Advanced Medical Journal, Vol.9, No.1, P.56-67, 2024 https://doi.org/10.56056/amj.2024.237

Early Complications of Elastic Stable Intramedullary Nails in the Treatment of Pediatric Diaphyseal Fractures of Long Bones: an Experience in Duhok Center of Orthopedic Surgery

Ageed Ameer Abduljabar[*] Las Hwaizi[**] Laween Omar Musa[***]

Abstract:

Background and objectives: diaphyseal fractures in the pediatric age group should be perfectly treated. Treatment options are too many with long lists of pros and cons. This study aims to determine complications of elastic Table intramedullary as an evolving method in the era of operative treatment.

Methods: This is a prospective case series study, conducted at Duhok Emergency Teaching Hospital between march/2021 and April/2022. The sample size was 100 children (mean age was 6.53 years). Inclusion criteria were: diaphyseal fractures (open and closed) in children 3-12 years. Exclusion criteria were: humeral fractures, fractures of the radial neck, pathological fractures, and obese patients (>40kgs). All of them were operated on under general anesthesia and their fractures were fixed with elastic stable intramedullary nails under C-arm, follow up period was 6-9 months both clinically and radiologically.

Results: complications were found in the following order of frequency: 39.02% insertion site irritation, 14.02 joint swelling, 9.76% superficial infection, 7.93% loss of reduction, 7.32% stiffness, 3,66% delayed union, 3.05% limb length discrepancy and 0.61% deep infection. While the frequency of complications was significantly related to the type of fracture as (p-value: 0.031) and transverse fractures were seen to be associated with the highest complication rate, no significant relation was found between the frequency of complication with either age groups or gender as the (p-value: 0.447) for frequency of complications among both age groups and (0.711) between the two genders.

Conclusion: fixation with elastic stable intramedullary nails is a good choice of treatment for diaphyseal fractures in the pediatric age group however it is not free of complications.

Keywords: Diaphyseal fractures, Elastic stable intramedullary nails, Pediatric trauma Surgical intervention.

Introduction:

Musculoskeletal injuries are the second most common cause (after head injuries) of lifelong disability in childhood. Children taking part in sports are more liable for fractures of the diaphysis.

[*] MBChB, Senior house officer at Duhok Emergency & Trauma Teaching Hospital, dr.ageedbamerny@gmail.com. [**] MBChB, PROF-Orthopedic Surgery KHCMS/Erbil Teaching Hospital, bawagy56@gmail.com. [***] MBChB, FIBMS-Orthopedic Surgery/Lecturer-UoD/Duhok Emergency & Trauma Hospital, laween.musa@uod.ac

As an approach, after any pediatric injury, the kid should be able to resume all activities of daily living, without pain and long-term complications.[1] In the pediatric population, fractures in the upper limbs are much more common than those in the lower limbs and the most commonly fractured long bone is the radius, followed by the humorous.On the other side, the tibia is more commonly fractured than the femur in the lower limb.[2,3] When treating pediatric long bone fractures, one must first bear in mind that excellent results may be gained with non-operative treatment, with estimated 90% union rates or more, and about 100% functional recovery. But in some occasions maintenance of reduction is not possible due to angulation, excessive shortening, or malrotation at the fracture site, making operative treatment mandatory. In other cases, surgical treatment is warranted because of polytrauma, open fracture, or compartment syndrome.[4] Different ways are used to treat diaphyseal fractures in children including traction, splints, orthoses, plaster casts, ORIF with plate and screws, IM fixation by rods, and external fixation. These modalities do have their complications, some require prolonged hospitalization and long periods of inactivity along with the ugly scars they leave. Following many reports, Elastic stable Intramedullary Nailing (ESIN) has gained popularity as an evolving method and is now a well-recognized one for treating pediatric diaphyseal fractures. Advantages of these rods include; minimally invasive surgery, no absolute indication for cast immobilization postoperatively, shorter hospitalization, rapid recovery of joint function, and return to physical activity. In addition, the rate of complications is minimal as it has been reported.[5] This implant was developed in 1988 by Nancy, France, with different names e.g., Nancy nail or titanium elastic nail (TEN), with different materials; stainless steel or titanium. It was referred to as (Centro mé-Dallaire elastique sTable) (ECMES) system and it is suitable for patients aged between 5-16 years of age.[6] ESINs work by symmetrical bracing action of two pre-curved elastic nails so that the length of the curve is three times greater than the medullary canal inserted through a small stab on the metaphysis, stability is achieved through cortical end-to-end contact and surrounding soft tissue each nail holds the corresponding cortex at the entry point, fracture site and the distal tip, the so-called three-point fixation,[7] these load-sharing devices work as an internal splint allowing some micromotion that accelerates callus formation and the benefit of their intramedullary passage is to keep fracture hematoma undisturbed as it reduces infection possibility.[8] These implants are available with a range from 1.5 to 4 mm of their diameters. The width of the medullary canal determines the size, in a way that a nail diameter must be 40% of the medullary canal. Length is determined by putting a nail over the affected bone and measuring the length against the c-arm. Pre-bending the nails is crucial as the maximum curvature holding must be at the fracture site.[9] The benefit of immediate stability to the involved bone segment that ESINs offer, permits early mobilization and early return to the activities of daily living.[4.]

This study aimed to determine the frequency of short-term complications; (insertion site irritation, loss of reduction, infection, joint problems, delayed union or limb length discrepancy)[4,5] associated with the use of (ESINs) in the treatment of long bone fractures in the pediatric age group and identify complications that can be avoided.

Patients and methods:

This is a prospective case series study, conducted in Duhok Emergency Hospital between March/2021 and April/2022. During this period 100 cases in the pediatric age group were included. Inclusion criteria were: children between 3-12 years with diaphyseal (closed and open) fractures. Patients with fractures in the radial neck, humeral fractures, pathological fractures, and obese patients (>40kgs) were excluded from this study.

An Ethical approval letter was obtained from the Ethical Committee/ Directorate of Health in Duhok. An assigned consent was obtained from the parents of each child to get enrolled in the study. Preoperative evaluation for each patient included a detailed history and examination and X-Rays of the injured limb. All patients were operated on under general anesthesia by different orthopedic surgeons using titanium elastic nails (TENs) and an image intensifier. All patients were treated by closed reduction except two of them who had femur fractures, where a mini-incision has been used over the fracture site for reduction. The follow-up period was 6-9 months and during each visit, several parameters were studied including; evidence of union clinically and radiologically, loss of fracture alignment, change in the limb length, state of the pin insertion site, and range of motion of the nearby joint.

Statistical analysis was done using SPSS version 24 software for statistical analysis and Chi-square tests to analyze the data, the p-value of 0.05 was concord under a confidence interval of 95%. the p-value of 0.05 was concord under a confidence interval of 95%.

Results:

A total of 100 patients with diaphyseal fractures with a mean age of 6.53 years have been enrolled in this study, 135 fractures have been studied (40 radii 29.6%, 39 femoral 28.8%, 38 ulnae 28.1% and 18 tibias 13.3%) fractures. The frequency of fracture patterns in this study (49 transverse 49%, 33 short oblique 33%, 12 spiral 12%, and 6 comminuted 6%) fractures, the most frequent bone taken part was the radius and the most common fracture pattern was a transverse fracture. (Figure 1). For statistical purposes, participants of the study have been divided by two parameters the first one was age and the second one was gender, 55 patients (55%) in the first age group (1^{st} group) who ≤ 6 years and 45 patients (45%) in the second age group (2^{nd} group) were those who >6 and ≤ 12 years, 42 females (42%) and 58 males (58%), (Figure2). The frequency of complications was 164 complications in 100 patients being sorted by fractured regions (forearm, thigh, and leg) and it is 207 for the same number of patients being sorted by bones fractured (radius, ulna, femur, and tibia) in a manner that a patient might have more than one complication. The most common complication was insertion site irritation followed by joint swelling and the least common was deep infection and the second least common was limb length discrepancy (Tables 1 and 2). No Complications were found in 24 patients (14.63%), (Table1); 18 males (75%) and 6 females (25%), (Table 3) and 12 were from either age group 50% (Table 4).

Insertion Site Irritation was found in 64 patients (39%), (Table1); 36 cases were of the 1^{st} age group (56.25%) and 28 were from the 2^{nd} (43.75%), (Table4), 36 males (56.25%) and 28 females (43.75%), (Table3), 83 fractures (40.10%) of all fractures; 23 radial

fractures (27.71%), 20 ulna fractures (24.1%), 28 femur fractures (33.73%) having the big share and 12 with tibia fractures (14.46%) mostly in transverse fractures (45.31%) of all cases with this complication (Tables 2 and 5). Only one case of those with protruded nail tips (femur fracture), needed operative management after a period of dressing and antibiotics till a listed appointment for trimming of the nail ends (re-operation) then removed after the full union was achieved. In all other cases, this was found to be trivial and did not need surgical intervention. Joint Swelling was found in 23 patients (14.02%), (Table1); 14 were from 1st age group (60.87%) and 9 from the 2nd age group (39.13%), (Table 4), 10 males (43.48%) and 13 females (56.52%), (Table3), 25 fractures (12.08%); 3 radial fractures (12%),2 ulna fractures (8%), 9 femur fractures (36%) and 11 tibia fractures (44%). The knee joint was the most commonly swollen joint (Table 2). Superficial Infection was found in 16 patients (9.76%), (Table1); 7 were from the 1st age group (43.75%) and 9 were from the 2nd age group (56.25%), (Table 4), 8 patients for each gender (50%), (Table 3), 19 fractures (9.18%); 5 radius fractures (26.32%), 3 ulna fractures (15.79%), 5 femur fractures (26.32%) and 6 tibia fractures (31.58%) having the big share (Table 2). All of them were treated with antibiotics with complete clinical resolution and no further intervention. Mostly in tibia fractures. Loss of reduction was found in 13 patients (7.93%), (Table 1); 8 patients were from the 1st group (61.54%) and 5 were from the 2nd age group (38.46%), (Table 4), 6 males (46.15%) and 7 females (53.85%), (Table 3), 16 fractures (7.73%); 3 radial fractures, 3 ulna fractures (18.75) for each of them, 8 femur fractures (50%) and 2 tibia fractures (12.5%), (Table 2). Loss of reduction in our study was observed in association with 4 spiral fractures (38.46%) and 5 comminuted fractures (30.77%), 3 transverse fractures (23.08%), and 1 short oblique fracture (7.69%), (Table 5), All of them were below 10 degrees on both anteroposterior lateral x-ray films and radiological follow-up continued until the date of removal without intervention. It was mostly seen in femur fractures (Table 2) and the first age group (Table 4). Knee joint stiffness was found in 12 patients 7.32% (Table1); 6 patients (50%) for either age group (Table 4), boys more than girls, 7 males (58.33%) and 5 females (41.67%), (Table3), 12 fractures (5.80%); 4 femur fractures (33.33%) and 8 tibia fractures (66.67%), (Table 2). All of them were due to painful limitation that was closely related to insertion site irritation and all of them were treated by physiotherapy after the removal of their implants without further intervention. Delayed Union was found in 6 patients (3.66%), (Table 1); 3 patients (50%) for either age group (Table 4), boys more than girls; 4 males (66.67%) and 2 females (33.33%), (Table 3), 7 fractures (3.38%); 1 radial fracture (14.29%), (2 ulnae, 2 femora, and 2 tibias) fractures (28.57%) for each of them (Table 2). Limb Length Discrepancy (lengthening) was found in 5 patients (3.05%), (Table 1); boys were more than girls, 4 males (80%), and only one female (20%), (Table 3). All of them were from the 1st age group (Table 4), femur fractures exclusively (Table 2), and less than 2 centimeters which were clinically not significant. Deep Infection occurred only in one patient (0.61%), a female from the 2nd age group with an open femur fracture (Table 3), treated with formal debridement and antibiotic that ended up with a complete resolution and did not need early implant extraction. While there was a significant relationship between the frequency of

complications and fracture types (transverse fractures were seen to be associated with the highest complication rate as the p-value for this relation estimated by Pearson Chi-Square test was 0.031 (Table 5), overall in this study, no significant relation was found between the frequency of complication with neither age groups nor gender, as p-value were 0.477 and 0.711 for both relations (Tables 4 and 3) despite some variations that have been found between age groups or genders but all of them, were of no statistical significance.

Table (1). Order of Frequency of Complication

Complications	No	%
No Complications	24	14.63
İnsertion Site Irritation	64	39.02
Joint Swelling	23	14.02
Superficial Infection	16	9.76
Loss of Reduction	13	7.93
Joint Stiffness	12	7.32
Delayed Union	6	3.66
Limb length discrepancy	5	3.05
Deep infection	1	0.61
Total	164	100.00

Table (2). Frequency of Complications assorted by Bone

Comp	Radius		Ulna		Femur		Tibia		Total	
	No	%	No	%	No	%	No	%	No	%
No Complications	16	41.03	16	41.03	6	15.38	1	2.56	39	18.84
Insertion Site Irritation	23	27.71	20	24.10	28	33.73	12	14.46	83	40.10
Superficial Infection	5	26.32	3	15.79	5	26.32	6	31.58	19	9.18
Deep Infection		0.00		0.00	1	100.00		0.00	1	0.48
Joint Swelling	3	12.00	2	8.00	9	36.00	11	44.00	25	12.08
Joint Stiffness		0.00		0.00	4	33.33	8	66.67	12	5.80

Limb Length Discrepancy		0.00		0.00	5	100.00		0.00	5	2.42
Delayed Union	1	14.29	2	28.57	2	28.57	2	28.57	7	3.38
Loss of Reduction	3	18.75	3	18.75	8	50.00	2	12.50	16	7.73
Total	51	24.64	46	22.22	68	32.85	42	20.29	207	100.00

Table (3). Frequency of Complications assorted by Gender

Comp	Female		Male		Total	
	No	%	No	%	No	%
No Complications	6	25.00	18	75.00	24	14.63
İnsertion Site Irritation	28	43.75	36	56.25	64	39.02
Superficial Infection	8	50.00	8	50.00	16	9.76
Deep Infection	1	100.00		0.00	1	0.61
Joint Swelling	13	56.52	10	43.48	23	14.02
Joint Stiffness	5	41.67	7	58.33	12	7.32
Limb Length Discrepancy	1	20.00	4	80.00	5	3.05
Delayed Union	2	33.33	4	66.67	6	3.66
Loss of Reduction	7	53.85	6	46.15	13	7.93
Total	71	43.29	93	56.71	164	100.00

Chi-Square Tests: Sex Complications

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.577[a]	7	0.711
Likelihood Ratio	5.085	7	.650
Linear-by-Linear Association	.031	1	.860
N of Valid Cases	140		

a. 6 cells (37.5%) have expected count less than 5. The minimum expected count is .46.

Table (4). Rate of Complications by Age Groups

Comp	Equal and less than 6 years		More than 6 years		Total	
	No	%	No	%	No	%
No Complications	12	50.00	12	50.00	24	14.63
Insertion Site Irritation	36	56.25	28	43.75	64	39.02
Superficial Infection	7	43.75	9	56.25	16	9.76
Deep Infection		0.00	1	100.00	1	0.61
Joint Swelling	14	60.87	9	39.13	23	14.02
Joint Stiffness	6	50.00	6	50.00	12	7.32
Limb Length Discrepancy	5	100.00		0.00	5	3.05
Delayed Union	3	50.00	3	50.00	6	3.66
Loss of Reduction	8	61.54	5	38.46	13	7.93
Total	91	55.49	73	44.51	164	100.00

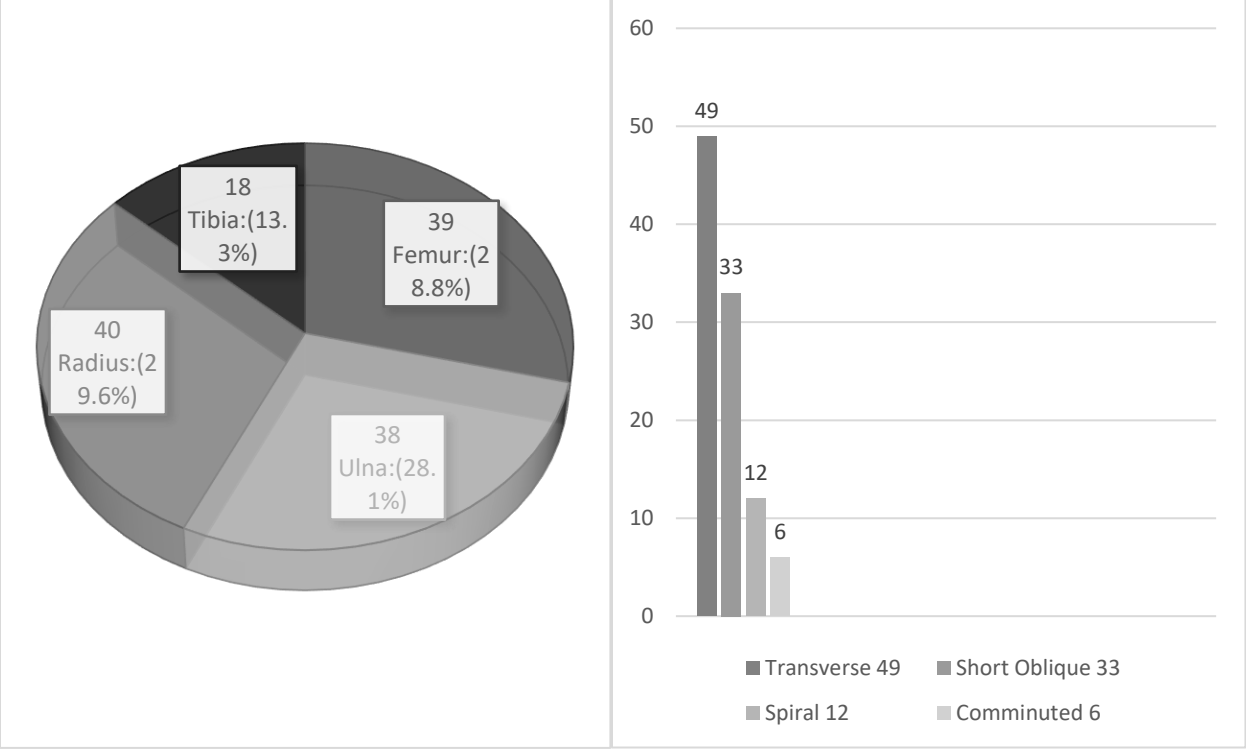

Figure (1). Bones and fracture types in the study

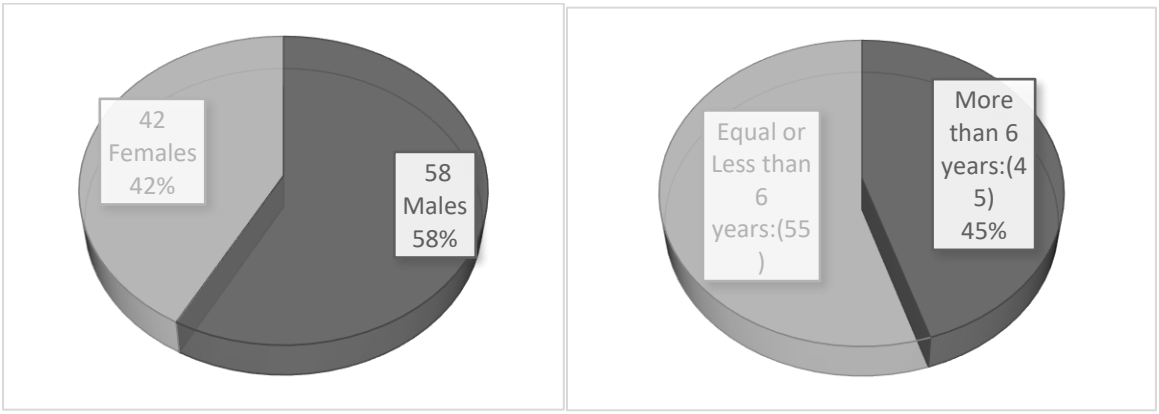

Figure (2). Age and gender distribution for the involved participants.

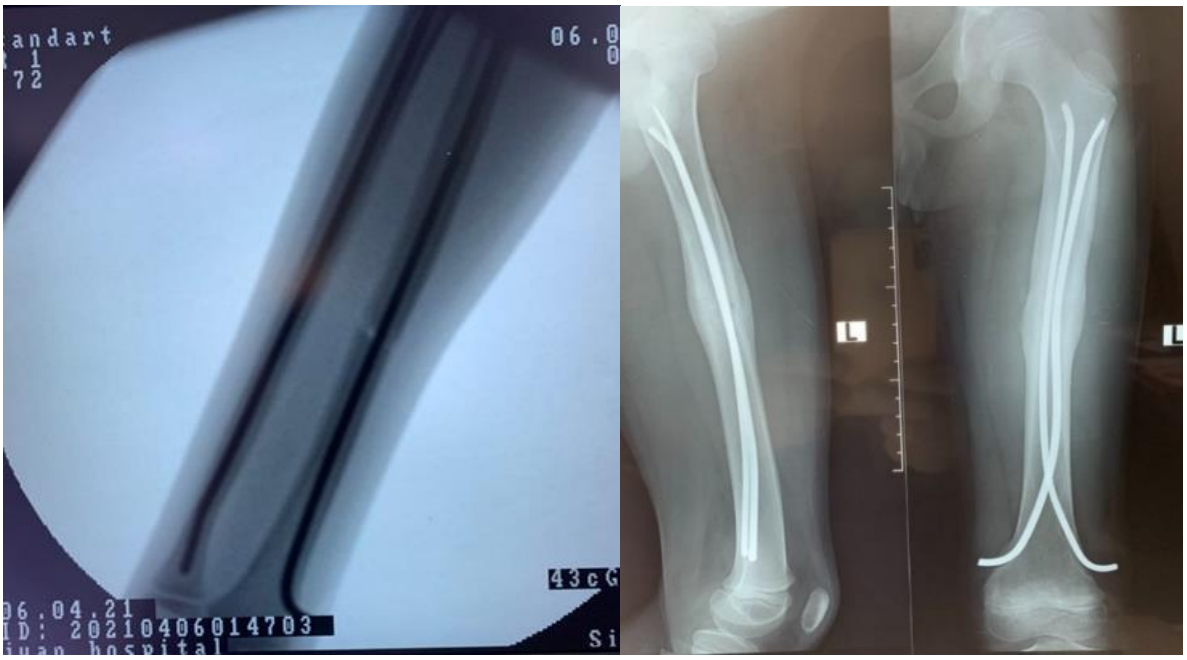

Figure (3): Radiographs, on the left radius and ulna transverse fracture fixation. On the right malunion on both AP and Lateral films with far protrusion of the nails from the cortex.

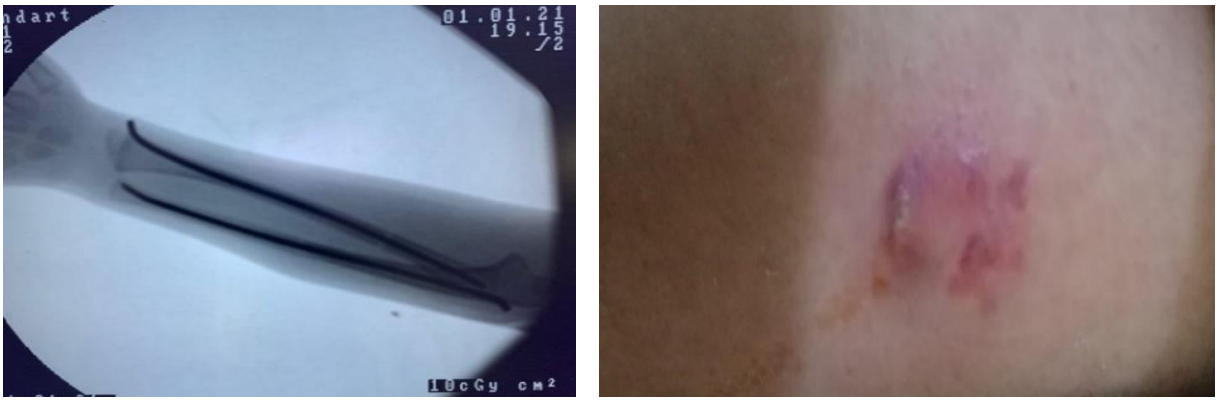

Figure (4): On the left is a radiograph showing a far protrusion of the implant approaching the subcutaneous tissue. On the right is a photograph of another patient with insertion site irritation around the knee joint.

Figure (5): photographs showing different stages of the protruded implant from the skin that was the only case with this sequelae.

Discussion:

Fixation with elastic Table intramedullary nails is a well-known method for treating pediatric diaphyseal fractures but is not free of complications. While there was a statistically significant relation between fracture type and rate of complications; the transverse fracture pattern has been associated with complications more than other types, which might be attributed to that most of the participants were with transverse fractures. No significant relation was found between the frequency of complications with neither age groups nor gender. Patients in this study have been divided into 3 different anatomic regions fixed with elastic nails for statistical purposes. We have had 43 patients with forearm fractures, with a mean age of 6.6+/-2.38 years, 17 cases were with no complications making (39.53%) compared to a study done by Nisar et al where they had 89

patients with forearm fractures in their study and it has been found that 59 of them were treated without complications (66.29%), it has been also found in that study that prominent nail tip happened in 17 patients and only one of them required surgical intervention for skin breakdown at nail tip, while the others were kept under follow up until union and implant extraction, comparing this to what we have found: insertion site complications like insertion site irritation have been found in 24 out of 43 patients (55.81%), which was nearly asymptomatic; the patients and their parents were not concerned about it (observed by the surgery team during the removal surgery) in nine (9/43) of them (20.9%). Only 3 patients (7%) of those have had joint swelling which was a bit interfering with joint movement but did not necessitate surgical intervention. Superficial soft tissue infection was found in five patients (5/43), (11.6%) which was managed with antibiotics and regular follow-up until clinical resolution, this complication is higher in our study compared to what Nisar et al have found which was (3.37%), 3 out of 89 patients; however in both studies these infections have been managed with antibiotics and regular follow up to the union dated removal without further intervention and in both studies, prominent hardware was the most common complication found[5]. We have found that a prominent nail tip was the cause behind this irritation, swelling in the nearby joints, and even infection in the superficial tissue.

Regarding union, we found that delayed union happened in 2 out of 43 patients (4.65%), and loss of reduction in 3 patients (7%), this is a higher rate compared to a study done by Fernandez et al where they found that delayed union happened in fourteen 14 out of 553 patients (2.53%) and secondary loss of correction happened in 6 out of 553 patients (1.08%) of forearm fractures, this was attributed comminution and spiral fracture patterns, however, both studies the patients were not functionally disabled and malunion was within the clinically acceptable range, while the delayed union was dealt with by follow-up with no surgical intervention[10].

Thirty-nine patients with femur fractures out of 100 patients have taken part in this study, with a mean age of 6.21+/-2.64 years. No complications were observed in 6 patients (15%), comparing this finding to a study by Amin et al where 15 of 18 patients (88.80%) have had no complications[11]. We have found that Insertion site irritation happened in 28 patients (71.79%), where 9 of them were associated with joint swelling (23%), and only one patient had skin breakdown that necessitated operative trimming of the nail ends and clinical follow-up for union progress did not interfere furthermore. The superficial infection happened in 5 patients (12.82) and it was observed exclusively in those with prominent nail tips. These rates are higher compared to a study done by Khanna et al investigating 45 children with femur fractures where Insertion site bursitis has occurred in 9 patients (20%) and superficial infection was observed in 3 patients (6.66%),[12] while they are comparable to Nisar et al results of investigating 13 children with femur fractures (53%) insertion site irritation in which three patients needed trimming of the nails before union achievement[5]. Prominent nail tip again here was the cause of these complications ranging from irritation to swelling and superficial soft tissue infection.

Knee stiffness has happened in four 4 out of 39 patients (10.25%), and only in one of them was associated with an open fracture which was of an oblique pattern we may blame the wound contamination, but in the other three

patients, stiffness was observed in association with insertion site irritation.

Limb length discrepancy (LLD); lengthening happened in 5 out of 39 patients (12.82%) which were less than 2 centimeters and not functionally disabling, again it is higher than what has been observed in the Khanna et al study where they found in 2 out of 45 patients (4.44%)[12] and comparable to Nisar et al study 5 out of 13 patients (38%) with a median of (1.7centimeters).[5] Compared to a study done by Sarkar et al where the median (LLD) was 1.5 centimeters which is comparable to our study, has happened in 2 out of 70 patients (2.85%).[13] Loss of reduction (less than 5 degrees in the coronal and less than 10 degrees in sagittal planes) was clinically acceptable and observed regularly until union happened in 8 out of 39 (20%) which was higher than that of Khanna et al study 3 out of 45 (6.66%), and comparable to what Sarkar et al found where varus mal-reduction has happened in 4 out of 70 (5.71%),[13] and to Nisar et al (46%) in which 2 patients required unplanned surgery to correct the fracture alignment.[5,12] Spiral and comminuted fracture patterns are blamed here in our study.

Out of 18 cases of tibia fractures in this study with a mean age of 5.38+/-1.03 years, insertion site irritation again was found in 12 patients (66%) as the commonest complication, superficial infection in 6 patients (33%) in which two of them were open fractures, and all of the cases were treated with antibiotics only till clinical resolution and there was no deep infection. Loss of reduction (less than 10 degrees in coronal and sagittal planes) which was clinically acceptable and delayed union happened in 2 patients (11.11%) and both have been dealt with by follow-up with no intervention. We found knee joint stiffness in (44.44%) and all the cases gained the functional range of motion with physiotherapy after the union-dated removal of their implants, with no cases of limb length discrepancy. Stiffness was observed in all of the cases associated with joint swelling and prominent nail tips that is to say painful limitation of movement has led to stiffness, compared to a study done by Kc et al where complications were ordered by frequency as prominent nail irritation was observed in a lower rate (13%), and limb length discrepancy (11%) which needed further clinical follow up to decide intervention. Delayed union was (8%) comparable to our results, and superficial infection (4.4%) was lower than our result, which might be due to the lower rate of prominent nail tips their study observed. Malunion was (4%) within 10 degrees in both sagittal and coronal views in which the rate is lower than that of our study but the range of deformity is almost the same.[14]

Conclusions: fixation with elastic stable intramedullary nails is a good choice for diaphyseal fracture fixation in the pediatric age group however it is not free of complications. Despite the high rate of complications in our study, most of them were minor and did not need surgical intervention. No association was found between the rate of complications with age nor with gender. We believe that proper patient selection (length stable fractures: transverse and short oblique) and proper trimming of the nail tip can avoid most of the complications of elastic stable intramedullary nails as the high rate of insertion irritation was attributed to prominent nail tips and loss of reduction was attributed to comminuted and spiral fracture patterns.

Conflict of interest

The researchers declare that there is no any conflict of interest.

References:

1. Buckley R, Moran C, Apivatthakakul T. AO Principles of Fracture Management. 3rd ed. Stuttgart: Thieme; 2017.
2. Joeris A, Lutz N, Wicki B, Slongo T, Audigé L. An epidemiological evaluation of pediatric long bone fractures — a retrospective cohort study of 2716 patients from two Swiss tertiary pediatric hospitals. BMC Pediatrics. 2014; 14(1).
3. Waters P, Skaggs D, Flynn J. Rockwood and Wilkins' Fractures in Children. 9th ed. Philadelphia: Wolters Kluwer Health; 2014.
4. Furlan D, Pogorelić Z, Biočić M, et al. Elastic STable Intramedullary Nailing for Pediatric Long Bone Fractures: Experience with 175 Fractures. Scand J Surg. 2011; 100(3):208-15.
5. Nisar A, Bhosale A, Madan SS, Flowers MJ, Fernandes JA, Jones S. Complications of Elastic STable Intramedullary Nailing for Treating Paediatric Long Bone Fractures. J Orthop. 2013; 10(1):17-24.
6. Osateerakun P, Limpaphayom N. Elastic STable Intramedullary Nail: The Viable Technique for Pediatric Long Bone Fixation. J Sea Ortho. 2014; 38(1):31-7.
7. Abosala A, Westacott D, Cunningham J. A Biomechanical Study of the Stability of Titanium Elastic Nails in the Treatment of Oblique Segmental Fracture of the Femur in Children. Internet J Orthop Surg. 2010; 19(1):1-8.
8. Pulate A, Jadhav A, Shah BN. Study of the Outcome of Titanium Elastic Nail System in Diaphyseal Femoral Fractures in Children. J Maharashtra Orthop Assoc. 2012; 7:6-8.
9. Vopat ML, Kane PM, Christino MA, Truntzer J, McClure P, Katarincic J, et al. Treatment of Diaphyseal Forearm Fractures in Children. Orthop Rev. 2014; 6(2):5325. Fernandez F, Langendörfer M, Wirth T, Eberhardt O. Failures and complications in intramedullary nailing of children's forearm fractures. J Child Orthop. 2010; 4(2): 159-67.
10. Amin A, Nahla A, Gaber A, Kamsawi M. Elastic STable Intramedullary Nailing Femoral Shaft Fractures in Children from Six to Ten Years Age. Egypt J Hosp Med. 2021; 84:1908-13.
11. Khanna M, Wadhwani J, Batra A, Yadav S, Iman S, Vashishth S. TENS for the surgical management of femoral shaft fractures in 6-14 years age group children. Pediatr Traum Orthop Reconstr Surg. 2017; 5(2):13-21.
12. Sarkar S, Bandyopadhyay R, Mukherjee A. Titanium Elastic Nail - Complications in the Treatment of Paediatric Diaphyseal Fracture of Femur. Open J Orthop. 2013; 7:12–7
13. Kc KM, Acharya P, Sigdel A. Titanium Elastic Nailing System (TENS) for Tibia Fractures in Children: Functional Outcomes and Complications. J Nepal Med Assoc. 2016; 55(204):55-60.
14. KM, Acharya P, Sigdel A. Titanium Elastic Nailing System (TENS) for Tibia Fractures in Children: Functional Outcomes and Complications. J Nepal Med Assoc. 2016;55(204):55-60. https://pubmed.ncbi.nlm.nih.gov/28029668/