Original article:

Titanium elastic percutaneous nails for pediatric long bone shaft fractures: current concept.

Sahu RL[1], Ahmed N[2]

Abstract:

Introduction: The objective of this study was to determine the effectiveness and the complications associated with elastic stable intramedullary nailing in long bone fractures in children. **Methods:** This study was conducted in the Department of Orthopaedic surgery in M. M. Medical College from July 2006 to November 2009. Eighty two patients were recruited from Emergency and out patient department having closed fracture of long bones of upper and lower limbs. All patients were operated under general or spinal anaethesia. All patients were followed for twelve months. **Results**: All children achieved union in a mean time of 10 weeks (range from 6 - 16 weeks) depending on the type of long bone. Full weight bearing was possible in a mean time of 8.8 weeks. Mean duration of hospital stay was 9.8 days. The mean follow-up period was 28 months (17-48 months). Complications were recorded in 5 (6.09%) patients and included: two entry site skin irritations, one protrusion of the wires through the skin and two delayed union. The results were excellent in 97.310% and good in 2.44% patients. **Conclusion:** We concluded that this technique is advantageous because of early mobilization (early weight bearing), less complication with good results and is economical.

Keywords: Titanium elastic percutaneous nail; Long bone; Shaft fractures; Diaphyseal fractures; Pediatric

Bangladesh Journal of Medical Science Vol. 16 No. 01 January'17. Page : 61-68

Introduction:

Globally, traumatic injuries of long bones shaft fractures in children are the most leading causes of morbidity and mortality in children and adolescents, with most of the burden borne by low- and middle-income countries, in particular in the developing world. Majority of the children are treated nonoperatively with union rates of more than 90% and 100% full functional recovery[1]. Occasionally, reduction cannot be maintained due to excessive shortening, angulation, or malrotation at the fracture site, making operative intervention necessary [2]. Now a days the use of elastic stable intra-medullary nails has dramatically increased with the introduction of a variety of nails for pediatric fractures [3]. The Titanium Elastic Nail (TEN) for Elastic Stable Intra-medullary Nailing (ESIN) is intended for fixation of diaphyseal fractures of long bones where the medullary canal is narrow or flexibility of the implant is paramount. The aim of this study of biological, minimally invasive fracture treatment is to achieve a level of reduction and stabilization that is appropriate to the age of the child. The biomechanical principal of the TEN is based on the symmetrical bracing action of two elastic nails inserted into the metaphysis, each of which bears against the inner bone at three points[4,5.] The ESIN has the benefits of early immediate stability to the involved bone segment, which permits early mobilization and return to the normal activities of the patients, with very low complication rate[6,7].

1. Ramji Lal Sahu, Professor in Department of or Thopaedic SMS & R, Sharda University Greater Noida UP INDIA 110005
2. Nadeem Ahmed, Assistant Professor in department of or Thopaedic SMS & R, Sharda University Greater Noida UP INDIA 110005

Correspondence to: Dr. Ramji Lal Sahu, Associate Professor, Department of Orthopaedics, S.M.S and RI, Sharda University, Greater Noida, U.P. India. (Formerly at M. M Medical College Mullana, Ambala, Haryana, India.) Email id - drrlsahu@gmail.com

Methods:

This prospective study was carried out at Orthopaedics department of M. M. Medical College from July 2006 to November 2009. It was approved by institutional medical ethics committee. A total of 82 patients with closed fracture of long bones of upper and lower limbs admitted to our institute were included in present study. A written informed consent was obtained from all the patients; they were explained about treatment plan, cost of operation, and hospital stay after surgery, and complications of anaesthesia. They were followed up after surgery, were clinically and radiologically assessed for fracture healing, joint movements and implant failure. According to the criteria the results are graded as excellent when the fractures unites within 16 weeks without any complication, good when union occur within 24 weeks with treatable complications like superficial infection and knee stiffness and poor when union occur before or after 24 weeks with one or more permanent complications like infection (osteomyelitis), implant failure, non-union, limb shortening and permanent knee stiffness. Delayed union was recorded when the fracture united between three to six months while nonunion was noted when union had not occurred after eight months of treatment Follow-up was done. Patients with closed long fracture with age between 6-16 years and presented within a week of the injury and did not have any previous surgical treatment for the fracture were included in the study. Malnourished patients and those with open fractures, pathological fractures and fracture nonunion were excluded from the study. Examination of patients was done thoroughly at the time of admission to exclude other injuries. In majority of the patients close flexible titanium elastic nailing of the long bone was performed on seventh to fourteenth day after the injury. In patients who were not fit for surgery due to associated injuries to vital organs, were haemodynamically unstable or due to active infection at injury site, or were pyrexial delayed elastic nailing was performed when their over-all condition improved. There were eighty two patients in this study, sixty patients were male and twenty two patients were females. Long bone fractures at middle one third were forty eight out of eighty two, fractures in twenty one cases were at proximal one third and fractures in thirteen cases were at distal one third (Table 1, 2), (Figure 1a,1b, 2a, 2b, 3a, 3b and 4a,4b).

Table 1. Age and sex variations in study group (n=82)

Age (years)	Male	R	L	Female	R	L	Total
6-8	8	5	3	4	3	1	12
9-12	16	9	7	6	4	2	22
13-16	36	21	15	12	7	5	48
Total	60	35	25	22	14	8	82

Table 2. Site of fracture (n=82)

Site	Femur			Tibia			Humerus			Ulna			Radius	Total	%
		R	L		R	L		R	L		R	L			
Proximal 1/3rd	12	8	4	6	3	3	2	1	1	1	1	0	0	21	25.6%
Middle 1/3rd	26	15	11	12	7	5	8	5	3	2	1	1	0	48	58.6%
Distal 1/3rd	8	5	3	2	1	1	2	1	1	1	1	0	0	13	15.8%
Total	46	28	18	20	11	9	12	7	5	4	3	1	0	82	100%

Table 3. Percentage of cases who had unions, malunions, delayed unions, or non unions (n=82)

	Total Cases	Percentage of cases
Union	80	97.31%
Delayed union	2	2.44%
Non union	0	0%
Malunion	0	0%

Table 4. Out come of results of flexible titanium elastic nails. (n=82)

Out comes	No	Percentage
Excellent	80	97.31%
Good	2	2.44%
Poor	0	0%

Table 5. Complications

Complications	No
1 entry site skin irritations	2
2 protrusions of the wires through the skin	1
3 delayed union	2

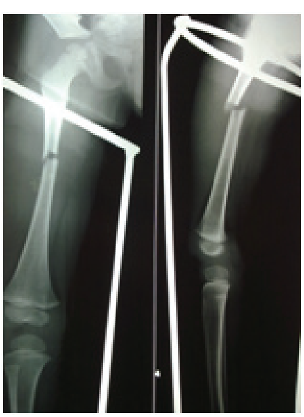

Figure 1a.

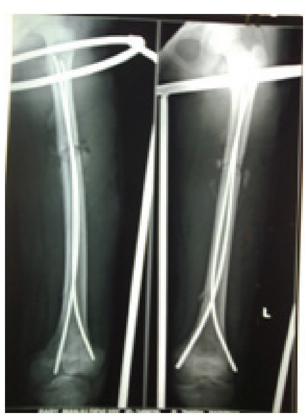

Figure 1b.

Figure-1 Pre and post operative radiographs of fracture Shaft of femur (a,b).

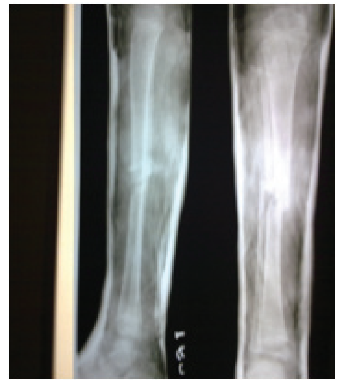

Figure 2a.

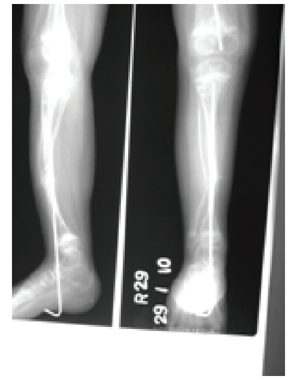

Figure 2b.

Figure-2. Pre and post operative radiographs of fracture Shaft of tibia (a, b).

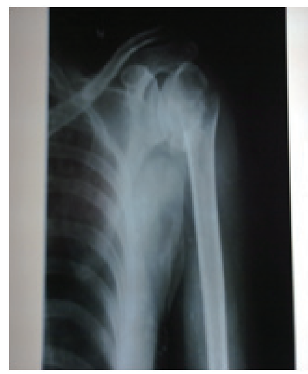

Figure 3a.

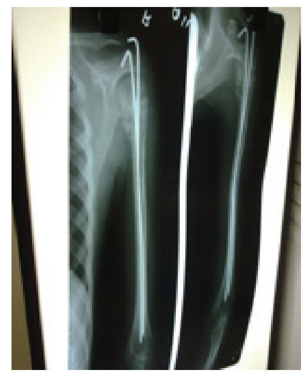

Figure 3b.

Figure-3. Pre and post operative radiographs of fractureupper end of humerus (a, b).

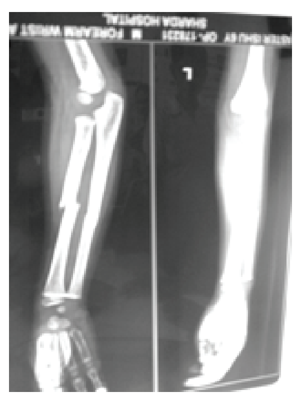

Figure 4a.

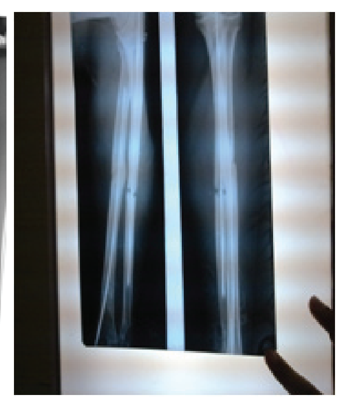

Figure 4b.

Figure-4. Pre and post operative radiographs of fracture mid shaft of radius and ulna(a,b).

The patients were divided in three groups according to their age for simplicity. Lower age group was between 6-8 years of age. In this group there were four females and eight males. Middle age group included patients, who were between the ages of 9-12 years. This group included six females and sixteen males. The older age group who were between the ages of 13-16 years. This group consisted of twelve female and thirty six male. The clinical results of our study were rated on the basis of the criteria of union, nonunion, delayed union or malunion (Table 3).

Technique of nail insertion: The patient was positioned on a radiolucent table with access to the IITV (image intensifier television). The bone was exposed with a longitudinal incision and the soft tissues spread in the same direction with help of blunt tip scissors. The periosteum was also incised longitudinally and the cortex exposed. With the help of sharp awl, the outer cortex was perforated and the awl angled to enter the medullary cavity. Care was taken to ensure that the entry point is in the middle of the width of the presenting cortex. With too anterior or posterior entry points the direction of nail insertion is altered. In femur, an anterior entry point can cause inadvertent penetration of the knee joint. In the humerus, two lateral entry points, one over the other are required to insert the nail. A medial entry portal requires exposure of ulnar nerve and care while leaving the nail end protruded. Once the entry points were made, the nails were inserted with the curve tip into the medullary cavity. The nails were manually pushed with the help of a "T" insertion handle until resistance was met and then gently hammered with the curve tip sliding on the inner cortex. Once the nails reach the fracture ends, especially in the femur where both nails were inserted first up to the fracture site, then the fracture site was manipulated to allow reduction. An IITV here was very useful and can confirm reduction and correct passage of the nail. The nails were inserted retrograde in the femur, humerus and ulna and antegrade in the radius and tibia. Nail sizing was crucial and was determined by measuring the width of the isthmus of the long bone, subtracting 20% for the magnification factor and dividing the remaining by two. Two nails of equal sizes appropriate for the width of the medullary cavity were selected. If nails of unequal sizes are used the torque imparted by the larger nail would be asymmetrical causing fracture angulation. Once across the fracture site, the nails were inserted unto the metaphysis with the tips facing opposite directions to give good three-point purchase in the cancellous bone. The nails were cut 1.5 cms long and bend to lie along the bony cortex to prevent skin and soft tissue impingement. Wound was closed with suction drain in standard manner and antiseptic dressing was done. Drain was removed on 2nd post-operative day. Rehabilitation such as touch down weight bearing was started on 2nd post-operative day and sutures were removed on 14th post-operative day. These patients were assessed clinically and radio logically for union timing at nine months following surgery. Patients were assessed for delayed union (more than 4-6 weeks postoperative) and non union (nine months following surgery). Stastical analysis was limited to calculation of percentage of patients who had unions, malunions, delayed unions, or non unions and Excellent, Good, and poor outcomes

Results:

All patients underwent surgery under general anesthesia and titanium nails were used in each patient. In all 82 patients the fracture was reduced by closed means. The commonest titanium nail size was 2.5 mm for humeral and forearm fractures, and 3 mm for femoral and tibial fractures. Length of hospital stay varied between 2–3 days for humeral and forearm fractures, and 5–7 days for femoral and tibial fractures. Physical therapy was started immediately if it was possible because of related injuries. Post-operatively, mean follow-up was 28 months (17 -48 months). No major complications were observed in relation to surgery. Complications as a result of the procedure were recorded in 5 (6.09%) patients and included two patients (2.44%) were labeled as delayed union because of obvious gap at the fracture site in subsequent radiographs (Table 4, 5). This was due to over distraction of fracture during operation, and was treated by bone graft, two entry site skin irritations; one protrusion of the wires through the skin although they had been buried during the procedure. This nail required removal 2–3 weeks prior to the planned date of removal. There was no instance of loss of reduction, or nail migration during the post-operative period. No clinically significant deformities were observed. Nonunion and malunion were not seen in this study. All patients achieved complete radiographic healing at a mean of 10 weeks (range from 6 -16 weeks). In general the mean healing for femur and tibia was 12 weeks and 11 weeks respectively. The healing time for upper limb fractures was shorter: 8 weeks for forearm and 10 weeks for humerus fracture. The results were excellent in 97.31% (80/82) and good in 2.44% (2/82) patients (Table 4, 5). At final follow-up, all patients went on to osseous union and regained a full range of movement after rehabilitation.

Discussion:

The majority of long bone fractures in older children are treated operatively and younger children nonoperatively. External fixator was used previously

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had high risk of nonunion, refractures and pintract infections[2,8]. In skeletally mature children, reamed locked intramedullary nails were effective but had risk to the long bone physis, and in femoral fractures may increase the risk of a vascular necrosis if piriformis fossa is used as an entry point[2]. The titanium elastic nail is now commonly used for the treatment of pediatric long bones fractures and their use has minimised the surgical scarring previously caused by open reduction and plating [3]. This method achieve biomechanical stability from the divergent "C" configuration which creates six points of fixation and allows the construct to act as an internal splint[2,9]. The titanium elastic nails provide stable and elastic fixation, allowing for controlled motion at the fracture site which results in healing by external callus. Several studies have demonstrated the safety and efficacy of this technique[1,4,5,7,10,11]. The elastic nail is not without the possibility of complication. Complications usually are based on mistakes concerning the indication or technical errors[12,13]. The most common reported complications associated with these techniques include infection, overgrowth, entry site skin irritation and re-fracture[2,3,7]. My study showed a complication rate of 6.09%. The most common complication was irritation of the skin at entry site. We have not observed any major complications. This is similar with the complication rate reported by previous studies[2,3,12,13]. Majority of fractures of the proximal humerus are treated non operatively in the younger children with good remodelling potential while in older children with little remodelling potential operative approach are favoured. Various surgical techniques using staples, screws, pins and plates for fixation have been utilised, but these techniques have not been without complications[3]. Rajan et al. [12] reported fourteen patients with displaced proximal humeral physeal fractures treated by ESIN. All fractures were radiologically united at a median time of eight weeks. Subjectively 71% of patients were very satisfied and 29% were satisfied. They do not observed any major complications. Soft tissue irritation by the protruding distal end of the nail from the humerus was observed in three patients and one had radial nerve symptoms. They recommend stabilization using ESIN in the management of the displaced proximal humeral physeal fracture in older children[12]. Fractures of humeral shaft are result of direct force during a direct impact, traffic accidents or crush injuries. Indirect forces such as fall on elbow or extended arm or strong muscular contractions can result with a fractured humerus. The most frequent site ESIN for pediatric long bone fractures 213 of the fracture is between the middle and the distal third of humerus[14,15.] Fernandez et al[13] reported 31 children operated because of humeral shaft fracture. After the treatment all children could take part in sports activities like before the accident. Thirty children and their parents were very satisfied with the treatment success and 1 patient was satisfied. They have reported a complication rate of 16.1% and concluded that ESIN of humerus shaft fractures has a low complication rate if attention is paid to biomechanical principles[12]. In my study 12 children were operated with humeral shaft fractures. Two cases were at proximal third, 8 cases at middle third and 2 cases at distal third. All the cases were treated with elastic nails with 100% union rate and without complication. The majority of the diaphyseal forearm fractures in children are treated with closed reduction and the application of an above elbow cast for a varying period, depending on the age of the child. Some forearm diaphyseal fractures require osteosynthesis mainly because of the presence of an unacceptable angular deformity, fracture instability, presence of an open injury or failure of conservative management in the form of redisplacement in the cast after manipulation. Weinberg et al. in 77 children. They recorded postoperative complications in three patients, a superficial pin entry site infection [16]. Garg et al. reported 21 pediatric patient treated with ESIN for displaced and unstable diaphyseal forearm fractures[22]. All their fixations were protected in an above elbow plaster cast. Clinical and radiologic union was achieved within 13 weeks after the procedure in 19 children. They reported one patient that had delayed union of the ulna which finally united at 9 months after operation without any further intervention and another patient that had nonunion of ulna that required autologous bone marrow injection after 1 year before full consolidation occurred. All patients in their series achieved a good functional clinical outcome [17]. Monteggia and Galeazzi fractures are rare injuries of the forearm, but they are important because of their special biomechanics. Schmidt et al. reported clinical cases of pediatric Monteggia fractures that were operated upon using ESIN. In correct indications ESIN could be used as a minimally invasive therapeutic alternative to plate osteosynthesis for treating pediatric Monteggia injuries [18]. Although in literature many complications including osteomyelitis [19], superficial radial nerve injury [3], extensor pollicis longus rupture [3, 20], extensor pollicis breves rupture [3], delayed healing or nonunion were described [17, 21.] In my study we operated 4 cases of fractures shaft of ulna with 100% of union rate. We found two cases of entry site skin irritations. Femoral shaft fractures in children are usually treated by conservative means, such as immediate spica cast immobilisation or initial traction followed by hip spica application [11]. Traditional methods do give satisfactory results in younger children but older children may have complications such as malunion, delayed union, rotational deformities and psychological problems. Operative methods for femoral shaft fractures in children include external fixation, plating, rigid or flexible intramedullary nailing [11]. More recently Métaizeau advocated the use of elastic titanium nails (Nancy nails) for femoral shaft fractures in children [11]. Their technique is known as Elastic Stable Intramedullary Nailing (ESIN) or Métaizeau technique. Fixation by flexible nails is appropriate for patients over the age of five years [10, 23, and 24]. Usually, femoral shaft fractures in children younger the age of five years are treated conservatively. Simanovsky et al. retrospectively reviewed 13 cases of diaphyseal femoral fractures treated with close reduction and TENs, in children aged 3–5 years. They do not noted cases of nonunion or malunion, only minor complications were observed in two children. Although the operative approach to simple diaphyseal fractures of the femur at such a young age is not routinely recommended, it can be a valuable option as an initial treatment, or when a conventional treatment with a spica cast has failed [24]. Buechsenschuetz et al. analyzed treatment of pediatric femoral fractures by traction and spica casting versus ESIN. They found that the ESIN was associated with a lower overall cost than traction and spica casting. The ESIN also resulted in better scar acceptance, and higher overall parent satisfaction[25]. Khazzam et al. evaluated use of TENs in the treatment of femoral shaft fractures in 135 children. They recorded very good functional results, low complication rate and concluded that use of TENs in the treatment of femoral shaft fractures in children is successful regardless of patient age, fracture location, or fracture pattern [26]. Nonunion and major complications are not very common in pediatric fractures. Fixation of complicated pediatric femoral fractures with ESIN is also a good option [27]. With the increasing rate of childhood obesity and tendency for sagittal and coronal angulation of femur fractures treated with TENs, it is necessary to determine the load at which permanent sagittal and coronal deformation of the nails occurs because this may result in an unfavorable outcome. Li et al. provided biomechanical evidence that patients weighing more than 40 to 45 kg who undergo stabilization of a transverse midshaft femur fracture with TENs are at risk for loss of reduction in the sagittal and coronal planes [4]. Although in literature many complications including osteomyelitis [7, 10, 27], varus or valgus malalignments [7, 15, 25], refractures [10, 15, 25], asymptomatic proximal nail migration [7, 25], delayed healing or nonunion were described [7, 25]. In my study 46 cases were operated with titanium elastic nails and found 100% union rate. There was only one case of asymptomatic protrusion of the wires. Majority of the Fractures of the shaft of tibia can generally be managed with casting. Less than 10° of angulation should be the goal in older children. Varus angulation remodels better than valgus or posterior angulation. Occasionally, reduction cannot be maintained due to excessive shortening, angulation, or malrotation at the fracture site, making operative intervention necessary. The elastic nailing of long bone fractures in the skeletally immature has gained widespread popularity because of its clinical effectiveness and low risk of complications [2, 15]. Sankar et al. reported a series of 19 children with tibial shaft factures treated with elastic nail. All patients in their series achieved complete healing at a mean of 11 weeks. At final follow-up, mean angulation was 2° in the sagittal plane and 3° in the coronal plane. Five patients complained of irritation at the nail entry site; there were no leg length discrepancies or physeal arrests as a result of treatment [2]. O'Brien et al. reported a series of 16 children with tibial shaft fractures treated with ESIN. All patients went on to radiographic healing by an average of 9 weeks. No patients had greater than 10° of angular deformity at final follow-up, and no clinically significant leg length discrepancies resulted from treatment [28]. Similarly, Goodwin et al. reviewed 19 patients with tibial shaft fractures treated with ESIN. After a mean follow-up of 13 months, all achieved union. Two patients had angular deformities in excess of 10°, and one child developed a clinically insignificant physeal arrest [29]. Several studies have described irritation at the nail entry site as the most common complication following the use of titanium elastic nails, ranging in incidence from 7 to 40% [2, 10, 14, and 26]. Although in literature many complications including osteomyelitis [30], angular deformity [2], refractures [28], asymptomatic proximal nail migration [2, 28], delayed healing or nonunion were described [14, 32]. Griffet J et al. [31] included 86 children in his study and after 2 years of follow-up, he found the superiority of the ESIN technique over other fixation techniques, such as locking compression plate and percutaneous plating, in terms of postoperative complications. Volpon JB et al. [32] concluded that the end caps inserted into the nail extremity contributed to an increase in the construct stability for torsion and axial-bending forces but not for 4-point bending forces. In my study 20 cases were treated with titanium elastic nails. Slight delayed union was observed in two cases. This study did not have a control group nor did we compare other methods of treatment. However titanium elastic nailing provided excellent results in the management of long bone fractures in children. There are distinct advantages in terms of duration of hospital stay, fracture stability and early return to function.

Conclusion: The study of Titanium elastic percutaneous nails for pediatric long bone shaft fractures: current concept provides satisfactory results in 97.31 % of the patients. The percentage of complications that we recorded is slightly lower than that published in similar studies in the literature. The elastic nailing shows very good functional and cosmetic results. It provides an early functional and cast-free follow-up with quick pain reduction. The elastic nailing for shaft fractures is a safe and minimally invasive, does not interfere with growth, and is associated with few complications, short hospital stays, and rapid return to daily activities. Severe complications are rare, with most problems arising from incorrect technique or indication. A comprehensive understanding of the principles, indications, and operating techniques is mandatory to obtain excellent results, but in experienced hands a broad spectrum of pediatric long-bone fractures can be treated using this method.

Acknowledgement: None.

Conflict of interest: None.

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