THE FUNCTIONAL OUTCOME OF ELASTIC STABLE INTRAMEDULLARY NAILING FOR DIAPHYSEAL TIBIAL FRACTURES IN CHILDREN

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ABSTRACT

Background

Fracture of the tibia is a common fracture among children. A method that has become popular among surgeons in recent years for treating tibial fractures is the elastic stable intramedullary nailing technique. It has many advantages compared to conventional methods in that it has faster healing, earlier weight bearing, and fewer complications.

Objectives

The objective is to assess the outcome of the intramedullary nailing technique used to treat diaphyseal fractures of the tibia according to clinical and radiological measurements.

Materials and Methods

This prospective observational study analyzes 37 cases of fractured tibiae, aged between 4 and 11 years, treated by elastic intramedullary nailing technique. The duration of sample collection was from Aug. 1, 2020, to Feb. 1, 2022. Follow-up appointments were scheduled in weeks 2, 4, 6, 10, and 20 after the surgery, and a final follow-up after one year for removing titanium stable elastic IM nailing. The samples were analyzed by using Flynn's criteria score system.

Results

86.5% of the samples scored excellently, 10.8% scored satisfactorily, and 2.7% scored poor according to Flynn's criteria. Full weight bearing was achieved in the average time of 9.1 weeks. It was determined that there is a significant correlation between the level of fracture, time of weight bearing, the pattern of fracture, and body weight with the variables of Flynn's criteria.

Conclusion

Elastic intramedullary nailing technique is a productive approach for managing tibial fractures in children. They are less invasive, carry fewer complications, and have a high prevalence of "good" and "excellent" outcomes in pediatric patients.

Keywords: *ESIN (Elastic Stable Intramedullary Nail), Pediatric Patient, Fractured Tibia.*

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INTRODUCTION

Elastic stable intramedullary nailing is a technique that is growing increasingly popular as a treatment option for long bone fractures in pediatric patients, especially in fractures of the tibia [1]. In many cases of tibial fracture in pediatric patients, the treatment is through closed reduction and casting for 6-8 weeks. However, surgery must be considered should the conservative treatment fail to ensure appropriate alignment, rotation, and length [2-5]. Other reasons guaranteeing the need for surgery are in cases of open fracture as Gustilo type I [3]. ESIN is becoming the favored surgical option for long bone fractures in pediatric patients [6]. The pros of this technique are early mobilization, reduced hospitalization, and decreased soft tissue damage leading to less scaring [5]. The material of choice that has gained popularity for this technique in recent years is titanium. Titanium is a bio-friendly material and does not cause an adverse reaction in the human body [7].

In addition to these good points, it has a few disadvantages, such as patient radiation, risk of anesthesia, and epiphyseal plate injury. [8,6]. Also, using the ESIN technique, the results of patients of older age and heavier body weight have shown not to be as good as the younger and lighter participants [9]. A recent study also showed that patients who weigh above 45 kg have a higher chance of fracture displacement [10]. Most complications of using the ESIN technique are related to the surgeon, patient selection, and surgical technique (improper size nail, improper placement of the nail, or inadequate cutting of exposed nail) [11].

An earlier study, carried out in 2019 by Meena and Tiwari, [12], documented the use of flexible intramedullary nails in pediatric patients suffering from polytrauma to achieve stability, soft tissue preservation, and reduced immobilization period. The stability of bone in this study was obtained through the utilization of two elastic nails at the opposite cortices and hence ensuring a three-point fixation. Although the method of this study has been used more extensively in fractures of the femur, its utilization has expanded to multiple types of long bone fractures [12].

This retrospective observational study aims to understand better the functional outcome of stable intramedullary elastic nail use for diaphyseal tibial fracture in children through the review of multiple past cases.

MATERIALS AND METHODS

This research, conducted from Aug. 1, 2020, to Feb. 1, 2022, is a prospective observational study involving the review of 37 cases of pediatric patients that have undergone titanium stable elastic IM nailing for the fracture diaphyseal tibia. The patients of this study were selected in a random sampling method in Sulaimani, Shar, and Shorsh Teaching Hospitals in Sulaimani, Iraq. Our analysis involved arranging follow-up appointments for each patient in weeks 2, 4, 6, 10, and 20 after the surgery and a final follow-up after one year for removing titanium stable elastic IM nailing. The trauma in these cases was due to cycling accidents, motorway accidents, and falls from height. Permission was obtained from the parents of all patients in the form of written consent, illustrating the possible complications.

Inclusion criteria

Skeletally immature patients between 4 and 11 years of age

1- Recent diaphyseal fractures

2-Transverse and oblique fracture patterns

3-Gustilo (1), closed fractures

4-Bilateral tibial shaft fractures

Exclusion criteria

1-Pathological fractures

2-Neurovascular injuries

3-Open fracture– Gustilo (2-3-4)

4-Refracture

As the patient was being prepared for surgery, a thorough history was taken. A temporary splint in the form of a back slab was applied. Each admitted patient received emergency aid and was examined for associated injuries. A good quality radiograph of an injured leg from knee to ankle AP and lateral view were taken. The patient was also given the appropriate analgesics. All necessary investigations were conducted, and anaesthesia clearance was given.

The patient is set in a supine position. The access area is marked 1 cm distal and from the physis and 2 cm behind the tibial tubercle. Under fluoroscopy, the width of the medullary canal is determined. This is

important to the selection of the nail size. The titanium elastic nails chosen should be able to take up 80% of the medullary canal to achieve appropriate stability. Two incisions are made on the lateral and medial sides of the tibial metaphysis, and an Awl is used to penetrate the cortex of the bone perpendicularly. Under fluoroscopy, the nail is inserted on the T shape handle and slid alongside the adjacent cortex until it reaches the fracture site. Afterward, the knee is held in an extended position. With the help of holding the ankle to reduce the fracture, the nail is advanced past the fracture site and implanted in the distal tibial metaphysis. Then, the same is done with a second nail adjacent to the first one. The distal and proximal ends of the nails are bent and cut 1 cm from the surface of the cortical bone.

This sample followed preoperatively and postoperatively is a patient that suffered from a midshaft transverse fracture treated with the elastic intramedullary stable nailing method, along with the details of nails and Implant used.

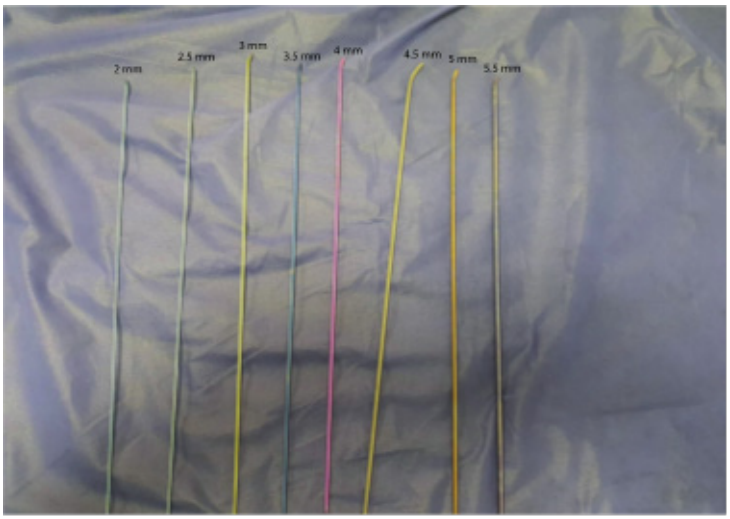
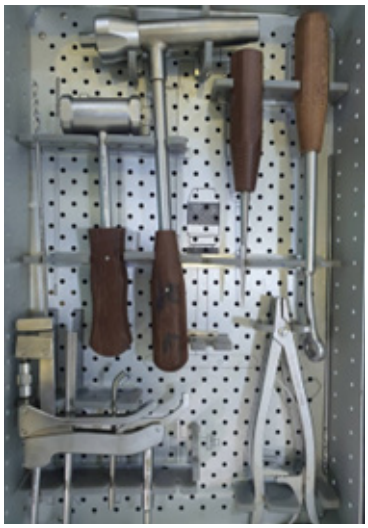


Figure 1. The different sizes of the Implant. **The brands of the implants used in this surgery were Zimed and Watson.**

Figure 2. Watson Instrument set.



1-Bender
2-Hummer
3-Hummer
4-Wire Cutter
5-T shape handle
6-Impactor
7-Wire Holder
8-Awl
9-Impactor

Figure 3. Zimed Instrument set. A set of follow-up radiographs was taken and documented.

Figure 4. Preoperative X-ray.

Figure 5.2 days postoperative radiograph.

Figure 6. 5 weeks postoperative radiograph.

Figure 7. 8 months postoperative radiograph.

Figure 8. After nail removal.

Figure 8. Post-op image of the patient.

All patients were subjected to a systematic follow-up in weeks 2, 4, 6, 10, and 20 after the surgery and a final follow-up after one year for removing titanium stable elastic IM nailing. The assessments were made based on the incidence of complications such as discomfort, shortening, etc. Further assessment was made regarding the functional outcome, such as the scope of mobility and the amount of time it takes for the patient's leg to be able to bare total weight. Finally, a radiographic analysis is performed to look for complications, such as the presence of misalignments. To illustrate, the systematic assessment was performed based on Flynn's criteria, as presented in Table 1.

Table 1. Flynn's Criteria [25].

No.	Variables	Excellent	Satisfactory	Poor
1.	**Limb length discrepancy**	< 1 cm	1 - 2 cm	> 2 cm
2.	**Malunion (Ap & lateral)**	5	5 - 10	> 10
3.	**Pain at the fracture site (at 6 months)**	None	None	Present
4.	**Other complications**	None	Minor & resolved	Major & lasting

Statistical analysis

All statistical computation is analyzed using Statistical Package for the Social Sciences (SPSS 24). The data had been coded, tabulated, and presented in a descriptive form. The statistical procedure that was applied to determine the results of the present study included the following: Descriptive statistical, such as Frequency, Percentage, and Mean, and Inferential data analysis, such as the Spearman correlation test.

RESULTS

Thirty-seven 37 patients randomly selected for this research study were classified according to many different categories. For example, the patients were categorized into two different age groups. Of the 37 patients, 22 (59%) weighed between 16-24 kg. The weights of the other 15 (41%) patients were 25-32 kg. The patients were divided into 3-7 years of age and 8-11 years of age. Twenty (54%) patients fell under 3-7 years, while 17 (46%) fell under 8-11 years of age. Regarding sex, 26 (70%) patients were male, as indicated in Table 2.

When it comes to the fracture site, we look into fracture pattern, level of fracture, type of fracture, and associated injuries. We have fractures in the upper, middle, and distal parts. Of the 37 patients, there were 2 cases of upper, 24 cases of middle, and 11 cases of distal third fractures, which translated to 5.40%, 64.9%, and 10.8% of the whole, respectively. We included two types of fracture: closed and Gustillo type 1. We had 31 (83.9%) patients with closed fractures and 6 (16.1%) with Gustillo 1 fractures.

As for associated injuries, most cases did not have any. Of the 37 patients, 29 (78.4%) had no related injuries. As for the side of the fracture, 23 (62.2%) patients suffered from a right-sided tibial fracture. For patterns of fractures, we had three categories: transverse, short oblique, and spiral. In our sample groups, we had 9 (24.3%) cases of transverse, 24 (64.9%) cases of short oblique, and 4 (10.8%) cases of spiral fractures. The mechanism of injury in this study is classified into two categories: road traffic accident or fall from height. Thirty (81.1%) patients suffered RRA, and 7 (18.9%) suffered from FFA, as shown in Table 3. After the surgery is complete, we document a measurement stating how much time it takes the patient to be able to walk again with and then without assistance. The time it took 7 (19%) of the patients to walk with assistance was within the period of 3-5 weeks, and the remaining 30 (81%) patients could walk with assistance within 5-7 weeks. As for walking free of assistance, the periods are 7-9 weeks and 9-11 weeks. Eight (21.6%) patients could walk within 7-9 weeks, while 29 (78.4%) could do so within 9-11 weeks, as shown in Table 4.

Accounting for postoperative complications, specific measurements were noted. Two (5.4%) patients showed an angulation between 5-10 degrees in the form of valgus. One (2.7%) patient showed lengthening less than 0.5 cm, and 1 (2.7%) patient showed shortening less than 0.5 cm. Of the 37 patients, 4 (10.8%) patients showed restriction in knee movement, and 1 (2.7%) patient showed pain at the fracture site. Skin irritation was the most common complication in this study as 9 (24.3%) patients showed skin irritation, as illustrated in Table 5.

The time of complete union was categorized into two different groups: patients in whom the complete union was achieved in between 8 to 10 weeks and patients that achieved it in 10 to 12 weeks. Of the 37 patients, 31 (83.8%) achieved complete union in 8 to 10 weeks, while 6 (16.2%) patients did so between 10 to 12 weeks. For the postoperative immobilization (back slab) the timespans were categorized into 1 to 3 weeks, 3 to 4 weeks, and 5 to 6 weeks. Of the 37 patients, 21 (56.8%) of them were immobilized for 1 to 3 weeks, 10 (27%) were immobilized for 3 to 4 weeks, and 6 (16.2%) were immobilized for 5 to 6 weeks, as shown in Table 6. As for Flynn's criteria, 86.5% of the patients scored excellently, 10.8% scored satisfactorily, and 2.7%

scored poorly. The cases that scored satisfactorily were four cases, two of which had vulgus malalignment, and one of them had a shortening of less than half a centimeter. The other had a lengthening of less than half a centimeter. One case scored poor because it presented pain at the fracture site, as shown in Table 6.

To determine the correlation between the variables, the p-value was determined. If the P value of a specific contrast is more than 0.05, then there is a significant correlation. To yield the functional outcome of the samples used in this study, we must draw a correlation between the variables of the research and the variables of Flynn's criteria. The way to determine whether a relationship between two variables is significant is to test it for the p-value. We discovered a significant correlation between the variables of Flynn criteria and level fracture as well as the fracture pattern, as their p-value is lower than 0.05. There was also a significant correlation between the variables of Flynn's criteria and the body weight of the patient. Furthermore, there was a significant correlation between the variables of Flynn criteria and the period of immobilization. The remainder of the correlations between Flynn's criteria and the variables of this study were discovered to be insignificant as their p-value was more than (0.05). All details are shown in Table 7, Table 8, Table 9, and Table 10.

Table 2. Patient Demographics and details of the fracture.

Variables	Categories	Frequency	Percentage
Age (Years)	3 - 7	20	54%
	8 - 11	17	46%
Body weight	16 - 24 Kg	15	41%
	25 - 32 Kg	22	59%
Sex	Male	26	70%
	Female	11	30%
Level of fracture	Upper	2	5.40%
	Middle	24	64.9%
	Distal	11	29.7%
Pattern of fracture	Transverse	9	24.3%
	Short oblique	24	64.9%
	Spiral	4	10.8%
Type of fracture	Closed	31	83.9%
	Gustillo 1	6	16.1%
Associated	Yes	14	37.8%
Injury	No	23	62.2%
Mechanism of Injury	RTA	30	81.1%
	FFH	7	18.9%
Side of Fracture	Right	23	62.2%
	Left	14	37.8%

Table 3. Weight-bearing.

Variables	Categories	Frequency	%
Time of partial weight bearing	3 - 5 weeks	7	19%
	5 - 7 weeks	30	81%
Time of full weight bearing	9 - 11 weeks	29	78.4%
	7 - 9 weeks	8	21.6%

Table 4. Complications of the fracture.

Variables	Categories	Frequency	Percentage
Malunion	No	35	94.6%
	5 - 10 degrees	2 (VALGUS)	5.4%
Lengthening	< 0.5cm	1	2.7%
	No	36	97.3%
Shortening	No	36	97.3%
	< 0.5cm	1	2.7%
Limitation of knee movement	No	33	89.2%
	Yes	4	10.8%
Pain at the fracture site	Yes	1	2.7%
	No	36	97.3%
Skin irritation	Yes	9	24.3%
	No	28	75.7%

Table 5. Immobilization and union periods.

Variables	Categories	Frequency	Percentage %
Immobilization	1 - 3	21	56.8
	3 - 4	10	27
	5 - 6	6	16.2
Time of union	8 - 10	31	83.8
	10 - 12	6	16.2

Table 6. Flynn's criteria score.

No	Variables	Excellent	Satisfactory	Poor
1	**Limb length discrepancy**	35	2(5.4%)	0
2	**Malunion**	35	2(5.4%)	0
3	**Pain at the fracture site**	36	0	1(2.7%)
4	**Other complications**	37	0	0

Table 7. P value of patient demographics concerning Flynn's criteria.

Variables		Age	Weight	Gender
Limb length discrepancy	Spearman Corr.	0.28	0.68	0.42
	P-value	0.584	0.000	0.500
Malunion	Spearman Corr.	0.14	0.37	0.22
	P-value	0.593	0.001	0.14
Pain at the fracture site	Spearman Corr.	0.11	0.2	0.1
	P-value	0.067	0.032	0.79
Other complications	Spearman Corr.	0.18	0.53	0.32
	P-value	0.082	0.000	0.312

Table 8. P value of fracture details concerning Flynn's criteria.

Variables		Limb length discrepancy	Malunion	Pain at fracture site	Other complications
Level of fracture	Spearman Corr.	0.36	0.41	0.29	0.23
	P-value	0.001	0.000	0.001	0.007
Pattern of fracture	Spearman Corr.	0.61	0.49	0.53	0.28
	P-value	0.000	0.000	0.000	0.001
Type of fracture	Spearman Corr.	0.44	0.53	0.39	0.71
	P-value	0.310	0.976	0.67	0.054
Associated Injury	Spearman Corr.	0.65	0.7	0.47	0.68
	P-value	0.677	0.0564	0.034	0.676
Mechanism of Injury	Spearman Corr.	0.45	0.51	0.63	0.55
	P-value	0.122	0.23	0.087	0.076
Side of Fracture	Spearman Corr.	0.62	0.7	0.67	0.73
	P-value	0.982	0.654	0.807	0.132

Table 9. P value of patient mobilization in relation to Flynn's criteria.

Variables		Time of partial weight bearing	Time of full weight bearing
Limb length discrepancy	Spearman Corr.	0.60	0.58
	P-value	0.000	0.000
Malunion	Spearman Corr.	0.54	0.68
	P-value	0.000	0.000
Pain at the fracture site	Spearman Corr.	0.71	0.69
	P-value	0.000	0.000
Other complications	Spearman Corr.	0.70	0.66
	P-value	0.000	0.000

Table 10. P value of patient immobilization and time of union in relation to Flynn's criteria

Variables		Immobilization	Time of union
Limb length discrepancy	Spearman Corr.	0.71	0.74
	P-value	0.21	0.54
Malunion	Spearman Corr.	0.68	0.65
	P-value	0.584	0.973
Pain at the fracture site	Spearman Corr.	0.72	0.59
	P-value	0.052	0.962
Other complications	Spearman Corr.	0.70	0.76
	P-value	0.496	0.96

DISCUSSION

We cannot argue that conservative management of the fracture of the tibia is the optimal route to take because it does have disadvantages. The disadvantages include longer hospital stay, increased chance of malunion, and higher incidence of repeated displacement. Because of this, a lot of surgeons opt for surgical intervention [13].

As surgery becomes the treatment of choice, the surgeon also has to choose the appropriate method to achieve stabilization. The methods classically used are internal fixation via plates or external fixation. Both of these methods showed disadvantages because, with plates, you would need a bigger incision and hence increasing the chance of infection, loss of fracture hematoma, and damage to the periosteum. With external fixation, one increases the incidence of malunion, loss of reduction fracture, and pin tract infection. A method increasingly becoming more popular with surgeons is using the intramedullary elastic nail technique. With it taking the form of a C shape after insertion, it uses a three-point fixation system to ensure a managed motion and stability at the fracture site [14].

The study sample we randomly selected comprised 70% male and 30% female patients. This sample is similar to the sample of a study conducted by (Uludag and Tosun, 2019). In this study, the age of the patients was documented to be between 3 and 11 years of age, with a mean age of 7.2 years old. This aspect of the study is comparable to that of a study done by (P R Onta et al., 2015) in which they noted a mean age of 8.2 years old. As for the patient's weight, we documented a weight range of 16 to 32 kg, with an average patient weight of 25.3 kg. This outcome is similar to a study (Hong et al., 2021), which documented a mean weight of 28.4 kg.

When speaking of the fracture level, three levels were considered in this study: proximal third, middle third, and distal third. In our study, we had 24 cases of the middle third, 2 cases of the proximal third, and 11 cases of the distal third. This was similar to the sample of a study done by (Savery et al, 2021) in which they covered 24 cases of the middle third, 2 cases of the proximal third and 6 cases of the distal third.

When considering the type of fractures, our sample contained two kinds of fractures: closed and Gustillo 1. The closed fractures comprised 83.9% of the cases while the remaining 16.1% were all categorized at Gustillo 1. This was similar to the result of a study conducted by (Ahmed et al, 2021), in which they documented a closed fracture rate of 84.21% and an open fracture rate of 15.79%.

The fractures are further categorized based on the pattern in which the bone is broken. We covered three types of fracture patterns: transverse, short oblique, and spiral. The patients documented 9 (24.3%) cases of transverse fracture, 24 (64.9%) cases of short oblique fractures, and 4 (10.8%) spiral fractures. This was similar to the result of a study done by (Tawfeeq and Saeed, 2020) in which they stated 58% short oblique, 32% transverse, and 10% spiral fractures.

Associated injuries other than the fracture of the tibia were also noticed and recorded in this sample group. Of the 37 cases, 14 (37.8%) had associated injuries, while the rest (62.2%) had no recorded associated injuries. This result is close to that of a research study (Widbom-Kolhanen and Helenius, 2020). In their sample group, they documented that 46% of their cases had associated injuries while the remaining 54% suffered from tibia fractures only.

For the limb immobilization period, 21 (56.8%) patients were immobilized for 1 to 3 weeks, 10 (27%) patients were immobilized for 3 to 4 weeks, and 6 (16.2%) patients were immobilized for 5 to 6 weeks. This was comparable to a study by (Tawfeeq and Saeed, 2020), in which they documented that 48% of the patients were immobilized for 2 to 3 weeks, and 34% were immobilized for four weeks, and 18% were immobilized for 5 to 6 weeks.

In our study, most patients suffered from a fracture on their right side. In total, 62.2% of the patients suffered from a fracture of the right tibia, while 37.8% of the patients suffered from a left tibia fracture. This sample is close to that of a study by (Eladawy et al., 2021), which stated that 58.3% of right-sided fractures and 41.7% of left-sided fractures.

The mechanisms by which the fractures were caused were also documented and categorized into two categories: road traffic accident and fall from height. We documented that the mechanism of RTA is responsible for 81.1% of the cases, while FFA was the cause for 18.9%. This outcome was similar to that of a research study (Jayaram et al., 2021), in which they recorded that 75% of the cases in their sample were caused by RTA and 20% were caused by a fall or FFA. The remaining 5% were caused by trauma at the workplace.

In this study, the average time for complete union of the bone was 9.2 weeks after surgery. This outcome is compatible with that of a study conducted by (Eladawy et al, 2021). They stated that their average union time is 8.9 weeks. Another study that yielded a result close to one of our studies is a study done by (Panthi et al., 2021), in which they documented a union time of 10.03 weeks. One other study that showed a result similar to that of our research study is a study conducted by (Jayaram et al., 2021), in which he noted the union time to be 8.10 weeks.

Our study showed no cases of nonunion. It did, however, show 2 cases of angulation in the form of valgus, which amounted to 5.4% of the cases. This result is close to the result of research conducted by (Nisar et al., 2013), in which they covered a sample group with a malunion rate of 9%.

A potent tool for the assessment of the outcome of a surgery is Flynn's criteria. Flynn criteria cover categories including malunion, limb length discrepancy, pain, and other complications. Flynn's criteria score for this research was that 86.5% scored excellently and 10.8% scored satisfactorily, and 2.7% scored poorly. In the case in which the poor outcome suffered from pain at the fracture site, after following up and investigations, the cause was determined to be cross union, and a treatment plan was set. This result was similar to that of a study (KC KM et al., 2016) since their result showed that 90% of their cases were excellent and 10% were satisfactory. Of all the complications, skin irritation was the most prominent one, with 9 cases of skin irritation which accounted for 24.3% of the cases. The cause of this complication was determined to be nail protrusion. The cases of skin irritation subsided after the removal of the nails. This prevalence was similar to that of a study by (Sanker et al., 2007), in which the skin irritation rate was 26%.

Another complication that must be accounted for is the freedom with which the knee can perform. Of the 37 patients in our research sample, 4 (10.8%) of them suffered limitations in knee movement. The cause of this was determined to be the skin irritation caused by the protrusion of the nails. After the removals of the nails, the limitations in knee movement subsided. The outcome of our study is similar to that of a study done by (Ahmed et al., 2021), in which they noted that 10.52% of their sample cases suffered from limitations in knee movement.

When speaking about bearing weight on the fractured area, we categorize this measurement into two groups: partial weight bearing and full weight bearing. For partial weight bearing, 30 (81%) of our patients could walk with assistance between 5-7 weeks. The remaining 7 (19%) patients could perform the same feat in 3-5 weeks. The average time of partial weight bearing was noted at 5.8 weeks. As for full weight bearing, 29 (78.4%) patients could walk unassisted between 9-11 weeks. The remaining 8 (21.6%) patients could walk unassisted in 7-9 weeks. The mean time for complete weight bearing in this study was 9.1 weeks. These outcomes are comparable to that of a study by (Jayaram et al., 2021), in which their mean time for partial weight bearing was 6.2 weeks, and for total weight bearing, it was 8.2 weeks for all cases of tibia fractures.

CONCLUSION

Elastic stable intramedullary nailing is a method that is becoming very reliable for cases of tibia fracture in children. It is relatively quick and less complex than the conventional method. During the postoperative period, this study showed that this technique reduces the prevalence of complications. It also promotes healing at a quicker rate than the conventional method with a lowered rate of malunion. This study showed that the intramedullary elastic nailing method could produce a more adequate outcome than its conventional counterparts.

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