



Research Article

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## **Surgical Outcome of Femur Fractures in Children Treated with “Titanium Elastic Nailing System (TENS)”**

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## Introduction

In the paediatric age group, the shaft femur fractures account for 1.66 of all bony injuries. They are most common in boys(1,2) (2.6:1) and bimodal age distribution is seen during early adolescents and toddlers(3,4,5). During childhood, a child's bone changes from primary weak woven bone to stronger lamellar bone(6), thus leading to an increase in diameter(7) and cortical thickness resulting in an increase in area moment of inertia which increases the strength which explains the bimodal distribution of femoral fracture.

Children younger than 5 years have an excellent outcome with spica casting due to faster time to union, decreased risk of unacceptable shortening, small body size allowing easy parental cast care and transfer.

The treatment of long bone fractures in children is improving as newer treatments are developed. Most fractures were previously effectively managed conservatively, with only unstable and displaced fractures requiring surgical fixation.

Clinicians have learned through experience that children with diaphyseal femur fractures do not always recover with conservative treatment(8). Conservative treatment methods do not effectively correct shortening, angulations, or malrotation.(9)

Although the indication for operative treatment of paediatric fractures is still debated(10), there has been an increase in interest in it in the last three decades due to the evolution of orthopaedics, especially in orthopaedic trauma, a better understanding of biomechanics, variety and quality of implants, principles of internal fixation, antibiotics, and asepsis. There is still a lack of consensus on how to treat long bone fractures in children under the age of six, i.e. POP Spica casting or intramedullary nailing in children over 15 years or skeletally immature children.[9] However, the treatment of femur fractures in children and adolescents (ages 5 to 15) is still debatable(11).

Other options for management include early spica casting, skin traction, and external fixation, flexible intramedullary nails, open reduction and internal fixation with plating,reamed intramedullary nails(12). Prolonged bed rest, which separates the child from routine activities, and the cost of various types of traction and plaster cast immobilisation are the two major drawbacks.

Plates provide solid stabilisation for a femoral shaft fracture, but they need a bigger incision, which increases the risk of blood loss and scarring. It's a load-bearing device, thus re-fracture and growth disruption are both possibilities.

Children with long bone fractures can be treated with a number of intramedullary devices, such as the Rush or Enders nails, although these have poor elasticity and rotational stability, and fracture stabilization requires many nails (13).

Metaizeau and his Nancy(13), France-based team invented the stable intramedullary elastic nailing technique in 1988, which changed the management of fractures in children.

Internal elastic fixation in the form of Titanium TENS (Elastic Intramedullary Nailing System) creates a healthy environment for fracture healing without physical damage, micro-motion that promotes callus formation, minimally invasive surgery, and early return to school.

## **Materials and Methods**

### **Aim:**

To study and evaluate the clinical outcome of surgical treatment of fracture femurs in children by TENS nail.

### **Objectives of the study:**

To assess fracture union using Anthony et al. scale

To assess clinical outcome using Thoresen scoring system.

To assess complications like malalignment, limb length discrepancy, pain, etc using “Flynn’s Criteria”. Pain will be assessed using Visual Analogue Scale (VAS score).

**Study Design:** Prospective, Observational, Therapeutic study.

**Site and Place of study:** Children presenting with femur fractures in the Department of Orthopaedics at a tertiary care center in Southern Rajasthan.

### **Inclusion criteria:**

The patient with shaft femur fracture unilaterally or bilaterally.

Aged between 05-18 years of age.

Patient with a diaphyseal, subtrochanteric femur fracture.

### **Exclusion criteria:**

Patients with pathological fractures.

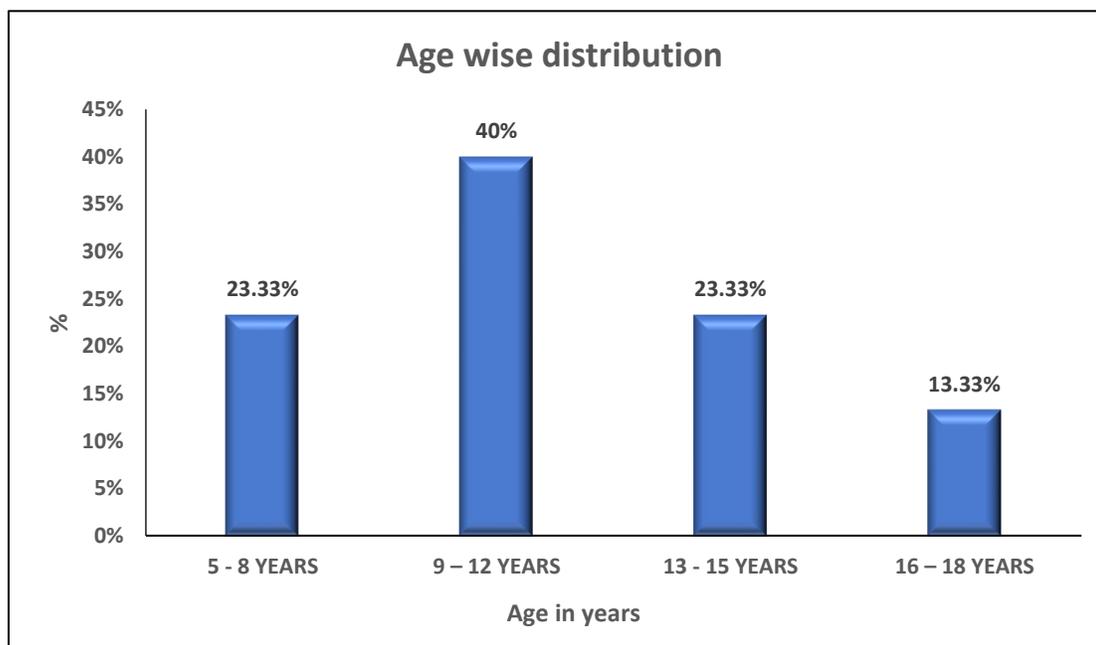
Patients/Parents of children who refused to give appropriate consent.

**Results**

Age in years	Cases	Percentage (%)
5 - 8 YEARS	7	23.33 percentage
9 - 12 YEARS	12	40 percentage
13 - 15 YEARS	7	23.33 percentage
16 - 18 YEARS	4	13.33 percentage
Total	30	100.00 percentage

**Table 1:** According to age Distribution

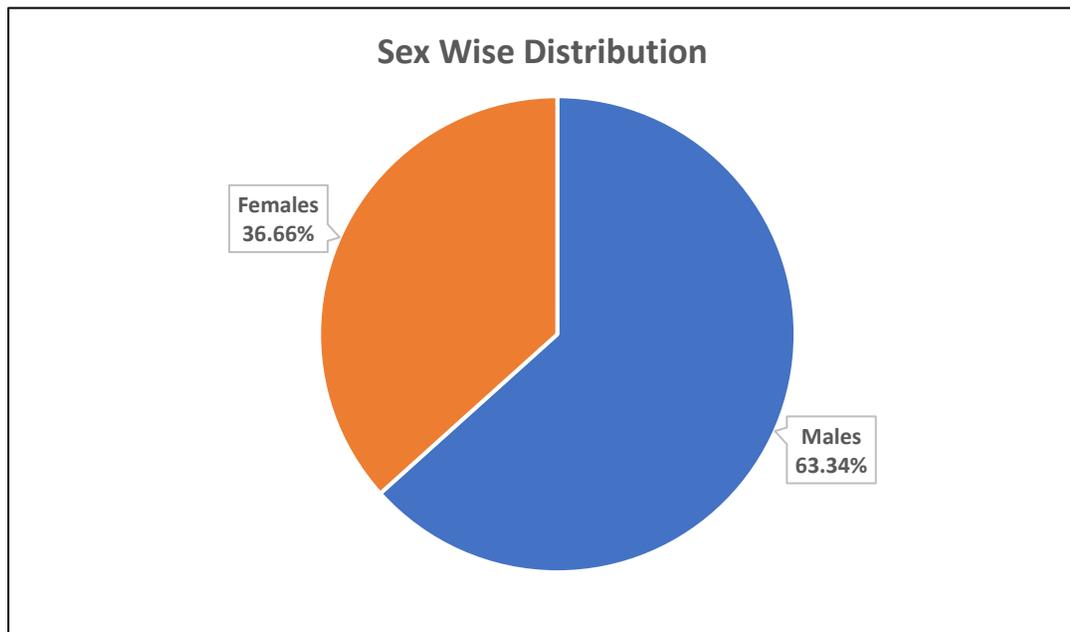
- Most common encountered age is between 9-12 years counting for 12 cases (40%).



Gender	No of cases	Percentage (%)
BOYS	19	63.33%
GIRLS	11	36.66%

**Table 2:** Sex Wise Distribution

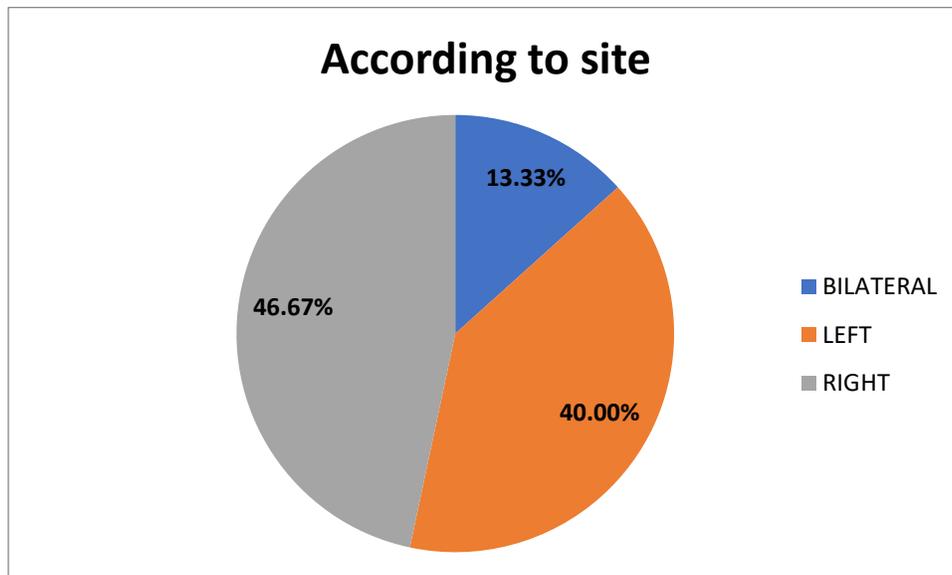
- Majority of the patients who sustained fracture were boys 19 cases (63.33%)when compared to girls patients 11 cases (36.66%).



Side	No of cases	Percentage
BILATERAL	4	23.53 %
LEFT SIDE	12	35.29 %
RIGHT SIDE	14	41.18 %

**Table 3:** According to site

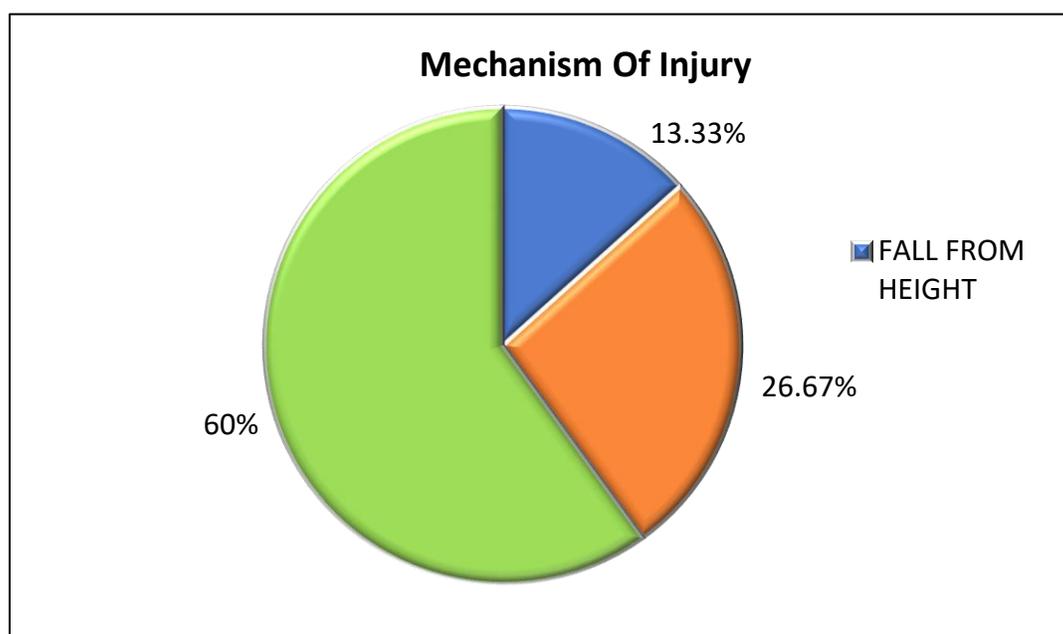
- Most commonly right side (14cases- 41.18 %) was affected than the left side (12 cases - 35.29) and 4 cases (23.53 %) had bilateral fractures.



Injury Mechanism	No of cases	Percentage
FALL FROM HEIGHT	4	13.33%
FALL WHILE PLAYING	8	26.67%
RTA	18	60%

**Table 4:** Injury Mechanism

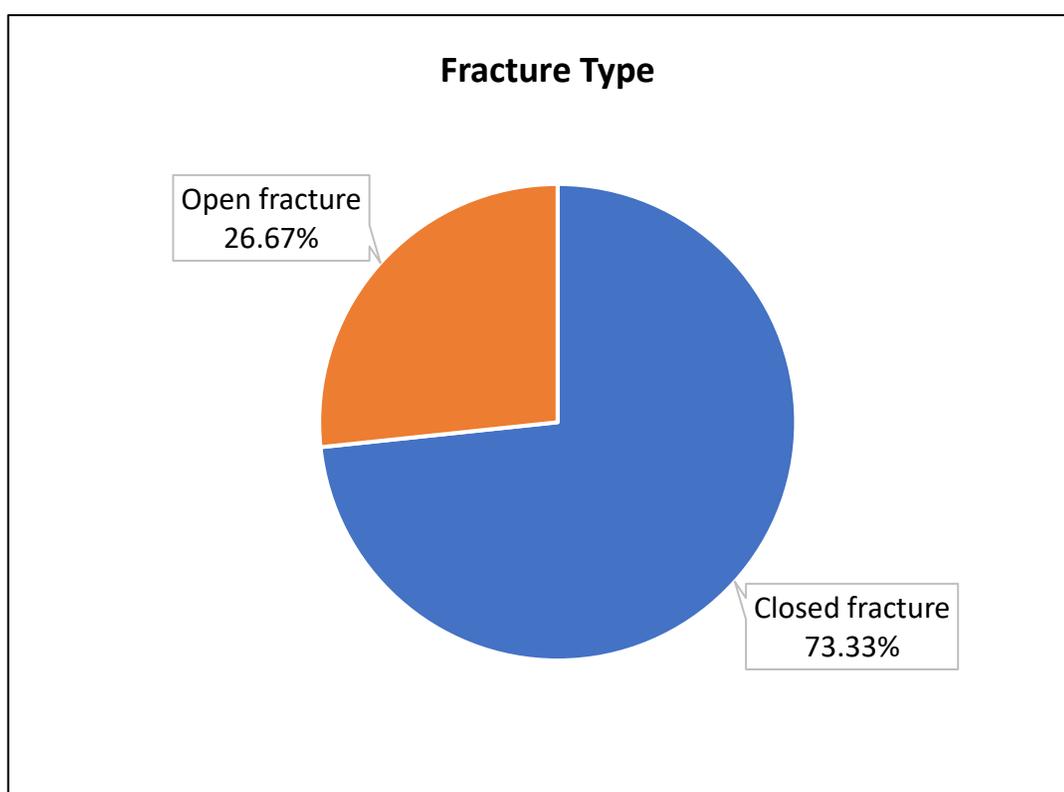
- Most common mode of injury was road traffic accidents in 18 cases (60%) followed by 8 cases (26.67%) due to falls while playing, and 4 cases (13.33%) were caused due to falling from height.



Type of fracture	No. of cases	Percentage (%)
Closed Fracture	22	73.33%
Open Fracture	8	26.67%

**Table 5:** Fracture Type

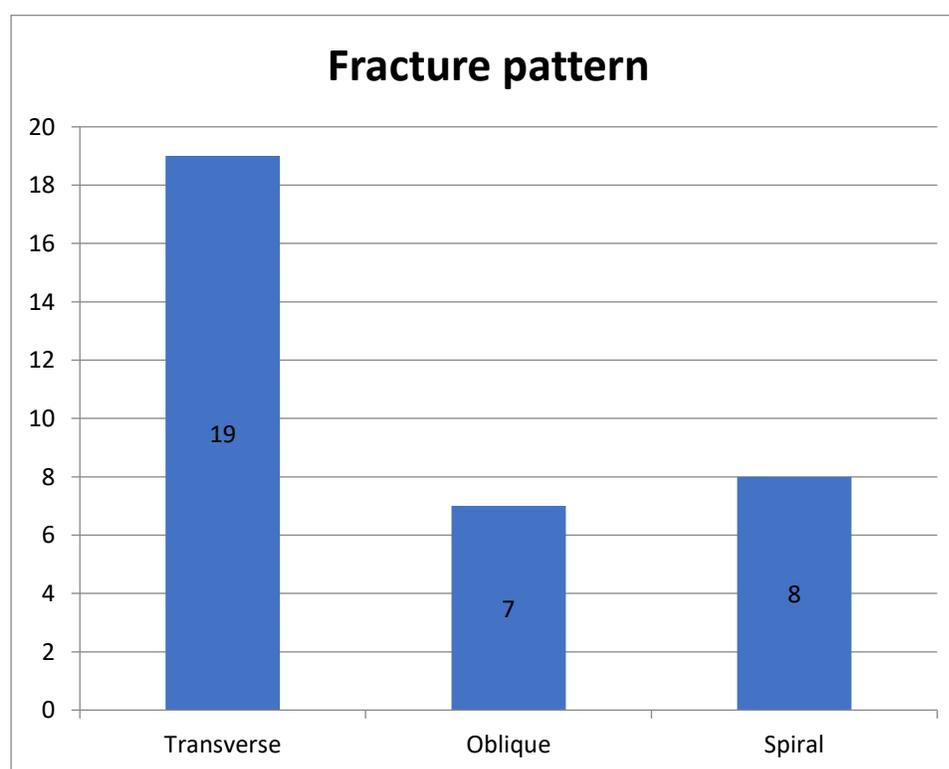
- 22 patients (73.33%) had closed injury and 8 patients (26.67%) had open fracture



Fracture pattern	No. of cases	Percentage (%)
Transverse pattern	19	55.88%
Oblique pattern	7	20.59%
Spiral pattern	8	23.52%

**Table 6:** Fracture pattern

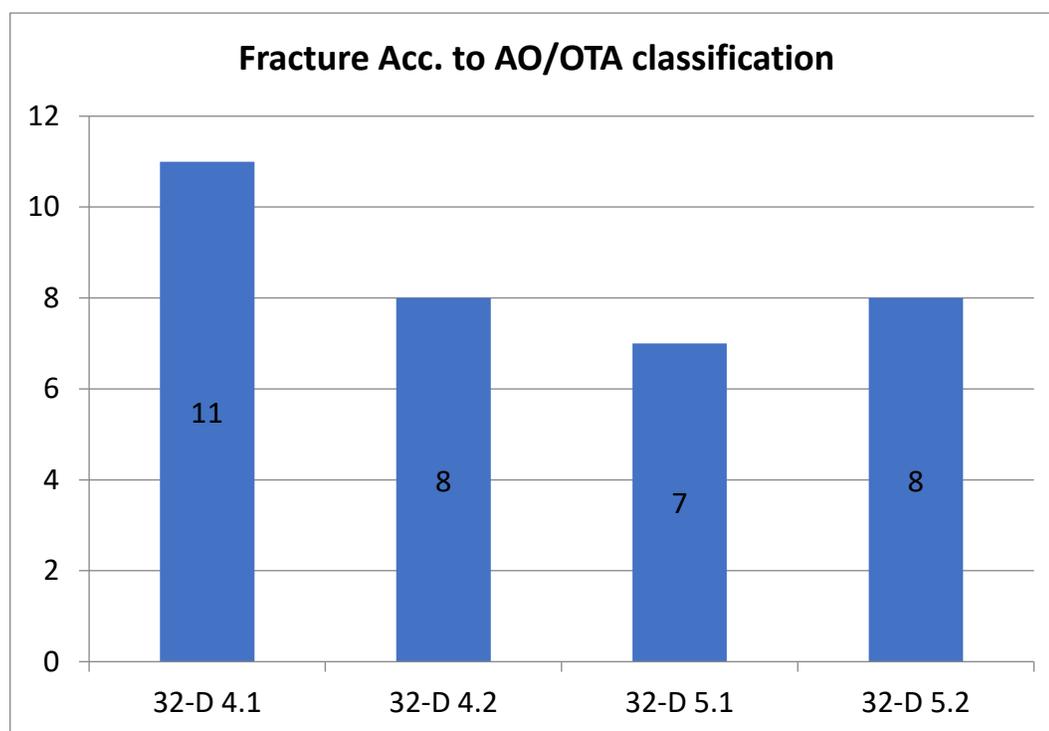
• In our investigation, the transverse fracture was the most prevalent pattern, accounting for 19 (55.88 percent) of the cases.



AO/OTA Classification	No. of Cases	Percentage
32-D 4.1	11	32.35 %
32-D 4.2	8	23.52 %
32-D 5.1	7	20.59%
32-D 5.2	8	23.52%

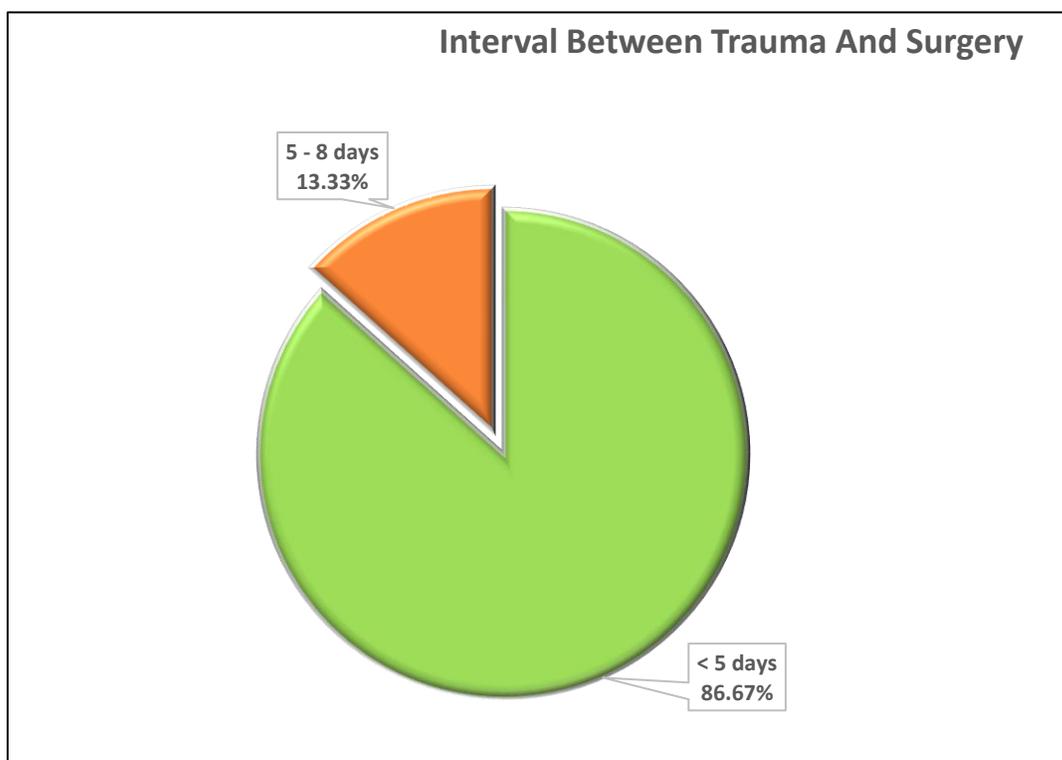
**Table 7:** Fracture According To AO/OTA Classification

- According to AO classification 32-D 4.1 was the most common type fracture pattern seen in our study in 11 cases (32.35%).



Interval	Cases	Percentage(%)
Less than 5 days	26	86.67%
5 - 8 days	4	13.33%

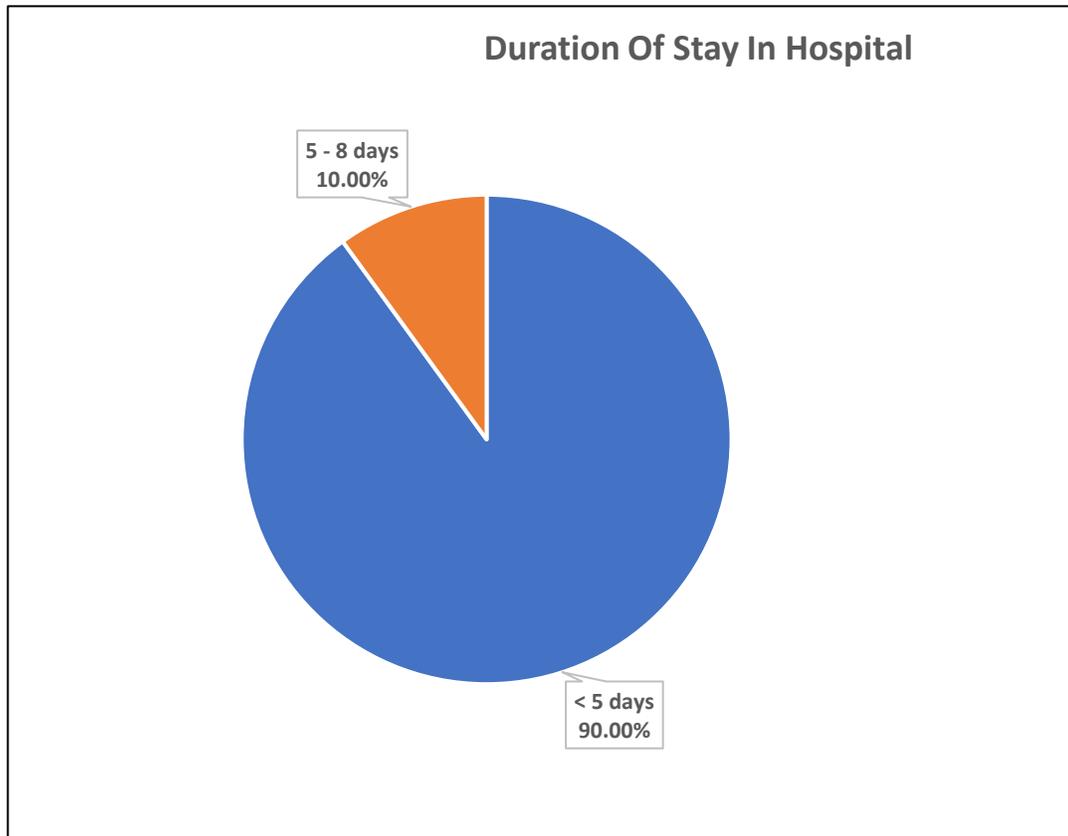
- 26 (86.67%) cases presented to the hospital within 5 days of trauma, whereas 4 (13.33%) cases presented in 5-8 days.



Duration	No of cases	Percentage
< 5 days	27	90 %
5 - 8 days	3	10 %

**Table 9:** Duration of Hospital Stay

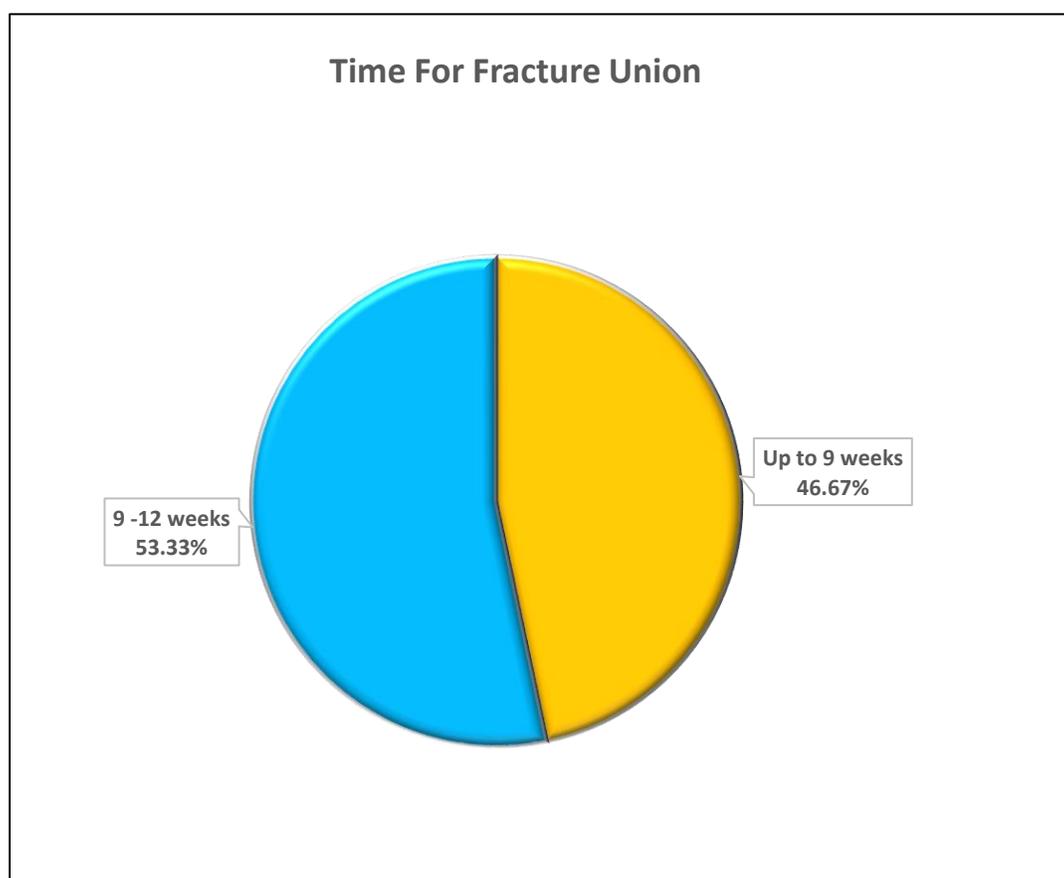
- In our study, 27 patients (90%) were discharged within 5 days and the remaining 3 patients (10%) were discharged between 5-8 days.



Fracture union time	No. of cases	Percentage(%)
Up to 9 weeks	14	46.67 %
9 -12 weeks	16	53.33%

**Table 10:**Fracture Union Time (Anthony et al. scale)

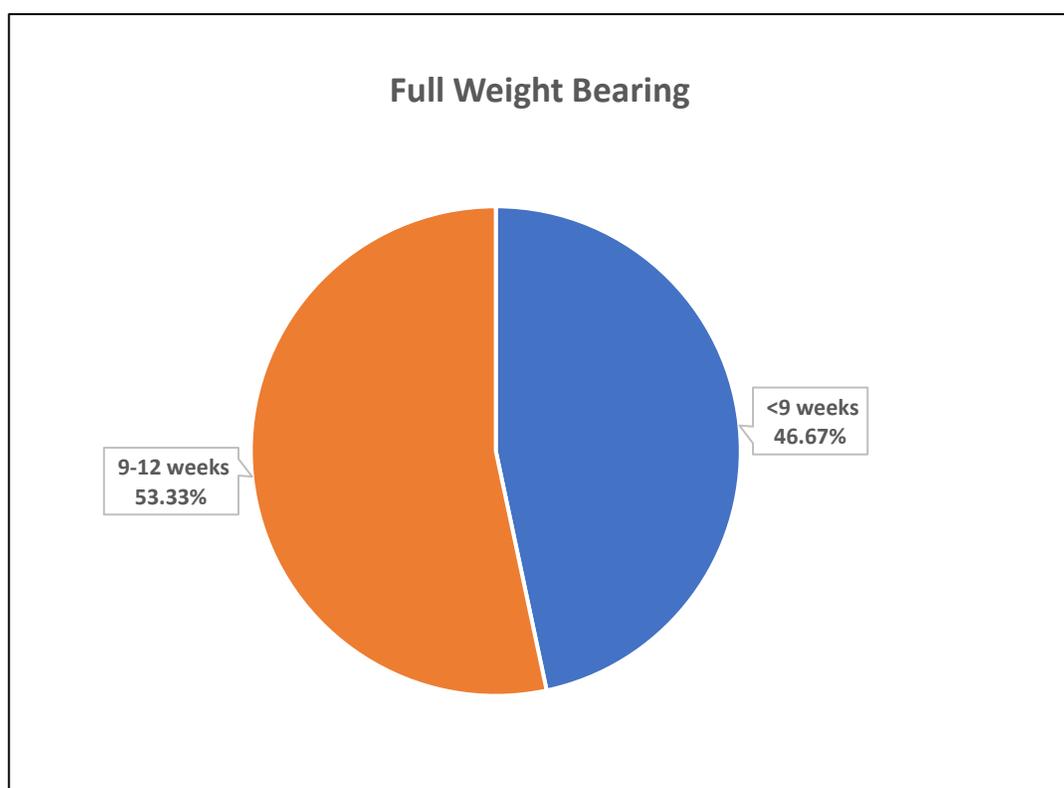
• In our study fracture union was evaluated using Anthony et al. scale. Grade -3 was considered as a radiological union. In 14 cases (46.67%) radiological union was seen within 9 weeks &in the remaining 16 cases (53.33%) within 12 weeks.



Full weight-bearing	No. of cases	Percentage
<9 weeks	14	46.67%
9-12 weeks	16	53.33%

**Table 11:** Full Weight Bearing

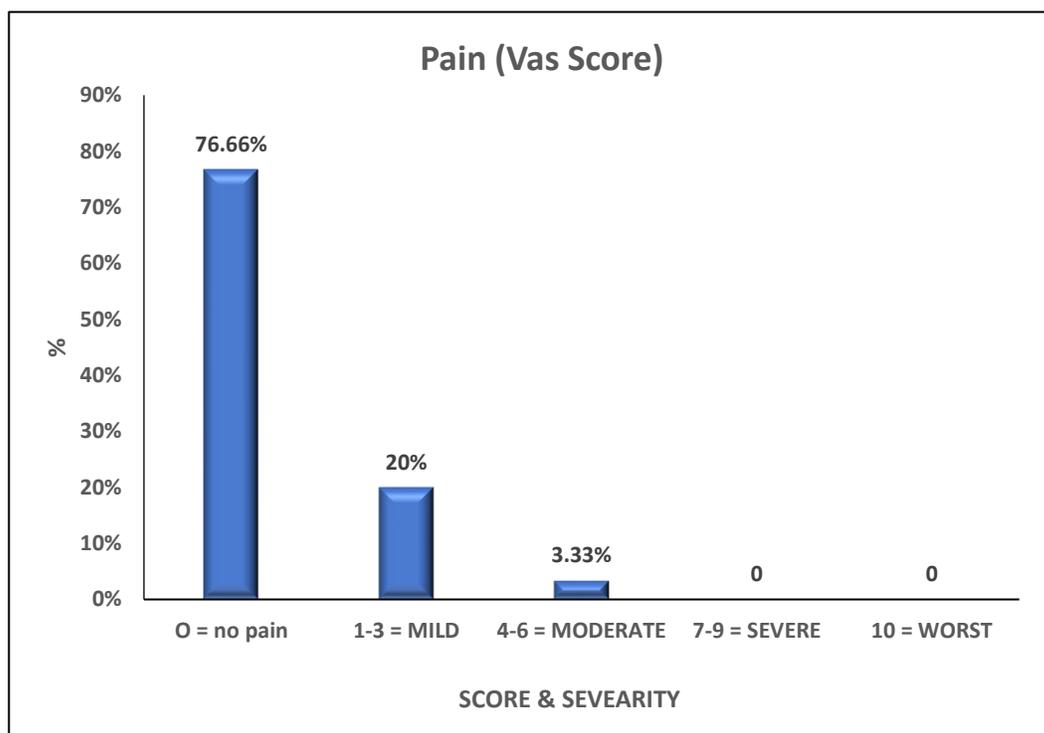
- 14cases (46.67%) with early union have startedthe early full weight-bearing comparison to the other 16 cases (53.33%).



Score & Severity	No. of Cases	Percentage
0=no pain	23	76.66 %
1-3=MILD	6	20 %
4-6=MODERATE	1	3.33%
7-9=SEVERE	0	-
10=WORST	0	-

**Table 12:** Pain (VAS Score)

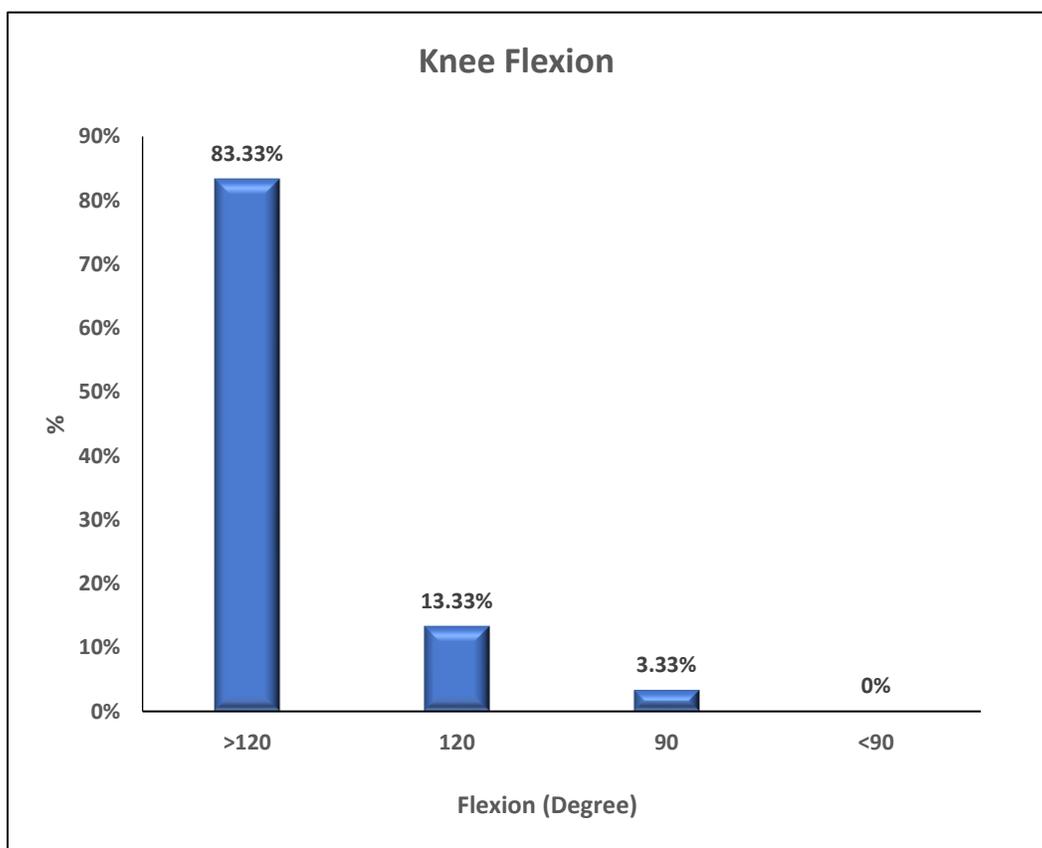
• The pain was evaluated using the VAS score in our study. Out of 30 patients, 23 (76.66%) had no pain, 6 had mild pain (20%) and 01 (3.33%) patients had moderate pain.



Flexion (Degree)	No of cases	Percentage
>120	25	83.33%
90-120	4	13.33%
Up to 90	1	3.33%

**Table 13:** Knee Flexion (Degree)

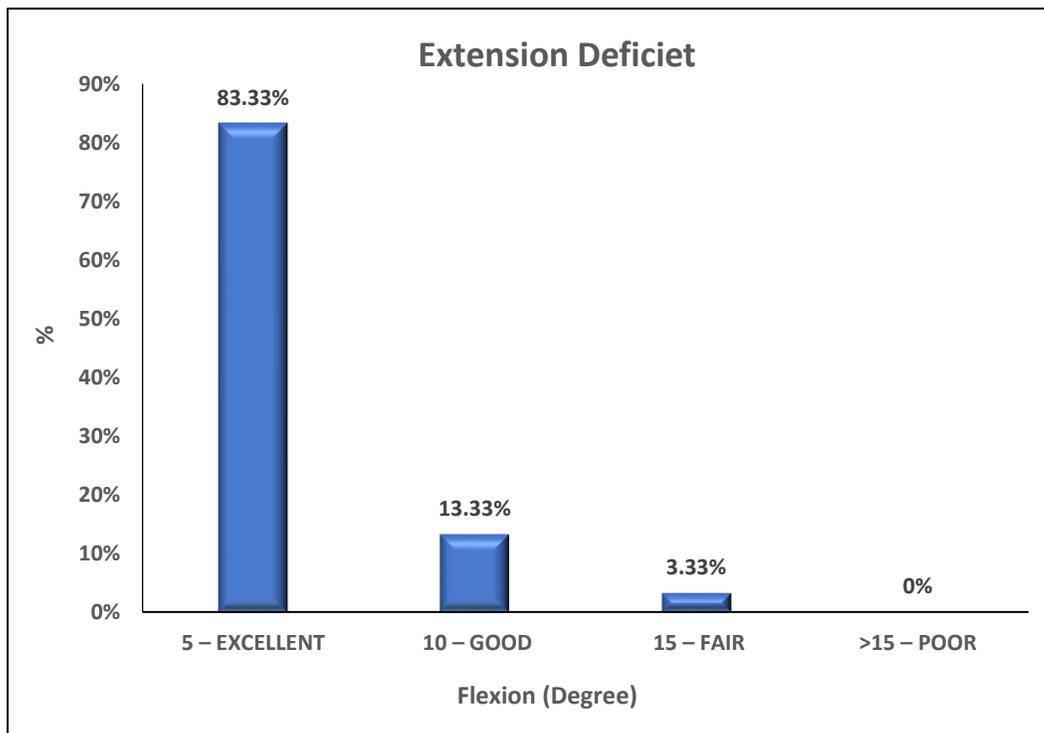
• In our study majority of the 25 patients (83.33%) had a knee flexion degree of more than 120 at discharged. Four (13.33%) had flexion 90-120 degrees and only one (3.33%) had flexion up to 90 degrees postoperatively.



Flexion (Degree)	No. of cases	Percentage
5° – EXCELLENT	25	83.33%
10° – GOOD	4	13.33%
15° – FAIR	1	3.33%
>15° – POOR	0	0%

**Table 14:** Extension Deficit (Degree)

- Out of all 30 patients 25 patients had a normal extension and 5 patients had some extension deficit.



Variables	Result			
	Excellent	Good	Fair	Poor
<b>Malalignment</b>				
Varus/valgus	5	5	10	> 10
Procurvatum/recurvatum	5	10	15	> 15
Internal rotation	5	10	15	> 15
External rotation	10	15	20	> 20

VARIABLES	RESULTS			
	EXCELLENT	GOOD	FAIR	POOR
MALALIGNMENT				
VARUS/VALGUS	24	-	-	-
PROCUVATUM/ RECUVATUM	30	-	-	-
INTERNAL ROTATION	30	-	-	-
EXTERNAL ROTATION	30	-	-	-
LIMB LENGTH DISCRIPANCY	30	-	-	-

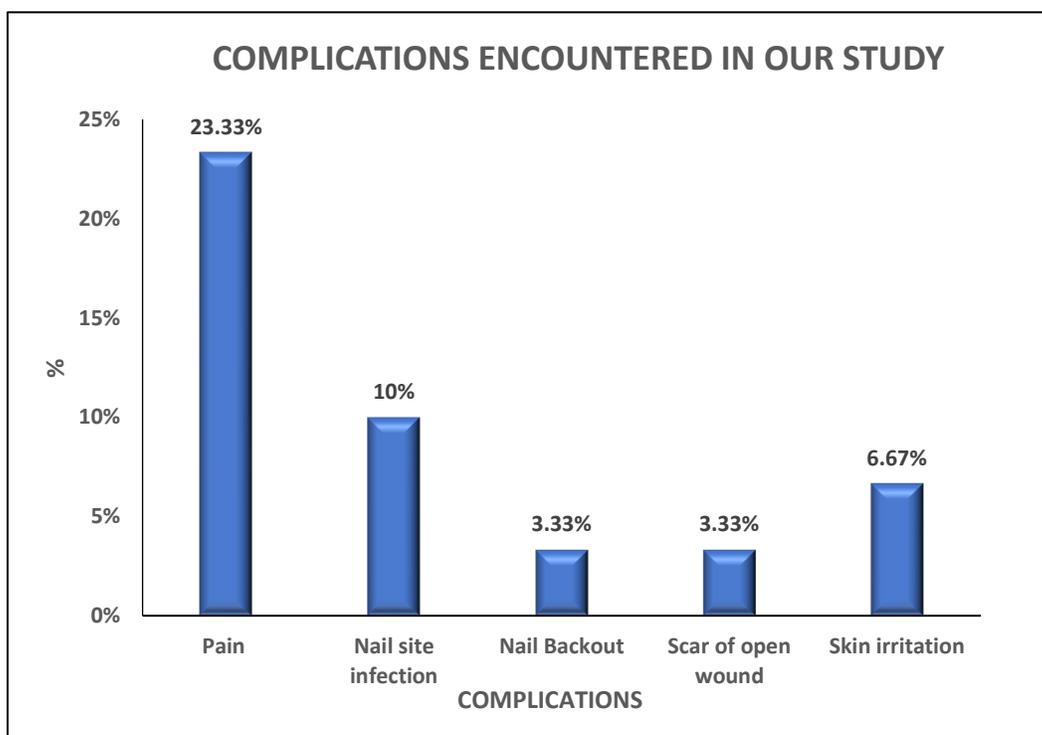
**Table 15: MALALIGNMENT**

- None of the above deformity was encountered during our study.

Complications	No. of Cases	Percentage
Pain	7	23.33%
Nail site infection	3	10%
Nail Backout	1	3.33%
Scar of an open wound	1	3.33%
Skin irritation	2	6.67%

**Table 16:** Complications Encountered In Our Study

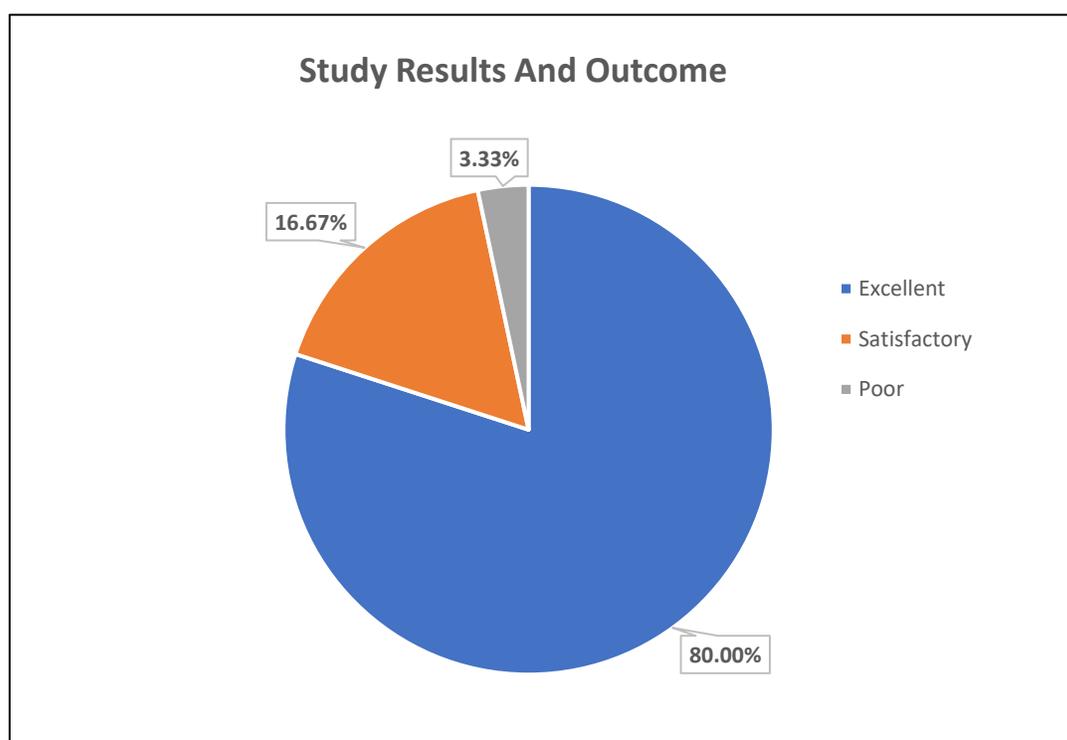
- In the follow up, pain was the most common complaint in the majority of patients (7 -23.33 percent), which was managed with analgesics. In most cases, the pain subsided after one week. Nail site infection occurred in three cases, all of which were treated with antibiotics and the infections were resolved.



Outcome	No. of Patients	Percentage
Excellent	24	80%
Satisfactory	5	16.67%
Poor	1	3.33%

**Table 17:** Study Results And Outcome

• As the above results suggest, 24 cases (80%) had an excellent outcome, 5 (16.67%) cases had a satisfactory outcome and 1 (3.33%) case had a poor outcome according to Flynn’s classification and Thorson scoring system.



## Discussion

Paediatric femoral shaft fracture is the most common injury for hospitalization during the paediatric age group. The femoral shaft fractures in this age group vary according to age and there are controversies between conservative and surgical treatments. While in adults femoral fractures are mostly treated with surgery.

Conservative method had been the treatment of choice for femur shaft fractures, but the union was at the expense of an extended period of immobilization, loss of school attendance, intolerance and prolonged hospital stay. To overcome these issues, now surgical approach is gaining popularity.

There are many options for surgical management like rush nails, enders nail, external fixator, open reduction and internal fixation with plating, flexible/reamed intramedullary nails(12).

But many studies and literature suggest that surgical treatment of paediatric femur fracture using titanium elastic nailing system is the safe and best method for the age group between 5-18 years.

The flexible intramedullary nail (FIN), also known as the elastic stable intramedullary nails (ESIN), is an excellent therapeutic option for paediatric femoral shaft fractures. Due to its healthy environment for fracture healing without physical damage, micro-motion leading to increased callus formation, minimally invasive and reduced hospital stay and early return to school has been gaining popularity for the last two to three decades in comparison to the conservative management. Patient and parent satisfaction is good and implant removal is easy.

For open and severely comminuted fracture fixation using the external fixation is indicated as having good stability and early mobilization. But it has a risk of infection and re-fractures through the pin tract. (Aronson and Turksy, 1992 &Krettek et al., 1991).(14)

Internal fixation with an interlocking nail produces good outcomes, but it destroys the physis and blood supply of the femoral head, resulting in avascular necrosis, coxa valga and growth disturbances (Beaty et al., 1994 Letts et al., 2002)(15) So, it is indicated after the skeletal maturity avoiding the entry at the point of piriformis fossa.

Plating can be utilised in paediatric patients with open physis, length unstable fractures, and pathological fractures to maintain length and aid in bone repair. Implant failure, larger soft tissue dissection, a large scar, increased risk of infection, delayed weight-bearing and a second major operation for implant removal (Kovar; 2015) and refracture after implant removal are the significant complications.(16)

Having poor rotational stability and require multiple nails to achieve a good fixation with Rush nail. Furthermore, Ender's nail is tough to use because it is rigid and difficult to manipulate when the medullary canal is narrow. Whereas the Titanium Elastic Nailing has good elasticity compared to Ender's

nail. Ligier et al.(1988)(13) & Heinrich et al.,1998(17) show that Titanium Elastic Nailing has a good surgical outcome compared to Ender's nail.

Titanium elastic nailing system (TENS) is a titanium made flexible nail that is a load shearing implant, acts as a brace and maintains length and alignment. Due to its elasticity, it provides micromotion at the fracture site, which helps in the rapid development of bridging callus, early mobilization and early weight-bearing. Because the surgery is closed, there is no disruption of the fracture hematoma or periosteum, reducing the risk of infection and nonunion. It also combines the advantages of titanium such as lightweight, more strength, corrosion resistance and MRI compatibility.

Ligier et al had highlighted the beneficial use of titanium elastic nails in the paediatric femur fractures successfully between 5-16 years for the first time. (Ligier et al 1988).(13)In our study 12cases were between 9-12 years followed by the same no. of cases 7 in the age group of 5-8 & 13-15 years. The mean age was 11.57 years.

Surendar et al. made similar observations to ours, with 40 percent of the patients in their study being in the age group of 8-10 years and 8 patients being in the age group of 5-7 years (40 percent). The younger patient was 5 years and the oldest was 11 years. The mean age was 9.56 years.(18)

Many studies show that paediatric femur fracture is most common in boys compared to girls. In our study 19 patients (63.33%) were male and 11 (33.33%) patients were female.Surendar et al. had observed male preponderance over females in their study with a ratio of 1.5:1.(18) The most common site of fracture in the paediatric age group is the shaft femur, which is caused by direct impact and axial loading. According to our observations, the most frequent pattern of fracture is transverse and it is a 32-D 4.1 according to AO classification.

TENS has been shown to be effective in treating oblique and spiral fractures by Ligier et al.(13) In our study, TENS was used to treat six oblique and eight spiral fracture cases, with outstanding functional results.

In our interpretations right side (41.18%) fractures were found more common than the left side (35.29%). 23.53% had bilateral fractures. Surendar et al. observed in their study that the right side (55%) is more commonly involved than the left side (45%) which was quite similar to our results.(18)

In our observations, most common mode of trauma was RTA in 18 cases (60%), 8 cases (26.67%) patients sustained a fracture due to fall while playing and 4 (13.33%) patients fracture was due to fall from height.

The most common mode of injury was road traffic accidents in patients more than 10 years, while falling while playing in children younger than 10 years. Manikandan et al.(19) in their study reported RTA as a major cause of fracture in 55% of patients in their study, followed by fall while playing in 35% and fall

from height in 10% cases. Surendar et al. supported the same with almost 90% of cases with RTA in their study(18).

In the present study 22 patients (73.33%) had sustained a closed fracture and 8 patients (26.67%) were open fracture. Surendar et al. reported 100% as a closed fracture in their study(18) whereas Manikandan et al. reported 90% of cases with closed fracture and 10% as an open fracture in their study(19).

The transverse pattern of fracture was seen in almost 70% of cases followed by 20% as oblique and 10% as a spiral in the study by Manikandan et al.(19) Similar was the observations of Surendar et al.(18) who reported 85% of cases with transverse pattern and 10% with oblique followed by 5% with spiral fracture. In our study, transverse fracture was the most prevalent pattern found in 19 (55.88 percent) cases, oblique fracture was detected in 7 (20.59 percent) instances, and spiral fracture was seen in 8 (23.52 percent) patients.

Fracture According to AO/OTA classification. In our study, the most common accounted fracture was 32-D 4.1 according to AO classification 11 cases (32.35%).

After trauma to surgery interval was 0-9 days (Mean 3.54 days) and the duration of surgery varied according to fracture pattern, open or closed, and according to limb involvement from varies from 20-60 minutes (Mean 35.3 minutes).

In our study surgery was done in less than 5 days in 26 cases(86.67%) and in 4 cases (13.33%) we waited for more than 5-8 days. Similar findings were observed by Manikandan et al. who reported an average time interval between trauma and surgery as 3.95 days(19).

As per Flynn et al. and Ligier et al., the average hospital stay was 5-10 days.(13) In our study, the length of hospital stay ranged from 1 to 8 days with a mean of (3.4)days.

When compared to patients who were treated conservatively with casting for an average of 29 days as described in other research, the majority of the 27 patients (90%) were discharged within 5 days, with the remaining 3 patients (10%) discharged after 5 days. This suggests that surgical treatment have a clear advantage of decreased hospital stay compared to conservative treatment.

The most frequent consequence of a femur fracture is limb length disparity. Limb shortening was seen in five patients with LLD <1cm in our investigation. The patients' gait was not affected.

Another complication is angular deformity due to malunion. Herdon et al.(20) studied that out of 24 patients 7 treated with spica casting had malunion but none of the patients had malunion who are treated with an elastic intramedullary nail. In our study, 6 patients had varus deformity. Five patients had varus 50 and one patient had 70 malunion but didn't have any functional difficulty.

The pain was evaluated using the VAS score in our study. Out of 30 patients, 23 (76.66%) had no pain whereas 7 (20% + 3.33%) patients had pain with associated complications, which subsided after with associated treatment and time.

In our study fracture union was evaluated using the Anthony et al scale. In our study knee and hip range of movement was started postoperatively. Partial weight-bearing was allowed once the signs of union was seen radiographically. Grade -3 was considered as a radiological union. In 14 cases (46.67%) radiological union was seen within 9 weeks & in 16 cases (53.33%) within 12 weeks after which complete weight-bearing was allowed with a mean of 9.8 weeks.

In our study, those with early union 14cases (46.67%) have an early full weight-bearing comparison to the other 16 cases (53.33%). Manikandan et al. in reported time of union was defined as the period between operation and full weight-bearing without external support(19) and a radiographically healed fracture. The average time of union is about 8.2 weeks. According to Surendar et al., fracture union was accomplished in 15 patients (75 percent) in more than 12 weeks(18). Union was obtained in 4 instances (20%) between 8-12 weeks & one case had 8 weeks after surgery.

Rotational deformity also not occurred in our study. Two cases of open injury and two cases had nail entry site infection which is superficial and treated with antibiotics. No cases of deep infection were encountered. One patient experienced skin discomfort. One patient had a nail come out, which was managed by cutting the outer portion of the nail to less than 2.5 cm and suturing it. In their study, Luhmann et al. recommended that the nail left outside be no more than 2.5 cm long.(21)

Ligier et al. study 13 patients had knee stiffness out of 128 cases.(13) In our study, only five cases had knee stiffness and with extension deficit and decreased flexion. Out of which 4 patients had 1200 flexion with 50 extension deficits which were corrected with physiotherapy and one had100 extension deficits (100 to 900 knee ROM) with a poor prognosis.

In their study, Khazzam et al. out of 135 cases 14 had complications: two delayed unions, three re-fractures, three occurrences of malalignment, five nail tip irritations, and one proximal nail migration.(22)

In studies, they have encouraged walking with crutches once the discomfort has subsided. In contrast, Flynn et al.(23) advocated allowing partial weight-bearing with walker assistance only after the callus is seen radiographically. Full weight-bearing is advised only after clinical and the radiographically complete union has occurred.

When compared to conservative therapy, elastic nails were found to be superior in terms of union, scar development, and overall patient satisfaction in a research by Rashid Al-Abriet al.(24)

Narayanan et al.(25) discovered elastic nails to be an effective treatment method in paediatric group. In our study, fracture union and patient satisfaction were excellent, with very few problems.

In our study 2 patients had skin irritation, one had a nail back out 3 patients had superficial infections and one had a scar of open injury.

In our study using Flynn score 24 cases (80%) have an excellent outcome, 5 (16.67%) cases have satisfactory and 1 (3.33%) cases have a poor prognosis due to related complications.24 patients had excellent Flynn score accounting for malalignment, pain, complication. All the cases were also evaluated with Thorson scoring system accounting for malalignment, flexion, extension deficit and pain shown 24 cases had an excellent outcome.

In their investigation, Manikandan et al.(19) found no incidences of delayed union or non-union. There were no incidences of malunion with varus or valgus angulation. Using the Flynn et al score, the findings were judged to be outstanding. 8 were outstanding, 10 were good, and 2 were poor.

## **Conclusion**

Based on our expertise and findings, the "TITANIUM ELASTIC NAILING SYSTEM" is a simple, cheap, quick, and successful technique of treating paediatric shaft femur fractures in children aged 5 to 18 years.

It is an appropriate choice of therapy for paediatric shaft femur fractures due to its shorter surgical time, less blood loss, shorter hospital stay, early fracture healing, early mobilisation, and avoidance of physical harm. It also has a low complication rate when compared to other therapeutic techniques.

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