DISCUSSION

Tibia is the third most common location of diaphyseal fractures in children after forearm and femur, with a high prevalence (75%) in young boys around the age of 8. Their increasing incidence rate is attributable to road traffic accidents, and above all to injuries at sport. [71]

Tibia fractures in skeletally immature patients have traditionally been treated successfully by closed methods and casting. [2, 72]

However, few of these fractures require surgical stabilization, such as open fractures, fractures associated with neurovascular injuries, fractures in the multiply injured patient, and fractures with soft tissue injury, burns, skin loss, and compartment syndrome.[73]

There are few treatment options for these difficult fractures. External fixation is a common option but has a significant complication rate. Flexible intramedullary titanium nails allow for immediate stabilization of the fracture in the multiply injured child, facilitate access to compromised soft tissues, and obviate the need for prolonged immobilization. [74]

The aim of the work was to evaluate the results of using the flexible intramedullary nail (Elastic Stable Intramedullary Nailing; ESIN) in the management of tibial shaft fractures in children between 6 and 12 years of age. 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-points principle since the nails are medially and laterally placed. Both elasticity and stress distribution of the titanium elastic nails facilitate callus formation. [35]

The development of the Titanium Elastic Nails (TENs) fixation method has put an end to criticism of the surgical treatment of paediatric long bone fractures, as it avoids any growth disturbance by preserving the epiphyseal growth plate, it avoids bone damage or weakening through the elasticity of the construct, which provides a load sharing, biocompatible internal splint, and finally it entails a minimal risk of bone infection. [54]

TENs are more elastic, thus limiting the amount of permanent deformation during nail insertion; they promote healing by limiting stress shielding in addition to their biocompatibility without metal sensitivity reactions [55,56].

The principle of Ender nail fixation is canal filling with the nails, while TENs work by balancing the forces between the two opposing flexible implants. To achieve this balance, the nail diameter should be 40% of the narrowest canal diameter or more; the nails should assume a double-C construct. They should have similar smooth curve and the same level entry points [14,56].

According to the used criteria for evaluation, [55] the results obtained in the twenty patients included in this study were excellent in fifteen patients (75%), and satisfactory in five patients (25%). These five satisfactory cases had pain at nail insertion which resolved

after nail removal at about three months, two cases of the satisfactory cases had about 10 degrees angulation, and three cases of the five satisfactory patients had about 1.5 cm limb length inequality. The results obtained were found comparable to the results of other studies that used the same method of treatment. [54, 74, 75]

O'Brien et al. [74] reported 16 fractures of the tibia, fixed internally with flexible titanium nails, which achieved a very good functional outcome with no significant angulation or leg length discrepancy and no infections.

EL-Adl G et al [54] treated 25 tibial fractures by ESIN. Based on Flynn et *al*'s outcome rating system, 75.8% of the results were excellent, 24.2% were satisfactory and there were no poor results.

Vallamshetla et al. [76] reported on 56 fractures of the tibia, fixed internally with intramedullary elastic nails with excellent outcome in 84% of cases (two residual angulations of the tibia, two leg-length discrepancy, two deep infections, one delayed union and two failures of fixation).

Sankar et al. [77] , managed 19 cases with tibial shaft fractures with ESIN, according to the Flynn classification, they had 12(63%) excellent, Six(31.5%) satisfactory, and one(5.3%) poor result.

Vrsansky et al.[78], reviewed 308 children with fractured long bones fixed with flexible intramedullary nails, of which 36 involved the tibia. An excellent functional outcome was reported, with all patients mobilising independently by three to five months.

Other studies were conducted to compare between ESIN and other methods of fixation

In 2005, Kubiak et al. [79] Compared between external fixation and ESIN in the treatment of pediatric tibial shaft fractures and found that, the mean time to union was eighteen weeks in the external fixation group, compared with seven weeks in the elastic stable intramedullary nailing group and the time to full weight-bearing in the elastic stable intramedullary nailing group (seven weeks) was three weeks shorter than that in the external fixation group (ten weeks).

Kubiak et al. [79] have reported increased levels of patient satisfaction in association with elastic stable intramedullary nailing. Till et al. [11] reported a similarly high level of patient satisfaction in a series of seventy patients with long-bone fractures that had been treated with elastic stable intramedullary nailing, fourteen of which involved the tibia. Sixty-four patients (91%) described their functional ability as perfect, and sixty-five patients (93%) reported that their contentment with the procedure was great.

Bar-On et al. [80] reported that all of the parents of the ten children who had been managed with elastic stable intramedullary nailing would have their children undergo the same treatment again, whereas the parents of two of the eight patients who had been managed with external fixation would prefere nonoperative treatment for their children in the future.

Cullen et al. [15], reported a mean time to union of fifteen weeks in their series of eighty-three open tibial fractures in children (mean age, nine years) who had been managed with external fixation.

Also, Kubiak et al [79] reported superior functional outcomes with less complications in the group treated with TENs.

Factors that might affect the results

Age

In this study, all children had open tibial growth plates at the time of fixation. The mean age of excellent patients was 9.3 years, whereas the mean age of satisfactory patients was 10.6 years. The difference was statistically insignificant. This indicates that age was not an influencing factor on the results. This coincides with several reports on the same subject. [54, 74, 75, 81]

Shape, level and type of the fracture

Fracture geometry and location are important determinants for the selection of surgical techniques. [35] Transverse, short oblique and minimally comminuted fractures are suitable for ESIN. [55]

In the present study; shape, level and type of the fracture had no significant impact on the final score.

Average hospitalization time

In the present series, the average hospitalization time was 3.5 days. 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 and school children return back to school; causing less disturbance in continuation of their studies.

In EL-Adl G et al [54] work, the average hospital stay was 5.7 days with a range of 2 to 28 days.

Time to radiological union

In this series, the mean time to radiological union was 8.9 weeks (range from six to eleven weeks), which was comparable to other studies using the same method of fixation. The mean time to radiological union in Gordon et al. [81] work was 8 weeks (range from four to eighteen weeks), In Vallamshetla et al. [76] work was 10 weeks (range from seven to eighteen weeks). And in Sankar et al [77], the mean time to union was 11 weeks (range 6–18 weeks), with closed fractures healing more rapidly than open fractures.

Our results are also similar to those of Qidwai[57], who reported a mean time to union of 9.4 weeks in a study of eighty-four tibial fractures (including thirty open fractures) in children (mean age, 10.2 years) who had been managed with Kirschner wires that had been placed in the same fashion as described for the flexible titanium nails in the present study.

Srivastava et al. [82] reported a longer time to union than the other studies at 20.7 weeks (range 8–42 weeks). However, union was described as ''painless full weight bearing with radiographic evidence of tricortical callous formation.'' This is in contrast to the other studies that solely considered radiographic union.

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 five (25%) patients. Nails that are left too long in the proximal tibia can irritate skin causing limited knee motion in two patients. Review of these cases showed that in the five cases nails were left too long. The problem resolved in all our patients once the nails were removed.

Irritation at the nail entry point was the most common complication reported by Sankar et al. [77] Ligier et al [56] reported that this was the most common complication in their study.

O'Brien et al. [74] reported the formation of a local bursa beneath the skin overlying the nail ends that can result in mild irritation, but no patient had to modify his or her activity due to irritation from the hardware. And no patient had any loss of motion at the knee.

Infection

In the present series, no cases of infection were encountered. Srivastava et al. [82] reported two cases with infection. Vallamshetla et al. [76] reported one superficial infection that settled with antibiotics and two deep infections requiring removal of the nails.

O'Brien et al. [74] reported one superficial infection of a surgical wound that responded to nonoperative care and oral antibiotics.

Nonunion

In this series all fractures united. This was comparable to results reported in other studies using ESIN as reported by Vallamshetla et al. [76] and also by Sankar et al. [77]

However; Srivastava et al. [82] reported two nonunited cases and Gordon et al. [81] reported also two cases of non union

Rotational Alignment

In the present series, no in-toeing or out-toeing was seen in any of the patients. We checked the anatomical position of the patella and the second toe during the fixation in our patients. This was comparable to results reported in other studies using ESIN. [76, 77, 81, 82]

Rotational malalignment was not noted in EL-Adl G et al [54] study due to utmost care being taken during intraoperative limb positioning. Ligier *et al* [56] and Flynn *et al* [55] have reported a similar finding, supporting the concept that TENs can give rotational stability if good care is taken intra-operatively during nail insertion and postoperatively, especially for comminuted, spiral, and long oblique fractures.

Angulation

In this series, one patient had varus malalignment (less than 10°). Analysis of this fracture showed improper contouring of the nails; the apex of curvature was distal to the fracture site. One patient had 10° anterior angulation, however, the angulation was corrected by remodelling after six months. Analysis of this fracture revealed that one of the nails was improperly contoured.

Goodwin et al. [75] reported two cases of angulation (more than 10°). Sankar et al.[77] Reported four patients had a malunion with malalignment greater than 5°, one in the sagittal plane and three in the coronal plane.

Limb-length inequality

In this series two patients (10%) had lengthening (range from one to two centimetres). one patient had distraction at the fracture site and one had a comminuted middle third fracture. One patient (5%) had shortening (1.5 cm). The limb length discrepancy was not described as a complaint by the patients or their relatives.

Vallamshetla et al. [76] reported two patients with significant leg length discrepancies of 1.5 and 2 cm and both had epiphysiodesis of the contralateral leg. Also, in Srivastava et al. [82] work, there were two cases with leg length discrepancies.

Gordon et al. [81] reported three patients with asymptomatically long tibia (6–11 mm) and four patients had a shorter tibia (7–24 mm). Three of these were asymptomatic and one had unrelated early physeal closure.

Image intensifier time

In this series the mean operative image intensifier time was 49.25 seconds (range from 30 to 70 seconds), which was less than that reported by EL-Adl G et al.[54] They reported that the average fluoroscopy time was 69 seconds (range from 30 to one 135 seconds).

Nail retrieval

In this study, all patients had their nails removed as a day case procedure under general anaesthesia after an average period of twenty weeks (range from twelve to twenty-eight weeks postoperatively), without any complication during or after the procedure.

In Kubiak et al. [79] work; nails were removed after an average period of thirty-six weeks (range, sixteen to seventy-eight weeks)

In EL-Adl G et al.[54]work ,The TENs were removed in 87.8% of patients, on average 5.9 months after operation (range, 3 to 9 months).

SUMMARY

Tibial 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 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 tibial shaft fractures in skeletally mature children well established.

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

The aim of this work was to assess the results of using the flexible intramedullary nail in the management of tibial shaft fractures in children between the age of six and twelve years.

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

The mean age was 9.63 ± 1.88 years.Seven patients were girls (35%), while thirteen patients were boys (65%). Ten patients had right side affection (50%), and ten had left side affection (50%). The mechanism of trauma in the patients was road traffic accidents in nine patients (45%) and sport injuries in eleven patients (55%). Eighteen fractures were closed (90%), while two cases (10%) were open grade II fractures. The level of the fractures was in the middle third in eleven patients (55%), proximal third in four patients (20%) and distal third in five patients (25%). Five fractures (25%) were transverse, seven (35%) were oblique and eight (40%) were comminuted. The minimum time lapse before surgery was half a day, the maximum was eight days and the mean was 2.93 days.

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 antegrade fashion with antromedial and antrolateral incisions two centimetres below 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 distally so that both were divergent and the tips got impacted at their final distal points just proximal to the distal tibial epiphyseal plate

Postoperatively below knee cast was done. Patients were ambulated without 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.

Pain at the insertion site of the nail was encountered in five patients; it was associated with prominent nail ends. Symptoms improved after nail removal.

Radiographic angulation occurred in two patients; one patient had varus malalignment (less than 10°). And one patient had 10° anterior angulation. However, 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 cm), and shortening occurred in one patient (1.5cm). None of these patients had functional limitations secondary to the limb-length inequality; however precise final difference in limb length requires a longer follow up period.

The final results obtained were excellent in fifteen patients (75%) and satisfactory in five patients (25%).The mean time of clinical union was 6.15 ± 0.99 weeks, while the mean time of radiological union was 8.90 ± 1.29 weeks. There was no statistically significant relation between age, sex, side affected, time lapse before the operation, nail diameter used, intra-operative image intensifier time, mechanism of trauma, type/level/shape of fracture, presence of associated injuries and final score.