and four (26.7%) were comminuted. The minimum time lapse before surgery was one day, the maximum was four days and the mean was 2 days.

But, The mean age in **group II** was 10.53 years, four patients were girls (26.7%), while sixteen patients were boys (73.3%). six patients had right side affection (40%), while eight had left side affection (53.3%) and one case was bilateral (6.7). The mechanism of trauma in the patients was road traffic accidents in eleven patients (73.3%) and falling from height in four patients (26.7%). all fractures were closed, the level of the fractures was in the middle third in eleven patients (68.8%), proximal third in four patients (25%) and distal third in one patient (6.3%). Ten fractures (62.5%) were transverse, one (6.3%) were oblique and five (31.3%) were spiral. The minimum time lapse before surgery was one day, the maximum was three days and the mean was 2.13 days.

In **group I**, the final results obtained were excellent in eleven patients (73.3%), good in one patient (6.7%), fair in one patient (6.7%) and poor in two cases (13.3). There was a continuous significant improvement of the total score throughout the follow up period. The mean time of clinical union was 12.27 weeks. There was no statistically significant relation between age, sex, side affected, time lapse before the operation, mechanism of trauma, type/level/shape of fracture, presence of associated injuries, technique of reduction and final score.

In **group II**, the final results obtained were excellent in fifteen patients (100%). There was a continuous significant improvement of the total score throughout the follow up period. The mean time of clinical union was 10.73 weeks. There was no statistically significant relation between ages, sex, side affected, time lapse before the operation, minimum canal diameter, nail diameter used, intra-operative image intensifier time mechanism of trauma, type/level/shape of fracture, presence of associated injuries, technique of reduction and final score.

In **group II**, three patients had superficial wound infection (20%) that was controlled by medical treatment only, and deep infection was recorded in one case (6.7%) with hypertrophic nonunion and skin sinus.

Implant failure was reported in two cases (13.3%), one was replated with bone graft and another was treated with external fixator (ilizarof).

Metal failure in the form of screw pull out was reported in one patient (6.7%). Replating was done for him one month after trauma.

Blood transfusion was given to three children (20%).

No anterior angulation or rotational malalignment was reported in any case.

In **group II**, pain at the insertion site of the nail was encountered in three patients; it was associated with prominent nail ends. Symptoms improved after nail removal.

Two patients had 10° external rotation deformity without secondary functional limitations.

Radiographic angulation occurred in six patients; one patient had 10° valgus angulation, one patient had 10° varus angulation, one patient had 10° anterior angulation and one patient had 10° posterior angulation. However, all of these angulations were partially corrected by remodelling after about six months and none of these patients had any evidence of clinical deformation.

Lengthening occurred in two patients (range from one to two centimetre), and shortening occurred in two patient (1.5cm). None of these patients had functional limitations secondary to the limb-length inequality; however, precise final difference in limb lengths requires a longer follow up period.