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# Functional Outcome of Pediatric Long Bone Fractures in Children by Closed Reduction and Internal Fixation with Titanium Elastic Nails

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**ABSTRACT**

Background
Childhood injury is most common among the children in age of 5- 16 years. Most of the fractures are not detrimental but, few require immense care to avoid future problems. The worldwide data analysis showed that there is a rising in fracture related death in children population. Thus, those fractures alarm the need of concerned treatment methods for healthier life of those children.
Materials and Methods
Thirty-one patients with fractures of the femur (12), tibia (9), radius/ulna (6), clavicle (2), humerus (2) were treated with titanium elastic nailing between May-2015 to June-2017 at Sri Lakshmi Narayana Institute of Medical Sciences Hospital, Pondicherry. Children and adolescents aged between 3 to 17 years were included in the study.
Results
Among the patients. 35.48% of patients were between 3-8 years, (32.48%) in 912 years, (32.26%) in 13-17 years of age group with the average age being 9.8 years. 77.42% of the patients were boys. RTA/self-fall was the most common mode of injury accounting for 15 (48.39%) cases each, battered baby accounted for 1(3.22%). Transverse fractures accounted for 14(45.16%) cases, oblique fractures 9(29.03%) and spiral fractures 8(25.81%). Fractures involving the middle 1/3rd accounted for 24 (77.42%) cases. All the patients were prepared and operated as early as possible once the general condition was stable and the patient was fit for surgery. The average duration between trauma and surgery was 11 days with 20 (64.52%) patients undergoing surgery within <48 hrs and 11 (35.48%) patients undergoing surgery more than > 48 hrs. Average duration of stay in hospital was 12 days.
Conclusion
The development of the 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.

**Keywords:**
Bone fractures, closed reduction, internal fixation, titanium Elastic Nails, biocompatible

## 1. Introduction

Childhood injury is a major public health problem that requires urgent attention. Injuries is a health concern in every country around the world, affecting both developed and developing countries, causing over 5.8 million deaths per year or 15,000 deaths per day. [1] It is a major killer of children throughout the world, responsible for about 9,50, 000 deaths in children and young people under the age of 18 years each year. [2] Unintentional injuries account for almost 90% of these cases. They are the leading cause of death for children aged 10–19 years. [3] Injuries collectively caused 11.2% according to Robin Daly's study with many different injuries making important contributions. The majority was contributed by road traffic injuries, which accounted to 27% of total injuries. Overall, according to the Global Burden of Disease study in 2010, injuries contributed to 278, 665,000 in all age groups.

Fractures are common, comprising up to 25% of pediatric injuries. Tibial and femoral fractures constitute roughly 15% of all pediatric fractures. Forearm fracture accounts for about 20% of total fractures. Treatment of fractures has changed during recent decades. Traditionally fractures have been treated with manipulation and cast-immobilization. Traction was introduced after the First World War, intramedullary nailing in children after the Second World War and external fixation in the 1960s. The choice of treatment of fractures in children depends on the child's age and skeletal maturity. Methods first utilized in adult treatment are gradually being implemented in children. Despite extensive research, the treatment of pediatric fractures remains controversial even though there is a trend in favour of surgery. Fractures in children always heal" is a widespread saying often repeated when discussing the treatment of paediatric fractures. There is little information on the functional outcome in pediatric long bone fracture treatment. Results reported earlier have generally been good, but the follow-up times in previous studies on childhood paediatric long bone fracture fractures tend to be rather short. Complications in the treatment of paediatric long bone fracture fractures vary according to the method used. In conservative treatment complications include malunion, non-union, limb-length discrepancies and various skin problems. In addition, operative treatment may lead to neurovascular injuries and infections [4] Treatment injuries are injuries occurring in connection with medical treatment. In Finland the Patient Insurance Centre (PIC) is responsible for financial compensation in injuries associated with medical treatment.

The anatomy and biomechanics of paediatric bone differ from that of adult bone, leading to unique paediatric fracture patterns, healing mechanisms, and management. In comparison to adult bone, paediatric bone is significantly less dense, more porous and penetrated throughout by capillary channels. Pediatric bone has a lower modulus of elasticity, lower bending strength, and lower mineral content. The low bending strength induces more strain in paediatric bone than for the same stress on adult bone and the low modulus of elasticity allows for greater energy absorption before failure. The increased porosity of paediatric bone prevents propagation of fractures, thereby decreasing the incidence of comminuted fractures. The paediatric periostium is extremely strong and thick, functioning in reduction and maintenance of fracture alignment and healing.

In the last two decades there was an increased interest in the operative treatment of paediatric fractures, although debate persisted over its indications (1). There is a little disagreement concerning the treatment of long bone fractures in children less than 6 years (POP cast) and adolescents older than 16 years (locked intramedullary nailing).[1]

Recently there has been a growing trend towards surgical treatment of Diaphyseal fractures in children. To some extent this reflects a more interventionist attitude among Orthopaedic Surgeons but is also due to technical development notably that of ESIN [14]. The treatment for children between the ages of 6 and 10 years is the most controversial. Many such patients may be treated successfully with immediate closed reduction & casts. However, external fixation and flexible intramedullary rod fixation are being used more frequently, particularly in patients with multiple trauma. However, in older children and adolescent's operative treatment should be considered to avoid complications such as delayed union, malunion, rotational deformity, refracture, knee stiffness, limb length discrepancy and psychosocial problems. Operative treatment results in shorter hospitalization and early mobilization, which has psychological, social, educational and economic advantages over conservative treatment. A variety of therapeutic alternatives mentioned above such as external fixator, compression plating, rigid Intramedullary nailing and elastic stable intramedullary nailing are being used for Diaphyseal fractures in children. With the use of external fixator, there is a high incidence of pin tract

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infection, refracture after removal of external fixator. Also the external fixator is more uncomfortable and cumbersome for the child.

Rigid intramedullary nails have their own pros and cons. They not only increases risk of AVN of femoral head in children and adolescents, but also there is a high incidence of abnormalities at the proximal end of the femur including coxa valga, arrest of growth of greater trochanter, thinning of the neck of the femur because of damage to trochantero-cervical region. Ideally, fixation of paediatric diaphyseal fractures should produce an "internal splint" that shares loads, maintains reduction until hard callus formation, and does not endanger the growth areas or blood supply. Results from several studies have shown that FIN / TENS fixation meets these requirements because it allows rapid mobilization, potentially no risk for osteonecrosis, low risk for physical injury, and reduced risk for refracture. ESIN meets the requirements of this ideal device [7]. Upper age limit for ESIN in Paediatric Diaphyseal fracture is until the time of closure of the proximal growth plate after which conventional rigid locked intramedullary nailing can be used safely. The choice of treatment may be influenced by the age of the child, the level and pattern of the fracture and to a great extent, by regional, institutional or surgeon's preferences.

There are no previous studies on treatment injuries associated with paediatric long fractures. Metaphyseal fractures of the distal forearm are the most frequent lesions in childhood and account for 20 to 25 % of all fractures [63,64]. Half of these fractures are angulated, with the two bone segments remaining in contact.

Currently, there are no standard guidelines on how these patients should be treated. Treatment varies from simple immobilization to open reduction and plate osteosynthesis. Closed reduction of paediatric fractures commonly requires sedation and analgesia to achieve an anatomic reduction and to alleviate the child's reaction to and recall of a painful and stressful situation. Inserted implants must be removed after bony healing and aneasthesia or sedation therefore is needed. Complications associated with procedural anesthesia include respiratory depression, hypoxia, hypotension, vomiting and aspiration [65,67]. Therefore, some authors advocate non-manipulative therapy for distal forearm fractures [66].

Primary closed reduction leads to secondary loss of reduction with the necessity of manipulation under general anaesthesia in >30 % of cases [68]. Although percutaneous K-wire pinning prevents redisplacement, effects on longer-term outcomes, including function have not been established [70,71]. Inserted K-wired need to be removed.

Reliable remodelling of displaced radial fractures is often described, whereas the grade of possible remodelling differs in various publications [71,72,73,74,75]. In many uncontrolled or retrospective studies, although some children retained malalignment after an accident, after 2 years and until the age of 14, remodelling of the axis of up to 30° occurred due to growth.

Advantages of conservative therapy without manipulation are outpatient treatment, no need for anaesthesia, cleaning of pins or wound control. Parents are often afraid of operations, and children, of manipulation while cleaning the pins. Disadvantages are the extended time of healing until remodelling is achieved and the visible angulation that can lead to questions and comments on incorrect treatment.

The advantage of the operation is the immediate transfer of the fracture into a stable anatomic position and less chance of secondary angulation. The disadvantage is the need of anaesthesia for osteosynthesis, need for implant removal and inpatient treatment, as well as the cleaning of the pins or wound control to prevent infection. The purpose of this study was to assess the functional outcome of the treatment of paediatric long bone fractures treated with TENS.

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This study was done to assess the functional outcome, safety and efficacy of Titanium Elastic Nailing for the treatment of paediatric long bone fractures in children in the age group between 3 to 17 years. Titanium Elastic Nail (TEN) fixation was originally meant as an ideal treatment method for femoral fractures, but was gradually applied to other long bone fractures in children, as it represents a compromise between conservative and surgical therapeutic approaches with satisfactory results and minimal complications.

Surgical treatment of long bones fractures in children must first consider the fact that excellent results can be achieved with non-operative care, with reported union rates of more than 90%, and 100% full functional recovery [(60)]. Occasionally, reduction cannot be maintained due to excessive shortening, angulation, or malrotation at the fracture site, making operative intervention necessary [(61)]. In other cases, surgical treatment is warranted because of polytrauma, open fracture, or compartment syndrome. Historically, external fixation and plate and screw fixation were the treatment options available for those unstable fractures [(60,61)]. Over recent years the use of elastic stable intra-medullary nails has dramatically increased with the introduction of a variety of nails for pediatric fractures [(62)]. The Titanium Elastic Nail (TEN) for Elastic Stable Intramedullary 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. In paediatric applications, the flexibility of the TENs allows it to be inserted at a point which avoids disruption of the bone growth plate. The use of an intra-medullary device is indicated for open fractures, unstable fractures or irreducible fractures. The aim of this 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).] This produces the following four properties that are essential for achieving optimal results: flexural, axial, translational and rotational stability [(63)]. 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 [(65,66).]

Whatever the method of treatment, the goals should be to stabilise the fracture, to control length and alignment, to promote bone healing, and to minimise the morbidity and complications for the child and his/her family[1], and Titanium Elastic Intra medullary fulfil all the goals for fixation of paediatric long bone fracture, provides good functional outcome.

## 2. Materials & Methods

This is the Prospective study of 31 patients who had history of trauma to pediatric long bone (Femur, Tibia, Radius/Ulna, Humurus, and Clavicle) came to casualty or Orthopaedic Outpatient Department from May- 2015 to June- 2017 and were admitted under the department of Orthopaedics at Sri Lakshmi Narayana Institute of Medical Sciences. The study was done after getting the clearance from the Ethical Committee and informed written consent from the study participants. Initially patient was given analgesics to relieve pain. Detailed history about mode of injury was taken and recorded; thorough clinical examination was done and documented. Then patient was sent for the x-ray of injured part in antero posterior and lateral view. Once the diagnosis of long bone fracture was confirmed the patient was admitted and put on POP slab. Patient was included in this study after satisfying inclusion and exclusion criteria made for this study. The patients who were in the age of 3-17 years and who had simple or diaphyseal or metaphyseal fractures were included in the study. The patients who had compound and pathological fractures were excluded in the study. The diameter of the nail was calculated using

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Flynn et al's (Table. 1) formula [2-7]. Titanium Elastic Nail System was used in the study with the standard procedure. The assessment was done at 6, 12 and 24 weeks and the details related to complications based on clinical, radiological examinations were noted (Table. 2).

**Table 1.** TENS outcome score

| **RESULTS**<br>**VARIABLES at 24 weeks** | **Excellent** | **Satisfactory** | **Poor** |
|---|---|---|---|
| Limb-length inequality | < 1.0 cm | < 2.0 cm | > 2.0 cm |
| Malallignment | 5 degrees | 10 degrees | >10 degrees |
| Unresolved pain | absent | Absent | present |
| Other complications | None | Minor and resolved | Major and lasting morbidity |

**Table 2:** Additional Variables

| **Variables**<br>**†Outcome *** | **Excellent** | **Satisfactory** | **Poor** |
|---|---|---|---|
| Range of movements | Full range | Mild restriction | Moderate – severe restriction |
| Time for union | 8– 12 weeks | 13– 18 weeks | >18 weeks |
| Unsupported weight bearing | 8– 12 weeks | 13– 18 weeks | >18 weeks |

## 3. Results

In the present study 11 (35.48%) of the patients were 3-8 years, 10 (32.26%) were 9 to 12 years and 10 (32.26%) were 13 to 17 years' age group. Numbers of patients were equally distributed in all section of age group. In our study Males are more than female. There were 7(22.58%) girls and 24 (77.42%) boys in the present study (Table. 3 and Figure. 1).

**Table 3:**Age Distribution of Patients Study

| **AGE IN YEARS** | **NO.OF PATIENTS** | **%** |
|---|---|---|
| **3-8** | **11** | **35.48** |
| **9-12** | **10** | **32.26** |
| **13-17** | **10** | **32.26** |
| **TOTAL** | **31** | **100** |
| | | |

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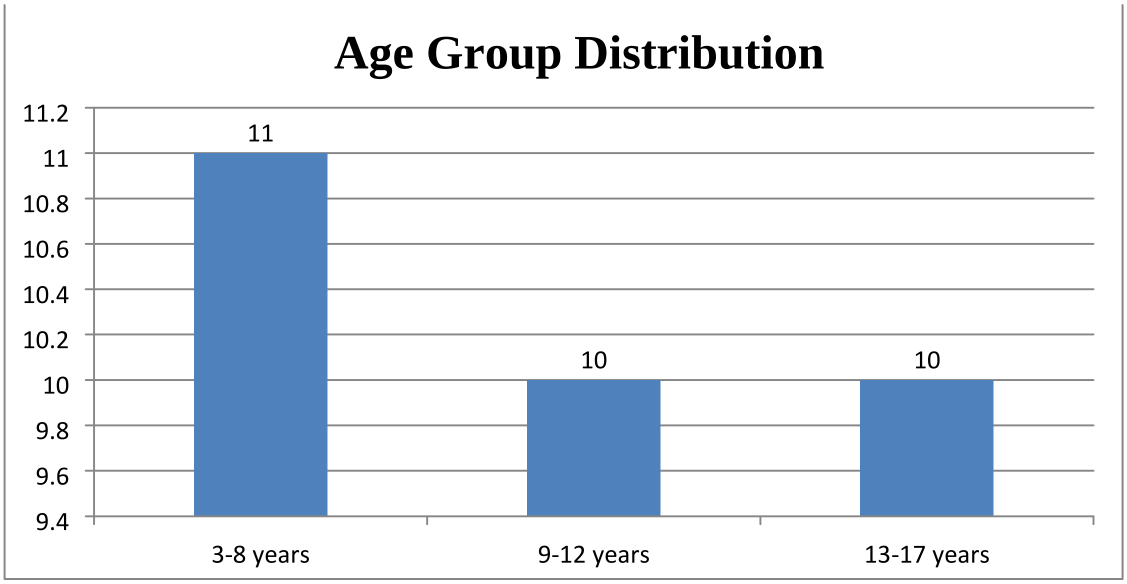


**Figure. 1.** Age Distribution of Patients Study

Male patients 24 male (77.42%) and female 7 (22.58%) were included in our study (Table. 4 and Figure.3).

**Table 4:** Gender Distribution of Patients Study

| GENDER | NO. OF PATIENTS | % |
|---|---|---|
| MALE | 24 | 77.42 |
| FEMALE | 7 | 22.58 |
| TOTAL | 31 | 100 |

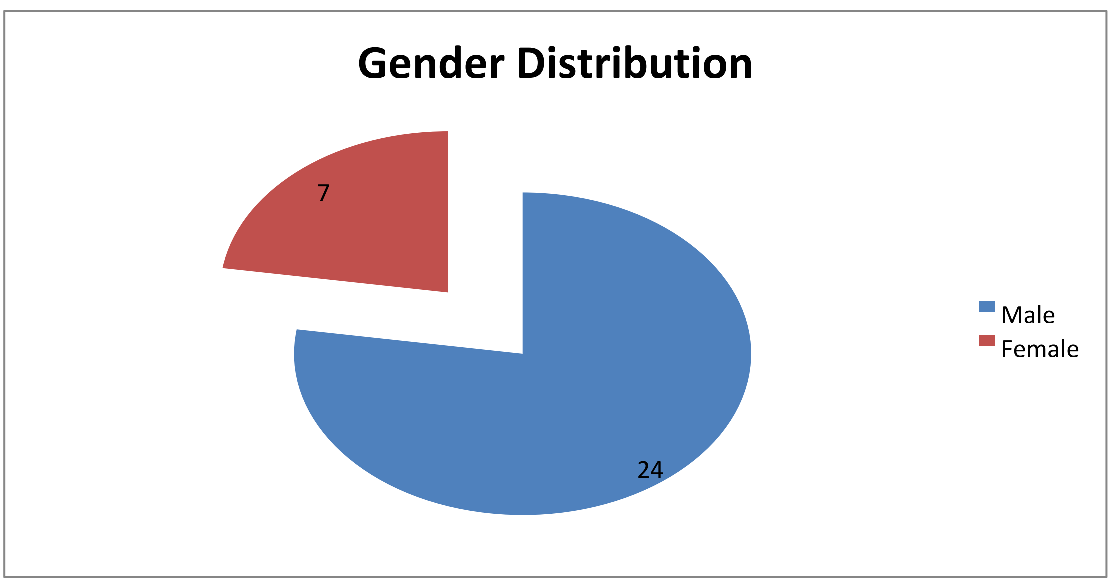


**Figure. 2**. Gender Distribution of Patients Study

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In the present study RTA and self-fall was the most common mode of injury accounting for 15(48.39%) in each cases, battered baby accounted for 1 (3.22%) cases and no cases reported fall from height (Table. 5 and Figure. 3).

**Table 5:** Mode of Injury

| MODEOF INJURY | NO. OF PATIENTS | % |
|---|---|---|
| RTA | 15 | 48.39 |
| SELF FALL | 15 | 48.39 |
| BATERED BABY | 1 | 3.22 |
| TOTAL | 31 | 100 |

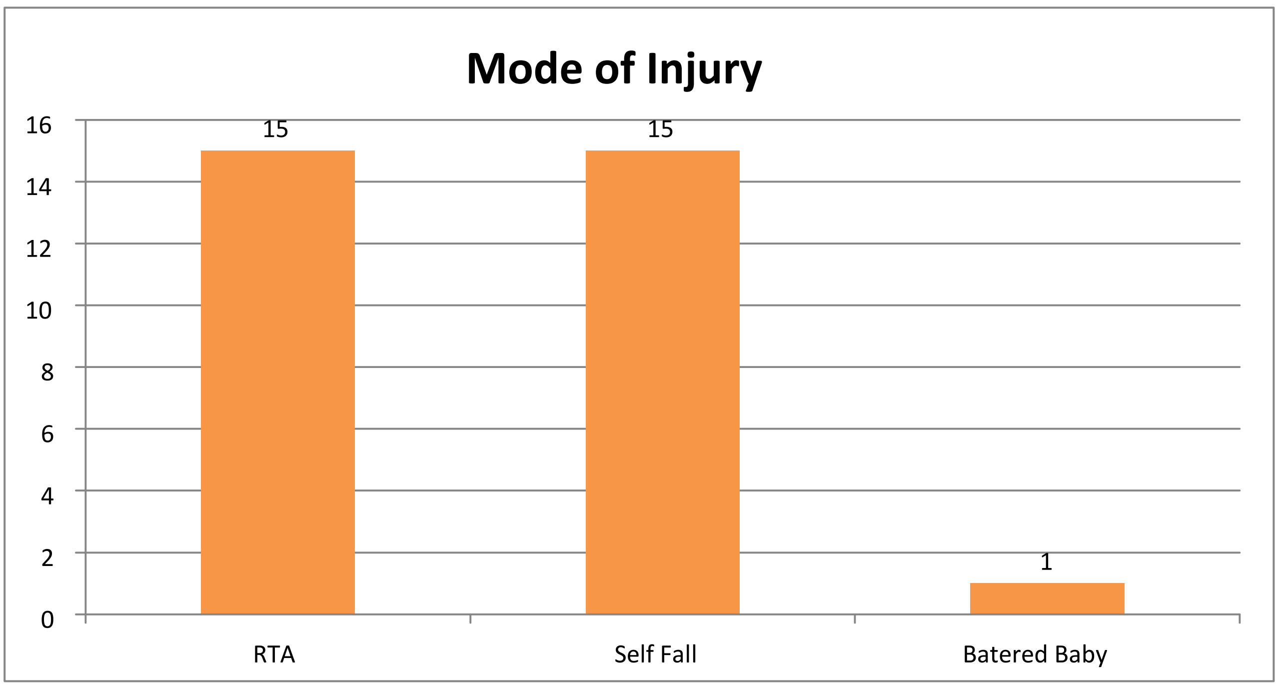


**Figure. 3.** Mode of Injury

In our study 12 (38.71%) femoral, 9 (29.03%) tibial, 6 (19.35%) forearm, 2 (6.45%) clavicle and 2 (6.45%) humeral fractures were included (Table. 6 and Figure 4).

**Table 6:** Bone Affected

| BONE AFFECTED | NO. OF PATIENTS | % |
|---|---|---|

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| | | |
|---|---|---|
| **TIBIA** | **9** | **29.03** |
| **FEMUR** | **12** | **38.71** |
| **RADIUS/ULNA** | **6** | **19.35** |
| **CLAVICLE** | **2** | **6.45** |
| **HUMURUS** | **2** | **6.45** |
| **TOTAL** | **31** | **100** |

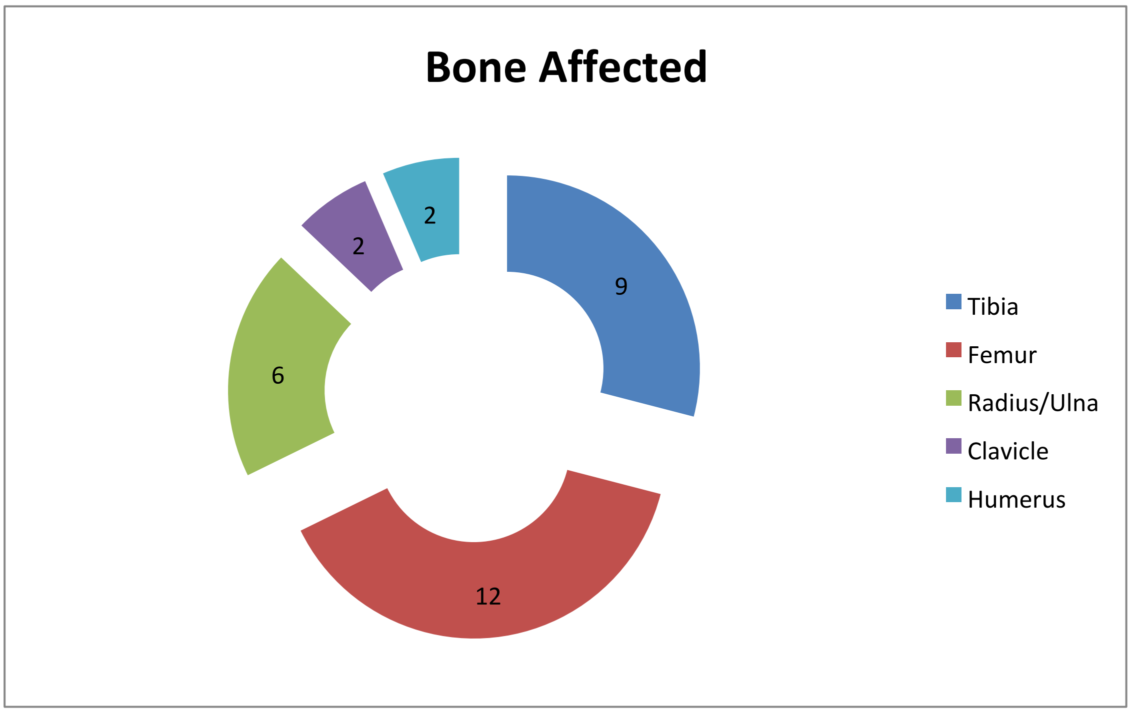


**Figure. 4.** Bone Affected

**SIDE AFFECTED:**
In our study 16 (51.61 %) right, 14 (45.16%) left, and 1 (3.22%) bilateral patients were affected (Table. 7 and Figure. 5).

**Table 7.** Side affected

| **SIDE AFFECTED** | **NO. OF PATIENTS** | **%** |
|---|---|---|
| **RIGHT** | **16** | **51.61** |

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| | | |
|---|---|---|
| **LEFT** | **14** | **45.16** |
| **BILATERAL** | **1** | **3.22** |
| **TOTAL** | **31** | **100** |

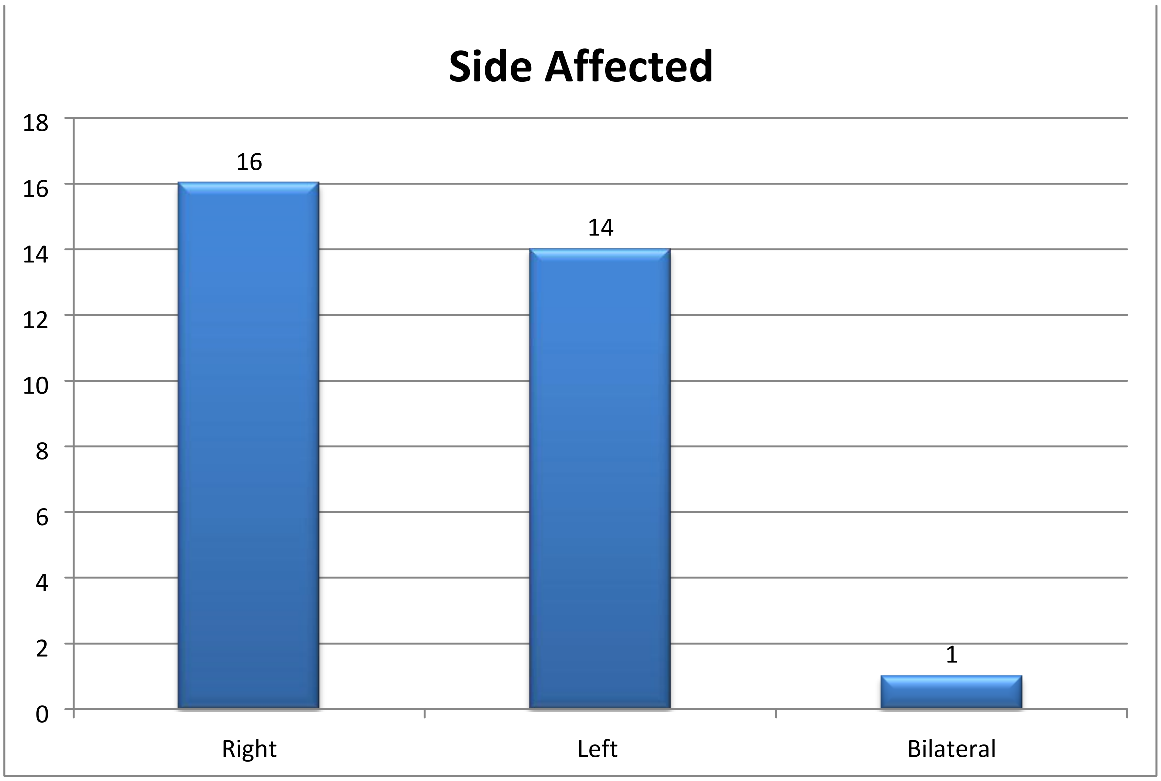


**Figure. 5.** Side affected

In our study, transverse fractures accounted for 14 (45.16%) cases, oblique fractures – 9 (29.03%), spiral fractures – 8 (25.81%) and there were no segmental fractures and communised fractures (Table. 8 and Figure. 6).

**Table. 8:** Pattern of Fracture

| PATTERN OF FRACTURE | NO. OF PATIENT | % |
|---|---|---|
| **TRANSVERSE** | **14** | **45.16** |
| **OBLIQUE** | **9** | **29.03** |
| **SPIRAL** | **8** | **25.81** |

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| | | |
|---|---|---|
| **SEGMENTAL** | **0** | **0** |
| **COMMUNITED** | **0** | **0** |
| **TOTAL** | **31** | **100** |

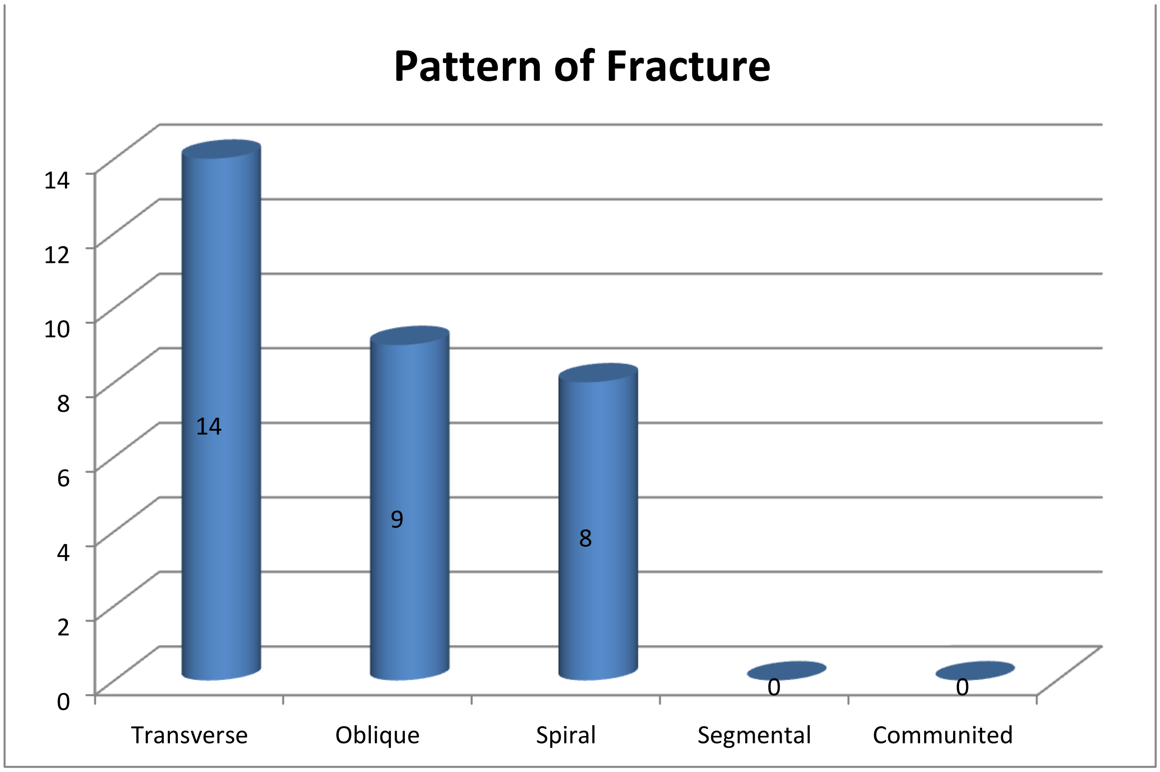


**Figure. 6.** Pattern of Fracture

In our study fractures involving the middle 1/3rd accounted for 24 (77.42%), proximal 1/3rd – 2 (6.45%) and distal 1/3rd – 5 (16.13%) of cases were included (Table. 9 and Figure 7).

**Table 9:** Level of Fracture

| LEVEL OF FRACTURE | NO. OF PATIENT | % |
|---|---|---|
| **PROXIMAL 1/3 RD** | **2** | **6.45** |
| **MIDDLE 1/3 RD** | **24** | **77.42** |
| **DISTAL 1/3 RD** | **5** | **16.13** |

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| | | |
|---|---|---|
| **TOTAL** | **31** | **100** |

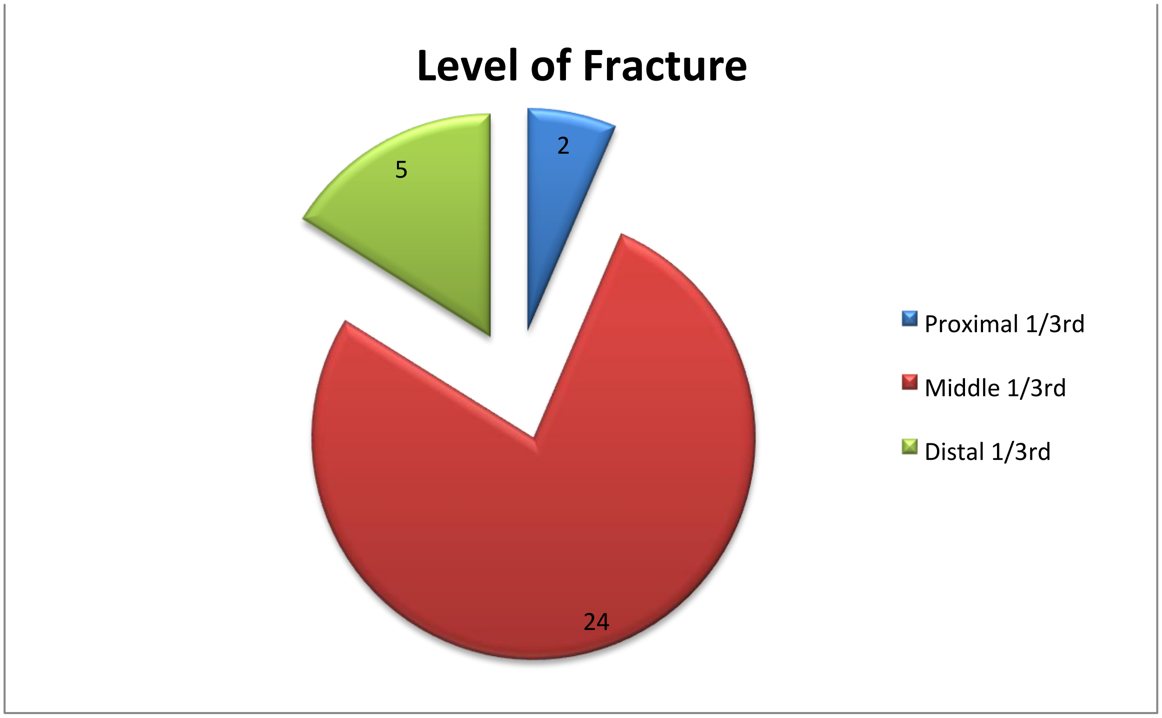


**Figure. 7.** Level of Fracture

In our study, 20 (64.52%) patients underwent surgery within 48 hours after trauma, remaining 11 (35.48 %) patients underwent surgery after 48 hours of trauma (Table. 10 and Figure 8).

**Table 10:** Time Interval Between Trauma And Surgery

| TIME INTERVL BETWEEN TRAUMA AND SURGERY | NO. OF PATIENT | % |
|---|---|---|
| **< 48 HOURS** | **20** | **64.52** |
| **> 48 HOURS** | **11** | **35.48** |
| **TOTAL** | **31** | **100** |

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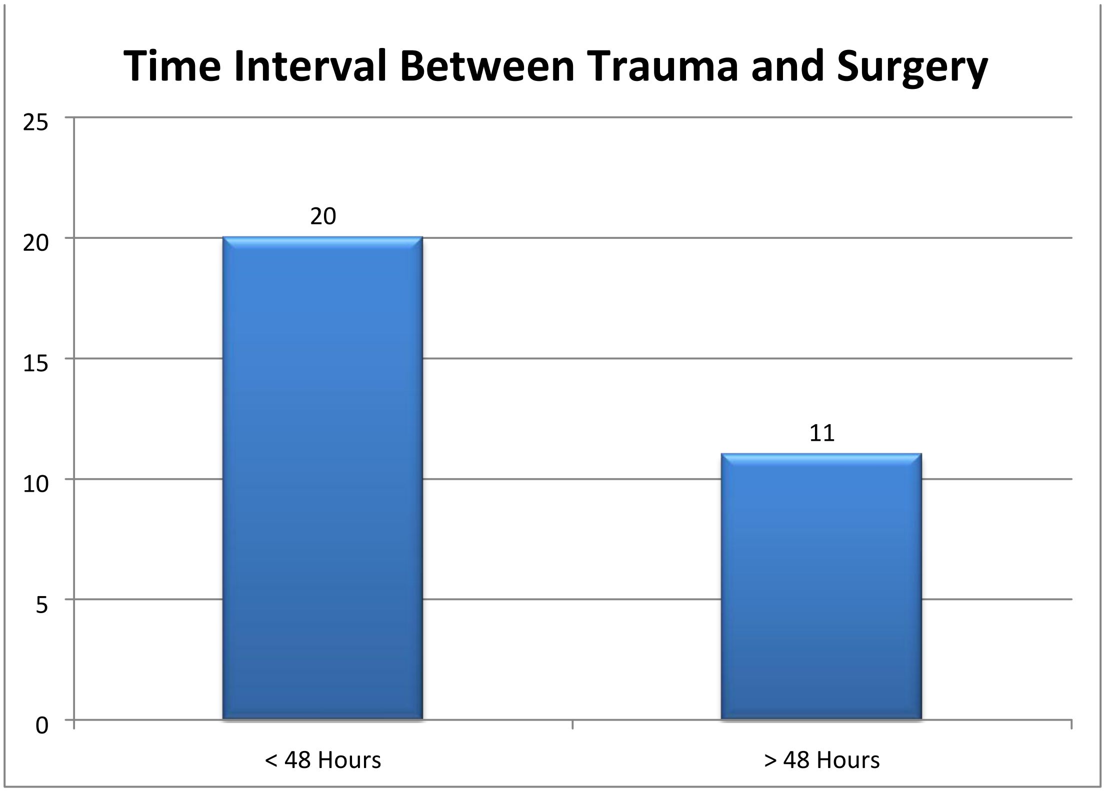


**Figure 8.** Time Interval Between Trauma And Surgery

The duration of stay in the hospital ≤ 7 days for 15 (48.39%) patients, 8-10 days for 7 (22.58%), 11-15 days for 3 (9.68%) and 6 (19.35%) patients stayed for more than 15 days (Table. 11 and Figure. 9).

**Table 11.** Duration of Hospital Stay

| DURATION OF HOSPITAL STAY (IN DAYS) | NO. OF PATIENT | % |
|---|---|---|
| < 7 | 15 | 48.39 |
| 8-10 | 7 | 22.58 |
| 11-15 | 3 | 9.68 |
| >15 | 6 | 19.35 |
| TOTAL | 31 | 100 |

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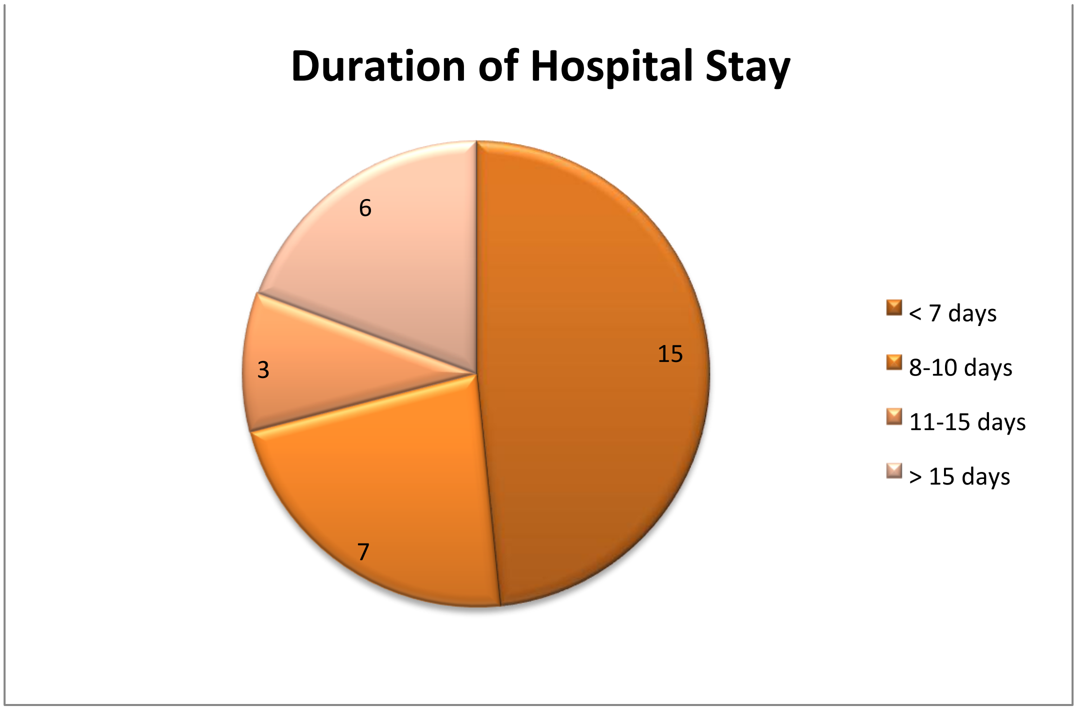


**Figure. 9.** Duration of Hospital Stay

In our study, 21 (70%) cases were immobilized (long leg slab with a pelvic band for femur fracture / above knee POP slab for tibia fracture, above/below POP slab for humerus / forearm fractures respectively and with broad arm sling for clavicle fracture.) postoperatively for 6 weeks and such immobilization was for 9 weeks in rest of the 10 (32.26%) of the cases (Table. 12 and Figure. 10) .

**Table 12:** Post Operative Immobilization

| POST OPERATIVE IMMOBILIZATION | NO. OF PATIENT | % |
|---|---|---|
| **6 WEEKS** | **21** | **67.74** |
| **10 WEEKS** | **10** | **32.26** |
| **TOTAL** | **31** | **100** |

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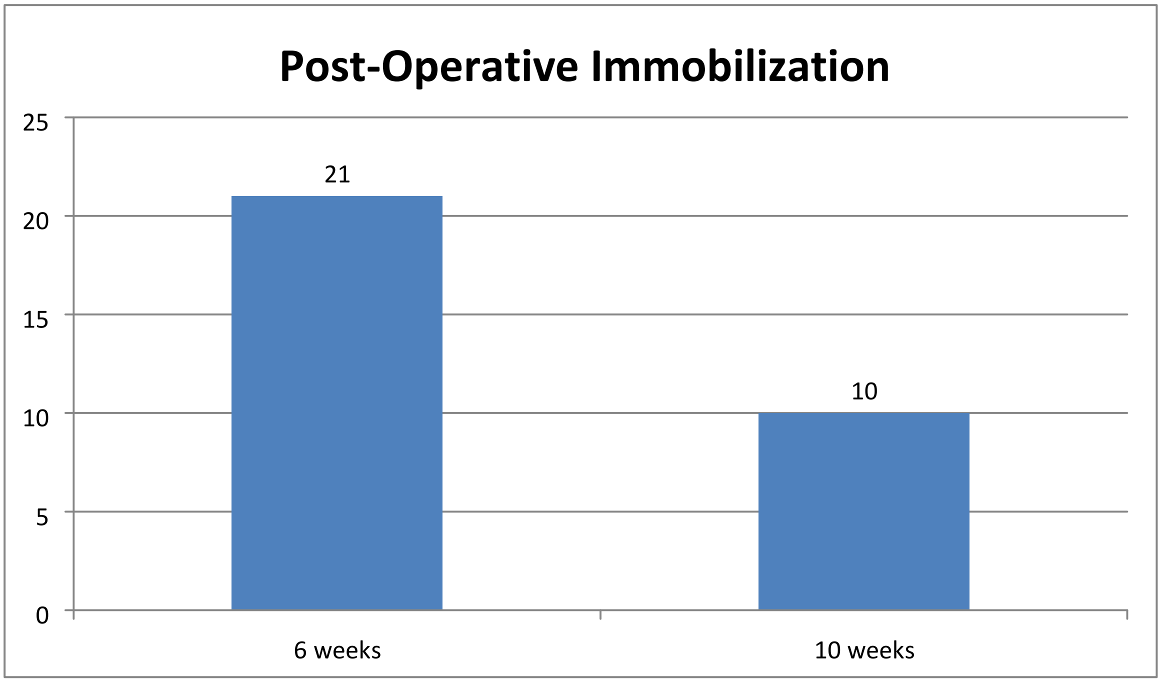


**Figure. 10.** Post Operative Immobilization

In our study 26 (83.87%) of patient, antibiotics were used for 0-3 days, 4 (12.90%) of patient, antibiotics were used for 4-5 days and 1 (3.23%) of patient, antibiotics were used for 6-9 days (Table. 13 and Figure. 11).

**TABLE 13:** No. of days of use of antibiotics

| NO. OF DAYS OF USE OF ANTIBIOTICS | NO. OF PATIENT | % |
|---|---|---|
| 0-3 | 26 | 83.87 |
| 4-5 | 4 | 12.90 |
| 6-9 | 1 | 3.23 |
| TOTAL | 31 | 100 |

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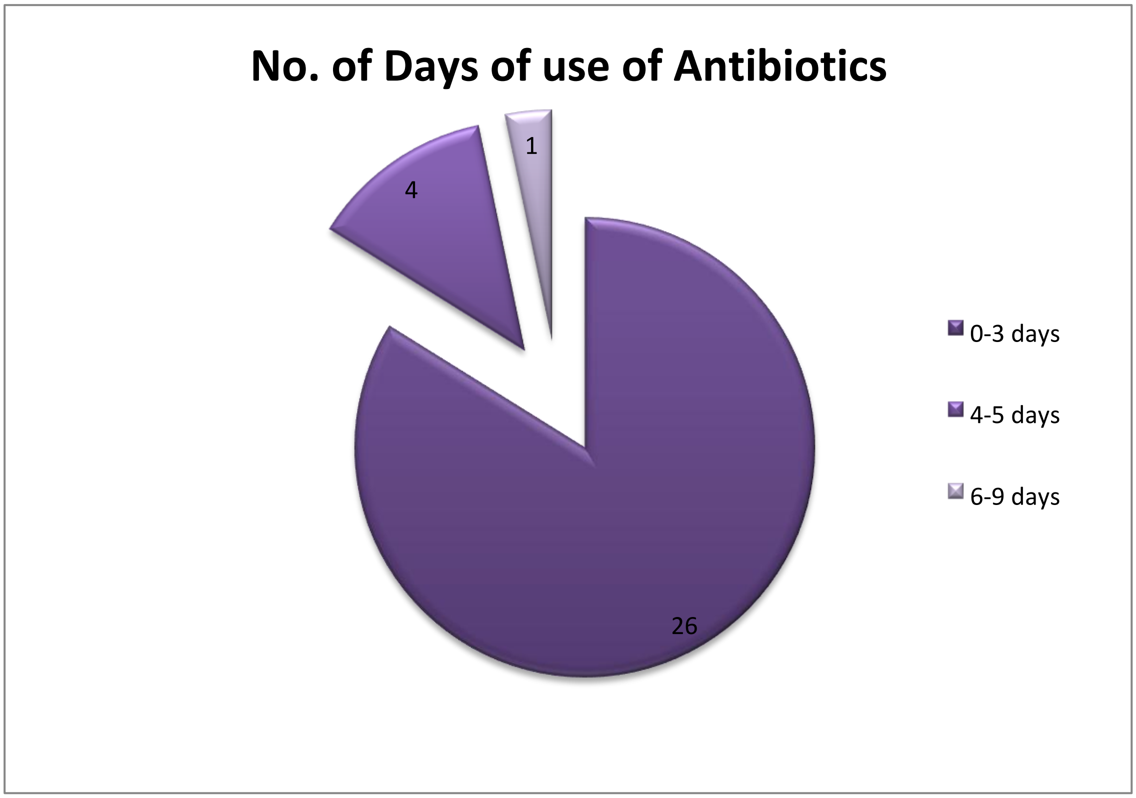


**Figure. 11** No. of days of use of antibiotics

In our study union was achieved in <3 months in 29 (93.55%) of the patients and 3 – 4.5 months in 2 (6.45%) (Table. 14 and Figure.12).

**Table 14.** Time for Union

| TIME FOR UNION | NO. OF PATIENT | % |
|---|---|---|
| </= 12 WEEKS | 29 | 93.55 |
| >12 – 18 WEEKS | 2 | 6.45 |
| >18-24 WEEKS | 0 | 0 |
| TOTAL | 31 | 100 |

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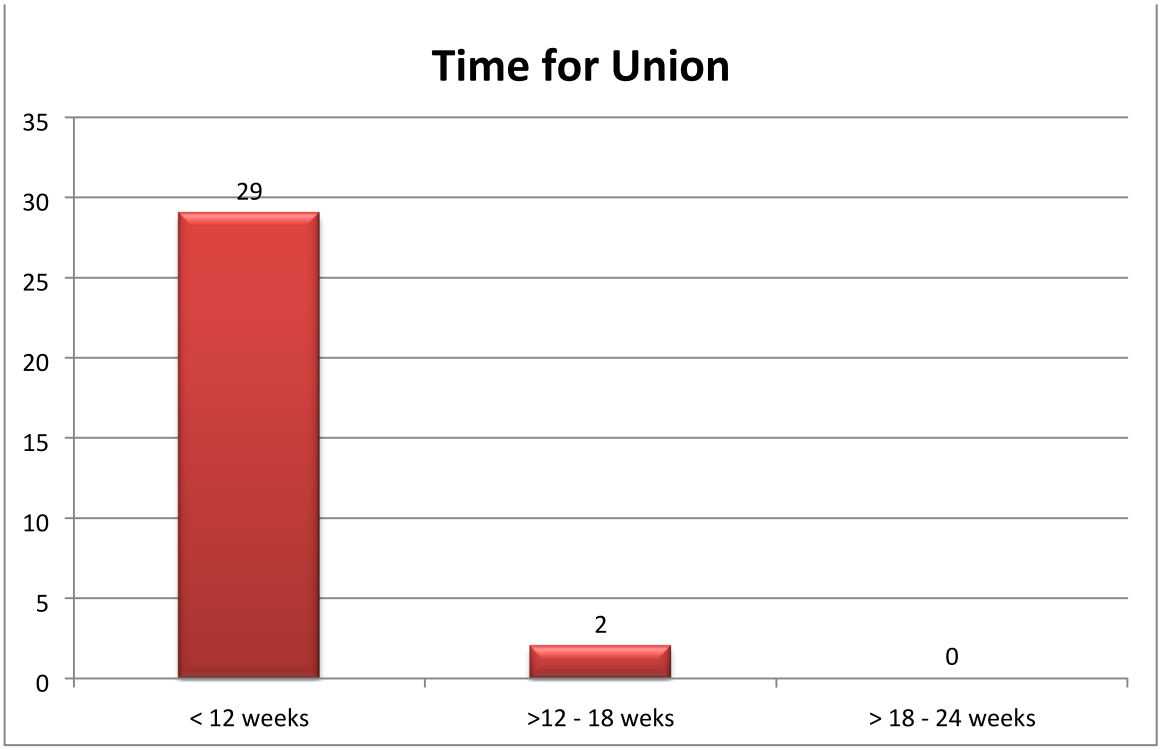


**Figure. 12.** Time for Union

In our study 29 (93.55%) patients had full range of motion and 2 (6.45%) patients had mild restriction in knee flexion (Table. 15 and Figure. 13).

**Table 15.** Range of Movements At 24 Weeks (Degress)

| Range of movements (degrees) | No. of patient | % |
|---|---|---|
| Full range | 29 | 93.55 |
| Mild restriction | 2 | 6.45 |
| Moderate restriction | 0 | 0 |
| Severe restriction | 0 | 0 |
| Total | 31 | 100 |

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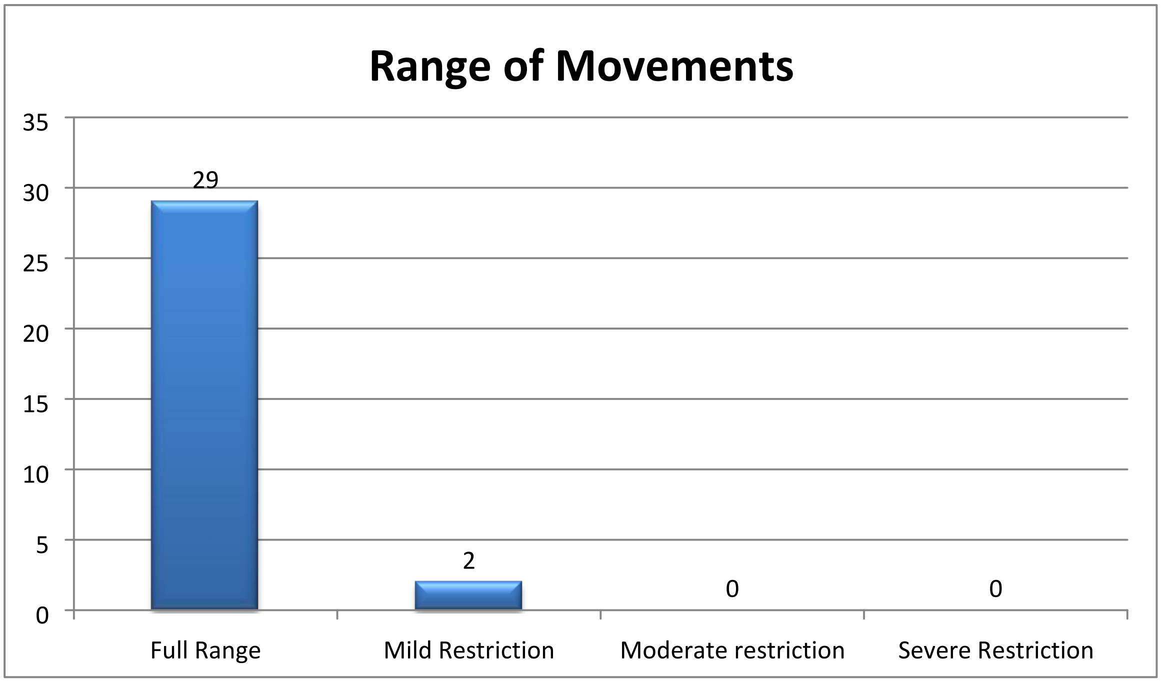


**Figure.13.** Range of Movements At 24 Weeks (Degress)

In the present study, unsupported full weight bearing walking was started in <12 weeks for 29 (93.55%) of the patients, between 12 and 18 weeks in 2 (6.45%) and no patient at 20 weeks (3.3%) patient (Table. 16 and Figure. 14).

**Table 17.** Time of Full Weight Bearing

| **Time of full weight bearing** | **Number of patients** | **%** |
|---|---|---|
| **≤ 12 weeks** | **29** | **93.55** |
| **>12– 18 weeks** | **2** | **6.45** |
| **>18 – 24 weeks** | **0** | **0** |
| **TOTAL** | **31** | **100** |

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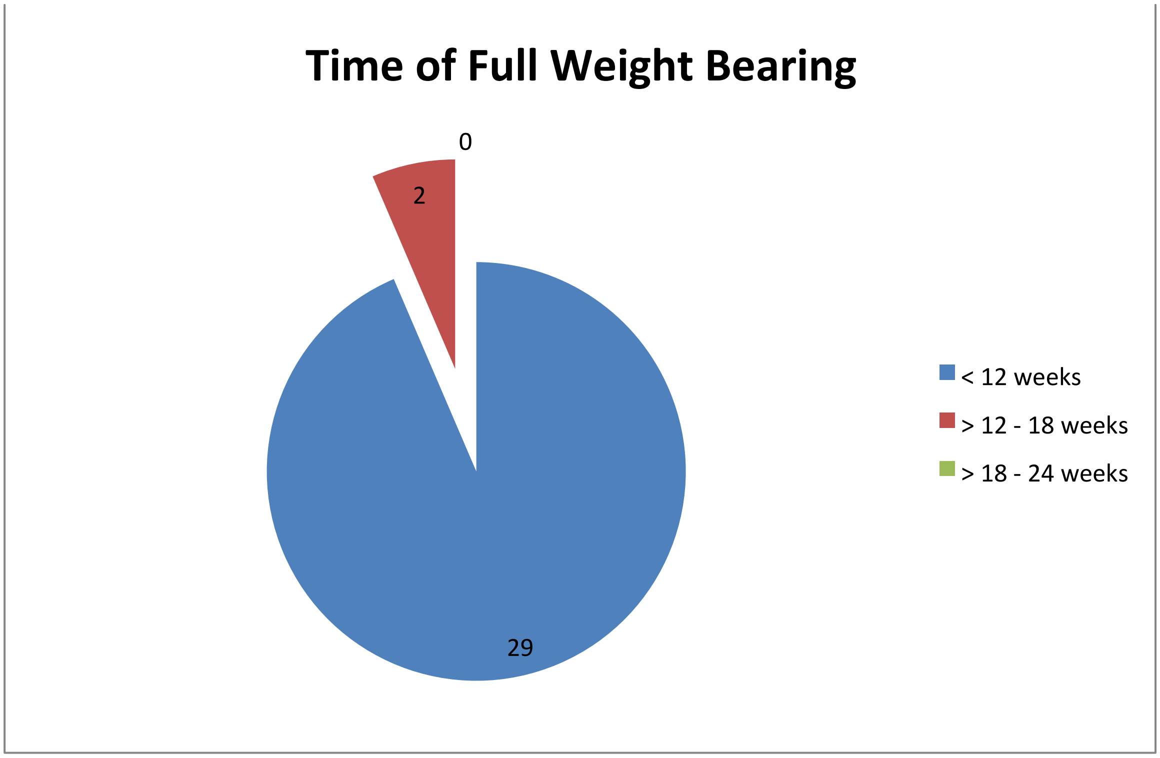


**Figure. 14.** Time of Full Weight Bearing

In our study there were, no major and minor complications reported at 24 weeks (Table. 17 -18, Figure. 15 -19).

**Table 17. Complications**

| | **Minor** | **Major** | **Nil** | **Total** |
|---|---|---|---|---|
| **No.of Patients** | **0** | **0** | **31** | **31** |
| **Percentage** | **0** | **0** | **100** | **100** |

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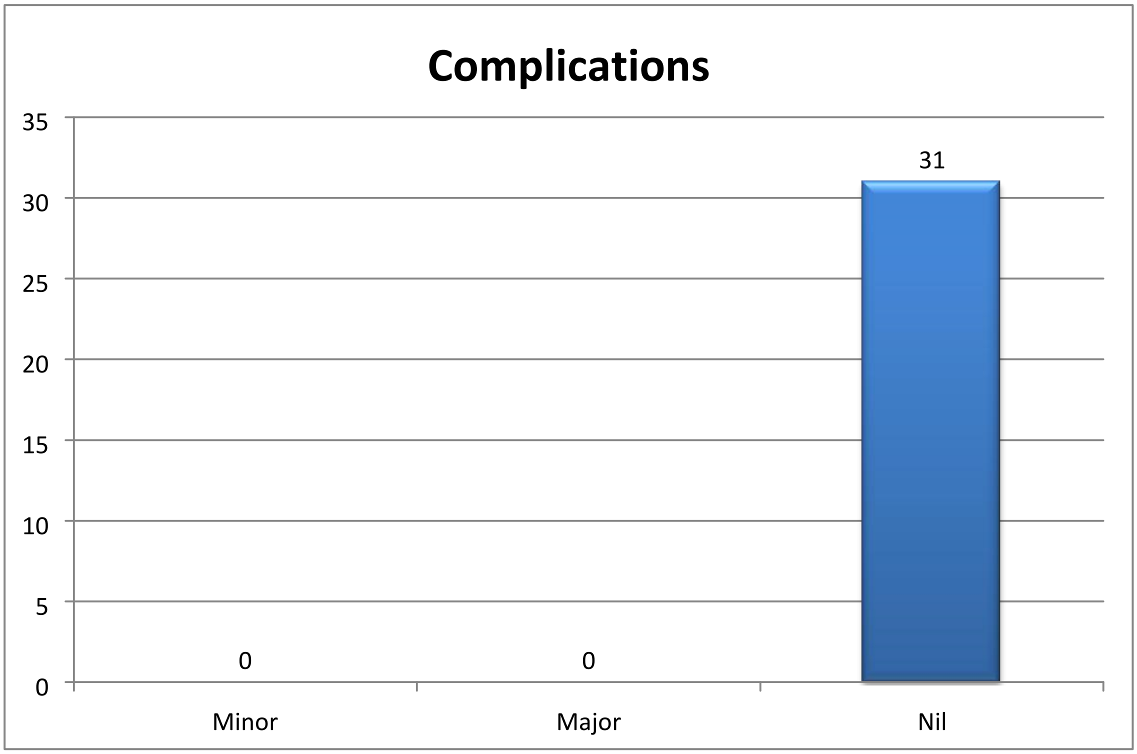


**Figure. 15.** Complications

**Table 18.** COMPLICATIONS (6 Weeks)

| Complications | No. of cases | Percentage |
|---|---|---|
| **Pain** | **7** | **22.5** |
| **Infection** | **0** | |
| **Superficial** | **0** | |
| **Deep** | **0** | |
| **Inflammatory reaction** | **0** | |
| **Delayed union and non-union** | **0** | |
| **Limb lengthening** | | |
| **< 2 cm** | **0** | |
| **> 2 cm** | **0** | |
| **Limb shortening** | | |

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| | | |
|---|---|---|
| **< 2 cm** | **0** | |
| **> 2 cm** | **0** | |
| **Nail back out** | **0** | |
| **Malalignment a. Varus angulation** | **0** | |
| **Valgus angulation** | **0** | |
| **c. Anterior angulation** | **0** | |
| **d. Posterior angulation** | **0** | |
| **e. Rotational malalignment** | **0** | |
| **Bursa at the tip of the nail** | **1** | **3.25** |
| **Sinking of the nail into the medullary cavity** | **0** | |

RADIOLOGICAL AND CLINICAL ASSESSMENT CASE 11 CLINICAL PICTURE 1

*PRE OP POST OP*

12Weeks24Weeks

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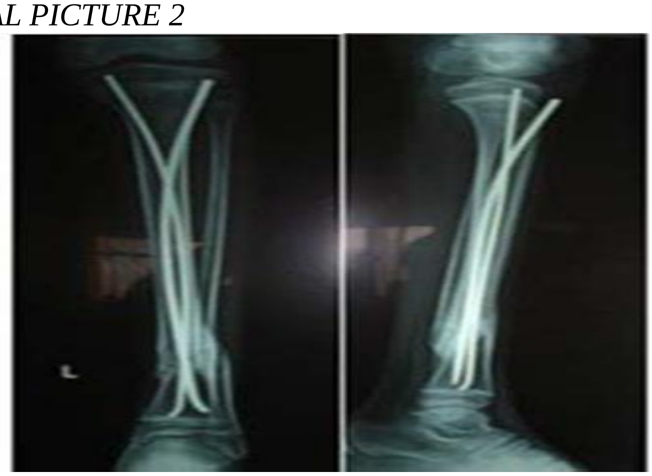
*Flexion in squatting position*

**Figure 17**

*Extension CASE 17 CLINICAL PICTURE 2*



*PRE – OP* *POST OP: 6 WEEKS*

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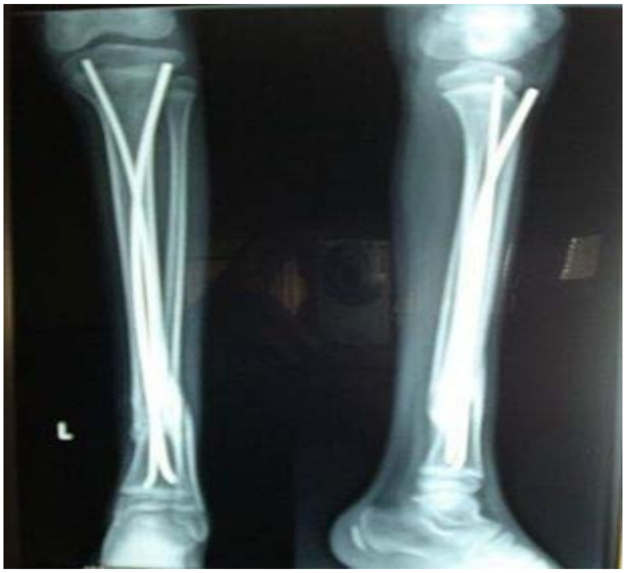
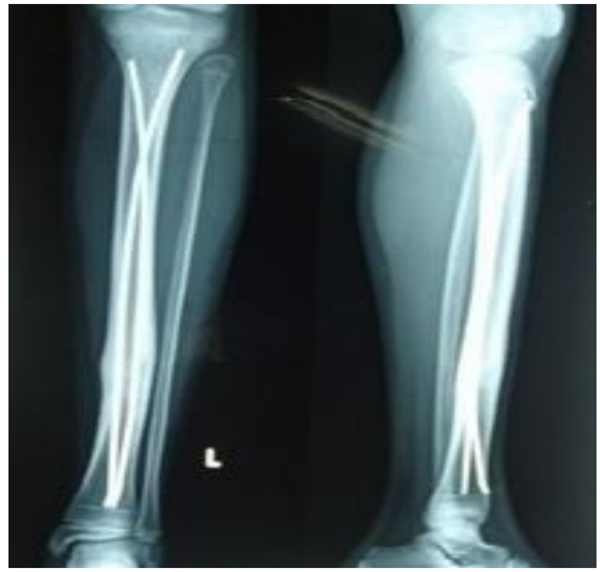



**POST OP: 12 WEEKS**




**POST OP: 24 WEEKS**

**Figure. 18**

*KNEE FLEXION*

*KNEE EXTENSION*

*ANKLE DORSI FLEXION*

*ANKLE PLANTAR FLEXION*

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**SQUATTING**

**Figure 19**

## 4. Discussion

Surgical management of long bones of paediatric age group has been controversial. Multiple treatment options have been tried over past two to three decades. Complications were found to be associated with every treatment option. Immobilization with POP alone or along with traction was found to be associated with complications like limb-length discrepancy, angulation, psychological and economic complications. Also it involved prolonged bed rest and loss of days from school for adolescents and school-aged children and it added to the baby sitting problem in homes with both the parents working. External fixator resulted in pin tract infection, loss of reduction refracture after removal of external fixator, malunion and loss of days from school. Plating as a treatment modality is not practiced commonly for paediatric fractures in children as it involves bigger surgical incision leading to higher likelihood of infection, stripping of periosteum and loss of fracture haematoma.

Wound infection and impingement was found to be associated with minimally invasive plate osteosynthesis (MIPO) used in management of paediatric tibial fractures. In case of femoral fractures, MIPO has been associated with malalignment and delayed union. Intramedullary K-wire fixation has also been used for pediatric femoral fracture. But stability and fracture angulation is a disadvantage to be taken care of. An ideal implant for the treatment of paediatric lower extremity long bone fractures should be load sharing, allowing early mobilisation, without disrupting the blood supply of epiphyseal growth plates, maintains limb length and alignment till the fracture healing marked by bridging callus occurs. TENS has been designed for the treatment of diaphyseal fractures in children and is being used presently for the treatment of paediatric femoral fractures, and, increasingly, for surgical management of paediatric tibial, humeral, forearm and clavicle fractures. It is based upon the principle of three-point fixation that works by balancing forces between two opposing flexible implants. This method achieves biomechanical stability from the divergent ‘‘C’’ configuration which creates six points of fixation and allows the construct to act as an internal splint. This is in contrast to Enders nails that achieve stability from nail stacking and canal fill. Titanium nails provide stable and elastic fixation, leading to controlled motion at the fracture site leading to healing by callus formation.

In the present study hospital stay was more in comparison to the previous studies. Our average age, sex determination, time for surgery, were quite similar to previous reports. Rotational

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misalignment was not noted in this study due to utmost care being taken during intraoperative limb positioning. Flynn et al. [4] have reported a similar finding, supporting the concept that TENS can give rotational stability provided adequate care is taken during nail insertion and following operation. None of the patients in our study developed compartment syndrome during their course of treatment which was different from findings of Sanker et al. who reported four patients developing compartment syndrome during course of treatment and three patients with impending compartment syndrome for whom fasciotomies were performed at the time of index surgery. None of the patients in our series required any secondary surgical intervention or re-admission following discharge, except for nail removal. Limb shortening was not noted. No major complications and minor complications were noted. Outcome was graded by Flynn's criteria as excellent, satisfactory and poor. In our present study we achieved 100% excellent outcome, no poor outcome was noted.

In the present study 11(35.48%) of the patients were 3-8 years, 10 (32.26%)were 9 to 12 years and 10(32.26%) were 13 to 17 years' age group with the average age being 9.8 years. Ligier et al studied children ranged from 5-16 years with a mean of 10.2 years. [8] Wudbhav et al., studied children ranged from 7.2-16 years with a 8 mean of 12.2 years.[17] There were 7 (22.58%) girls and 24 (77.42%) boys in the present study. The sex incidence was comparable to previous studies. In their study, Ligier et al. out of 118 cases, had 80 (67.7%) boys and 38 girls.[8] Gamal El-Adl et al. had showed that out of 66 patients, there were 48 (72.7%) male and 18 (27.3%) females.[2]Their results could be concordant with our results.

In the present study RTA and self-fall was the most common mode of injury accounting for 15 (48.39%) in each cases, battered baby accounted for 1 (3.22%) cases and no cases reported fall from height. Flynn et. al, in their study assessing 234 cases, 136(58.1%) were following RTAs, 46 (19.6%) were following self-fall and remaining 43(28.8%) were as a result of fall from height.[7]

In our study we had 12 (38.71%) femoral, 9 (29.03%) tibial fractures, 6 (19.35%) forearm, 2 (6.45%) clavicle and 2 (6.45%) humeral fractures. In studies conducted by Gamal El-Adl et al., there were 48 (65.7%) femoral and 25 (34.3%) tibial fractures.[2]

A total of 30 children aged 5-15 years of age were present with displaced diaphyseal forearm fractures and underwent titanium elastic nailing in the study conducted by D. Cumming et al.,.[76]. A total of 38 patients, were present with clavicle fractures and were treated with TENS in the study conducted by Anish P. Kadakia, et al., [77].

In our study, transverse fractures accounted for 14(45.16%) cases, oblique fractures – 9 (29.03%), spiral fractures – 8 (25.81%) and there were no segmental fractures and communited fractures. In their study Ligier et al. out of 123 femoral fractures studied 47 (38.2%) were transverse fractures, communited fractures- 25 (20.3%), oblique fractures – 7 (23.3%), spiral fractures – 19 (15.4%) and 4 (3.2%) were segmental fractures.[8] sWudbhav studied 19 tibial shaft fractures out of which 9 (47.3%) were transverse, 7 (36.8%) were oblique, 2 (10.5%) were spiral and 1 (5.2%) was communited.[17]

Fractures involving the middle 1/3rd accounted for 24 (77.42%) cases, proximal 1/3 – 2 (6.45%) and distal 1/3 – 5 (16.13%) of cases in our study. In their study Ligier et al among 123 femoral shaft fractures, 42 fractures were in the proximal 1/3, 45 in the middle 1/3 and 36 were in the distal 1/3 rd [8]

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Wudbhav N. Sankar studied 19 tibial shaft fractures out of which 15 were middle 1/3rd, 2 – proximal 1/3rd and 2 were distal 1/3 rd[17.]

In the present series, 20 (64.52%) patients underwent surgery within 2 days after trauma, 8 (26.7%) and 11 (35.48%) underwent surgery >48 hours. Delay in surgery is due to reason that patient belonging to lower socio economic status and took time to arrange for the expenses of the surgery. Gamal et al operated 56.1% of cases between 3-4 days after injury, 21.2% cases between 3 -4 days and 22.7% cases after 7 days.[2] Saika et al. operated 77.27 % patients within 7 days of injury.[3]

In our study, 21 (70%) cases were immobilized (long leg cast with a pelvic band for femur fracture / above knee POP cast for tibia fracture) postoperatively for 6 weeks and such immobilization was for 9 weeks in rest of the 10 (30%) of the cases.

Below /above elbow pop slab for forearm and humeral fracture. Broad arm sling for forearm/ humeral /clavicle fracture was used in later period of immobilization. The period of immobilization was followed by active hip and knee / knee and ankle mobilization with non-weight crutch walking. The average duration of immobilization was 8 weeks. The average length of immobilization in plaster was 9.6 weeks in Gross et al study.[48]

John Ferguson et al treated 101 children with immediate hipspica casting. They immobilized children on an average duration of10 -12 weeks with spica casting.[18] The advantage of the present study was early mobilization of the patients.

The duration of stay in the hospital ≤ 7 days for 15(48.38%) patients, 8-10 days for 7 (22.58%), 11-15 days for 3 (9.68%) and 6 (19.35%) patients stayed for more than 15 days.

The average duration of hospital stay in the present study is 11. 6days.The mean hospital stay was 12 days in Kalenderer O et al., study.[20] Average hospitalization time was11.4 days in the study conducted by Mann DC, et al.[21]

Gross R H, et al., conducted a study on cast brace management of the femoral shaft fractures in children and young adults. The average length of hospitalization in their study was 18.7 days.[48]

Compared to the above studies conducted on conservative methods and cast bracing, the average duration of hospital stay was less in our study i.e. 11.6 days. The reduced hospital stay in our series is because of proper selection of patients, stable fixation and less incidence of complications.

In our study union was achieved in<3 months in 29 (93.55%) of the patients and 3 – 4.5 months in 2(6.45%). Average time to union was 16 weeks. Oh et al reported average time for union as 10.5 weeks.52 Aksoy C, et al compared the results of compression plate fixation and flexible intramedullary nail insertion. Average time to union was 7.7 (4 to10) months in the plating group and 4 (3 to 7) months for flexible intramedullary nailing.[5]

In our study, closed reduction of the fracture, leading to preservation of fracture hematoma, improved biomechanical stability and minimal soft tissue dissection led to rapid union of the fracture compared to compression plate fixation.

In the present study, unsupported full weight bearing walking was started in<12 weeks for 29 (93.55%) of the patients, between 12 and 18

weeks in 2 (6.45%) and no patient at 20 weeks (3.3%) patient.

The average time of full weight bearing was 16weeks.

Wudbhav N. Sankar et al., in their study allowed full weight bearing between 5.7 – 11.6 weeks an average of 8.65 weeks.[17]

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In the present study, 7 (22.5%) patients had developed pain at site of nail insertion during initial follow up evaluation which resolved completely in all of them by the end of 16 weeks. Flynn et al. reported 38 (16.2%) cases of pain at site of nail insertion out of 234 fractures treated with titanium elastic nails.[7] Superficial infection was seen in none of the case in our study which was controlled by antibiotics.
J.M. Flynn et al., reported 4(1.7%) cases of superficial infection at the site of nail insertion out of 234 fractures treated with titanium elastic nails.[7] Pintract infection is a major disadvantage of external fixation application. Bar-on E et al reported 2 cases of deep pin tract infection in their patients treated with external fixation.[16].
In the present study 29 (93.55%) patients had full range of motion and 2 (6.45%) patients had mild restriction in knee flexion at 12weeks, but normal range of knee flexion was achieved at 8 months. Flynn et al. reported 2 (0.9%) cases of knee stiffness out of 234 fractures treated with titanium elastic nails.[7]

This is the most common sequele after femoral shaft fractures in children and adolescents. There were no patients reported with shortening. Beaty et al. reported, two patients had overgrowth of more than 2.5 cm necessitating epiphysiodhesis, after conservative treatment.[54]
Ozturkman Y. et al observed mean leg lengthening of 7mm in 4 (5%) patients and mean shortening of 6mm in 2 (2.5%) children.[55] Cramer KE, et al noted average limb lengthening of 7mm (range 119mm) in their study. Clinically significant limb discrepancy (> 2cm) did not occur in any patient in their study.[56] Wudbhav N. Sankar in their study of 19 tibial shaft fractures reported no leg length discrepancy.[17]
John Ferguson et al noted more than 2cm shortening in 4 children after spica treatment of pediatric femoral shaft fracture. In the present study, limb length discrepancy of more than 10mm was present in 2 (10%) cases.[49] Comparing to limb length discrepancy in conservative methods, limb length discrepancy in our study was within the acceptable limits.
In the present series, nail back out was not seen in any of the cases. But in the study conducted by Carrey T.P. et al., out of 38 cases, nail back was noted only in one case, which necessitated early removal.[60]

Some degree of angular deformity is frequent after femoral shaft fractures in children, but this usually remodels after growth.
Varus/valgus malalignment: In our study no patients were presented with varus/valgus angulation. Flynn et al., reported 10 (4.3%) cases of minor angulation out of 234fractures which were treated with titanium elastic nails.[7].
Heinrich SD, et al., reported 5° of varus angulation in one child in their study and 11 % of fractures had an average varus or valgus malalignment of 6°.[61.] Herndon WA, et al., compared the results of femoral shaft fractures by spica casting and intramedullary nailing in adolescents. They noticed varus angulation ranging from 7 to 25° in 4 patients treated with spica casting and no varus angulation in surgical group.62 The varus and valgus malalignment that occurred in our study are within the acceptable limits.

In the present study, no patients had anteroposterior angulation.
Ozturkman Y, et al., noted an anterior angulation of 7°and a posterior angulation of 6°in 2patients respectively.[55]. Herndon WA, et al., noticed anterior angulation ranging from 8°to35° in patients treated with traction and spica casting.[62.]

8% of the patients had an average anterior or posterior angulation of 8°in Heinrich SD, et al study.[61].
A difference of more than 10° has been the criterion of significant deformity. No patient in our study had significant rotational deformity. Heinrich SD, et al., out of 183 fractures studied, reported $8^0$ out toeing in 4 children and two children with $5^0$ in toeing following flexible intramedullary nailing[61].

No cases of proximal migration of nail were noticed in our study.
whereas Bar-on E, et al noticed proximal migration of the nail in one case.[16]
In the present study out of the 31 children's 12(38.71%) femoral, 9 (29.03%) tibial, 6 (19.35%) forearm, 2 (6.45%) clavicle and 2 (6.45%) humeral fractures, the final outcome was excellent in all of them. (100%). Gamal El Adl et al., in their study of 66 children with 48 femoral and 25 tibial shaft fractures reported (75.8%) excellent, 24.2% satisfactory and no poor results.[2]
Flynn et al., treated 234 femoral shaft fractures and the outcome was excellent in 150(65%) cases, satisfactory in 57 (25%) cases and poor in 23 (10%) of the cases.[7] Wudbhav N. Sankar in their study of 19 tibial shaft fractures reported 12 (63.15%) excellent, 6 (31.57%) satisfactory and 1 (5.26%) poor results.[17] Saikia et al., in their study of 22 children with femoral diaphyseal fractures reported 13 (59%) excellent, 6 (27.2%) satisfactory and 3(13.6%) poor results.[3] Thus the present study showed that the intramedullary Nailing technique is an ideal method for treatment of paediatric long bone fractures

## 5. Conclusion

Intramedullary Nailing technique is used to promote the rapid union at the site of fractures and restricted the early mobilization. The present study showed that it is a simple, easy, rapid, reliable and effective method for management of paediatric long bone fractures between the age of 3 to 17 years with many advantages such as minimal soft tissue damage, lesser blood loss, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing. Because of early weight bearing, rapid healing and minimal disturbance of bone growth, ESIN may be considered to be a physiological method of treatment.

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**Conflict Of Interest**
The authors declare no conflict of interest.
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