"A PROSPECTIVE STUDY OF FUNCTIONAL AND RADIOLOGICAL OUTCOMES OF SURGICAL MANAGEMENT OF DIAPHYSEAL FRACTURES OF FEMUR AND TIBIA WITH TITANIUM ELASTIC NAILS IN CHILDREN."

By

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SDUAHER

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MASTER OF SURGERY
IN
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Under the Guidance of

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"A PROSPECTIVE STUDY OF FUNCTIONAL AND RADIOLOGICAL OUTCOMES OF SURGICAL MANAGEMENT OF DIAPHYSEAL FRACTURES OF FEMUR AND TIBIA WITH TITANIUM ELASTIC NAILS IN CHILDREN."** is a bonafide and genuine research work carried out by me under the guidance of **Dr. SIDDARAM. N. PATIL**, Professor, Department of Orthopaedics, Sri Devaraj Urs Medical College, Kolar, in partial fulfilment of University regulation for the award "**M.S.DEGREE IN ORTHOPAEDICS**", the examination to be held in May 2018 by SDUAHER. This has not been submitted by me previously for the award of any degree or diploma from the university or any other university.

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Dr. VAIBHAV MITTAL

LIST OF ABBREVIATIONS

TENS	Titanium Elastic Nail System
ESIN	Elastic Stable Intramedullary Nail.
ECMES	Embrochage Centro Medullaire Elastique Stable
FIN	Flexible Intramedullary Nailing
FAA	Femoral Anteversion Angle
POP	Plaster of paris
RTA	Road traffic accident
CRIF	Closed reduction and internal fixation

ABSTRACT

Background

Treatment of long bones fractures in children continues to improve as newer techniques evolve. Though most of the fractures can be effectively managed conservatively, unstable and displaced fractures need fixation to provide good results.

An ideal fixation device for paediatric femur and tibia fracture would be a load sharing internal splint maintaining reduction for a few weeks until callus forms.

Titanium implants are increasingly being used for elastic stable intramedullary nailing. Titanium elasticity limits the amount that the nail is permanently deformed during insertion and promotes callus formation by limiting stress shielding. Titanium also has excellent biocompatibility.

Present study was undertaken to assess the outcomes of TENS nailing in paediatric femur and tibia diaphyseal fractures.

Aims and objectives:

To document the functional and radiological outcome following surgical management of diaphyseal fractures of femur and tibia in children aged between 5-15 years by using Titanium Elastic Nailing System at Department of Orthopedic, of R L J hospital using Flynn's criteria as excellent/ satisfactory / poor.

Materials and methods

A prospective study on about 30 consecutive patients in the age group 5years to 15 years with diaphyseal fracture of femur and tibia meeting the inclusion and the exclusion criteria, admitted to R L Jalappa Hospital and Research Center, attached to Sri Devaraj Urs Medical College, were taken up for the study after obtaining the informed consent and operated with TENS nailing.

Following surgery patients were regularly assessed by radiological imaging and clinically at 6 weeks, 12 weeks and 24 weeks. The outcomes using Flynn's criteria and complication arising, if any, were noted.

Results

Out of the total 30 cases, 23 (76.6.%) were boys and 7(23.3.%) were girls with a mean age of 9.2 years. Most common mode of injury was self fall/sports injury, accounting for 43.3.% of cases. The most common pattern of fracture observed was transverse (46.7). Majority of fracture were on right side(70%) and in the middle one-third on the bone(83.3%). Average time interval between trauma and surgery was 29.1 hours, average operative time was 49.83 minutes, average time taken till full weight bearing ambulation and union was 10 weeks. Minor complications were observed in 13 (43.33%) cases, none of the cases had major complications. Most commonly nail entry site pain/irritation was seen in 10 (33.33%) cases.

The final outcome was evaluated as per Flynn's criteria, 23 (76.66%) cases had an excellent outcome, 7(23.33 %) had satisfactory and none of the patient had a poor outcome.

Conclusion

At the end of our study it was concluded that TITANIUM ELASTIC NAILING for diaphyseal fracture of femur and tibia in age group 5 years to 15 years old children, is a safe, cost effective, physiological procedure with a relatively easy learning curve resulting in very few short term complications with mostly excellent outcomes irrespective of fracture location and pattern provided that the important biomechanical principles of TENS are followed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF CHARTS / GRAPHS

INTRODUCTION

Over the past 40 years, paediatric orthopedists have tried a variety of methods to treat paediatric long bone fractures to avoid prolonged immobilization and complications. Treatment of long bones fractures in children continues to improve as newer techniques evolve. Though most of the fractures can be effectively managed conservatively, unstable and displaced fractures need fixation to provide good results.

Orthopedic surgeons have long maintained that all children who have sustained a diaphyseal long bone fracture recover well with conservative treatment. The remodeling capacity of the paediatric bone can compensate for less than a perfect reduction. But time and experience of many clinicians have also shown that children with diaphyseal long bone fracture do not always recover completely with conservative treatment. Angulations, shortening and malrotation are not always corrected[1] .

There is little disagreement regarding the treatment of younger children (usually less than 5 years of age) and these can be treated with immediate spica casting[2]. These young children tolerate the cast well, are easily managed at home and mild to moderate fracture displacement and angulations correct well by growth and remodeling. The cost of care is low and outcome is generally good.

Older children (usually older than 15 years of age) show good response with standard locked intramedullary nailing techniques. For children that occupy the middle age group between 5-15 years, there are a wide variety of surgical and nonsurgical treatment options available as early spica casting, traction followed by casting, external fixation, plate fixation, reamed intramedullary rods and flexible intramedullary nails with no clear consensus as to the preferred treatment[3] .

A systematic review of the literature provides little evidence to support one method of treatment over another[4]

Over the past two decades the advantages of fixation and rapid mobilization has been increasingly recognised5. Health care cost containment and a desire for early discharge from the hospital have become important factors in treatment of femoral shaft fracture. As a result newer techniques have become popular.

An ideal fixation device for paediatric femur and tibia fracture would be a load sharing internal splint maintaining reduction for a few weeks until callus forms. Most importantly implant should endanger neither the physis nor the blood supply to femoral head[5].

Titanium implants are increasingly being used for elastic stable intramedullary nailing. Titanium elasticity limits the amount that the nail is permanently deformed during insertion. More importantly elasticity promotes callus formation by limiting stress shielding. Titanium also has excellent biocompatibility[5].

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[6].

OBJECTIVES

- To document the functional and radiological outcome following surgical management of diaphyseal fractures of femur and tibia in children aged between 5-15 years by using Titanium Elastic Nailing System at Department of Orthopedic, of R L J Hospital & Research Center using Flynn's criteria as excellent/ satisfactory / poor.

- Subjective and objective study of clinical parameters like pain, comfort to the patient, return of range of movement of hip, knee and ankle joints; early mobilization; operative techniques; radiological evaluation for union, stages of weight bearing at 6, 12 and 24 weeks and any associated complications by using Titanium Elastic Nailing System .

REVIEW OF LITERATURE

Paediatric trauma remains a leading cause of morbidity and mortality of children and entails exorbitant costs. These patients accrue an estimated $932.8 million in hospital charges. Femur fracture is the most frequent injury among this patient group (21.7% of orthopaedic trauma), followed by tibia and/or fibula fracture (21.5%), humerus fracture (17.0%), radius and/or ulna fracture (14.8%), and vertebral fracture (5.2%) [7].

The best line of treatment of paediatric lower limb fractures is based on several factors: age of the patients, fracture type (open or closed), fracture pattern (stable or unstable), patient and family compliance, social, psychological and economic status, and finally the surgeon’s preference[6].

Treating fractures of long bones in children presents special challenges to the orthopedic surgeon such as smaller size of bones, the presence of open diaphysis and immature vascularity of the bone tissue has to be taken care of.

Various methods are used to treat paediatric long bone fractures such as traction, splints/ orthosis, plaster casts, external fixation, and open reduction and internal fixation using plates and screws or intramedullary stabilization with a rod.

During conservative treatment a long stay in hospital for traction and immobilization in an uncomfortable cast is needed which is not well tolerated, especially in adolescents. Moreover, near the end of growth, accurate reduction is necessary, as malunion is no longer correctable by growth[8]. Similar findings were noted in study by Ligier J.N., Métaizeau J.P.,in which they opined that the method of paediatric femur management of traction followed by cast is although safe but has two major drawbacks : first is that prolonged bed rest separates the child from his normal environment; the second is the cost of such periods in hospital and the use of beds which might serve other patients[12].

Currently with development of new fracture implant and system, the management method have created a shift in case of femur and tibia shaft fractures strictly from non surgical care to surgical stabilization[9]. In fractures of lower limb using external fixation has many complications such as pin-tract infection, loss of knee range of motion, delayed union, non-union, and re-fracture after fixator removal. Solid antegrade intramedullary nailing results in severe complications like avascular necrosis of the femoral head, trochanteric epiphysiodesis, and coxa valga[10].

Various intramedullary nails are available for long bone diaphyseal fractures in paediatric population like Ender nail, TENS etc. The principle of Ender nail fixation is canal filling with the nails. Ender nails are stainless steel implants that were used for adult fractures initially but proved to be inadequate for adult femoral and tibial fractures but may be effective for paediatric fractures although they may not be elastic enough as their modulus of elasticity is higher than titanium nails.

TENs are more elastic, thus limiting the amount of permanent deformation during nail insertion; they promote healing by limiting stress shielding. TENS work by balancing the forces between the two opposing flexible implants. To achieve this balance, the nail diameter should be 40% of the narrowest canal diameter; the nails should assume a double-C construct, both nails should have entry pints at same level and have an identical smooth curved path[6].

In recent times there has been a rising trend in the use of intramedullary fixation in the paediatric population by the orthopedic surgeons. This interventionist attitude among the paediatric orthopedic surgeons could be attributed to many factors including impositions by the modern world as well as the major technical developments in field of implants including elastic stable intramedullary nail (ESIN).

History of intramedullary implants goes back to mid-19th century when ivory pins were used for this purpose and were then gradually replaced by various metal devices.

Kuntscher designed and used a v-shaped nail for intramedullary fixation in 1940. Hey Groves was the first to attempt intramedullary fixation by rods in 1960. The school of rigid intramedullary fixation was typified by the Kuntscher nail, which achieved great stability in all planes by occupying the entire medullary cross sectional area of the bone. Kuntscher developed the concept, but the extensive work had been previously worked upon nailing techniques.

In1979, Professor Jean Prévot and his young team of surgeons –Dr Métaizeau, Dr Ligier and Dr Lascombes of the Centre Hospitalier Universitaire of Nancy,France[11], developed and introduced a technique for the treatment of long bone fractures in children using flexible IM nailing.

In 1980s, elastic stable intramedullary nailing (ESIN) indications expanded significantly. It was first used in diaphyseal fractures[12,13]. Later then, metaphyseal fractures were also stabilized using different methods: Hackethal, Ender or also even Foucher for the 5th metacarpal[14].

In a study by Metaizeau in 1988, the Nancy group described the physiologic and biomechanical background for using the “embrochage centro medullaire elastique stable” (ECMES) system[15], the elastic stable centromedullary nailing system with its three point pressure stabilization of the fractured bone. Previously it was believed that elasticity and stability were not easily combined in one construct. However, working on the concept of three-point fixation, these surgeons were able to improve stability significantly by using two pre-tensioned nails inserted from opposite sides of the bone. Metaizeau and his colleagues in another study in 1983 were able to show that titanium nails, which were accurately contoured and properly inserted, could impart excellent axial and lateral stability to diaphyseal fractures in long bones[16]. Rotational stability which although was a major short coming of the technique, also showed better results.

Notable work in the evolution of design, biomechanics and techniques for using ESIN was done by Métaizeau J.P., Prévot J. and Lascombes P in 1990s. ESIN was given many names such as “FIN” (Flexible Intramedullary Nailing), Metaizeau technique, Nancy technique.

One of the pioneer study was done by Ligier J.N., Métaizeau J.P., Prévot J. and Lascombes P, between September 1979 and June 1985 including 118 children with 123 femoral shaft fractures who were admitted to the Nancy Children’s Hospital and treated with ESIN12. The ages of the children ranged from 5 to 16 years (mean 10 years ± 2 months) out of which 80 were boys and 38 girls who had sustained 64 right-sided and 59 left-sided fractures (five had bilateral injuries). Of the 63 transverse fractures, 16 presented with comminution of one cortex. Twenty-eight fractures were spiral, nine of which had a large butterfly fragment. There were 22 oblique fractures, six had comminution of both cortices, and four were double fractures.

The results of this study brought immense popularity to ESIN as there were no surgical failures and because the operation was rapid and uses only small incisions, blood loss was minimal. Although some complications were encountered such as discomfort at the knee due to the distal ends of the nails, skin ulceration or local inflammatory reaction due to nail protrusion but none of the patients complained of disability and gait abnormalities after a follow up period of over one year with an average period of one year and 10 months. Radiographically, and a mean lengthening of 1 .2 mm was noted, the residual angulation never exceeded 10 degrees.

The authors concluded with this study that because of early weight-bearing, rapid healing and minimal disturbance of bone growth, ESIN may be considered to be a physiological method of treatment. It was also found that the technique could be adapted to all cases and it gives better control of axial length and rotation, and can be adapted to treat other diaphyseal long-bone fractures in the child.

J.M.Flynn et al studied the use of TENS for treatment of paediatric femur shaft fractures between 1996 and 2003 in 6 institutions in the United States and France. Titanium elastic nailing was used instead of traction and casting in many European centers, but limited availability had prevented widespread use in North America. Full information was available concerning 230 fractures, of which the outcome was excellent in 150 (65%), satisfactory in 57 (25%), and poor in 23 (10%). Poor outcomes were due to leg-length discrepancy in five fractures, unacceptable angulation in 17, and failure of fixation in one. Minor or major complications occurred in 80 fractures. There was a statistically significant relationship ($p = 0.003$) between age and outcome, and the odds ratio for poor outcome was 3.86 for children aged 11 years and older compared with those below this age[5,17].

After this multicenter study and critical analysis of early results and complications of the initial experience the author opined that titanium elastic nailing should be the first preferred treatment for diaphyseal fractures of femur in children between 3 and 18 years, as the study had confirmed that the outcome after treatment were excellent or satisfactory in most patients.

In a study by Hassan Al-Sayed[18] in the period from January 2000 to September 2004, 25 children with 25 femoral shaft fractures were treated by retrograde titanium elastic nail fixation. . Two nails of the same diameter were used for the fixation of each femoral shaft fracture using a fracture table and under image intensifier control. Postoperatively, early graduated weight bearing was allowed and the children were followed up clinically and radiographically. The nails were removed after fracture consolidation.

After the results of the study the author illustrated the advantages of titanium elastic nail fixation and the complications of other methods of operative stabilization and opined that the titanium elastic nails are a good choice for operative fixation of most femoral shaft fractures in children 6 years and older whose skeleton is not fully developed.

In a study in 2005, Erik N. Kubiak, Kenneth A. Egol, David Scher, Bradley Wasserman et al retrospectively studied thirty-one skeletally immature patients operated for tibia fractures between April 1997 and June 2004. Out of the total, sixteen had been managed with elastic stable intramedullary nails and fifteen had been managed with unilateral external fixation. The clinical, radiographic outcomes and complications related to treatment, such as malunion, delayed union, nonunion, infection, and the need for subsequent surgical treatment were compared.

It was found that the mean time to union for the intra -medullary nailing group (seven weeks) was significantly shorter than that for the external fixation group (eighteen weeks) ($p<0.01$) and the functional outcomes measured using Paediatric Outcomes Data Collection Instrument were significantly better for the intramedullary nailing group than those for the external fixation group in the categories of pain, happiness, sports, and global ($p < 0.01$).

The study was concluded as when surgical stabilization of tibial fractures in children is indicated, the preferred method of fixation is with elastic stable intramedullary nailing[19].

V. R. P. Vallamshetla et al retrospectively reviewed the records and radiographs of 56 unstable fractures of the tibia in 54 children treated between March 1997 and May 2005. All cases were followed up for at least two months after the removal of the nails. Of the 54 children, the mechanism of injury in 35 (65%) was high energy trauma and low energy trauma in 19 (35%). There were 13 (23%) open fractures, which were classified according to Gustilo and Anderson, Eight (62%) were grade I, two (15%) were grade II and three (23%) were grade III. The mean time to clinical and radiological union was ten weeks. Complications included residual angulation of the tibia, leg-length discrepancy, deep infection and failures of fixation. There were no nonunions. The nails were removed between six and nine months after insertion as a day-case procedure. All achieved an excellent functional outcome.

V. R. P. Vallamshetla et al conclude that, where indicated, flexible intramedullary nailing is a relatively simple and effective way to stabilize open and closed fractures of the tibia in children with few complications, allowing early mobilisation and an excellent functional outcome[20].

Wudbhav N. Sankar, Kristofer J. Jones, B. David Horn, Lawrence Wells reviewed all children with tibial shaft fractures treated with TENS between 1998 and 2005 and identified 19 consecutive patients who satisfied inclusion criteria. The average age of the patients in the series was 12.2 years (range 7.2– 16 years), and mean follow-up was 15.7 months (range 6–28 months). Outcomes were classified as excellent, satisfactory, or poor according to the Flynn classification for flexible nail fixation. All patients achieved complete healing at a mean of 11.0 weeks (range 6–18 weeks). Five patients (26%) complained of irritation at the nail entry site; there were no leg length discrepancies or physeal arrests as a result of treatment.

With this study the authors opined that although the indications for operative fixation of paediatric tibial shaft fractures are rare, occasionally surgical treatment is warranted and for that TENS is an effective surgical technique which allows rapid healing of tibial shaft fractures with an acceptable rate of complications[21].

K.C.Saikia et al studied 22 children in age group 6-16 years femoral diaphysial fractures operated with TENS. These fractures were in proximal third (n=3), middle third (n=15) and in the distal third (n=4). Majority of the patients underwent surgery within seven days of their injury. Radiological union in all cases was achieved in a mean time of 8.7 weeks. Full weight bearing was possible in a mean time of 8.8 weeks. The outcomes using

Flynn's scoring criteria were excellent in 13 patients(59%), satisfactory in 6(27.2%)and poor in 3 patients (13.6%).

The team concluded that intramedullary fixation with titanium elastic nailing is an effective treatment of diaphyseal fractures of femur in properly selected patients of 6-16years age group[22].

In a study published in 2009, Gamal el-adl, et al.[6] had evaluated the results of treatment of 66 paediatric fracture patients with 48 femoral and 25 tibial diaphyseal fractures treated with TENS. Based on Flynn et al's outcome rating system, 75.8% of the results were excellent, 24.2% were satisfactory and there were no poor results. Following which they concluded that titanium elastic nail fixation is a simple, easy, rapid, reliable and effective method for management of paediatric femoral and tibial fractures between the age of 5 to 16 years, with shorter operative time, lesser blood less, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing.

Mark G. Swindells and R. A. Rajan carried out a systematic review of the literature published between 2004 and 2008 on the use of elastic intramedullary nailing in unstable fractures of the paediatric tibial diaphysis. Seven applicable retrospective case series were identified[19,20,24,25,26,27,28], with the outcomes from a total of 210 (range 16–60) patients were considered. The results from these studies were then analysed and critically appraised using a Critical Appraisal Skills Programme (CASP). The seven studies vary in size from 16 to 60 patients. The mean time to union ranged from 7 to 21 weeks. Reported complications included small numbers each of delayed union, non-union, malunion, leg length discrepancy and infection. Reported complication rates were similar in all of the studies. It was not possible to perform a formal meta-analysis of this topic from these papers because of the variation in practice and reporting.

They concluded that although there is only a small body of evidence currently published on this topic, but the published literature shows that unstable or open fractures, polytrauma and fractures with neurovascular compromise may each necessitate a surgical procedure and Elastic stable intramedullary nailing (ESIN) provides an acceptable option in such cases[23].

D. Furlan et al did study of paediatric long bone fractures treated with elastic stable intramedullary nailing including 41 patient (30 male, 11 female) of diaphyseal femoral fractures in age range 4–16 years (mean 10.9 years) and 36 patients (22 male, 14 female) of diaphyseal tibial fracture of age range 5–17 years (mean 12.5 years). The most common mechanism of injury was road traffic accidents and motorbike driving. Only one patient presented with open femur fracture and five patients presented with open tibia fracture. All patients with femur fracture achieved complete radiographic healing at a mean of 8.9 weeks (range 5–15 weeks) and patients of tibia fracture in 7.6 weeks (range 5–12 weeks). Minor complications such as entry site infection and irritation were noted. Most of patients reported their outcome as highly satisfied and satisfied. No patients reported their outcome as not satisfied. The implants were removed at a median time of six months from the index operation.

It was concluded that ESIN shows very good functional and cosmetic results. It allows an early functional and cast-free follow-up with a quick pain reduction. The ESIN for shaft fractures is a minimally invasive, simple and well reproducible technique with a steep learning curve. Because of the excellent objective and subjective results, the operative stabilization of long bones fractures with ESIN should be recommended to the paediatrics patients[29].

In a retrospective study Ahmed L.Z. reviewed the records and radiographs of 56 unstable fractures of the tibia in 54 children treated between March 2006 and May 2010.

After a complete followed up for at least 2 months after removal of the nails he found that there were no cases of non-union. The mean time to clinical and radiological union was 10 weeks and complications included residual angulation of the tibia, leg-length discrepancy, deep infection and failures of fixation. Overall functional outcome for all the patients was excellent.He concluded that flexible intramedullary fixation as an easy, safe and effective method of management of both open and closed unstable fractures of the tibia in children[30].

Sreenivasulu P.S.B. et al in study from Oct 2012 to Apr 2014 treated 18 patients between 6-12 years of various long bone fractures by Titanium Elastic nail fixation. All of the patients were operated within 5 days of injury. Average operating time was 50 minutes, average blood loss was 55ml and average hospitalization time was 5 days. Most of the patients were able to do partial weight bearing with crutches by the end of 2 weeks. 77.77 % of the patients were able to do full weight bearing by the end of 9weeks and all of the patients were able to do full weight bearing by 12weeks post-operatively. complications included 1 case of proximal migration of the nail, shortening of less than 2cms in one patient and knee stiffness was observed in 4 cases. They recorded zero mortality rates and no cases of infection either superficial or deep were noted. All the fractures united within 4 months of operation and average time taken for union was 10 weeks.

Author noted that the intramedullary position of the implant places it more in line with the weight bearing forces thereby reducing the tendency of the fracture to settle in a deformed position. The excellent biomechanics was reflected by the absence of implant failure. Early ambulation was one of the advantages of the Titanium Elastic Nailing which minimizes the duration of hospital stay and bed rest and related complications like pneumonias, bed sores, thrombo-embolic phenomenon[31].

A study by Salem K and his team with Seventy-three children (48 boys and 25 girls; mean age, 5.7 years) with unilateral femoral or tibial shaft fractures, which were treated using elastic intramedullary nails also concluded that paediatric lower limb fractures can be satisfactorily treated using elastic nails. Proper surgical technique and intraoperative control of limb alignment can help avoid postoperative deformities[32].

Michael J. Heffernan et al did a multicenter retrospective review of 215 patients in age group two to six years, 141 treated with immediate spica casting, and 74 treated with elastic nails. Time to fracture union was similar between the 2 groups (P= 0.652). The TEN group had shorter time to independent ambulation (Spica 51± 14 vs. TEN 29± 14 d, P < 0.001) and return to full activities (Spica 87± 19 vs. TEN 74 ± 28 d, P = 0.023). With this study the author concluded that TEN is a reasonable option for treatment of femur fractures in young children when compared with spica casting with shorter time to independent ambulation and full activities. Fractures associated with a high-energy mechanism are especially appropriate for consideration of treatment with TEN[33].

Jan Bauer, Corinna Hirzinger and Roman Metzger did a pioneer study from 2009 to 2015, of treating distal tibia paediatric fractures with Quadruple ESIN (Elastic Stable Intramedullary Nailing). Generally Nailing of the tibia shaft with 2 nails is the gold standard for tibia shaft fractures in children. In this technical report the author showed a simple way to stabilize paediatric distal tibial fractures without changing of the operation method. The modified ESIN technique hardly differs from the classic method, other than the addition of 2 other nails inserted using the same entry point. A retrospective assessment of eight children treated with the modified ESIN was done. The mean operation duration was 57 minutes (range, 33 to 88 min). In all cases 2 to 4 mm titanium nails were used. None of the patients required a postoperative cast. Within an average of 14.5 days all of the patients could fully bear their weight (2 to 30 d) and full range of motion was reached.

With this study Jan bauer et al concluded that the modified ESIN technique achieves good results regarding stability and early weight-bearing. Therefore, this technique could be applied in unstable distal tibial fractures[34].

Similar studies by Kaiser et al have been done using three nails instead of two, initially different configurations of ESIN with titanium nails were tested on eight composite femoral grafts (Sawbones®) with an identical spiral fracture. Studies showed that 3CL (third nail from lateral) configuration provided a significantly higher stiffness than 2C and 3CM (third nail from medial) configurations in the biomechanical model. These results were successfully transmitted into clinical practice where 11 boys and 6 girls (2.5-15 years) were treated with modified ESIN of whom 12 were '3CL'; 4 patients were treated with '3CM'. No additional stabilizations or re-operations were necessary. All patients achieved full points in the Harris-Score at follow-up; no limb length discrepancy occurred. As a conclusion author stated that new configurations of ESIN gives better stability and helps to overcome the complications seen in some cases of ESIN, which already is an established standard treatment for paediatric diaphyseal fractures[35].

ANATOMY OF FEMUR

The femur, also known as the thigh bone is the longest bone in the body with a cylindrical shaft and a forward convexity. It runs an oblique course from the neck of the femur to the distal end, as a consequence which the knee is close to the midline under the body's center of gravity.

It has a proximal end characterized by a head and neck with two large projections on the upper part of the shaft (the greater and lesser trochanters).

The head of the femur: its shape is spherical which articulates with the acetabulum of the pelvic bone. Its medial surface has a non-articular pit which is also known as fovea.

The neck of the femur: The head and the shaft of the femur are connected by this cylindrical bone. It runs superomedially from the shaft and projects forward at an angle of approximately 125°. This increases hip joint’s range of movement.

Greater trochanter: It extends superiorly from just lateral to the region where the shaft of femur joins the neck. Posteriorly, its medial surface is deeply grooved which forms the trochanteric fossa.

There are elongated ridges on its anterolateral surface and posteriorly on its lateral surface where the greater trochanter is palpable.

Lesser trochanter: it has a blunt conical shape and is smaller than the greater trochanter. Its projection is posteromedial from the shaft of femur, inferior to the neck junction.

Intertrochanteric line: It is a ridge of bone that descends medially from the anterior surface of the base of the greater trochanter to just anterior to the base of the lesser trochanter. It is in continuity with the pectineal line, also known as the spiral line, which curves medially and merges with the medial margin of the linea aspera on the posterior aspect of the shaft of femur. Intertrochanteric crest: It is situated on the posterior aspect of femur which descends medially from the posterior margin of the greater trochanter to the base of the lesser trochanter. On the upper half, it has a prominent quadrate tubercle.

Shaft of the femur: It descends in the coronal plane from lateral to medial at an angle of 7° from the vertical axis.

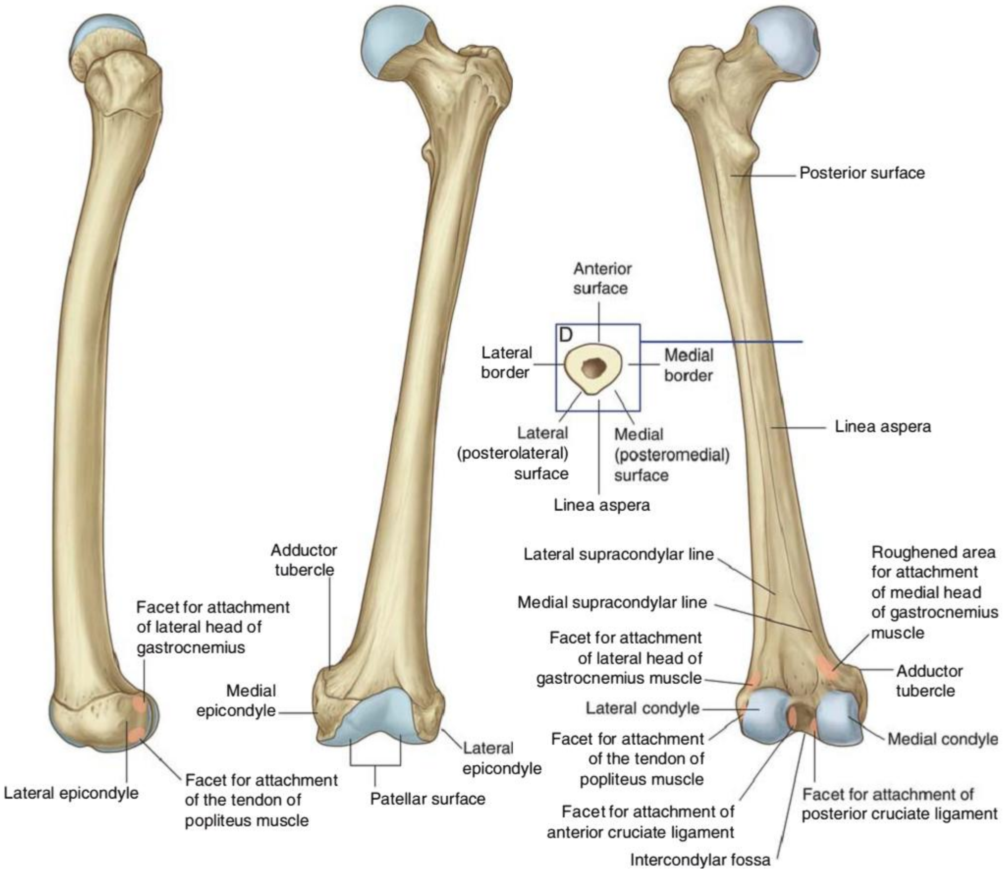


FIGURE 1 :Lateral, anterior, and posterior view of femur (right to left)

The middle third of the shaft is triangular in shape and has smooth lateral and medial margins and has anterior, lateral (posterolateral), and medial (posteromedial) surfaces. It has a broad posterior margin which forms the linea aspera.

Linea aspera is a major site of muscle attachment. The medial and lateral margins of the linea aspera diverge in the proximal third of the femur and continue as the pectineal line and gluteal tuberosity, respectively.

Pectineal line curves anteriorly and joins the intertrochanteric line under the lesser trochanter.

The gluteal tuberosity is a broad linear roughening and curves laterally to the base of the greater trochanter.

This forms a triangular area enclosed by the pectineal line, the gluteal tuberosity, and the intertrochanteric crest, which constitutes the posterior surface of the proximal end of the femur.

At the distal end of the femur, the posterior surface forms the floor of the popliteal fossa and its margins form the medial and lateral supracondylar lines. The medial supracondylar lines terminate at the adductor tubercle on the superior aspect of the medial condyle at the distal end.

The distal end of femur which is characterized by two large condyles, articulate with the proximal head of the tibia. The condyles are joined anteriorly, where they articulate with the patella and are separated posteriorly by an intercondylar fossa.

On each condyle, a shallow oblique groove separates the surface that articulates with the tibia from the surface that articulates with the patella. The surfaces that articulate with the patella together form a V-shaped trench facing anteriorly. The lateral surface of the trench is steeper and larger than the medial surface.

The walls of the intercondylar fossa bears the superior attachment of the cruciate ligaments, which helps to stabilize the knee joint:

- A large oval facet is present on the wall formed by the lateral surface of the medial condyle which covers most of the inferior half of the wall and provides attachment for the proximal end of the posterior cruciate ligament;
- A posterosuperior smaller oval facet is present on the wall formed by the medial

surface of the lateral condyle and provides attachment for the proximal end of the anterior cruciate ligament.

Epicondyles are bony elevations on the nonarticular outer surfaces of the condyles for the attachment of collateral ligaments of the knee joint. There are two facets posterior to the lateral epicondyle, which are separated by a groove.

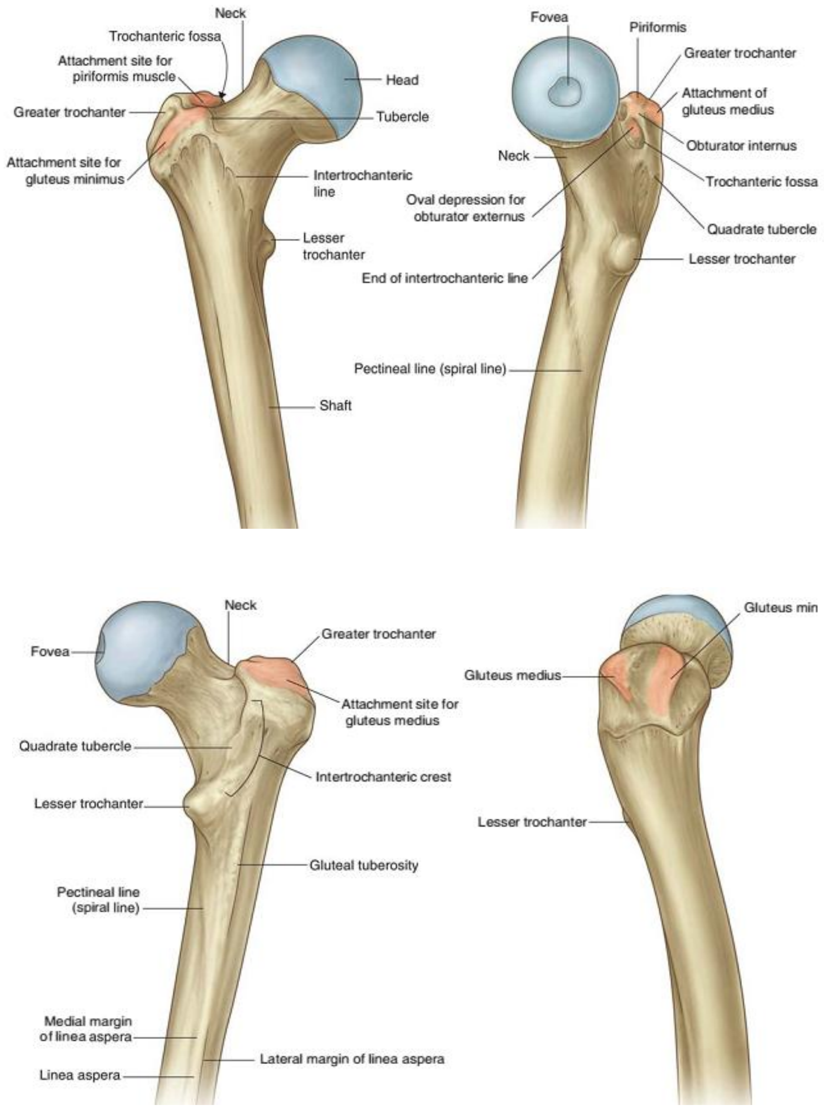


FIGURE 2: ANATOMICAL LANDMARKS OF UPPER END OF FEMUR (anterior view : top left, medial view: top right, posterior view : bottom left, lateral view: bottom right)

The upper facet provides attachment to the lateral head of the gastrocnemius muscle and the inferior facet provides attachment to the popliteus muscle. The medial surface of the medial condyle has the medial epicondyle which is a rounded eminence. The adductor tubercle lies posterosuperior to the medial epicondyle.

The shaft is so thickly covered with muscles that it cannot be felt through the skin. Its anterior and lateral surfaces provide attachment for the vastus intermedius in their three fourth. The superapatellar bursa covers the lower portion of the anterior surface. The vastus lateralis covers the lower portion of the lateral surface, and the vastus medialis covers the medial surface.

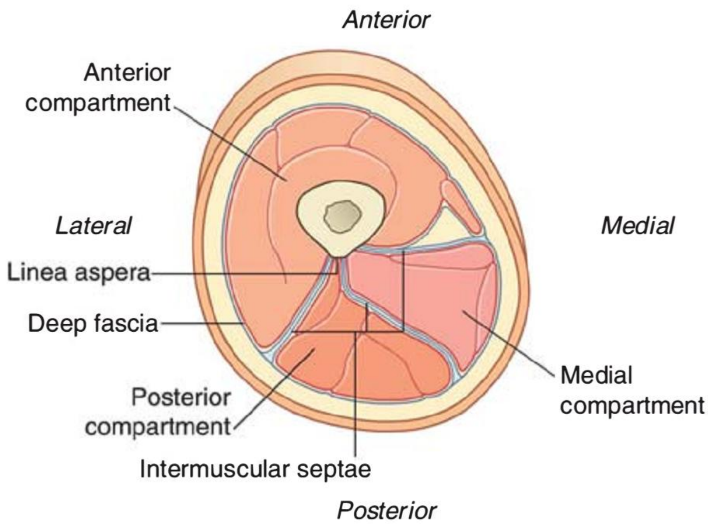


FIGURE 3 :CROSS SECTION OF FEMUR AT MID THIRD

TABLE 1 : MUSCLES OF ANTERIOR COMPARTMENT OF THIGH

Muscle	Origin	Insertion	Innervation	Function
Psoas major	Posterior abdominal wall (lumbar transverse processes, intervertebral discs, and adjacent bodies from TXII to LV and tendinous arches between these points)	Lesser trochanter of femur	Anterior rami (**L1, L2**, L3)	Flexes the thigh at the hip joint
Iliacus	Posterior abdominal wall (iliac fossa)	Lesser trochanter of femur	Femoral nerve (**L2**, L3)	Flexes the thigh at the hip joint
Vastus medialis	Femur—medial part of intertrochanteric line, pectineal line, medial lip of the linea aspera, medial supracondylar line	Quadriceps femoris tendon and medial border of patella	Femoral nerve (L2, **L3, L4**)	Extends the leg at the knee joint
Vastus intermedius	Femur—upper two-thirds of anterior and lateral surfaces	Quadriceps femoris tendon, lateral margin of patella, and lateral condyle of tibia	Femoral nerve (L2, **L3, L4**)	Extends the leg at the knee joint
Vastus lateralis	Femur—lateral part of intertrochanteric line, margin of greater trochanter, lateral margin of gluteal tuberosity, lateral lip of the linea aspera	Quadriceps femoris tendon and lateral margin of patella	Femoral nerve (L2, **L3, L4**)	Extends the leg at the knee joint
Rectus femoris	Straight head originates from the anterior inferior iliac spine; reflected head originates from the ilium just superior to the acetabulum	Quadriceps femoris tendon	Femoral nerve (L2, **L3, L4**)	Flexes the thigh at the hip joint and extends the leg at the knee joint
Sartorius	Anterior superior iliac spine	Medial surface of tibia just inferomedial to tibial tuberosity	Femoral nerve (**L2, L3**)	Flexes the thigh at the hip joint and flexes the leg at the knee joint

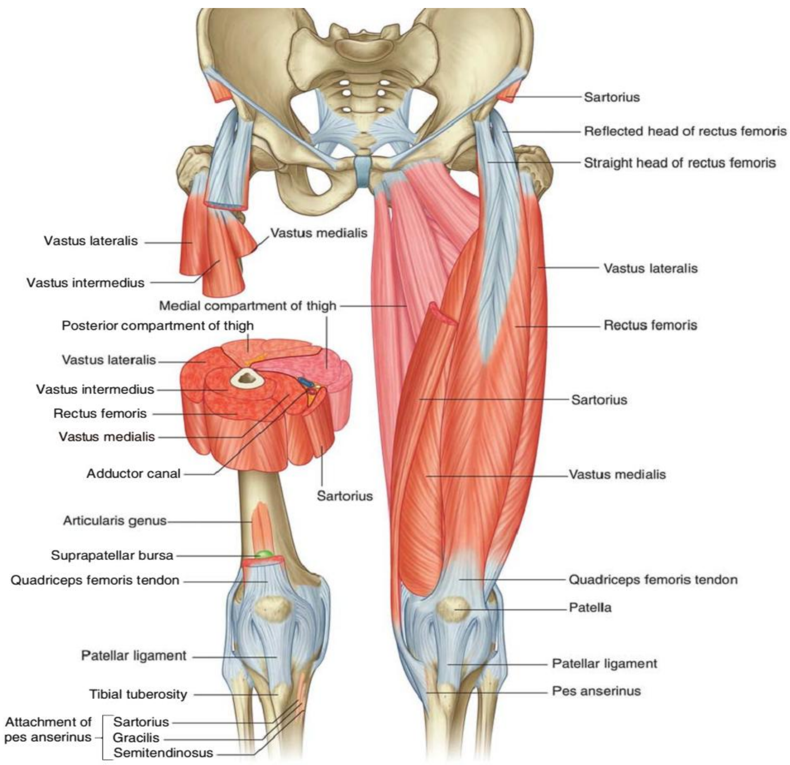


FIGURE 4: MUSCLES OF ANTERIOR COMPARTMENT OF THIGH

TABLE 2: MUSCLES OF MEDIAL COMPARTMENT OF THIGH :

Muscle	Origin	Insertion	Innervation	Function
Gracilis	A line on the external surfaces of the body of the pubis, the inferior pubic ramus, and the ramus of the ischium	Medial surface of proximal shaft of tibia	Obturator nerve (**L2**, L3)	Adducts thigh at hip joint and flexes leg at knee joint
Pectineus	Pectineal line (pecten pubis) and adjacent bone of pelvis	Oblique line extending from base of lesser trochanter to linea aspera on posterior surface of proximal femur	Femoral nerve (**L2**, L3)	Adducts and flexes thigh at hip joint
Adductor longus	External surface of body of pubis (triangular depression inferior to pubic crest and lateral to pubic symphysis)	Linea aspera on middle one-third of shaft of femur	Obturator nerve (anterior division) (**L2, L3,** L4)	Adducts and medially rotates thigh at hip joint
Adductor brevis	External surface of body of pubis and inferior pubic ramus	Posterior surface of proximal femur and upper one-third of linea aspera	Obturator nerve (**L2, L3**)	Adducts and medially rotates thigh at hip joint
Adductor magnus	Adductor part—ischiopubic ramus	Posterior surface of proximal femur, linea aspera, medial supracondylar line	Obturator nerve (**L2, L3,** L4)	Adducts and medially rotates thigh at hip joint
	Hamstring part—ischial tuberosity	Adductor tubercle and supracondylar line	Sciatic nerve (tibial division) (**L2, L3,** L4)	
Obturator externus	External surface of obturator membrane and adjacent bone	Trochanteric fossa	Obturator nerve (posterior division) (L3, **L4**)	Laterally rotates thigh at hip joint

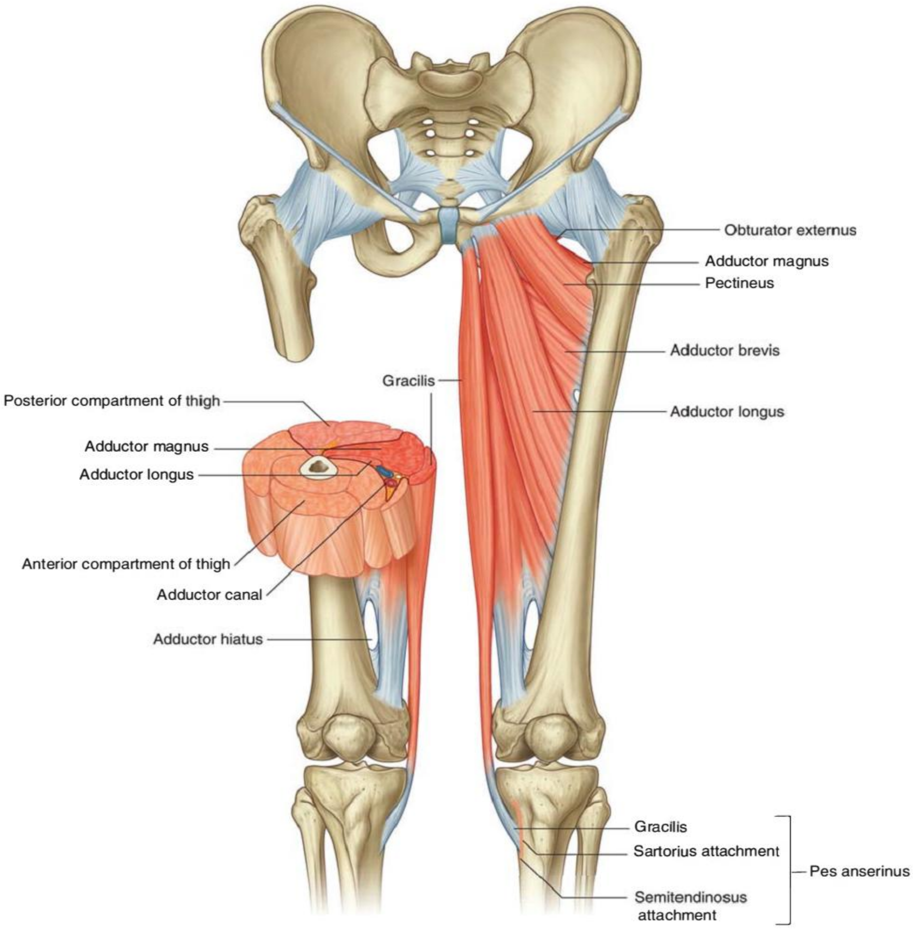


FIGURE 5: MUSCLES OF MEDIAL COMPARTMENT OF THIGH

TABLE 3: MUSCLES OF POSTERIOR COMPARTMENT OF THIGH:

Muscle	Origin	Insertion	Innervation	Function
Biceps femoris	Long head—inferomedial part of the upper area of the ischial tuberosity; short head—lateral lip of linea aspera	Head of fibula	Sciatic nerve (L5, **S1**, S2)	Flexes leg at knee joint; extends and laterally rotates thigh at hip joint and laterally rotates leg at knee joint
Semitendinosus	Inferomedial part of the upper area of the ischial tuberosity	Medial surface of proximal tibia	Sciatic nerve (L5, **S1**, S2)	Flexes leg at knee joint and extends thigh at hip joint; medially rotates thigh at hip joint and leg at knee joint
Semimembranosus	Superolateral impression on the ischial tuberosity	Groove and adjacent bone on medial and posterior surface of medial tibial condyle	Sciatic nerve (L5, **S1**, S2)	Flexes leg at knee joint and extends thigh at hip joint; medially rotates thigh at hip joint and leg at knee joint

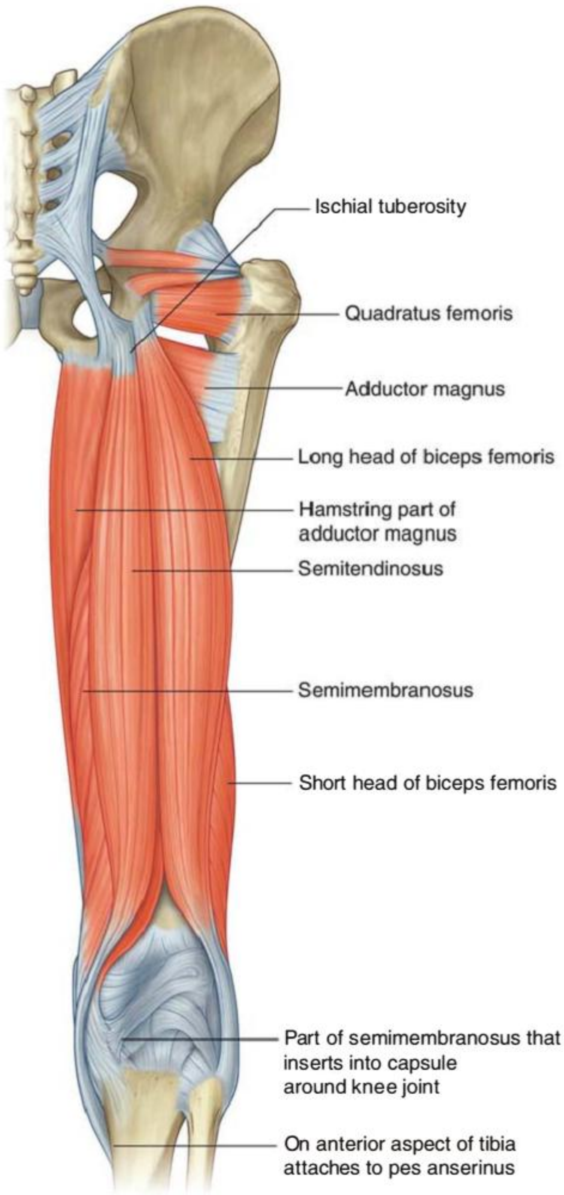


FIGURE 6 : MUSCLES OF POSTERIOR COMPARTMENT OF THIGH

The medullary cavity of femur : The shaft of femur is a cylinder of compact bone. It has a large medullary cavity. The wall of the cylinder is thick in the middle third of the shaft and above and below becomes thinner. Narrowest region of the medullary canal in located immediately proximal to the middle. The cortex has its greatest thickness in the isthumus region, and proximally the cavity becomes slightly larger towards the lesser trochanter. It then widens rapidly and gets filled with dense network of trabeculae. The canal widens gradually towards the distal diaphysis.

Ossification and femur growth : The femur ossifies from five centers: one for the body, one for the head, one for each trochanter, and one for the lower extremity. At about the seventh week of fetal life, the ossification commences in the middle of body and rapidly extends upward and downward.

The centers in the epiphyses appear in the following order: in the lower end of the bone, at the ninth month of fetal life from which the condyles and epicondyles are formed; in the head, at the end of the first year after birth; in the greater trochanter, during the fourth year; and in the lesser trochanter, between the thirteenth and fourteenth years. This order reverses in which the epiphyses are joined to the body; they are not united until after puberty, the lesser trochanter being first joined, then the greater, then the head, and, lastly, the inferior extremity, which unites after the twentieth year(figure 7).

The shape of femur changes during growth period. In frontal plane the neck shaft angle gradually decreases from approximately 155^o to 130^o at skeletal maturity. The slight lateral convexity of the femoral shaft straighten with the growth. Transverse plane changes occur accompanied by a gradual reduction of femoral anteversion from about 1100 at birth to approximately 100 in males and 150 in females at skeletal maturity. Growth rate is very rapid during early infancy and in the adolescent period. The femur makes up approximately 26% of the total height.

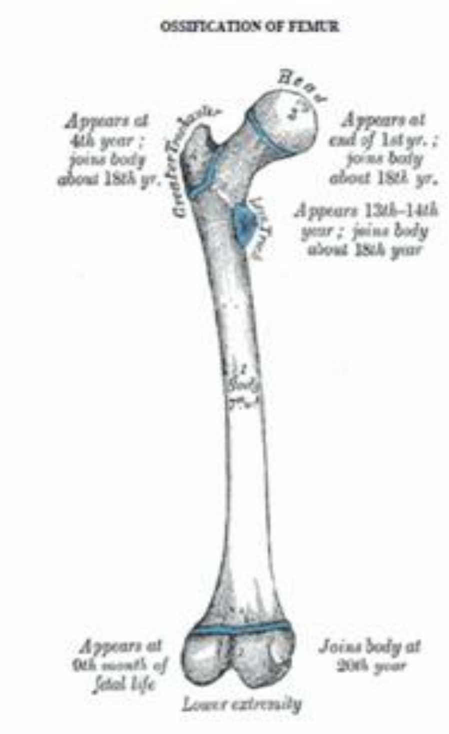


FIGURE 7: OSSIFICATION CENTER OF FEMUR

B**lood supply of femur**: as per the detailed account of the blood supply for the femoral shaft by P.G.Laning there are 4 main arterial system supplying femur, that are periosteal, diaphyseal, metaphyseal and epiphyseal and there are 2 nutrient artery which enter the shaft at lineaaspera. In children the superior artery passes downwards, and the inferior upwards. The nutrient artery arise as branches of one or the other of the perforating of arteria profundus femoris. No major artery entered the lower third of femur. A fracture at the upper third and middle third would deprive blood to proximal fragment and the junction of middle third and lower third, will deprive blood to lower third.

ANATOMY OF TIBIA

The tibia lies medially and is the larger of the two bones in the leg, and it is the only one that articulates at the knee joint with femur. The proximal end of the tibia consists of a medial condyle and a lateral condyle which are both flattened in the horizontal plane and overhang the shaft. It is expanded in the transverse plane for weight-bearing.

The superior surfaces of the medial and lateral condyles are separated by an intercondylar region, and it contains sites of attachment for strong ligaments like the cruciate ligaments and interarticular cartilages like menisci of the knee joint.

These articular surfaces along with the intercondylar region form a 'tibial plateau'. This articulates with and is anchored to the distal end of the femur. There is a large tibial tuberosity and roughenings for muscle and ligament attachment inferior to the condyles on the proximal part of the shaft.

The tibial condyles are thick horizontal discs of bone. They are attached to the top of the tibial shaft.

The medial condyle, which is larger than the lateral condyle, is better supported over the shaft of the tibia. Its superior surface articulates with the medial condyle of the femur. This articular surface extends laterally onto the side of the medial intercondylar tubercle.

The superior surface of the lateral condyle is circular. It articulates above with the lateral condyle of the femur. This surface extends onto the side of the lateral intercondylar tubercle.

The superior articular surfaces of both the lateral condyles and medial condyles are concave, more in the center. The outer margins of the surfaces are flatter, which are in contact with the interarticular discs (menisci) of fibrocartilage in the knee joint.

The medial condyle bears a distinct horizontal groove on the nonarticular posterior surface and a distinct circular facet for articulation with the proximal head of the fibula is present on the undersurface of the lateral condyle.

Between the articular surfaces of the medial and lateral condyles lies the intercondylar region of the tibial plateau. It is raised to form the intercondylar eminence centrally, and its sides are elevated further to form medial and lateral intercondylar tubercles.

Tibial tuberosity: It is a palpable inverted triangular area on the anterior aspect of the tibia. It lies below the site of junction between the two condyles which is the site of attachment for the patellar ligament, which is a continuation of the quadriceps femoris tendon below.

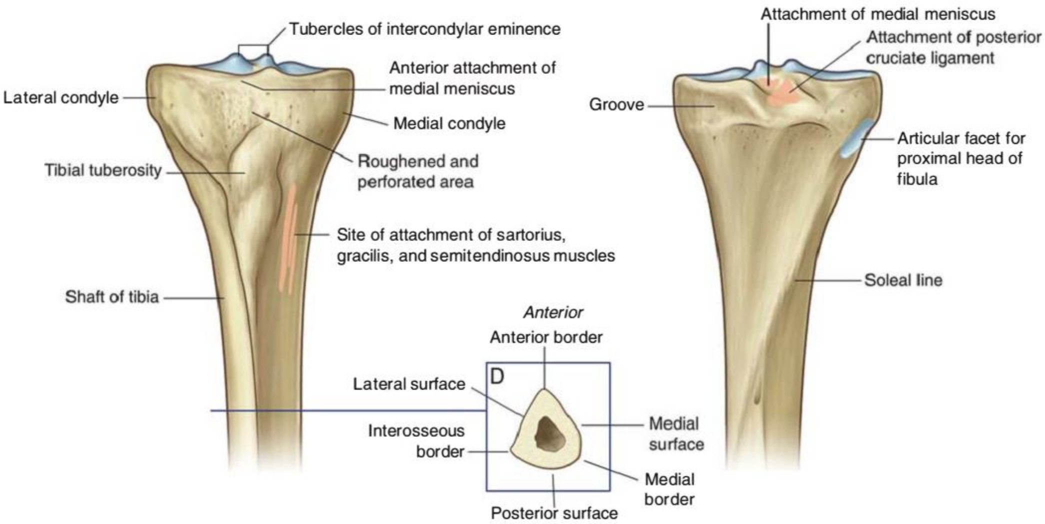


FIGURE 8 : PROXIMAL END OF TIBIA: ANTERIOR VIEW ON THE RIGHT, POSTERIOR VIEW ON THE LEFT.

Its shaft is triangular in cross-section and has three surfaces (posterior, medial, and lateral) and three borders (anterior, interosseous, and medial).

- the anterior border is sharp and descends from the tibial tuberosity. It is continuous superiorly with a ridge that passes along the lateral margin of the tuberosity and onto the lateral condyle.

- the interosseous border is a subtle vertical ridge. It descends along the lateral aspect of the tibia from anterior and inferior to the articular facet for the head of the fibula;
- the medial border is indistinct superiorly. It begins at the anterior end of the groove on the posterior surface of the medial tibial condyle.

The large medial surface of the shaft of the tibia is smooth, subcutaneous and palpable along almost its entire extent, between the anterior and medial borders. Medial and inferior to the tibial tuberosity, it bears a subtle slightly roughened and elongated elevation. This is the site of the combined attachment of three muscles which descend from the thigh above (sartorius, gracilis, and semitendinosus).

The posterior surface of the shaft of the tibia is widest superiorly, between the interosseous and medial borders. Here it is crossed by a roughened oblique line known as the soleal line.

The lateral surface of the shaft of tibia is smooth and unremarkable between the anterior and interosseous borders.

The shaft is triangular in cross-section and has medial, lateral, and posterior surfaces and, anterior, interosseous, and medial borders.

- The entire anterior surface and the anterior and medial borders are subcutaneous and easily palpable;
- The lateral border is connected to the interosseous margin of the fibula; by the interosseous membrane all along its length.
- The soleal line descends across the bone from the lateral to the medial side. Here it merges with the medial border. A vertical line descends down from the midpoint of the soleal line along the upper part of the posterior surface.
- The expanded upper and lower ends of the shaft of tibia support the body's weight at the knee and ankle joints.

The distal end of the tibia, shaped like a rectangular box, has the medial malleolus which is a bony protuberance on the medial side. The lower surface and the medial malleolus articulate with talus to form a large part of the ankle joint.

The posterior surface is marked by a vertical groove, which continues medially and inferiorly onto the posterior surface of the medial malleolus. This groove takes the tendon of the tibialis posterior muscle.

The lateral surface of the distal end of the tibia bears a deep triangular notch (the fibular notch), to which the distal head of the fibula is anchored by the interosseous membrane.

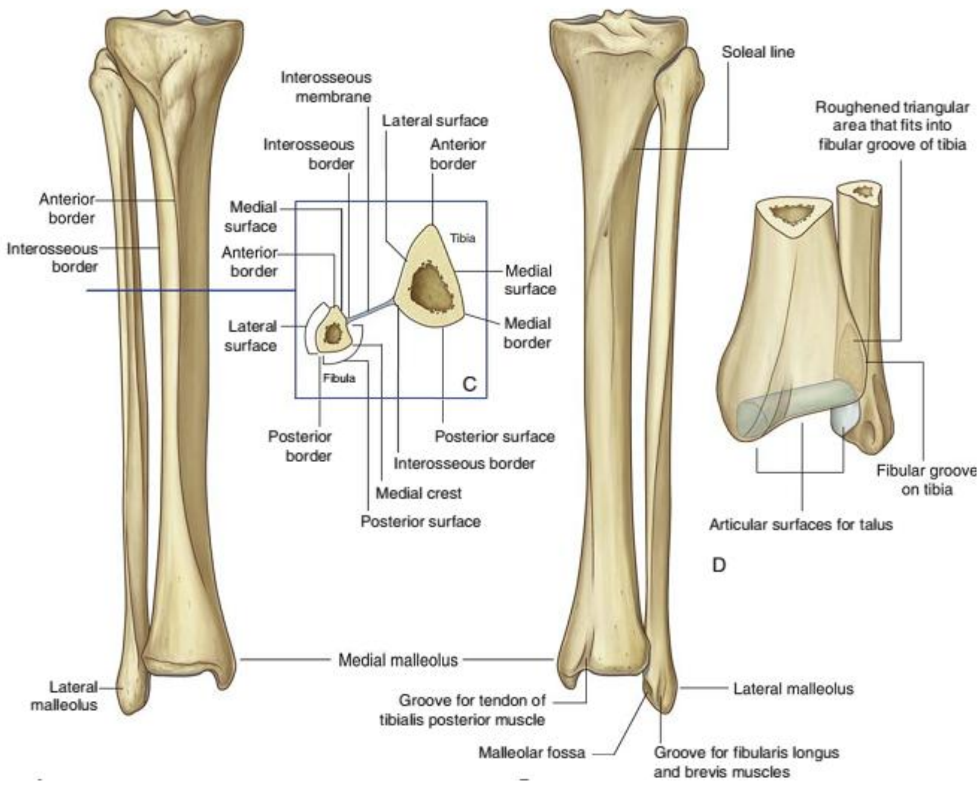
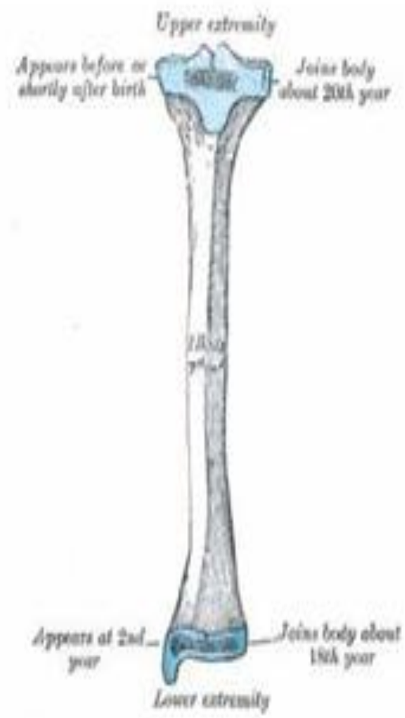


FIGURE 9: ANTERIOR (RIGHT) AND POSTERIOR (LEFT) VIEWS OF TIBIA AND FIBULA, WITH THEIR CROSS-SECTION (INSET BOX)

Ossification. - The tibia ossifies from three centers: one for the body and one for both the extremities. Ossification begins in the center of the body at about the seventh week of fetal life, and then it gradually extends toward the extremities. The ossification center for the upper epiphysis appears before or shortly after birth. It is in a flattened form, and also has a thin tongue-shaped process in the front which forms the tuberosity. Ossification centre for the lower epiphysis appears in the second year. The lower epiphysis joins the body at about the eighteenth year and the upper one joins around the twentieth year of life. Two additional centers occasionally exist, one for the tuberosity, and one for the medial malleolus.



Plan of ossification of the tibia. From three centers.

FIGURE 10: OSSIFICATION CENTER OF TIBIA

TABLE 4 : SUPERFICIAL LAYER OF MUSCLES OF POSTERIOR COMPARTMENT

Muscle	Origin	Insertion	Innervation	Function
Gastrocnemius	Medial head—posterior surface of distal femur just superior to medial condyle; lateral head—upper posterolateral surface of lateral femoral condyle	Via calcaneal tendon, to posterior surface of calcaneus	Tibial nerve (**S1, S2**)	Plantarflexes foot and flexes knee
Plantaris	Inferior part of lateral supracondylar line of femur and oblique popliteal ligament of knee	Via calcaneal tendon, to posterior surface of calcaneus	Tibial nerve (**S1, S2**)	Plantarflexes foot and flexes knee
Soleus	Soleal line and medial border of tibia; posterior aspect of fibular head and adjacent surfaces of neck and proximal shaft; tendinous arch between tibial and fibular attachments	Via calcaneal tendon, to posterior surface of calcaneus	Tibial nerve (**S1, S2**)	Plantarflexes the foot

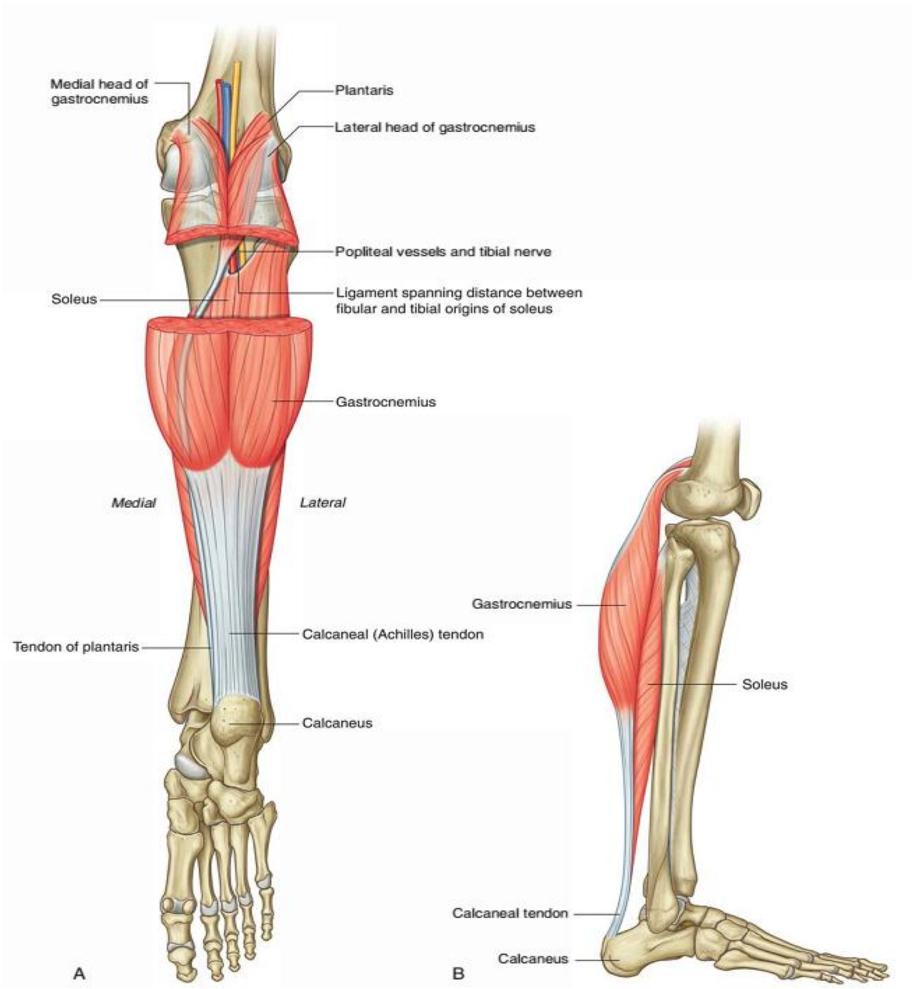


FIGURE 11: SUPERFICIAL LAYER OF MUSCLES OF POSTERIOR COMPARTMENT OF LEG

TABLE 5: DEEP LAYER OF POSTERIOR COMPARTMENT

Muscle	Origin	Insertion	Innervation	Function
Popliteus	Lateral femoral condyle	Posterior surface of proximal tibia	Tibial nerve (L4 to S1)	Stabilizes knee joint (resists lateral rotation of tibia on femur) Unlocks knee joint (laterally rotates femur on fixed tibia)
Flexor hallucis longus	Posterior surface of fibula and adjacent interosseous membrane	Plantar surface of distal phalanx of great toe	Tibial nerve (**S2**, S3)	Flexes great toe
Flexor digitorum longus	Medial side of posterior surface of the tibia	Plantar surfaces of bases of distal phalanges of the lateral four toes	Tibial nerve (**S2**, S3)	Flexes lateral four toes
Tibialis posterior	Posterior surfaces of interosseous membrane and adjacent regions of tibia and fibula	Mainly to tuberosity of navicular and adjacent region of medial cuneiform	Tibial nerve (L4, L5)	Inversion and plantarflexion of foot; support of medial arch of foot during walking

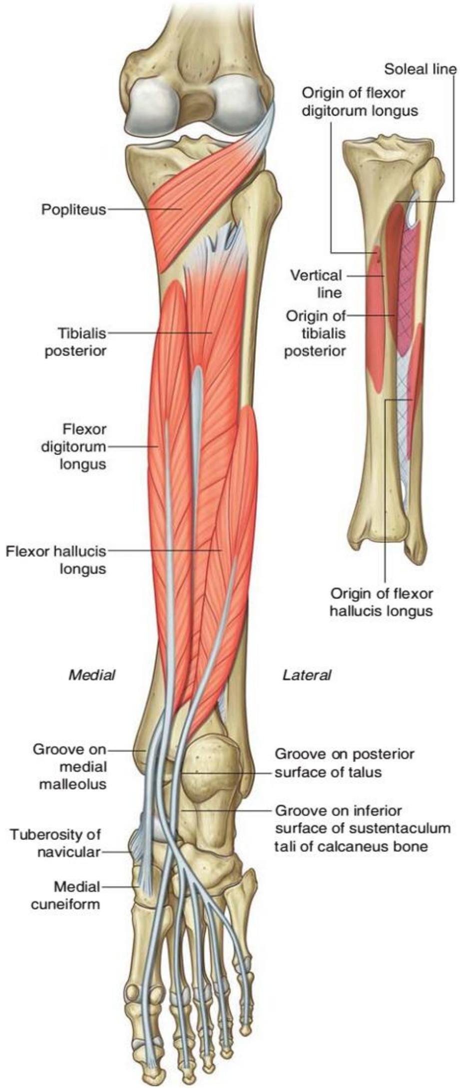


FIGURE 12 : DEEP LAYER OF POSTERIOR COMPARTMENT

TABLE 6: MUSCLES OF LATERAL COMPARTMENT

Muscle	Origin	Insertion	Innervation	Function
Fibularis longus	Upper lateral surface of fibula, head of fibula, and occasionally the lateral tibial condyle	Undersurface of lateral sides of distal end of medial cuneiform and base of metatarsal I	Superficial fibular nerve (**L5, S1**, S2)	Eversion and plantarflexion of foot; supports arches of foot
Fibularis brevis	Lower two-thirds of lateral surface of shaft of fibula	Lateral tubercle at base of metatarsal V	Superficial fibular nerve (**L5, S1**, S2)	Eversion of foot

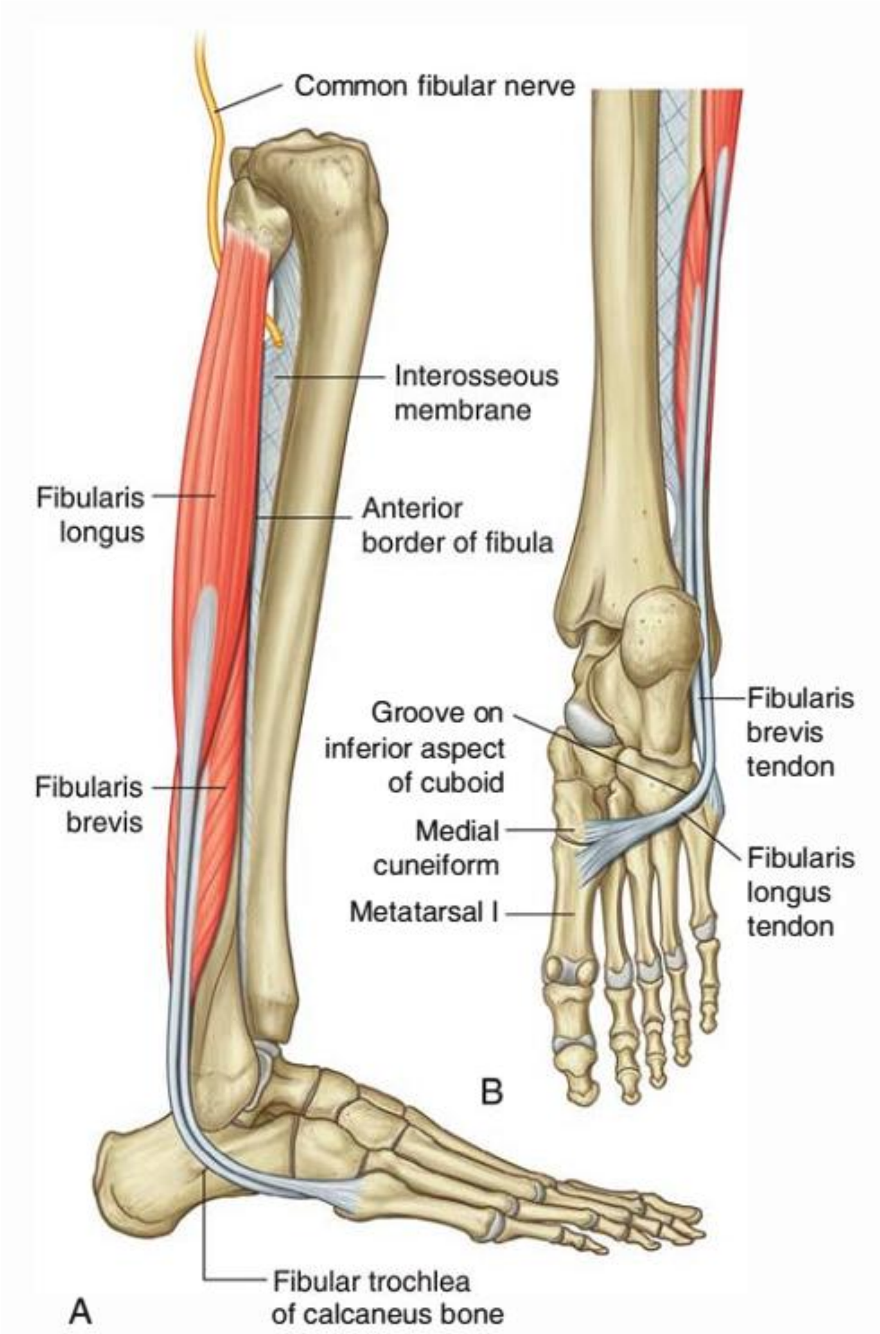


FIGURE 13 : MUSCLES OF LATERAL COMPARTMENT

TABLE 7 : MUSCLES OF ANTERIOR COMPARTMENT OF LEG

Muscle	Origin	Insertion	Innervation	Function
Tibialis anterior	Lateral surface of tibia and adjacent interosseous membrane	Medial and inferior surfaces of medial cuneiform and adjacent surfaces on base of metatarsal I	Deep fibular nerve (**L4**, L5)	Dorsiflexion of foot at ankle joint; inversion of foot; dynamic support of medial arch of foot
Extensor hallucis longus	Middle one-half of medial surface of fibula and adjacent surface of interosseous membrane	Dorsal surface of base of distal phalanx of great toe	Deep fibular nerve (**L5, S1**)	Extension of great toe and dorsiflexion of foot
Extensor digitorum longus	Proximal one-half of medial surface of fibula and related surface of lateral tibial condyle	Via dorsal digital expansions into bases of distal and middle phalanges of lateral four toes	Deep fibular nerve (**L5, S1**)	Extension of lateral four toes and dorsiflexion of foot
Fibularis tertius	Distal part of medial surface of fibula	Dorsomedial surface of base of metatarsal V	Deep fibular nerve (**L5, S1**)	Dorsiflexion and eversion of foot

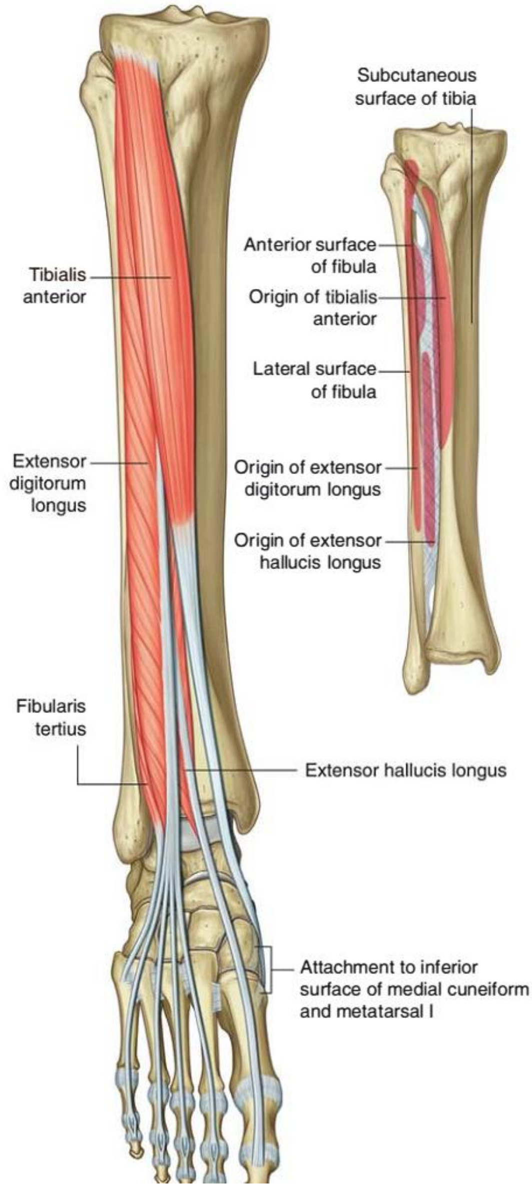


FIGURE 14 : MUSCLES OF ANTERIOR COMPARTMENT OF LEG

FRACTURES OF FEMUR SHAFT IN CHILDREN[38]

A femoral shaft fracture is the most common major paediatric orthopaedic injury that most orthopaedists will treat routinely and is the most common paediatric orthopaedic injury requiring hospitalization. Femoral shaft fractures including subtrochanteric and supracondylar fractures, represent approximately 1.6% of all bony injuries in children. The male to female ration in 2.6:1 with a bimodal distribution. The first peak in early childhood and second in mid adolescence.

For generations, traction and casting were standard treatment for all femoral shaft fractures in children, and patients with femoral fractures had long duration of hospitalization. Over the past 20 years, however, there has been a dramatic and sustained trend towards the operative stabilization of femoral shaft fractures in school-aged children. These advances have decreased the substantial early disability for the children, as well as the family's burden of care during the recovery period.

Mechanism of Injury

The etiology of femoral fractures in children varies with the age of the child. Before walking age, up to 80% of femoral fractures may be caused by abuse. Coffey et al. found that abuse was the cause of only 1% of lower extremity fractures in children older than 18 months, but 67% in younger than 18 months.

In older children, femoral fractures are most likely to be caused by high-energy injuries; motor vehicle accidents account for over 90% of femoral fractures in this age-group. Femoral shaft fractures are commonly isolated injuries or are associated with minor trauma such as abrasion or contusion. High velocity trauma in children produces unstable fracture pattern, with a constellation of other more severe and life threatening injuries.

Pathologic femoral fractures are relatively rare in children, but may occur because of generalized osteopenia in infants or young children with osteogenesis imperfecta. Osteogenesis imperfecta should be considered when a young child, with no history suggestive of abuse or significant trauma, presents with a femoral shaft fracture.

Stress fractures can occur in any location in the femoral shaft. In this era of high intensity, year-round youth sports, orthopaedists are encountering more adolescents with femoral stress fractures from running, soccer, and basketball. Stress fractures of the femur have been described in skeletally immature patients, and they result from sports activities. Most of the injuries in children were due to fall from swings on a play ground equipments also there injuries low energy accident may cause femoral shaft fractures in children with pathologic bone.

Classification of femoral shaft fractures:

Femoral fractures are classified as transverse, spiral, or short oblique; comminuted or noncomminuted; and open or closed. The presence or absence of vascular and neurologic injury is documented and is part of the description of the fracture. The most common femoral fracture in children (over 50%) is a simple transverse, closed, noncomminuted injury. Fractures of the shaft of femur may be classified in a variety of ways. Each fractures should be identified and described and each has clinical relevance.

Open versus closed fractures: Fortunately open fractures are rare in children, but any degree of skin penetration is highly significant. Open fractures should be classified on the basis of Gustillo and Anderson.

Level: Fractures of the shaft are usually described as occurring in the proximal, middle and distal third of shaft. Majority of fractures occur occur in mid shaft. Subtrochanteric fractures are those occurring upto 7.5cms below the lesser trochanter. Supracondylar fractures are those that occur just above the origin of gastroenemius. The level of the fracture leads to characteristic displacement of the fragments based on the attached muscles.

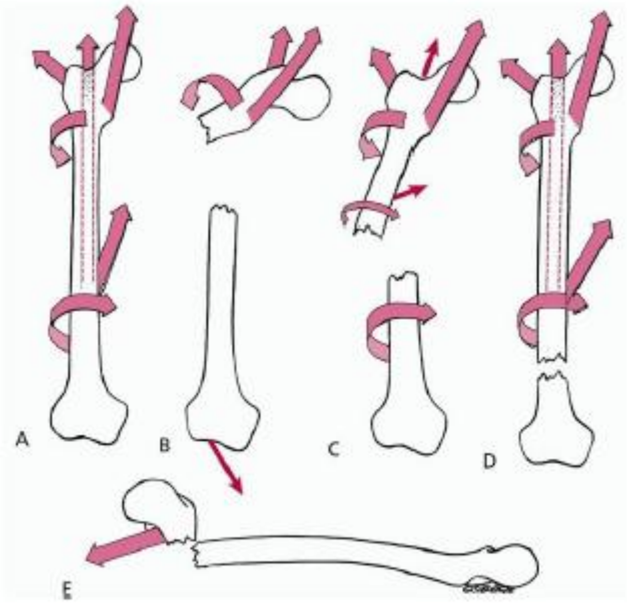
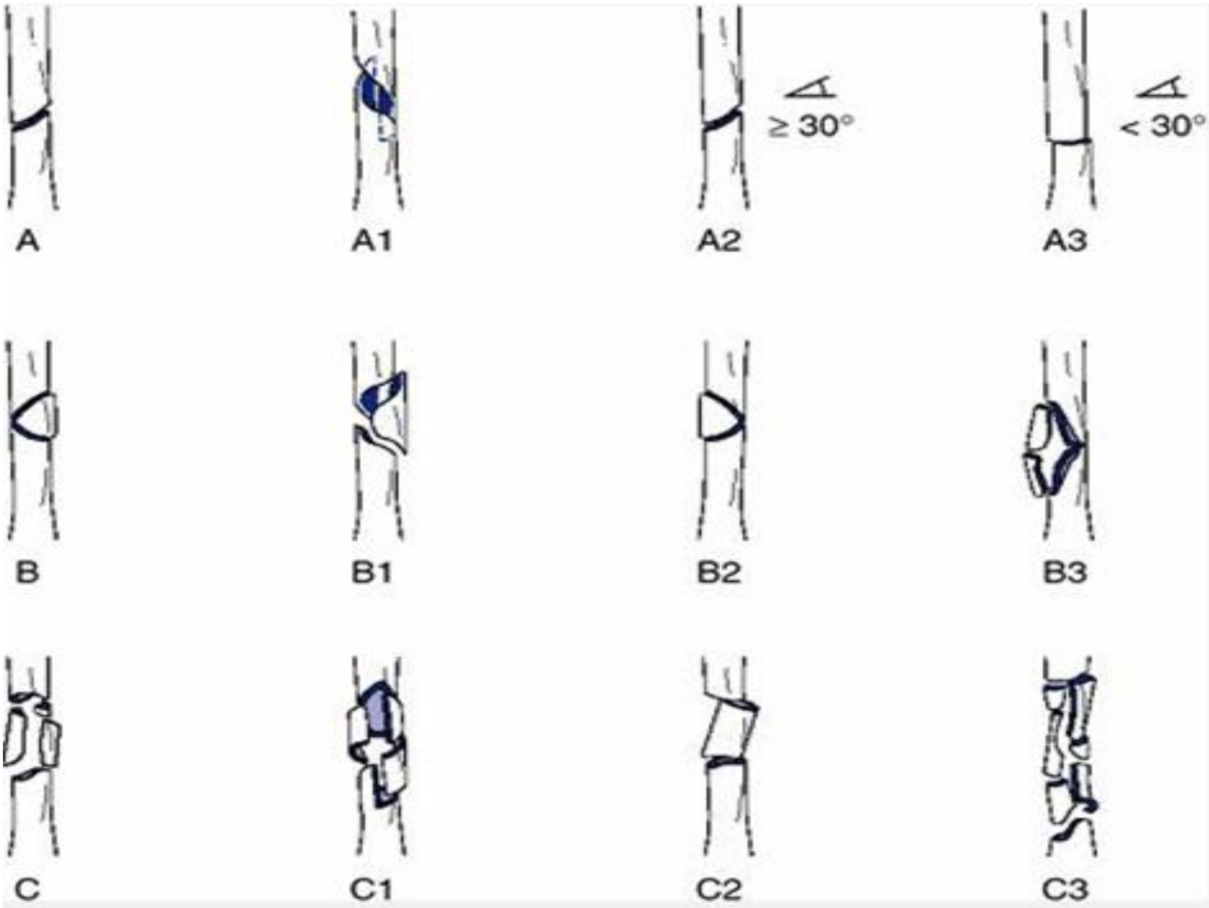


FIGURE 15 : THE RELATIONSHIP OF FRACTURE LEVEL AND POSITION OF THE PROXIMAL FRAGMENT

The relationship of fracture level and position of the proximal fragment. A. In the resting unfractured state, the position of the femur is relatively neutral because of balanced muscle pull. B. In proximal shaft fractures, the proximal fragment assumes a position of flexion (iliopsoas), abduction (abductor muscle group), and lateral rotation (short external rotators). E. Supracondylar fractures often assume a position of hyperextension of the distal fragment due to the pull of the gastrocnemius.

Pattern: Most children fractures are transverse, oblique or spiral in direction. Their fractures are rarely comminuted.

FIGURE 16 : AO CLASSIFICATION OF FEMUR DIAPHYSEAL FRACTURES



The AO/Orthopedic Trauma Association classification is based largely on the fracture morphology and includes the fracture location as well as the degree and type of comminution.(FIGURE 16).

Type A fractures are considered simple and include spiral **A1**, oblique **A2**, and transverse patterns **A3**.

Type B fractures are wedge fractures and include spiral wedge **B1**, bending wedge **B2**, and segmental wedge patterns **B3**.

Type C fractures are considered complex patterns that have no cortical contact between the major proximal and distal fractures. They are further devided as complex spiral **C1**, complex segmented **C2,** complex irregular **C3.**

Treatment of femoral shaft fractures in children:

Treatment of femoral shaft fractures in children is age dependent, with considerable overlap between age groups. In addition to age, the orthopaedic surgeon should consider the child's weight, associated injuries, fracture pattern, and mechanism of injury. Economic concerns, the family's ability to care for a child in a spica cast or external fixator, and the advantages and disadvantages of any operative procedure also are important factors.

The comparative economics of nonoperative and operative treatment of femoral shaft fractures have been evaluated by several researchers, but no

clear consensus has been reached. Newton and Mubarak36 analyzed the financial aspects of femoral shaft fracture treatment in 58 children and adolescents and determined that total charges were lowest for those treated with early spica casting and highest for those treated with skeletal traction or intramedullary nailing.

The Orthopaedic literature on paediatric femur consist primarily of uncontrolled retrospective clinical series focusing on treatment alternative. Humberger and Eyring stated, “The simplest, safest, and the most effective method should be the treatment of choice”.

Dameron and Thompson37 outlined seven principles of paediatric femoral shaft fracture care as follows :

1. The simplest form of satisfactory treatment is the best.
2. The initial treatment should be permanent treatment whenever possible.
3. Prfect anatomical reduction is not essential for perfect function.
4. Restoration of alignment is more important than position of fragments with respect to one another.

5. More potential growth equals more probable restoration of normal architecture because of remodelling.

6. Over treatment in usually worse than under treatment.

7. Injured limb should be kept in Thomas splint with skin traction before definitive therapy is begun.

Most Authors recommend treatment based on patients age. Treatment option for femoral shaft fractures in children and adolescents are as follows: (table 8)

TABLE 8 : TREATMENT OPTION FOR FEMORAL SHAFT FRACTURES ACCORDING TO AGE.

Age	Treatment
Birth to 24 months	Pavlik harness (newborn to 6 month)
	Immediate spica cast
	Traction → spica cast
24 months to 5 years	Immediate spica cast
	Traction → spica cast
	External fixation (rare)
	Flexible IM nail (rare)
6-11 years	Traction spica cast
	Flexible IM nail
	Compression plate
	External fixation
12 year to maturity	Flexible IM nail.
	Compression plate
	Locked IM nail

TABLE 9 : ADVANTAGES AND DISADVANTAGES OF DIFFERENT PROCEDURES OF TREATMENT OF FEMUR FRACTURES IN CHILDREN

Fixation	Advantages	Disadvantages
Spica casting	No scar, no operations	Uncomfortable, skin problems and loss of reduction.
Skeletal traction	No operation, closed treatment	Loss of reduction, long time immobilization, pin tract infection.
External fixation	Percutaneous fixation early mobilization	Pin tract infection, secondary fractures and re fractures
Plate osteosynthesis	Immediate stability and mobilization	Large incision and scarring, hardware removal
Flexible IM nails Locked	Small incision immediate, early mobilization	Possibility of rotational instability, hardware removal is necessary
Intramedullary nailing	Immediate stability and mobilization	Risk of AVN, implant removal necessary

Complications of femoral shaft fractures

1. **Limb length discrepancy:** The most common sequale after femoral shaft fracture in children**.** The fractured femur may be initially short from overriding of fragments at union. Growth acceleration occurs to make up the difference but often the acceleration continues and over growth occurs. In patients over 10 years of age, shortening is more likely, over growth in more likely in patients with age 2-10 years.

2. **Angular deformity:** Some degree of angular deformity is often seen after femoral shaft fracture in children, but this usually corrected by remodelling with growth. An angular malunion of up to 25^0 in any plane will remodel. In children older then 9 years, remodelling should not be relied on to correct angular deformity.

3. **Rotational deformity:** Rotational deformity in usually expressed in terms of Femoral Anteversion Angle [FAA] on the fractured side compared with the normal side. A difference of more than 10 degrees has been the criterion of significant deformity. The goal should be to reduce a rotational deformity to 10°.

TABLE 10 : ACCEPTABLE SHORTENING AND ANGULATION IN FEMUR FRACTURES OF CHILDREN

Age	Varus / Valgus (Degree)	Anterior / Posterior (Degree)	Shortening (mm)
Birth to 2 years	30	30	15
2-5 years	15	20	20
6-10 years	10	15	15
11 years to maturity	5	10	10

4. **Delayed and non union:** Are uncommon in children, typical causes are either infection or stress shielding often caused by fracture management itself.

5. **Infection:** Superficial infections are due to pin tract infection occurs with use of skeletal traction and external fixation which resolve with local wound care and antibiotic therapy, deep infections in case of intramedullary implants is although rare but a severe complication.

6. **Neurovascular Injury:** Nerve and vascular injuries are uncommon with femoral fractures in children.

7. **Compartment syndrome:** Rare, but it has been reported after femoral fracture and treatment. Thigh fasciotomy is indicated when the pressure in >30mm/Hg.

8. **Avascular necrosis of the femoral head**: usually seen in in antegrade nail insertion through piriform fossa, sometimes occur with hip spica cast, when hip in placed in wide abduction.

FRACTURE OF TIBIA IN CHILDREN[39]

Tibial and fibular fractures are the third most common paediatric long bone injuries (15%) after radial/ulnar and femoral fractures. The average age of occurrence is 8 years, and the frequency of occurrence does not change significantly with age. In age group 1 – 4years most commonly bicycle spoke injuries are seen while in age group 4 year and above its mostly due to sporting injury or road traffic injuries. The tibia is the second most commonly fractured bone in abused children. Approximately 16% to 26% of all abused children with a fracture have an injured tibia. Nine percent of paediatric tibial fractures are open. Seventy percent of paediatric tibial fractures are isolated injuries; ipsilateral fibular fractures occur with 30% of tibial fractures.

Fifty to 70% of tibial fractures occur in the distal third, and 19% to 39% in the middle third and only minor fraction of fractures are proximal third but the most problematic.

Thirty-five percent of paediatric tibial fractures are oblique, 32% comminuted, 20% transverse, and 13% spiral. Tibial fractures in children under 4 years of age usually are isolated spiral or short oblique fractures in the distal and the middle one third of the bone. Most tibial fractures in older children and adolescents are in the distal third. Rotational forces produce an oblique or a spiral fracture, and are responsible for approximately 81% of all tibial fractures that present without an associated fibular fracture. Most isolated fibular fractures result from a direct blow. Concomitant fractures of the ankle and foot are the most common injuries associated with fractures of the tibia and fibula, followed by humeral, femoral, and radial/ulnar fractures.

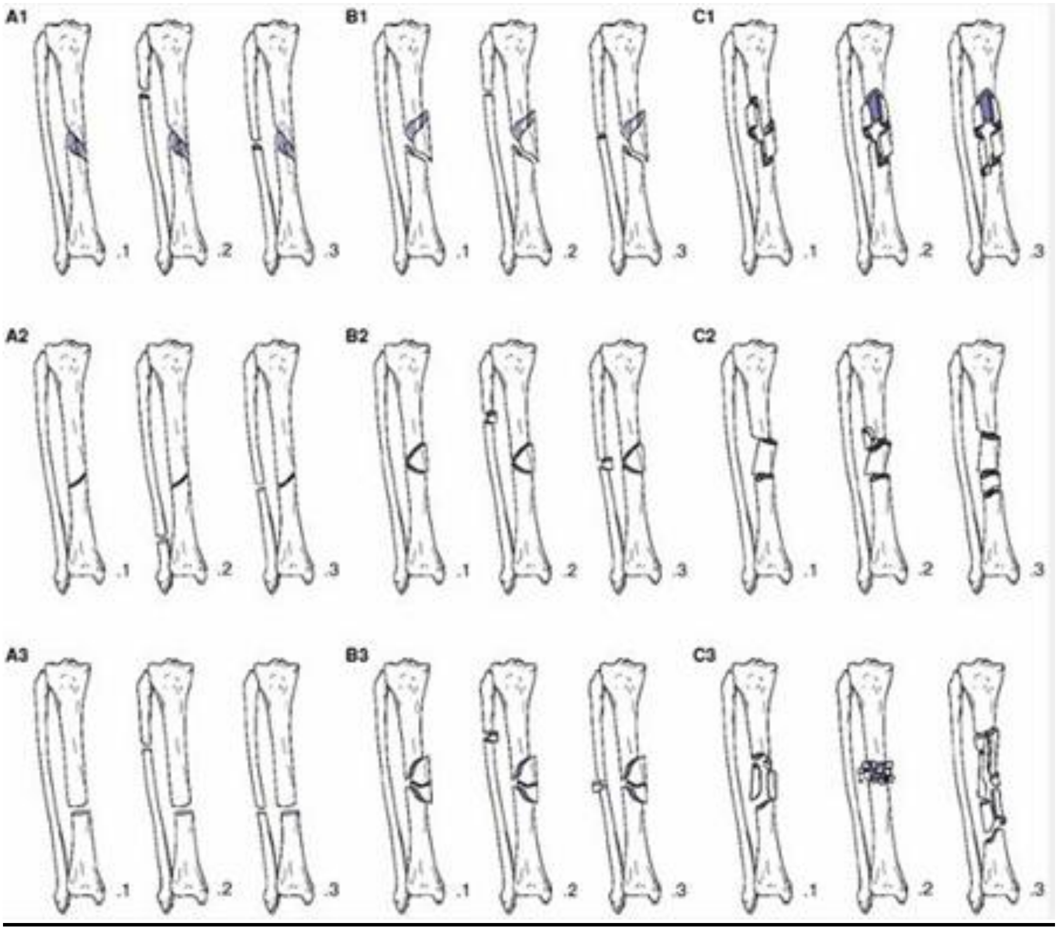
Mechanism of injury

The fractures can be incomplete (torus, greenstick) or complete. Most tibial fractures in children under 11 years of age are caused by a torsional force and occur in the distal third of the tibia. These oblique and spiral fractures occur when the body rotates with the foot in a fixed position on the ground. The fracture line generally starts in the distal anteromedial aspect of the bone and propagates proximally in a posterolateral direction. In case of intact fibula, it prevents significant shortening of the tibia; however, varus angulation develops in approximately 60% of isolated tibial fractures within the first 2 weeks after injury .

Isolated transverse and comminuted fractures of the tibia most commonly are caused by direct trauma. Transverse fractures of the tibia with an intact fibula seldom displace significantly. Comminuted tibial fractures with an intact fibula tend to drift into varus alignment similar to oblique and spiral fractures.

Approximately 30% of paediatric tibial diaphyseal fractures have an associated fibular fracture. The fibular fracture may be either complete or incomplete. A tibial diaphyseal fracture with an associated complete fracture of the fibula usually results in valgus malalignment because of the action of the muscles in the anterolateral aspect of the leg.

FIGURE 17 :AO CLASSIFICATION OF DIAPHYSEAL FRACTURES OF TIBIA WITH/WITHOUT FIBULA



It is the most comprehensive classification of tibial diaphyseal fractures described by the AO group . This is a morphologic classification based on the initial anteroposterior and lateral radiographs. It consists of three fracture types subdivided into three groups each of which are further subdivided into three subgroups.

The type A fractures : they are unifocal fractures and further deivided as **A1 group**, fractures are spiral; **A2 group** oblique fractures and **A3 group** transverse fractures.

The type B fractures : they are the wedge fractures, the subdivision is similar, as **B1 fractures** contain all the spiral wedge fractures and **B2 fractures** comprise the bending wedge fractures and **the B3 fractures** all have a fragmented wedge.

Further a suffix is added for type A and type B as follows:

1 : If there is no fibular fracture

2 : Fibular fractures present but distant from the tibial fracture

3 : Fibular fractures present with tibial and fibular fractures at the same level.

The type C fractures : The **C1 fractures** are all complex spiral fractures, **C2 fractures** are segmental fractures and **C3 fractures** are all comminuted fractures. They are further subdivided not according to the position of the fibular fracture but rather according to the severity of the tibial fracture.

TREATMENT OF TIBIA SHAFT FRACTURES IN CHILDREN:

Conservative management

The vast majority of uncomplicated paediatric tibial and fibular shaft fractures can be treated by manipulation and cast application.64 Fractures of the tibial shaft without concomitant fibular fracture may develop varus malalignment. Valgus angulation and shortening can present a significant problem in children who have complete fractures of both the tibia and the fibula. Displaced fractures should be managed with reduction under appropriate sedation, using fluoroscopic assistance when available. A short-leg cast is applied with the foot in the appropriate position with either a varus or valgus mold, depending on the fracture pattern and alignment. The cast material is taken to the inferior aspect of the patella anteriorly and to a point 2 cm distal to the popliteal flexion crease posteriorly.

The alignment of the fracture should be checked weekly during the first 3 weeks after the cast has been applied. Muscle atrophy and a reduction in tissue edema may allow the fracture to drift into unacceptable alignment. Cast wedging may be indicated in an attempt to improve alignment, and in some cases a second cast application with remanipulation of the fracture under general anesthesia may be necessary to obtain acceptable alignment.

Surgical management

Historically, operative treatment has been recommended rarely for tibial shaft fractures in children. However, in the last decade there has been an increasing interest in surgical stabilization, particularly for unstable closed tibial shaft fractures as well as open fractures or those with associated soft tissue injuries.

The current indications for operative treatment include open fractures, some fractures with an associated compartment syndrome, some fractures in children with spasticity (head injury or cerebral palsy), fractures in which open treatment facilitates nursing care (floating knee, multiple long bone fractures, multiple system injuries), and unstable fractures in which adequate alignment cannot be either attained or maintained. Common methods of fixation for tibial fractures requiring operative treatment include percutaneous metallic pins, bioabsorbable pins,6 external fixation, plates with screws, flexible intramedullary titanium or stainless steel nails,

TABLE 11: ACCEPTABLE ALIGNMENT OF A PAEDIATRIC DIAPHYSEAL TIBIAL FRACTURE

Patient Age	<8 Years	>8 Years
Valgus	5 A^0	$5A^0$
Varus	$10A^0$	$5A^0$
Anterior angulation	$10A^0$	$5A^0$
Posterior angulation	$5A^0$	$0A^0$
Shortening	10mm	5mm
Rotation	$5A^0$	$5A^0$

Complications associated with tibia diaphyseal fractures

1.Compartment Syndrome :A compartment syndrome may occur after any type of tibia fracture, ranging from a seemingly minor closed fracture to a severe, comminuted fracture. Any cast should be bivalved and the padding divided in a patient with increased or increasing pain. If, after removal of all encircling wraps, there is no relief, compartment syndrome should be considered. Any child who has objective or subjective evidence of a compartment syndrome should undergo an emergency fasciotomy.

2.Vascular Injuries : Vascular injuries associated with tibial fractures are uncommon in children; however, when they do occur, the sequelae can be devastating.

3. Angular Deformity and malrotation ***:*** unlike child's forearm or femur where spontaneous correction of significant axial malalignment after a diaphyseal fracture is common, remodeling of a angulated tibial shaft fracture, however, often is incomplete. As such, the goal of treatment should be to obtain as close to an anatomic alignment as possible.

4.Leg-Length Discrepancy : Hyperemia associated with fracture repair may stimulate the physes in the involved leg, producing growth acceleration. Tibial growth acceleration after fracture is less than that seen after femoral fractures in children of comparable ages.

5.Delayed Union and Nonunion : Delayed union and nonunion are uncommon after low-energy tibial fractures in children. In patients with a suspected delayed union or nonunion, a 1-cm fibulectomy will allow increased compression at the delayed union or nonunion site with weight bearing and often will induce healing.

TITANIUM ELASTIC NAILING SYSTEM – AN OVERVIEW

HISTORY

Elastic nailing for children was first performed on a child with Vitamin D resistant rickets in Nancy, France in 1977. The technique spread fairly rapidly for the stabilization of long bones, mostly in multiple trauma. The idea of using relatively low diameter intramedullary rods to stabilize long bone fractures, in particular those of the femoral shaft, was of course not new, German school had been using condylocephalic nailing of intertrochanteric fractures since 1950, Rush pins were being used for over three decades then[41]. In 1970, Ender described the nailing of trochanteric fractures using three pins that were smaller and more flexible than the previously described devices inserted through the medial femoral condyle and spread out in the femoral neck[40].

Prevot, the professor in Nancy at the time of the development of elastic nailing, wrote that several factors had proven important in the development of the technique[15,41].

1. Dissatisfaction of children with the prolonged conservative management of femoral shaft fractures.

2. Difficulties with schooling and psychological problemswith prolonged immobilization

3. Prevot’s personal conviction that open reduction and plate fixation was an unsuitable and unphysiological method for fracture fixation in a growing bone.

4. The new vision and drive to create a fracture stabilization system particular to children.

5. Technological advances to permit such development mainly (a) materials with a suitable tensile strength and modulus of elasticity and (b) modern image intensification with low pulse dosage and a memory.

BIOLOGICAL PROPERTIES

One of the principles of ESIN which led to its success is the respect that it has for the growing bone and the nature of children's fractures. The periosteum of a child is a much thicker and the periosteal circulation is an important source of cortical blood supply. Cutting the periosteum, or stripping it, has a deleterious effect on healing in terms of speed of healing, callus formation and bone length. In ESIN minimal periosteal stripping is achieved by a minimally invasive approach and in most cases a closed reduction. The elasticity of the construct allows for the ideal of micro-motion for rapid fracture healing[42]. Elastic nailing reduces diaphyseal and metaphyseal fractures satisfactorily in terms of length, rotation and alignment and any inaccuracy of reduction, particularly displacement are corrected as children's fractures remodel after healing.

BIOMECHANICS

ESIN is a successful method for treating children's fractures because they heal rapidly in less than half the time of an equivalent adult fracture[43].The elastic nails whether constructed of titanium alloy or of stainless steel, are adequately strong to maintain the reduction for the length of time required.

In the insertion of elastic nails, each nail is inserted to achieve a 3-point fixation of the bone. The nails are pre-curved to achieve this and in general the pre-curve that should be put on a nail should be approximately three times the diameter of a long bone at its isthmus. Two nails are used, identically pre-curved and inserted opposite each other to produce a perfectly balanced construct that maintains alignment.

The ends of the nails are anchored firstly in their entry points and secondly in the metaphysis of the other end of the bone. The dense metaphyseal area available in children's bone is another feature that makes this method most suitable for children's fractures. The curvature of the nails is achieved by bending them beyond their elastic limit. After bending the nails resist the tendency to be straightened (thus creating some tension within the intramedullary canal) as well as a tendency to be further bent, thus resisting deformation[41].

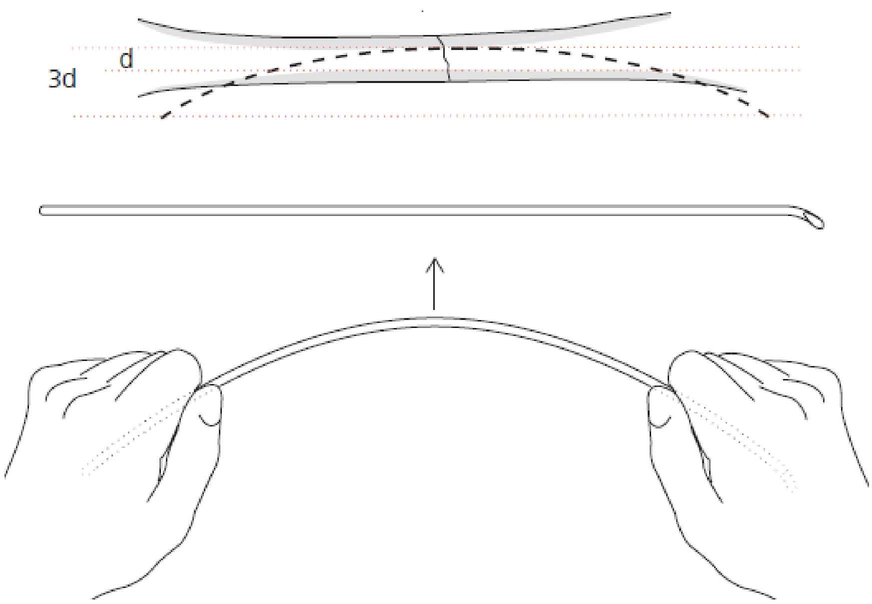


FIGURE 18 : PRE-BENDING OF TENS NAIL

Double-frame model :It illustrates the principle of the ESIN technique. The inner frame consists of the medullary canal containing the elastic flexible nails and the bone , where-as the muscles on the anterior/posterior, medial/lateral sides form the outer frame. Both frames have to be functional in order to provide sufficient stability for reducing and maintaining fracture reduction. In the tibia, the application of the principle of ESIN is more demanding because of the missing outer frame, and muscle coverage on the medial and lateral sides.

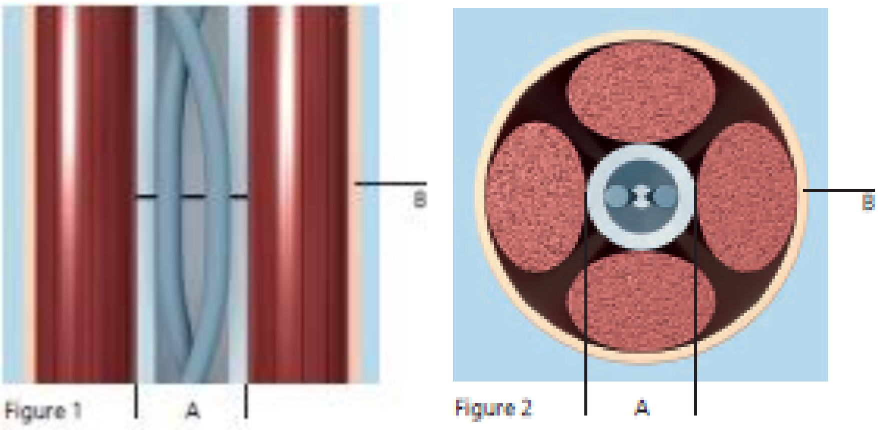
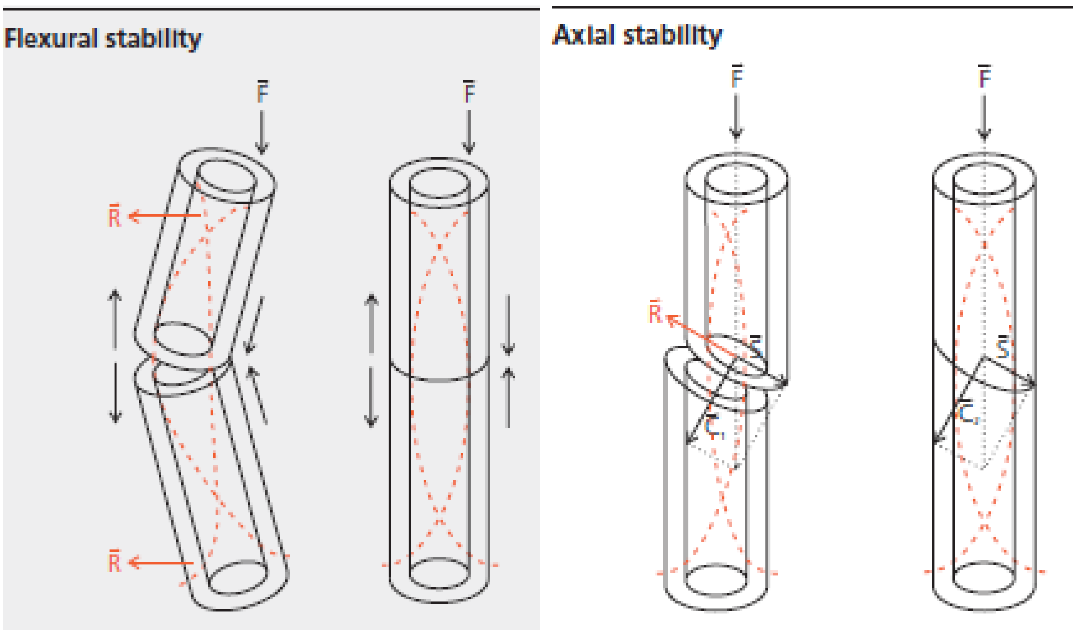


FIGURE 19 : DOUBLE-FRAME MODEL A: INNER FRAME, B: OUTER FRAME

Once inserted into the medullary canal, the nails resist angular, compressive and rotational forces by virtue of the elastic qualities of the material and the balanced insertion construct. When two elastic nails are inserted into the metaphysis, each of which bears against the inner bone at three points it produces a symmetrical bracing action. This produces the following four properties: flexural stability, axial stability, translational stability and rotational stability. All four are essential for achieving optimal result.



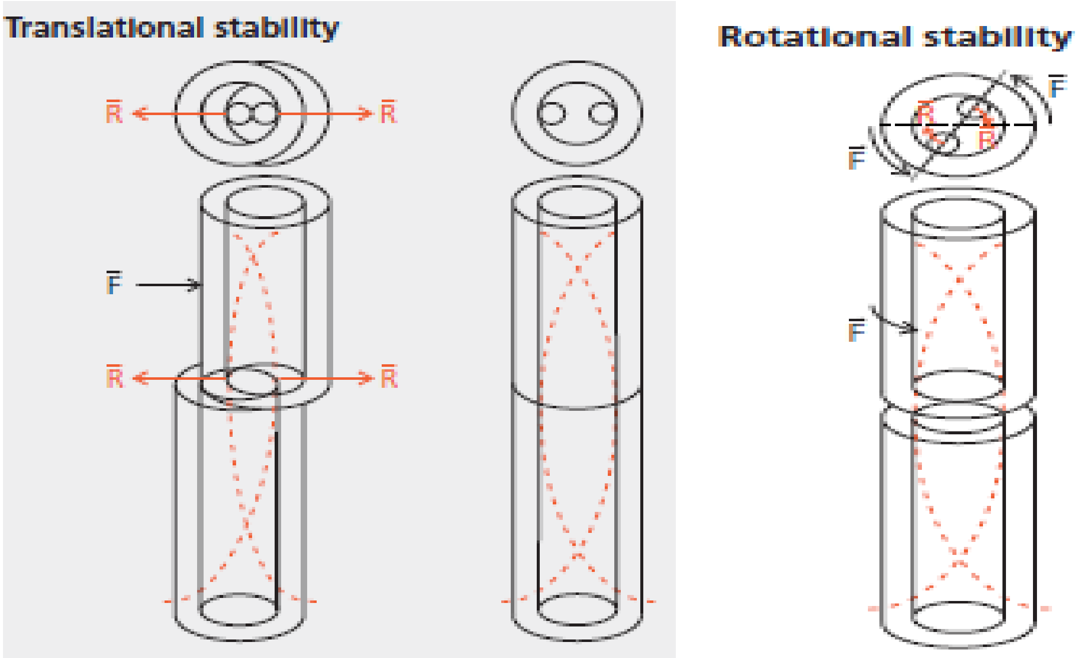


FIGURE 20: STABILITY OF TENS

F – force acting, R- restoring force of the nail

S – shear force, C – compressive force

Elastic nails are available in titanium alloy and in stainless steel. Titanium alloy has a modular of elasticity and handling characteristics very suitable to the child's diaphysis. It allows stable reduction, maintenance of reduction, micro motion at fracture site and early mobilization which develops early bridging callus and contributes to rapid restoration of bone continuity. Stainless steel is stronger with a higher tensile strength and a higher elastic limit. A stainless steel nail has the strength of a titanium alloy nail one size larger (e.g., a 2.5 mm stainless steel nail is as strong as a 3 mm titanium elastic nail), so stainless steel may be suitable when medullary canals are disproportionately narrow and may prove useful in the management of fractures in the heavier adolescent. The nails have beaked or hooked ends to allow satisfactory sliding down of the inner surface of the diaphysis without impacting on the opposite cortex on insertion[41].

Only correct tensioning of nail can fulfill the dynamic principles of this method. It is based on circular muscle mantle and restoring force of pre-stressed nails, which repeatedly bring the fragment back into anatomical position. When fracture of the distant part of diaphysis or metaphysis is to be fixed with ESIN, the entry points must be at opposite ends of bone e.g. for supracondylar fractures the entry should be made from trochnateric area.

The incorrect insertion points can have various negative effects like internal tension and imbalance of fracture stability and fixation. If entry points do not lie opposite to each other then it causes differential internal tension and inbalanceo fthe construct. Entry points that are too diaphyseal, damage the musculature during insertion and removal. The nails that are left too long cause severe muscle and skin irritation and breakdown. Injury to perichondral ring and growth plates may occur at time and formation of entry point as well as nail insertion and may lead to growth arrest.

Titanium elastic nails are available in 5 diameters : 2 mm, 2.5 mm, 3.0 mm, 3.5 mm and 4.0 mm. The 2.0 mm through 4.0 mm nails are 440 mm long. Additionally 1.5 mm diameter nail is available which is 300 mm long.. The nails are color coded for easy identification (figure 21).

The nail diameter should be selected to correspond to between 30% to 40% of the narrowest medullary space diameter. Nail diameter is usually 0.4 times the canal diameter. Always 2 nails of same thickness should be used, to avoid valgus and varus or axial deformity which may be due to different restoring force (figure 22).

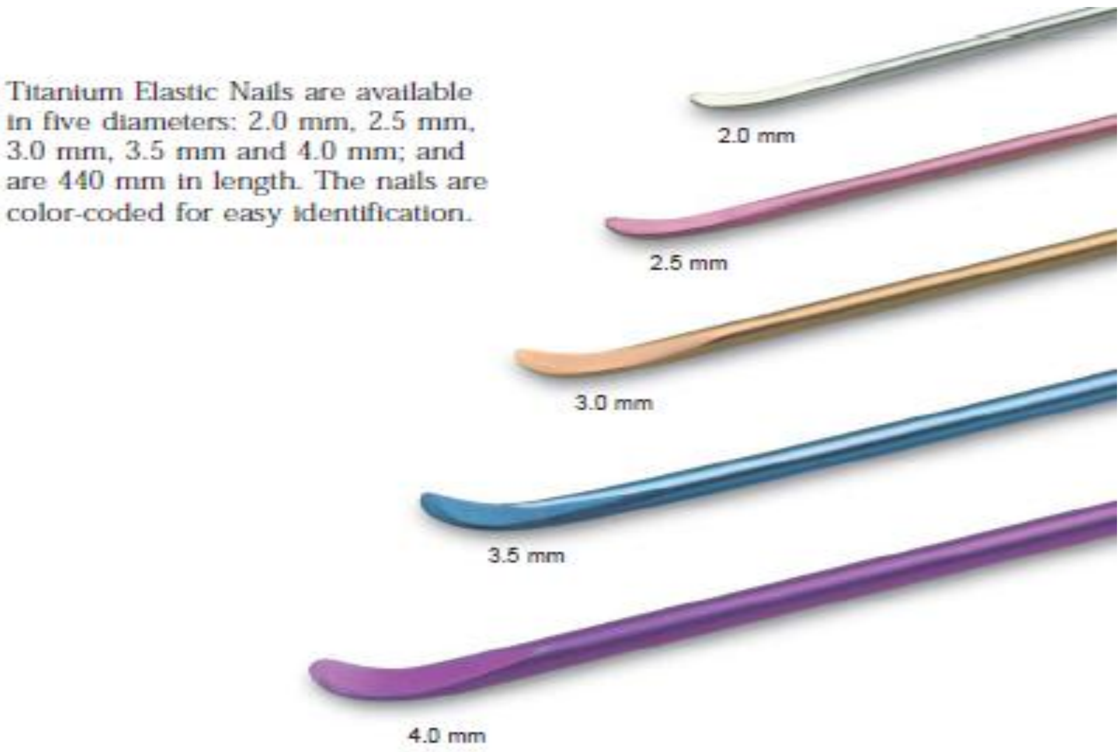


FIGURE 21 : DIFFERENT SIZES OF TENS NAILS WITH COLOR CODING

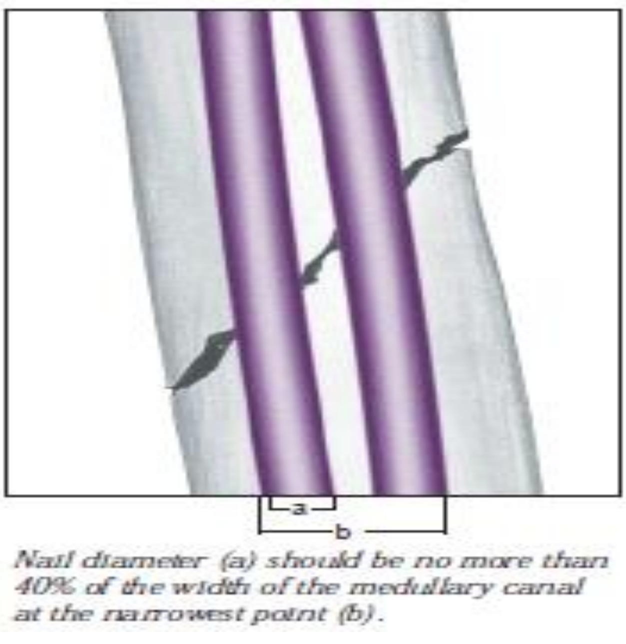


FIGURE 22: NAIL DIAMETER OF TENS NAIL ACCORDING TO MEDULLARY CAVITY DIAMETER.

6 – 8 years	3.0 mm nails
9 – 11 years	3.5 mm nails
12 – 14 years	4.0 mm nails

TABLE 12: TYPICAL SIZES USED FOR CHILDREN OF AVERAGE STATURE

The corkscrew phenomenon is when due to difficulties with fracture reduction as well as advancing the 2nd nail may tempt the surgeon to rotate the nail more than 180 degree. This may lead to one nail being wound around the other which reduces the internal tension of nails and they fail to provide axial or rotational stability and function like a central nail.

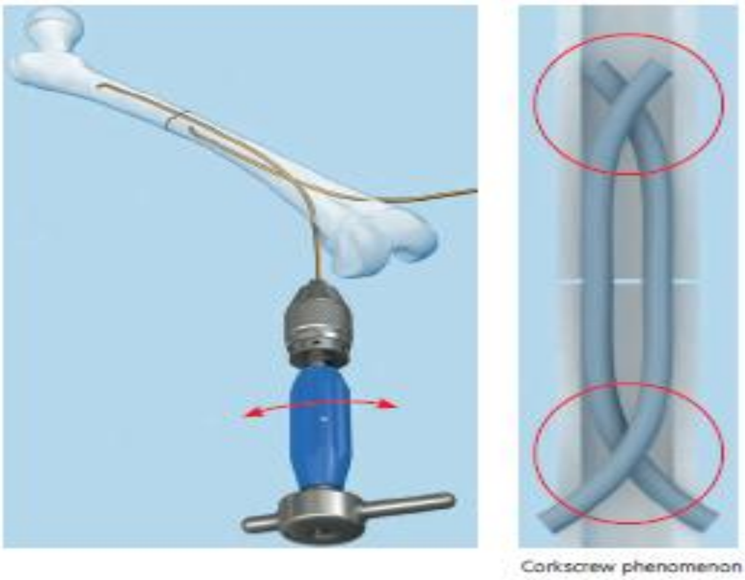


FIGURE 23: CORKSCREW PHENOMENON IN TENS

The nail backs out at entry points when correct biomechanical properties are missing. The end cap is new implant that prevents backing out movement of nail at entry point. The end cap offers counter force to longitudinal force in nail and retains the elasticity of nail.

METHOD OF STUDY

A **prospective study** on about 30 consecutive patients in the age group 5years to 15 years with diaphyseal fracture of femur and tibia meeting the inclusion and the exclusion criteria, admitted to R L Jalappa Hospital and Research Center, attached to Sri Devaraj Urs Medical College, were taken up for the study after obtaining the informed consent.

INCLUSION CRITERIA:

1. 5-15 years of age
2. Diaphyseal fractures Femur & Tibia
3. Simple fractures (closed fractures)
4. Ipsilatertal fractures
5. Fracture with head injury

EXCLUSION CRITERIA

1. Metaphyseal fractures
2. open fractures
3. Pathological fractures

As soon as the patient was brought to casualty, patient's airway, breathing and circulation were assessed. Then a complete survey was carried out to rule out other significant injuries. Plain radiographs of AP and lateral views of the involved extremity including one joint above and one joint below were taken to assess the extent and geometry of fracture, and thus the fulfillment of selection criteria.

On admission to ward, a detailed history was taken, relating to the age, sex, occupation (if any), mode of injury, and past and associated medical illness. Systemic examination was performed to recognize any preexisting medical and surgical illness. Local examination was conducted to know about the deformity, extent of swelling, local tenderness, and abnormal mobility. The neurovascular status was recorded in each case. Any associated injury was recorded and treatment carried out accordingly.

Routine blood investigations were done for all patients. These included haemoglobin, bleeding time, clotting time, complete blood count, urine examination, blood urea, and blood sugar. X-ray chest was also done to diagnose any pre-existing chest disease. Patients were operated as early as possible once the general condition of the patient was stable and patient was fit for surgery.

PREOPERATIVE PLANNING

Nail Size

1. **Nail width:** The diameter of the individual nail is selected as per

   A) Flynn et al's formula.

Diameter of nail= width of the narrowest point of the medullary canal on AP and LATERAL view X 0.4mm

B) Intra operative assessment Diameter of the nail is chosen so that each nail occupies atleast $1/3^{rd}$ or 40% of the medullary cavity.

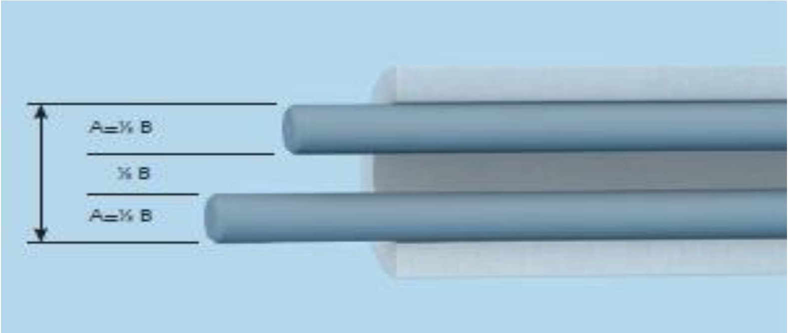


FIGURE 24 : INTRA OPERATIVE ASSESSMENT OF NAIL DIAMETER

2. **Nail length:** Lay one of the selected nails over the thigh / leg, and determine that it is of the appropriate length by fluoroscopy. The nail for femur should extend from the level of the distal femoral physis to a point approximately 2 cm distal to the capital femoral physis and 1 cm distal to the greater trochanteric physis and for tibia it should extend 2cm from the proximal physis till 5mm proximal to the distal physis.

FIGURE 25: NAIL LENGHTS IN FEMUR AND TIBIA

Preoperative preparation of patients:

- Patients were kept fasting overnight before surgery.
- All pre – op medication were administered.
- Adequate amount of compatible blood was kept ready for any eventuality.
- Entire lower limb including the genitalia and abdomen till umbilicus was prepared.
- A systemic antibiotic, usually a 3rd generation cephalosporin was administered 1 hour before surgery.

Under anaesthesia, closed reduction and internal fixation with TENS nails done under c-arm guidance.

FIGURE 26 : TENS NAILING SURGICAL SET

1. Titanium elastic nails
2. Bone awl
3. Inserter
4. Beveled tamp
5. Hammer
6. Steffe cutter

PROCEDURE FOR TENS NAILING OF DIAPHYSEAL FRACTURE OF FEMUR : RETROGRADE FIXATION

1. Under general / spinal anesthesia the patient is placed in supine on a radiolucent fracture table. The operative extremity is then scrubbed, painted and draped free.

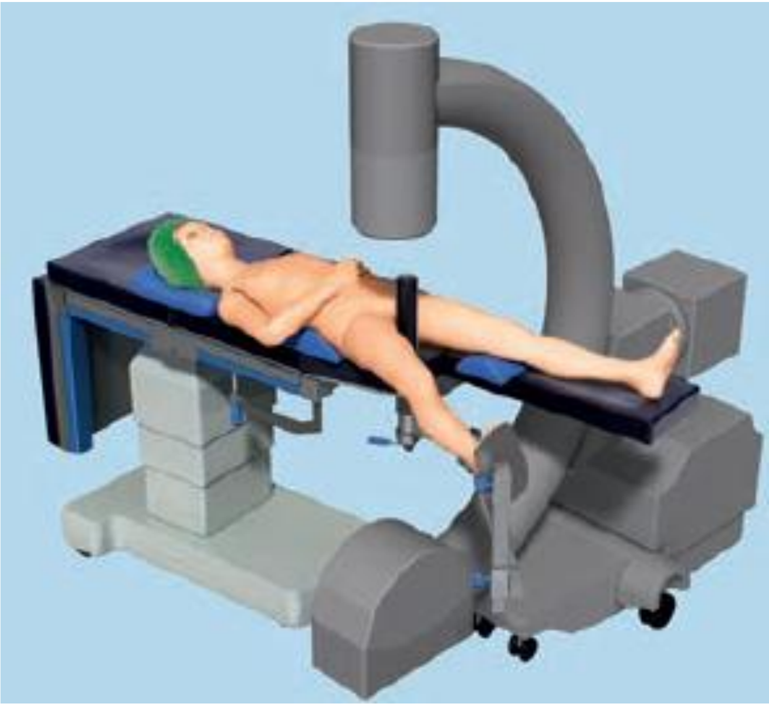


FIGURE 27 : POSITIONING AND PREPARATIONOF FEMUR FRACTURE CASE FOR TENS

2. Physis was identified by fluoroscopy, and mark its location on the skin.

FIGURE 28 : MARKING INCISION SITE

3. An incision was made on the lateral or medial aspect of the distal femur, starting 3 cm above the physis and extending distally for 2.5 cm. The entry point for the nail should be 2.5 cm– 3.0 cm proximal to the physis.
   Caution: When making an incision on the medial side one should be careful not to let the drill bit slip posteriorly in the region of the femoral artery.

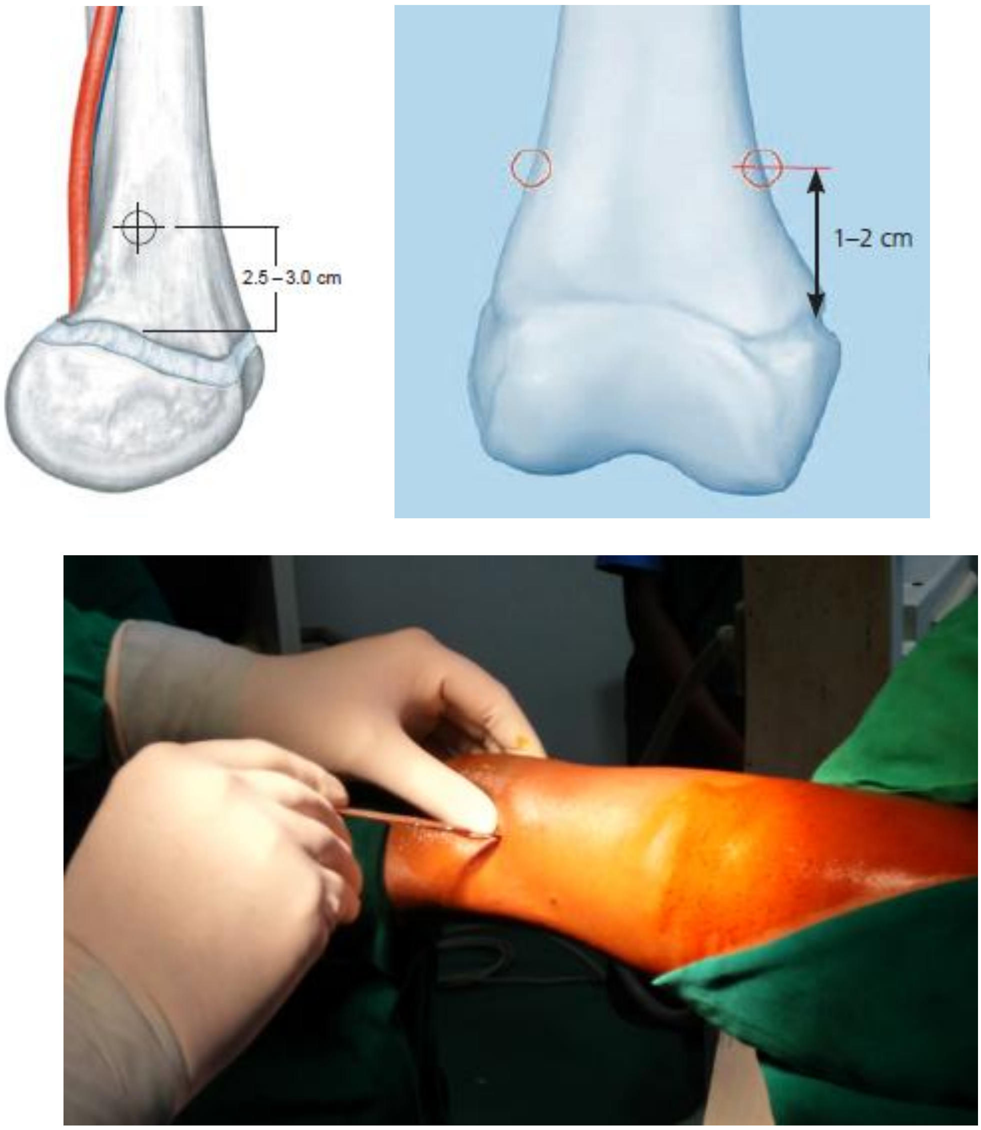


FIGURE 29 : MAKING INCISION FOR FEMUR ENTRY

4. Fascia lata was devided over a sufficient length. Using the awl at the upper end of the incision perpendicular to the bone with rotating movements a central mark was made. The awl was then lowered to an angle of 45° in relation to the shaft axis and perforating

of the bone was continued at an upward angle. The opening was made slightly larger than the selected nail diameter.

If use of end caps was intended for the nails, the holes were made corresponding to the core-diameter of the end cap.

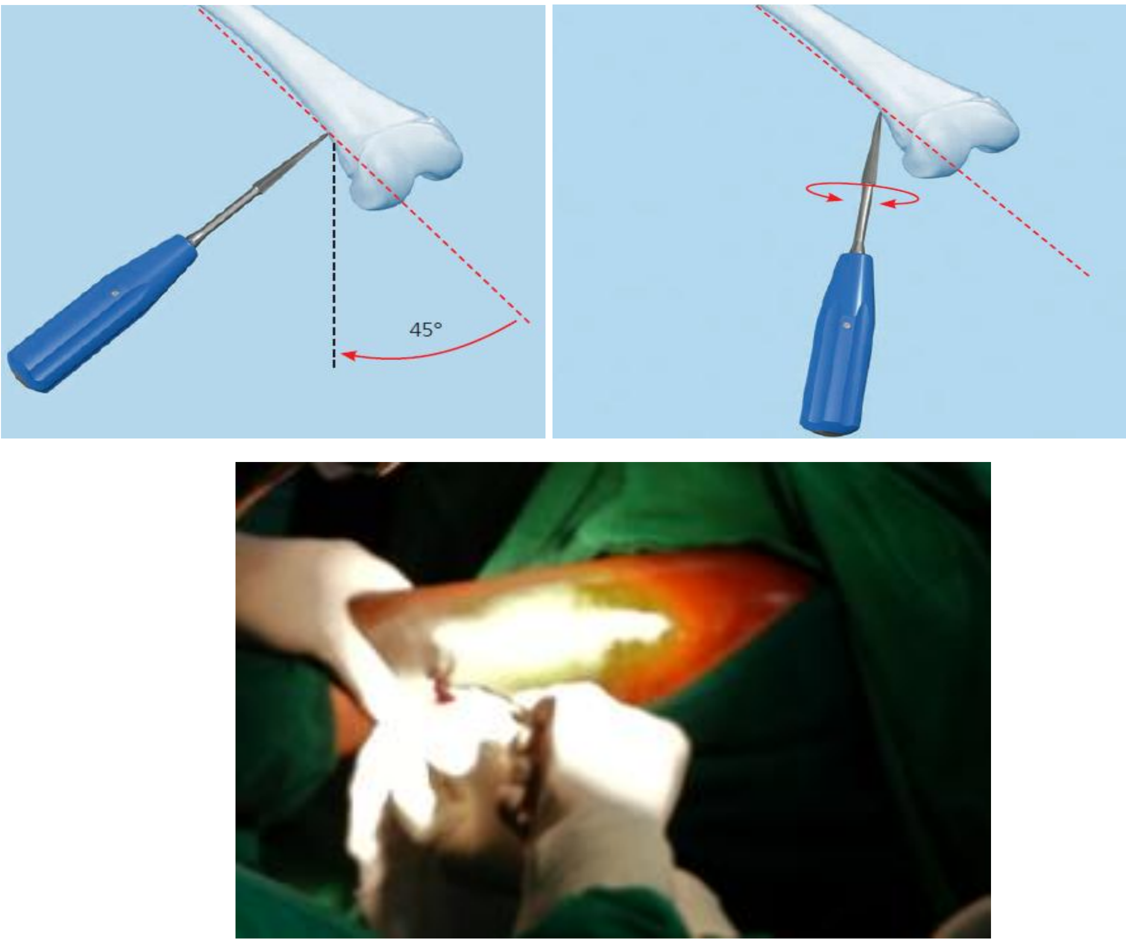


FIGURE 30 : USING AWL TO MAKE ENTRY FOR TENS

5. The position and insertion depth of the awl was checked with the image intensifier.

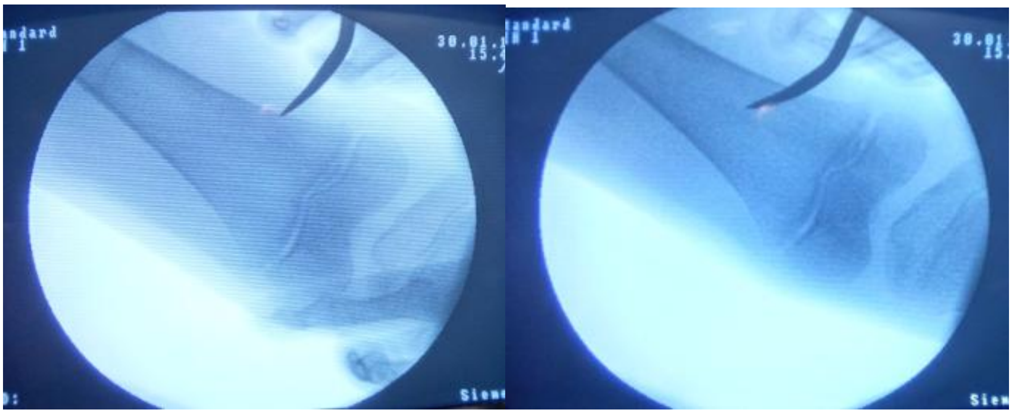


FIGURE 31: C-ARM IMAGES OF AWL ENTRY

6. The nail of suitable length and diameter which was selected with pre –op preparation was then stressed and bend according to the requirement and fracture pattern.

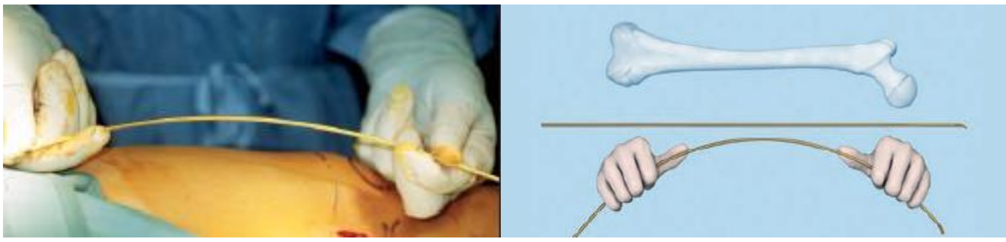


FIGURE 32 : PRE-BENDING NAIL INTRA-OPERATIVELY

7. First nail was loaded in the inserter. Laser marking on the straight nail end was matched with one of the guide markings on the inserter. The nail was inserted into the medullary canal with the nail tip at right angles to the bone shaft. Rotated through 180° and with the inserter the nail tip was alinged with the axis of the medullary canal.

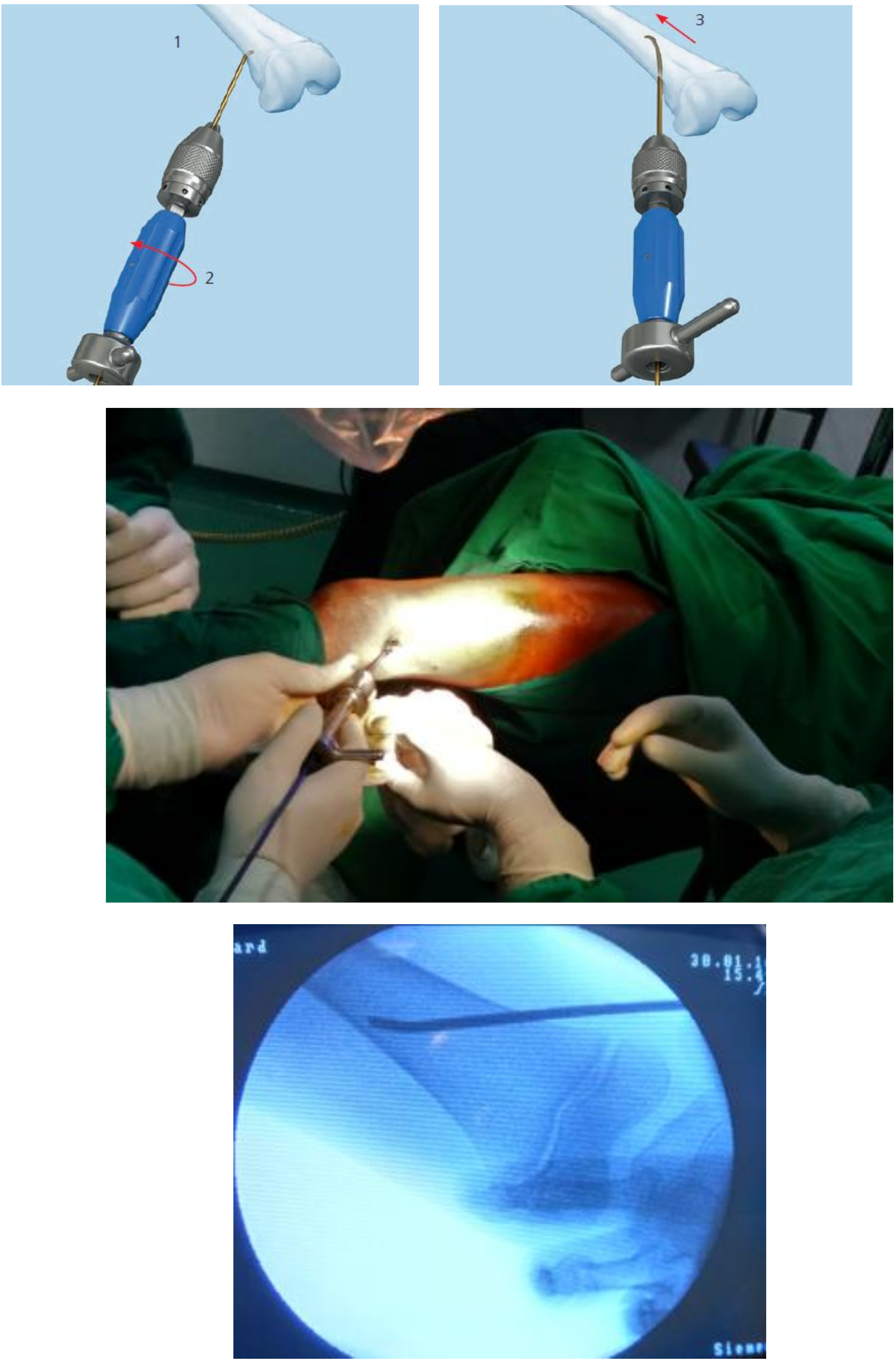


FIGURE 33: INSERTING TENS NAIL AND REALTED C-ARM PICTURE

8. Under image intensifier control, the nail was driven with rotatory movement occasionally using a hammer to the fracture site which was aligned to anatomical or near anatomical position with proper attention to limb rotation and length. By rotation movements of the T-handle with or without limb manipulation, the nail was directed to the proximal fragment which was pushed into better alignment by the nail.

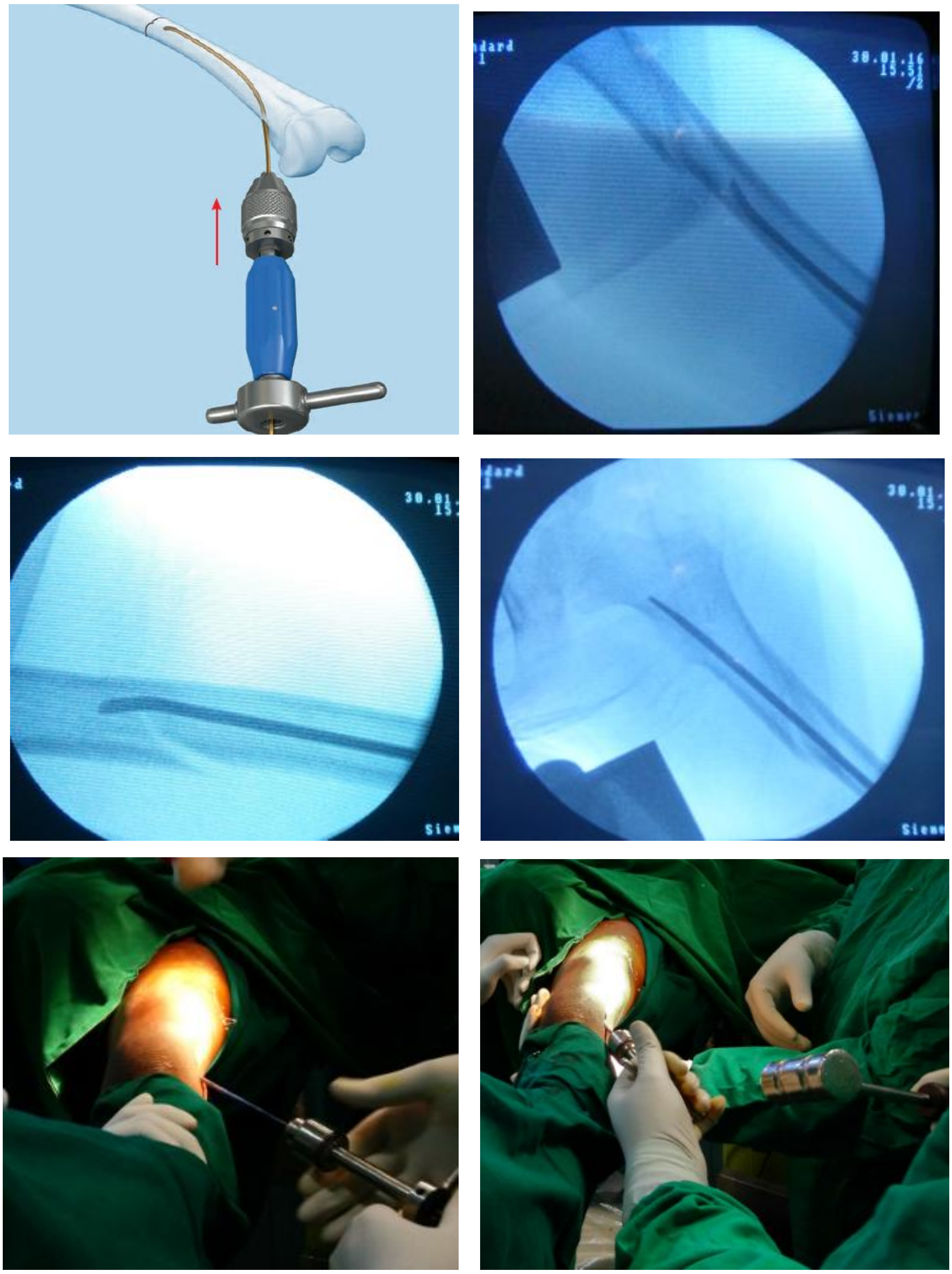


FIGURE 34 : ADVANCING TENS NAIL AND RELATED C-ARM IMAGES

9. At the same time the second nail was advanced to enter the proximal fragment and in the meantime any traction was released to avoid any distraction.

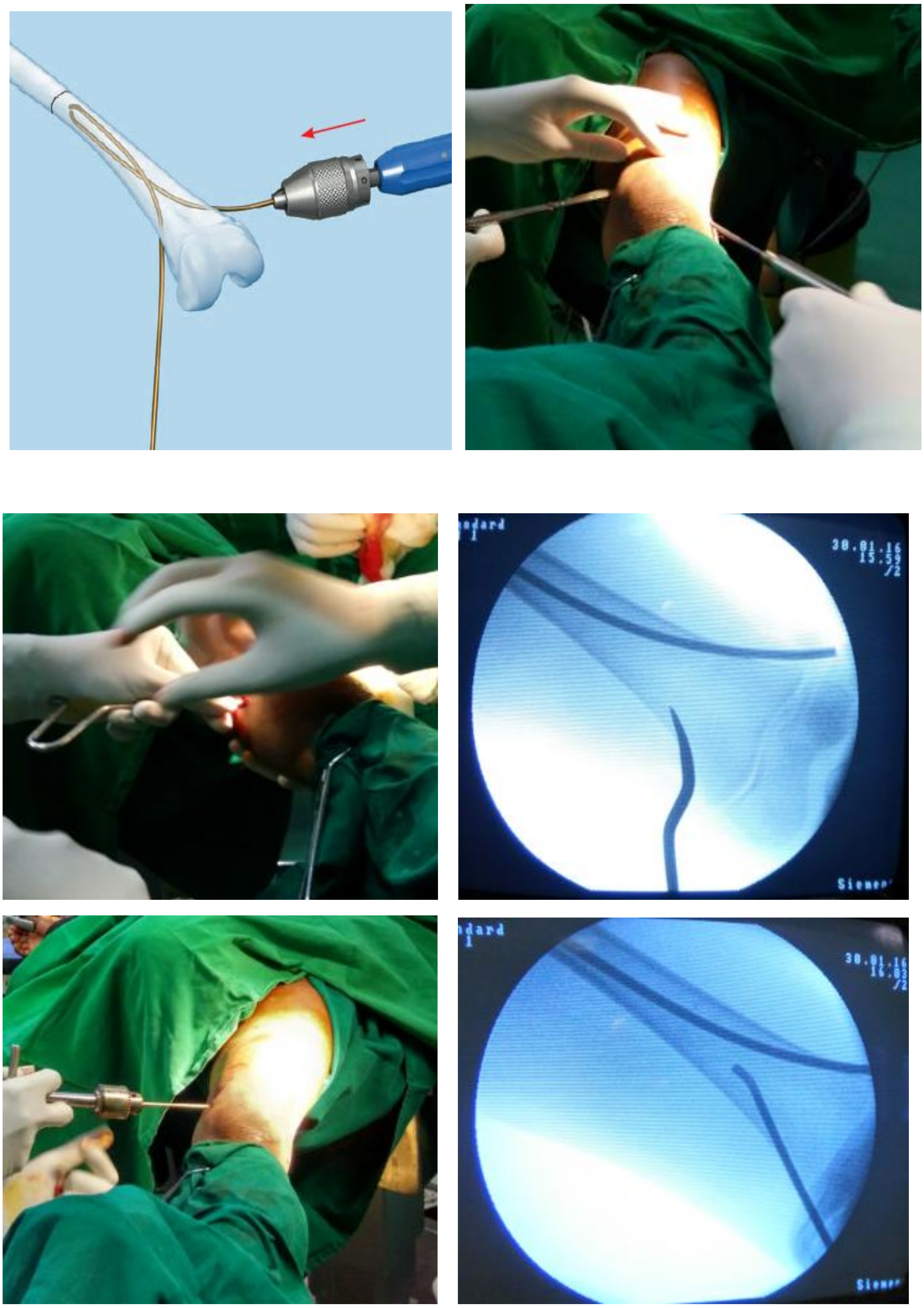


FIGURE 35: SECOND NAIL ENTRY AND ADVANCING WITH RELATED C-ARM IMAGES.

10. When the cavities were aligned correctly, the nails were advanced with gentle hammer blows or oscillating movements far enough across the fracture zone to ensure that the main fragments were held firmly. The nails were advanced as far as the metaphysis. The tips of the nails in the proximal fragment were correctly aligned in the frontal plane. At this point the stability and rotation were checked. Once the nails are fixed in the metaphysis it is no longer possible to adjust the rotation. Both nails were pushed further till their tips became fixed into the cancellous bone of the proximal femoral metaphysis without reaching the epiphyseal plate. The tips of the nail that entered the lateral femoral cortex should come to rest just distal to the trochanteric epiphysis. The opposite nail should be at the same level towards the calcar region ; too short nails should be avoided.

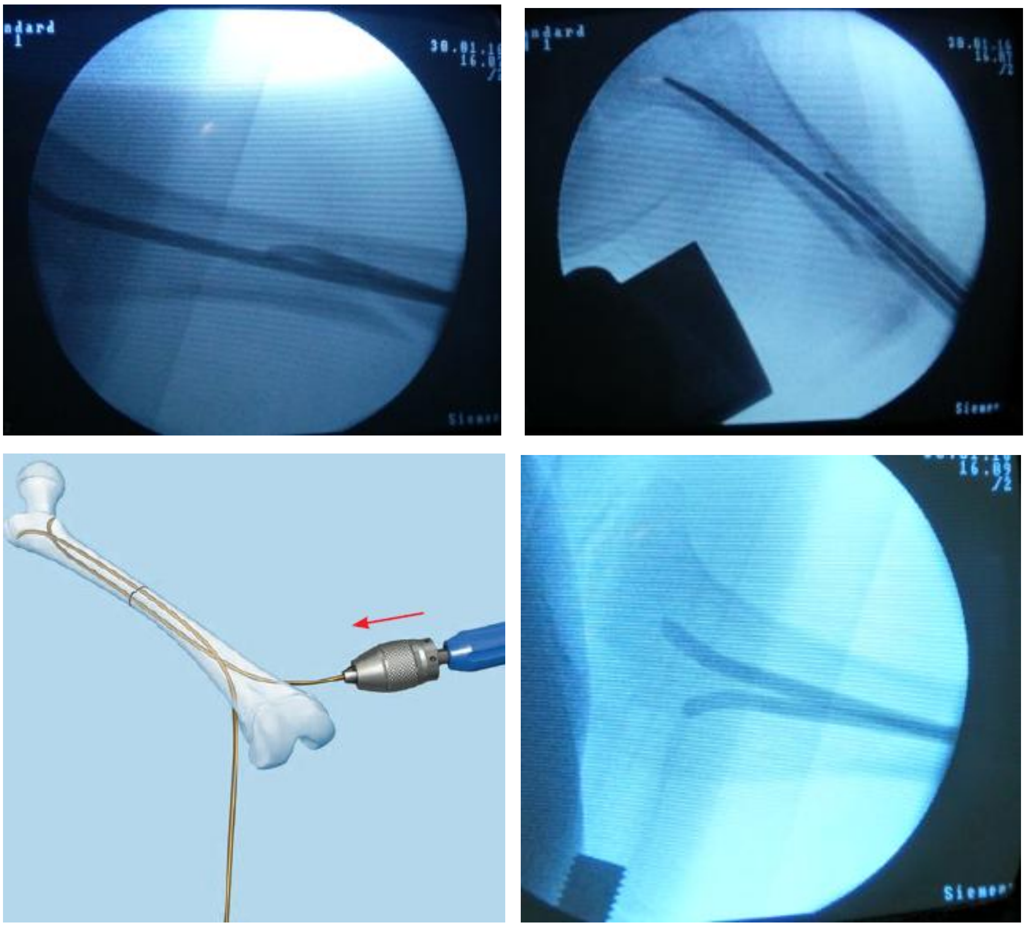


FIGURE 36 : CROSSING BOTH NAILS ACROSS FRACTURE LINE AND FIXATION IN CONTRA-LATERAL METAPHYSIS

11. The two-nail construct should be in a symmetrical alignment face to face with the maximum curvature of the nails at the level of the fracture .

12. Distally the nails were cut leaving only 0.5 - 1 cm outside the cortex. The extra osseous portion of the nails was slightly bent away from the bone to facilitate removal later on. To estimate the distance (X) between the current position of the nail tips (A) and the definitive anchoring position (B) in the proximal part on the image intensifier. This distance plus an extraction length of 10 mm (Y) produces the distance from the bone to the cutting point.

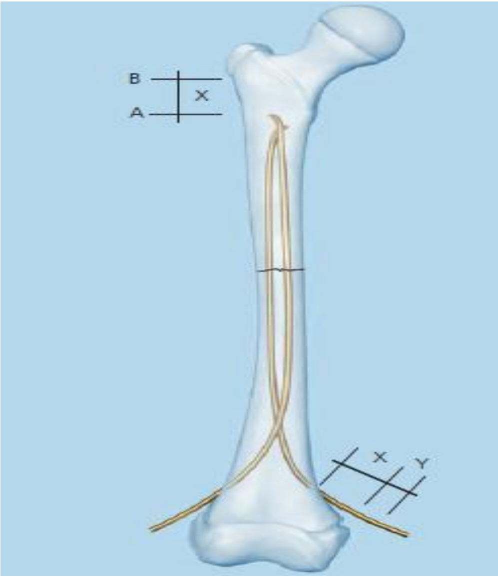


FIGURE 37 : CUTTING OF NAIL ENDS

13. After the nails were inserted and its length adapted, the corresponding bevelled impactor for TEN was used to bring the nails into their planned anchorage position in the proximal metaphysis with gentle hammer blows. In this process the bevelled part of the impactor must reach the cortical bone. This position guarantees a protection of about 8 – 10 mm.

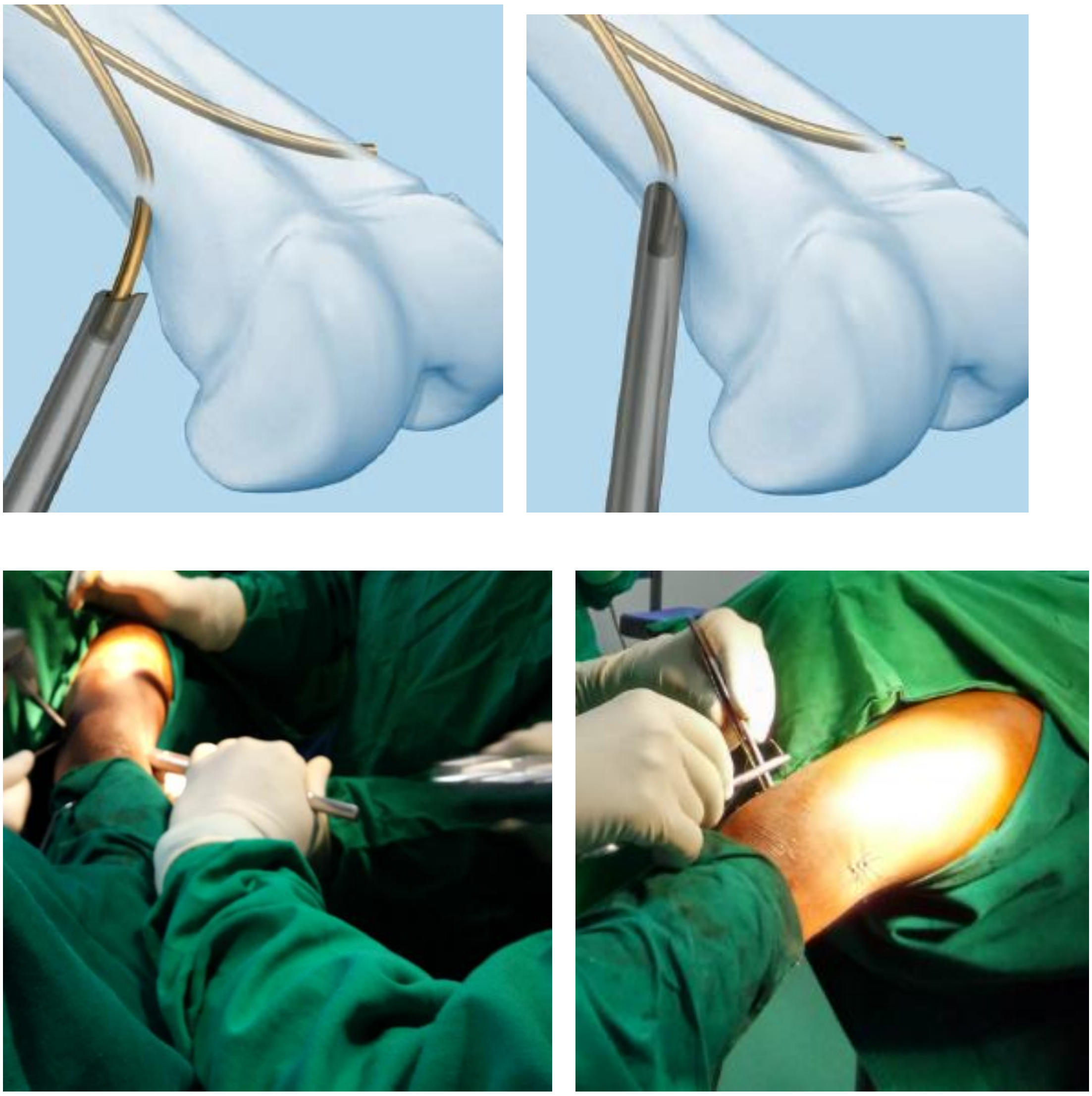


FIGURE 38 : BEVELING ENDS OF THE NAILS.

14. In all cases care was taken to :

- use nails with similar diameters
- to use the largest possible diameter
- to use the double C construct to ensure 3-point fixation.
- Care was taken not to twist the nails more than 90° to avoid "corkscrew phenomenon".

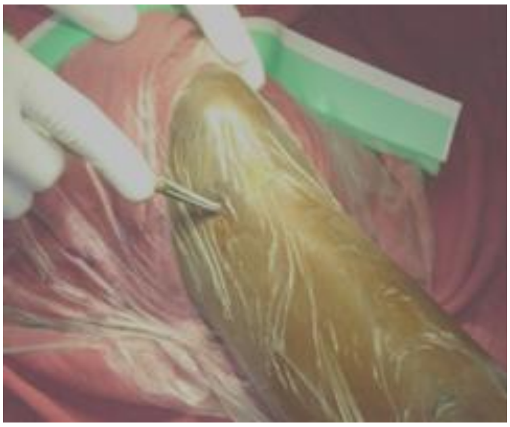
PROCEDURE FOR TENS NAILING OF DIAPHYSEAL FRACTURE OF : TIBIA ANTEGRADE FIXATION

1. General / Spinal anesthesia was administered, and patient was placed in supine on a radiolucent table, operative extremity was painted and draped, under fluoroscopy, the fracture site and proximal tibial physis were marked.

FIGURE 39 : ENTRY POINTS FOR TENS NAILING FOR TIBIA

FIGURE 40 : POSITION OF TIBIA FOR TENS NAILING

2. Nail entry point was marked as 1.5–2.0 cm distal to the physis, sufficiently posterior in the sagittal plane to avoid injury to the tibial tubercle apophysis. A longitudinal 2 cm incision was made on both the lateral and medial side of the tibia metaphysis just proximal to the desired bony entry point. Using a hemostat, the soft tissues were bluntly dissected down to bone.



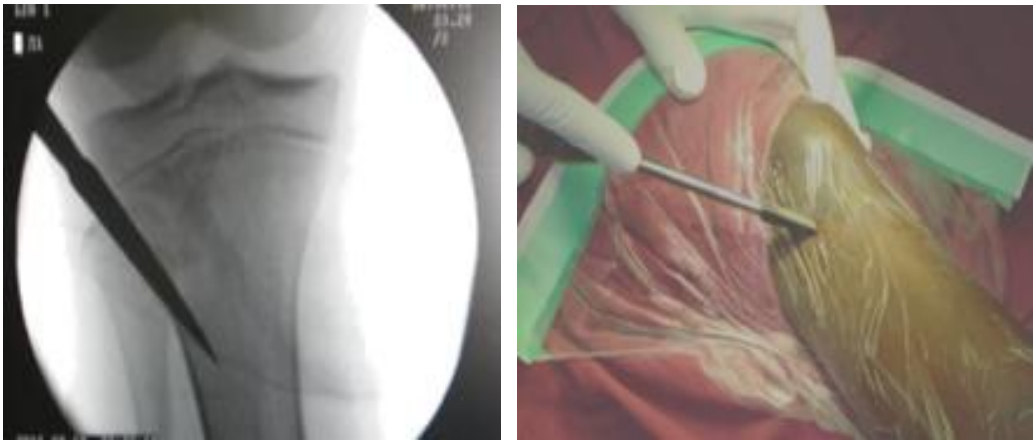


FIGURE 41: MAKING INCISION AND ENTRY IN TIBIA FOR TENS NAILING

3. Based on preoperative measurements, an appropriately sized implant was selected. Using an awl nail entry was made entering perpendicular to the bone surface then changing the angle to 45 degrees.

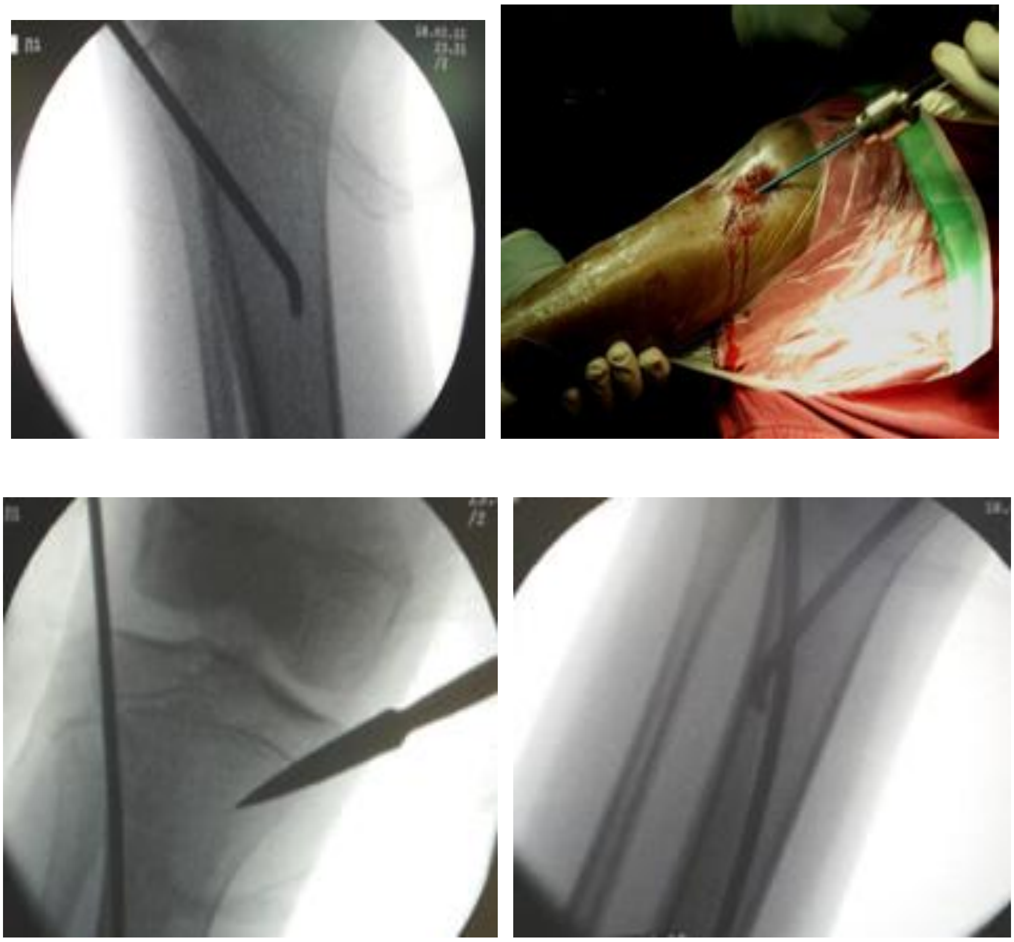


FIGURE 42: INSERTING TENS NAIL IN TIBIA

4. One nail was loaded in an inserter and then slowly under fluoroscopic guidance with rotator movements the nail was inserted till the fracture site. Under fluoroscopic guidance, the fracture was reduced in both the coronal and sagittal planes, and the first nail was advanced past the fracture site. Proper intramedullary position of the nail distal to the fracture site was confirmed on anteroposterior and lateral views and then the second nail was inserted using same method and then tapped across the fracture site.

FIGURE 43: TENS NAIL IN TIBIA AND WOUND CLOSURE

5. Both the nails were advanced until the tips lie just proximal to the distal tibial physis and under Fluoroscopic guidance proper fracture reduction as well as nail position was confirmed.

FIGURE 44: FINAL POSITION OF TENS NAIL IN TIBIA

6. Due to the triangular shape of the tibial medullary canal, both nails tend to lie dorsally, which would result in recurvation. Therefore, before hammering the nails in their final position in the distal metaphysic, the tips of both nails were turned slightly posteriorly in order to achieve the physiological antecurvation of the tibia. The fracture was compressed to prevent fixation in distraction and the nails were cut to length.

7. To minimize soft tissue irritation, the nails were backed out a few centimeters and cut along proximal tibial metaphysic using the same calculation method as in femur.

8. A tamp was used to re-advance the implants until <1 cm of nail lies outside of bone. In case of tibia the nails were not bend away from the bone to facilitate cutting, as this increased the nail prominence and subsequent skin irritation.

POSTOPERATIVE CARE:

- Patients were kept nil orally 4 to 6 hours post operatively
- IV fluids / blood transfusions were given as needed
- Analgesics were given according to the needs of the patient
- The limb was kept elevated over a pillow or BB splint as required.
- IV antibiotics were continued for 7 days and switched over to oral antibiotics on the 7th day and continued till the 14th day.
- Post operatively after 24 hours - Wound Inspection, Check X-ray to assess reduction and active static exercises/ passive exercises / active neighbouring joint movement at the earliest
- Sutures were removed on the 14^{th} postoperative day and patients were discharged.
- Patient was called for periodic follow up at 6 weeks, 8 weeks, 12 weeks, 6 months for clinical and radiological assessment.

. Post-operatively, in some cases of unstable fracture and where surgeon deemed necessary patients were immobilized with high groin POP slab for femur fracture or above knee POP slab for tibia fracture for 2 weeks and later changed to POP cast in deemed necessary at time of discharge and continued for another 6 weeks based on radiological assessment.

Partial weight bearing was started at 3 weeks as tolerated or after immobilization removal in cases put on slab/cast.

Full weight bearing was started by 8 - 12 weeks depending on the fracture configuration and callus response.

FOLLOW UP

Assessment done at 6, 12 and 24 weeks

At each follow up patients are assessed clinically, radiologically and the complications are noted

CLINICAL ASSESMENT

1) Pain

a. present

b. absent

2) Range of movements

JOINTS	HIP		KNEE		ANKLE	
MOVEMENTS	**FLEXION**	**EXTENSION**	**FLEXION**	**EXTENSION**	**DORSI - FLEXION**	**PLANTAR - FLEXION**
FULL RANGE	0 -160	0-10	0 -140	-	0 -35	0 -45
MILD RESTRICTION	0 -140	0-10	0 -120	-	0 -30	0 -35
MODERATE RESTRICTION	0 -100	0-10	0 -100	-	0 -20	0 -25
SEVERE RESTRICTION	<100	-	<100	-	< 20	< 25

TABLE 13: ASSESMENT OF RANGE OF MOVEMENT OF JOINTS

3)Measurement of limb length – noted for shortening / lengthening

4)Time of weight bearing

a. Partial weight bearing (in weeks)
b. Complete weight bearing (in weeks)

RADIOLOGICAL ASSESSMENT

X-ray thigh full length with hip and knee joints – AP and lateral views

X-ray leg full length with knee and ankle- AP and lateral

Alignment: 1. sagittal/coronal angulation (in degrees - <10 or >10)

2. rotational malallignment (in degrees - <10 or >10)

- Circumferential callus formation – good / adequate / poor.
- Visibility of fracture line – seen clearly / masked / not seen.

COMPLICATIONS

Minor complications :

a) When they resolved without additional surgery

b) Not resulting in long term morbidity.

Major complications :

a) When further operation was required

b) Long term morbidity ensued.

MINOR COMPLICATIONS:

1. Pain at the site of nail insertion
2. Minor angulation (< 10^0 – saggital/coronal; <10^0 rotational malallignment) at final follow-up (24 weeks)
3. Minor leg length discrepancy(< 2cm – shortening/lengthening) at final follow-up (24 weeks)
4. Inflamattory reaction to nails
5. Superficial infection at site of nail insertion
6. Delayed union

MAJOR COMPLICATIONS

1. Angulation exceeding the guidelines (>10^0 – saggital/coronal; or > 10^0 rotational malallignment) at final follow-up
2. Leg length discrepancy exceeding the guidelines (>2cm – shortening/lengthening) at final follow-up
3. Deep infection
4. Loss of reduction requiring revision surgery.
5. Surgery to revise nail placement
6. Compartment syndrome requiring surgery
7. Neurological damage after nailing
8. Delayed or nonunion leading to revision

The final outcome based on the above observations is done as per Flynn's criteria.

Flynn's criteria.

RESULTS / 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 14: OUTOCME ACCORDING TO FLYNN'S CRITERIA

ADDITIONAL VARIABLES included in our study

Variables 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

TABLE 15 : ADDITIONAL OUTCOME VARIABLES IN STUDY

Statistical Analysis :

Descriptive statistics like numbers , percentages , average , standard deviations , were used. Data was presented in the form of tables and graphs wherever necessary.

Inferential statistical tests like Chi- square and Fisher's exact probability test were applied to know the association between incidence of complications and clinical variables.

Insufficient reduction	Greater than 10° alignment defect in the coronal, sagittal or horizontal plane before onset of malunion.
Joint stiffness	Greater than 5° knee extension defect or greater than 20° hip or ankle range of motion.
Malalignment	Greater than 10° angulation in any plane after bone consolidation.
Recurrent fracture	New fracture during follow-up at the same level as the primary.
Surgical revision	Any fracture-related surgical procedure following TENS, other than those to remove material.
Delayed union	Failure to demonstrate complete union on X-rays taken after a specified time period following the fracture: 15 week for femur and tibia.

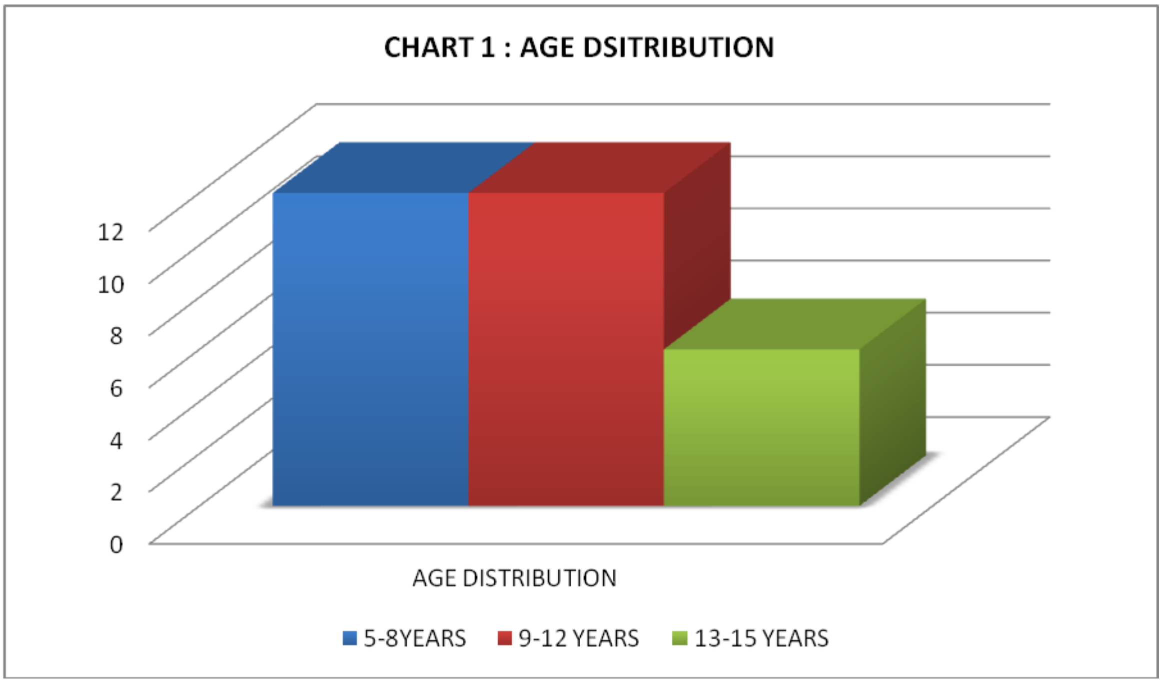
OBSERVATIONS AND RESULTS

Study design : A **prospective study** on about 30 consecutive patients in the age group 5years to 15 years with diaphyseal fracture of femur and tibia meeting the inclusion and the exclusion criteria, admitted to RLJ hospital attached to Sri Devaraj Urs Medical College.

1. **Age distribution :**

TABLE 16: AGE DISTRIBUTION

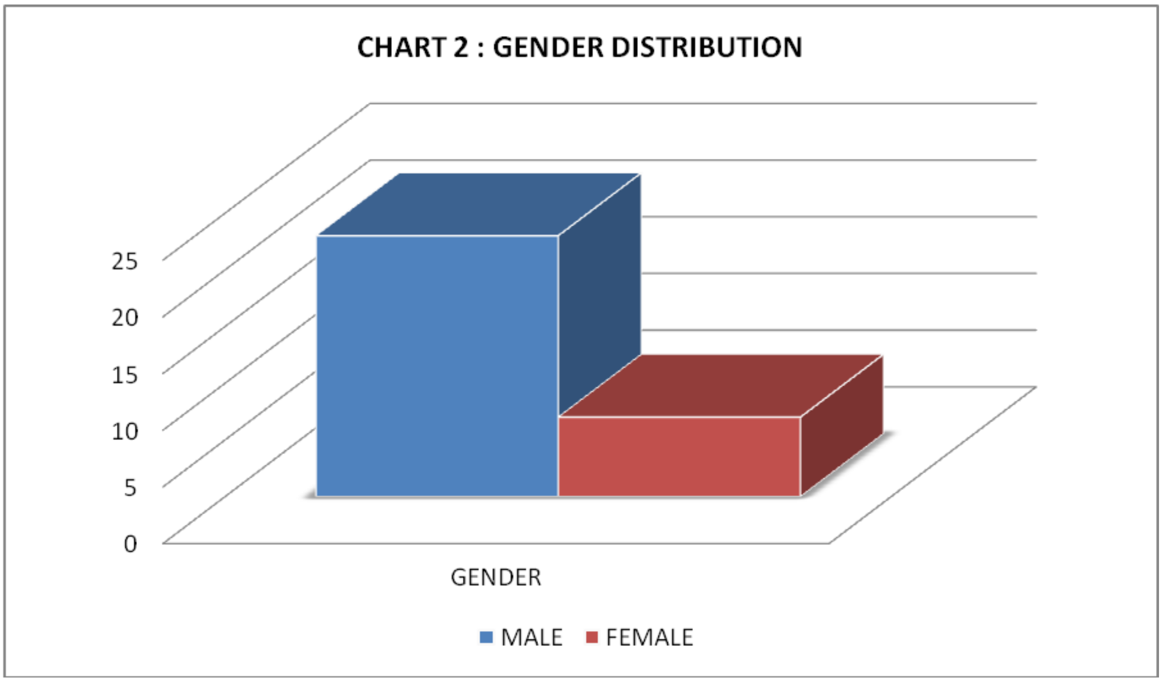
Age in years	Number of patients	%
5-8	12	40.0
9-12	12	40.0
13-15	6	20.0
Total	**30**	**100.0**



2.Gender distribution :

TABLE 17: GENDER DISTRIBUTION

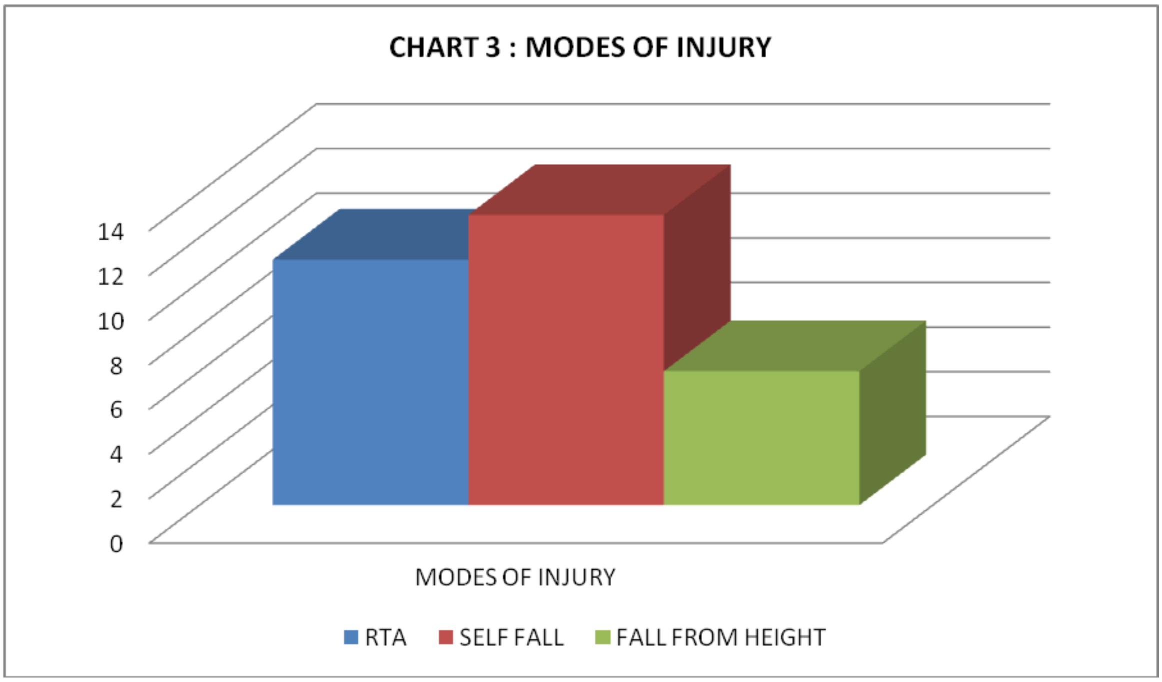
Gender	**Number of patients**	**%**
Male	23	76.6
Female	7	23.3
Total	**30**	**100.0**



3. Modes of injury :

TABLE 18: MODE OF INJURY

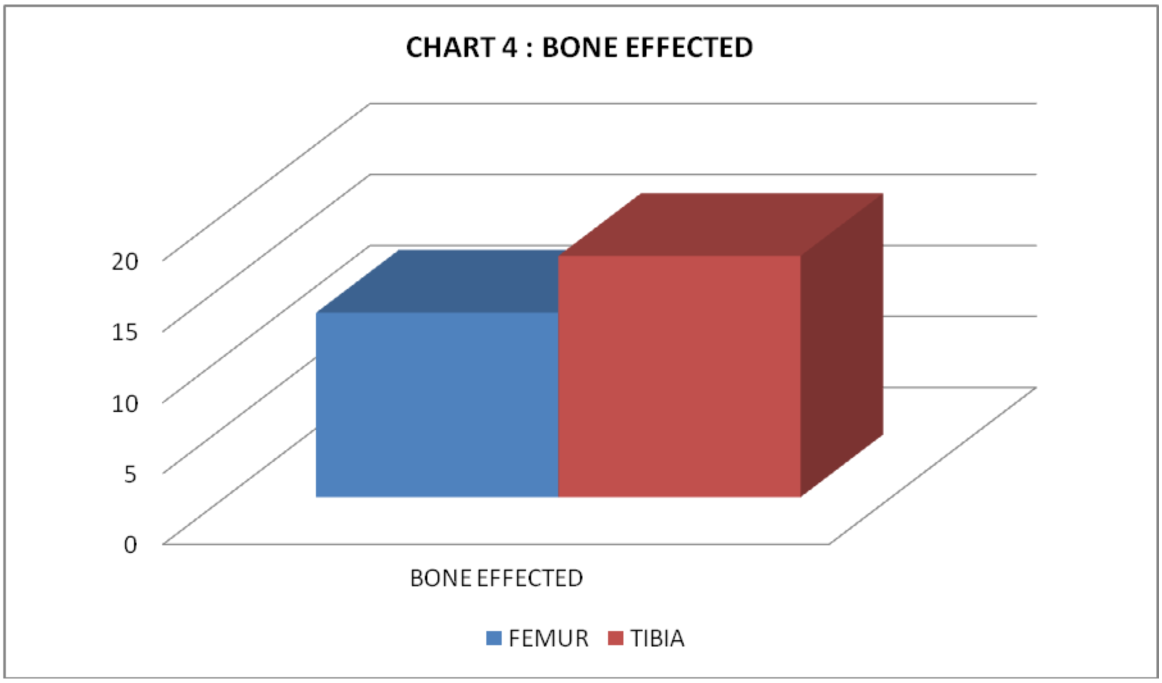
Mode of injury	Number of patients	%
RTA	11	36.7
Self fall/sports/weight fall	13	43.3
Fall from height	6	20
Total	**30**	**100.0**



4. Bones effected

TABLE 19: BONE AFFECTED

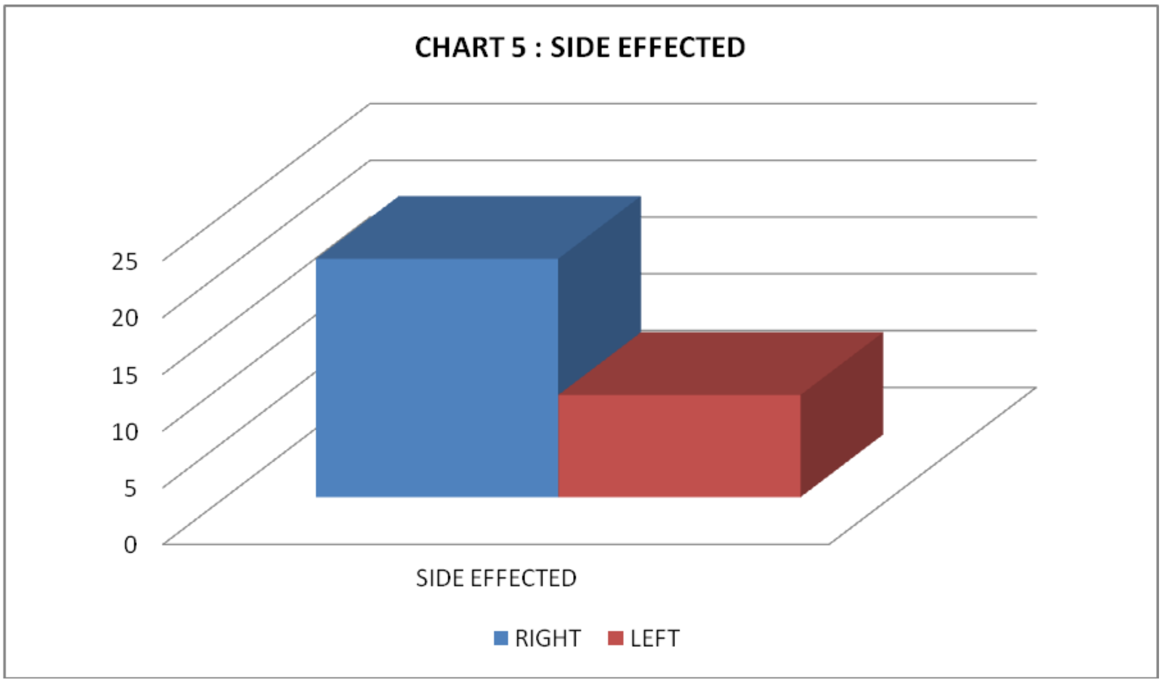
Bone affected	Number of patients	%
Femur	13	43.3
Tibia	17	56.7
Total	**30**	**100.0**



5. Side effected:

TABLE 20: SIDE AFFECTED

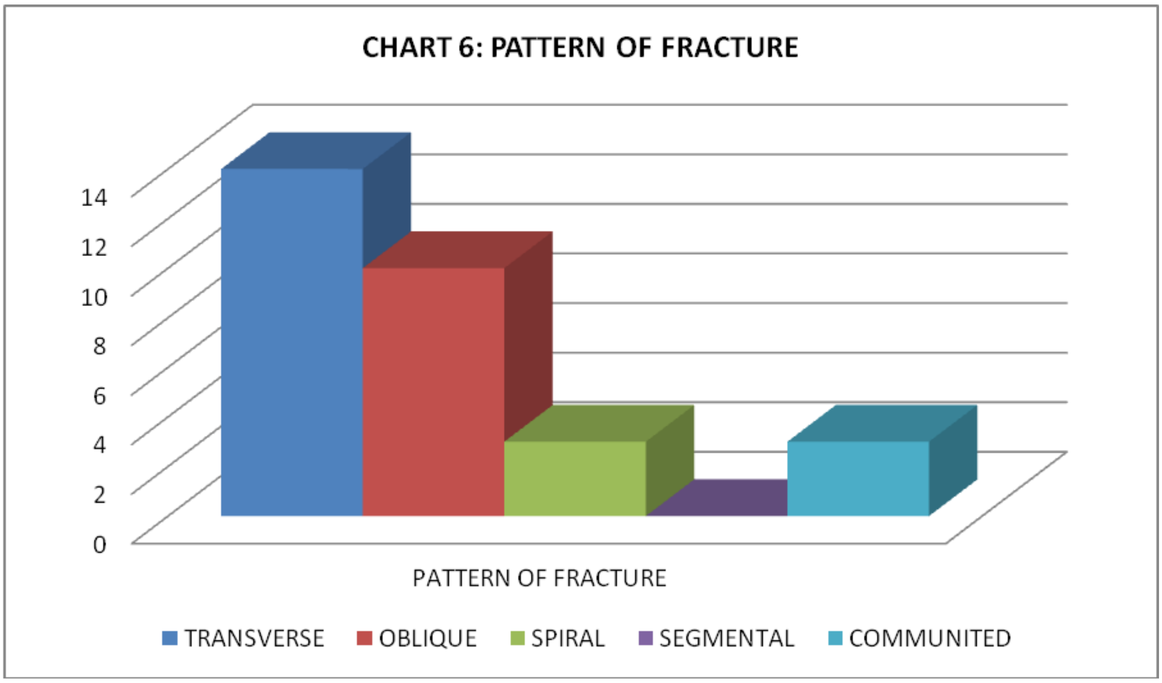
Side affected	Number of patients	%
Right	21	70.0
Left	9	30.0
Total	**30**	**100.0**



6. Pattern of fracture:

TABLE 21: PATTERN OF FRACTURE

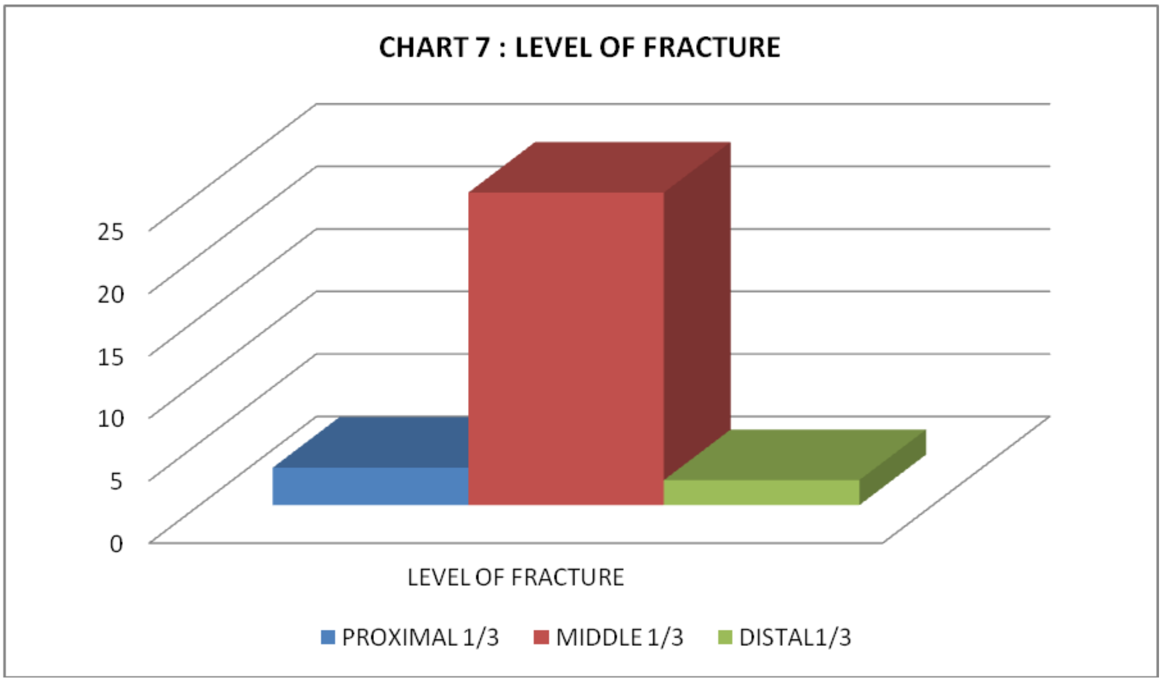
Pattern of fracture	**Number of patients**	**%**
Transverse	14	46.70
Oblique	10	33.33
Spiral	3	10.0
Segmental	0	0.0
Communited	3	10.0
Total	**30**	**100.0**



7. Level of fracture :

TABLE 22: LEVEL OF FRACTURE

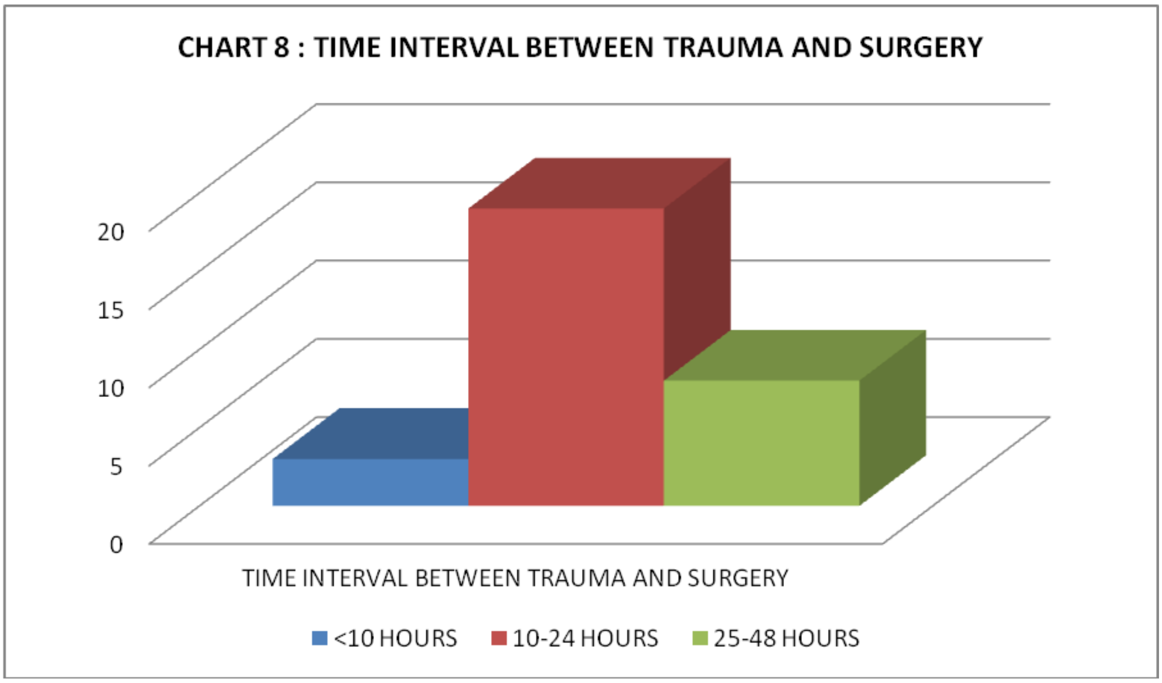
Level of fracture	Number of patients	%
1.PROXIMAL 1/3rd	3	10.0
2.MIDDLE 1/3rd	25	83.33
3.DISTAL 1/3rd	2	6.70
Total	**30**	**100.0**



8. Time interval between trauma of patient and the surgery .

TABLE 23: TIME INTERVAL BETWEEN TRAUMA AND SURGERY

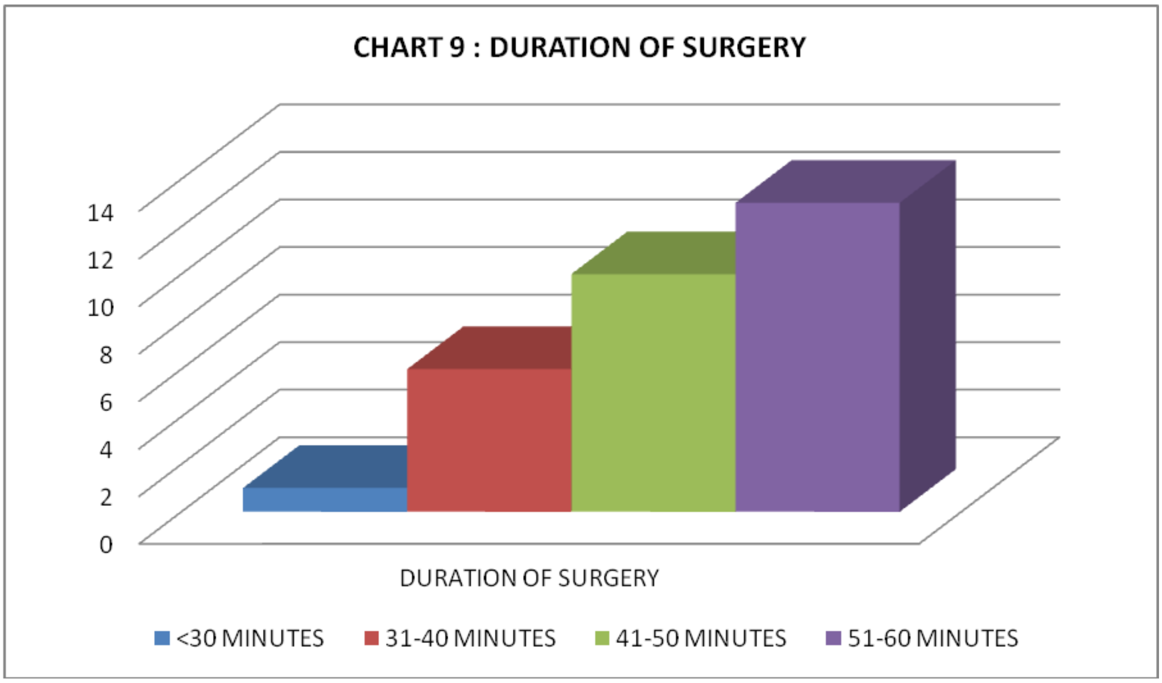
Time of interval between trauma & surgery	**Number of patients**	**%**
< 10 hours	3	10.0
10-24 hours	19	63.33
24 – 48 hours	8	26.67
Total	**30**	**100.0**



9. **Duration of surgery :**

TABLE 24: DURATION OF SURGERY IN MINUTES

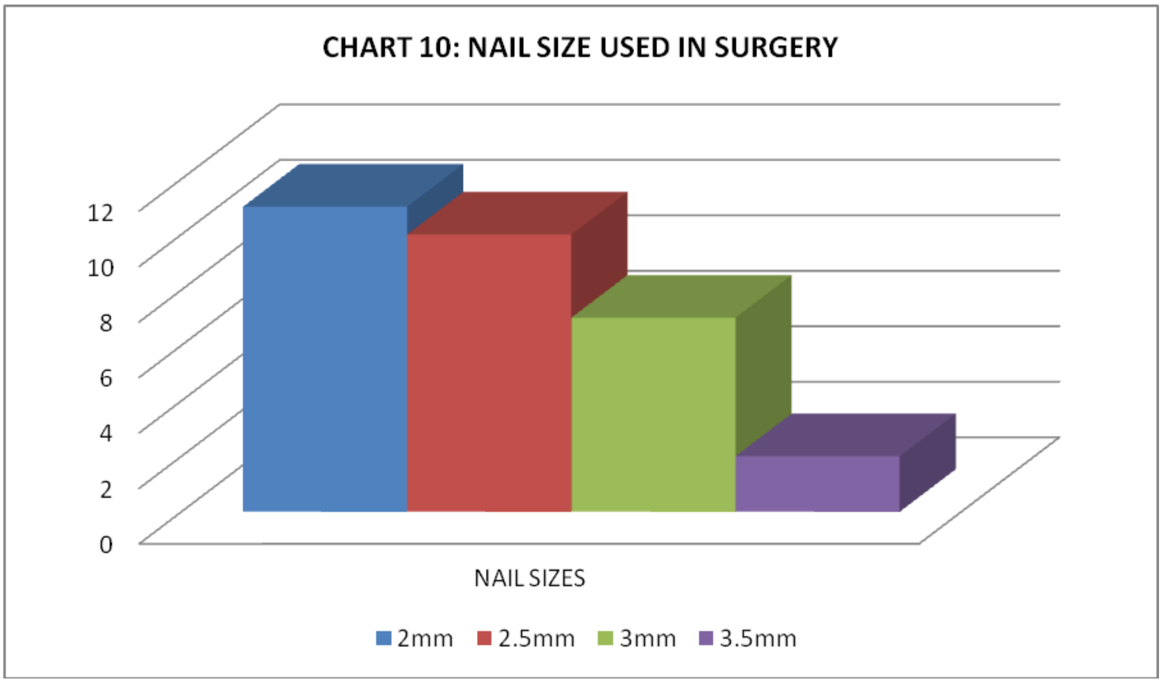
Duration of surgery (min)	**Number of patients**	**%**
<30	1	3.33
30-40	6	20.0
41-50	10	33.33
51-60	13	43.33
Total	**30**	**100.0**



10. Nail sizes used in surgeries. In all patients both the nails used were of same size.

TABLE 25: STANDARD NAIL SIZES USED IN MM.

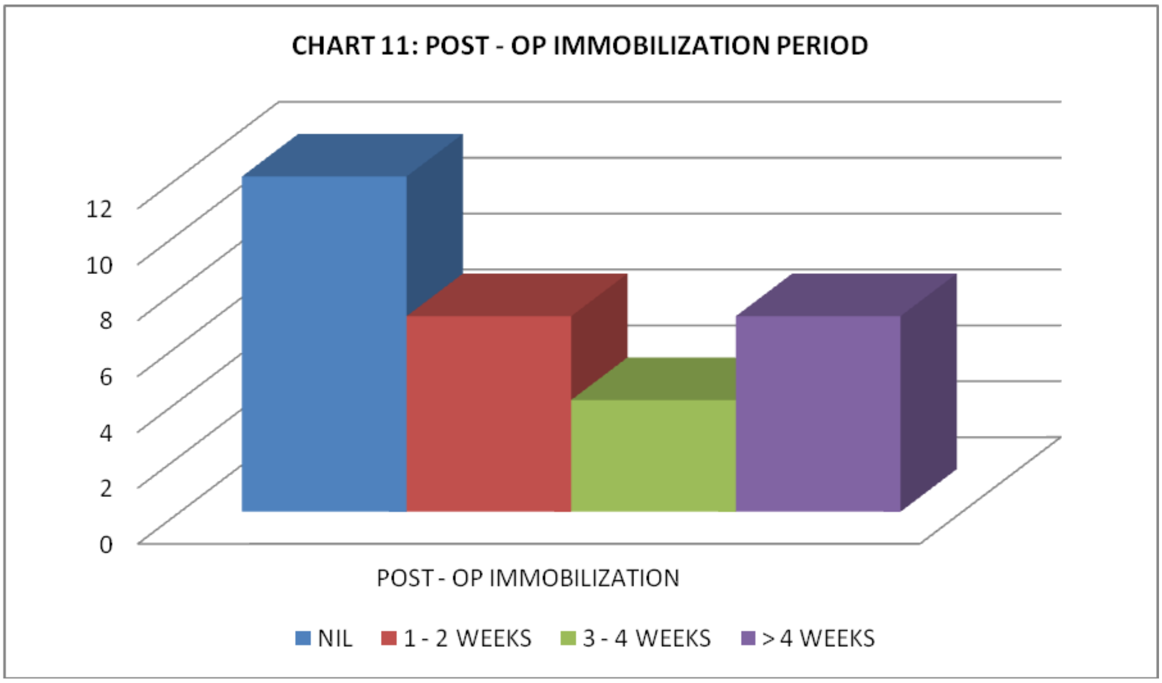
Nail size used	Number of patients	%
2 mm	11	36.67
2.5 mm	10	33.33
3 mm	7	7.78
3.5 mm	2	6.67
Total	**30**	**100.0**



11. **Post – op immobilization** given to patients till starting of partial weight bearing. During immobilization, patients were allowed for non weight bearing ambulation with the help of walking aid.

TABLE 26: POST-OPERATIVE IMMOBILIZATION

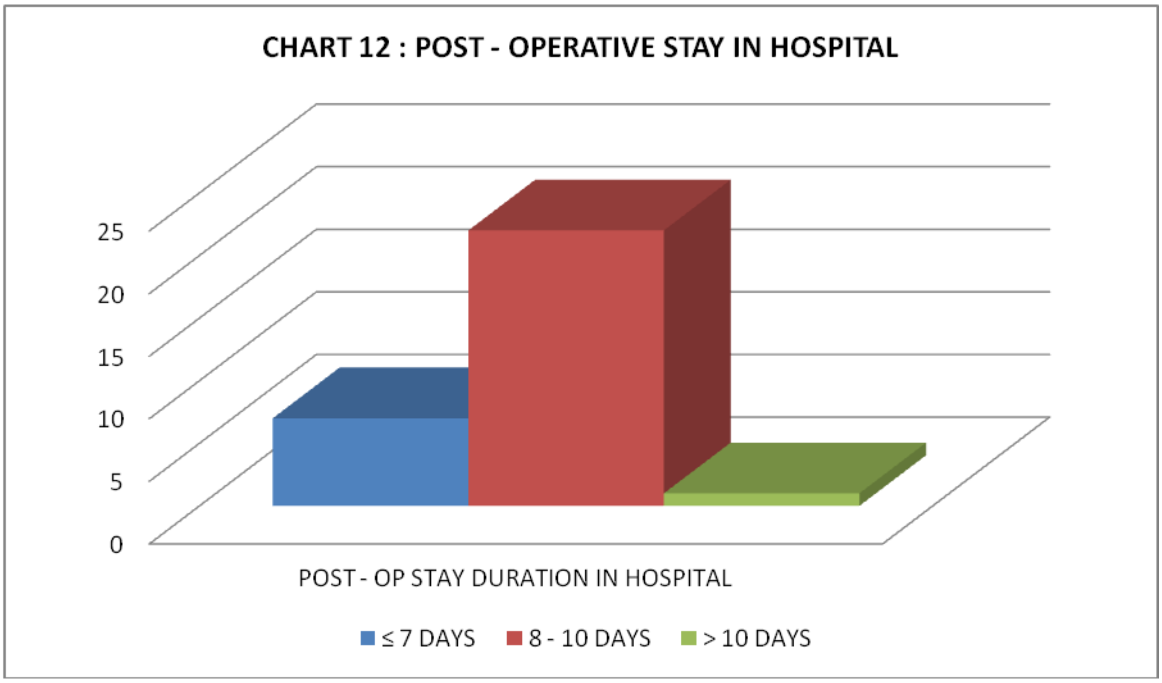
Post-op immobilization	**Number of patients**	**%**
NIL	12	40.0
1 – 2 weeks	7	23.33
3 – 4 weeks	4	13.33
>4 weeks	7	23.33
Total	**30**	**100.0**



12. Duration of stay in hospital following surgery :

TABLE 27: DURATION OF STAY IN HOSPITAL STAY IN DAYS.

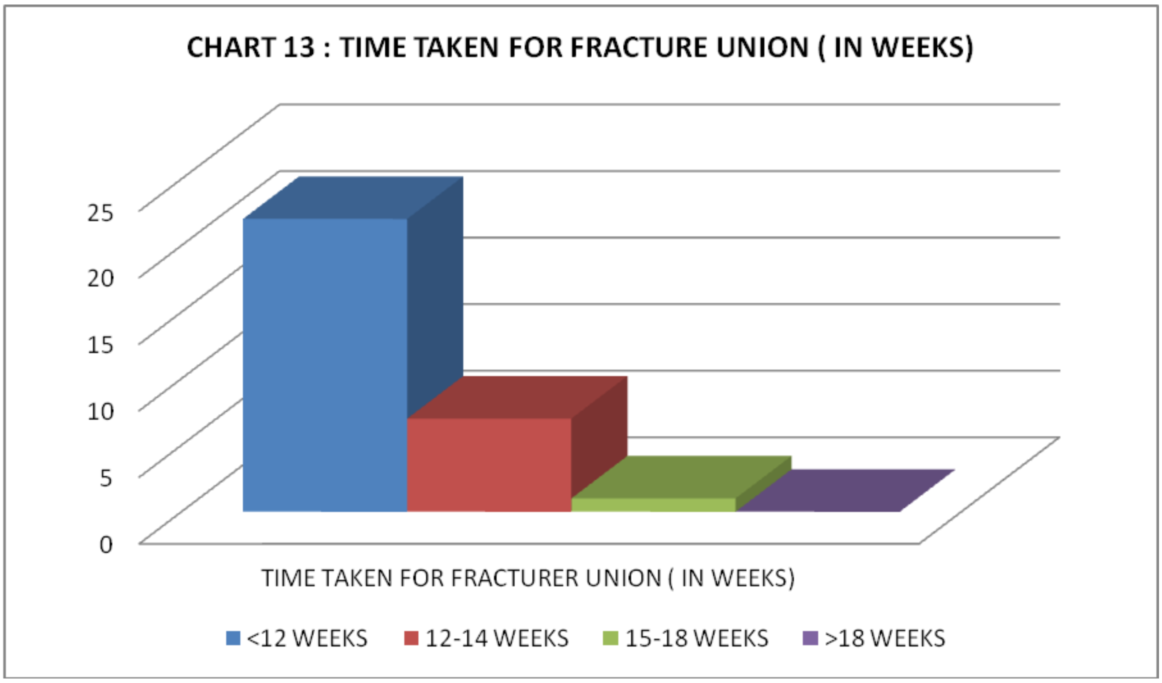
Duration of stay (days)	Number of patients	%
≤ 7	7	23.33
8 - 10	22	73.33
> 10	1	3.33
Total	**30**	**100.0**



13. **Time taken for union of fracture** as decided by clinical and radiological assessment following surgery (CRIF + TENS) for tibia and femur fractures in patients studied.

TABLE 28: TIME FOR UNION

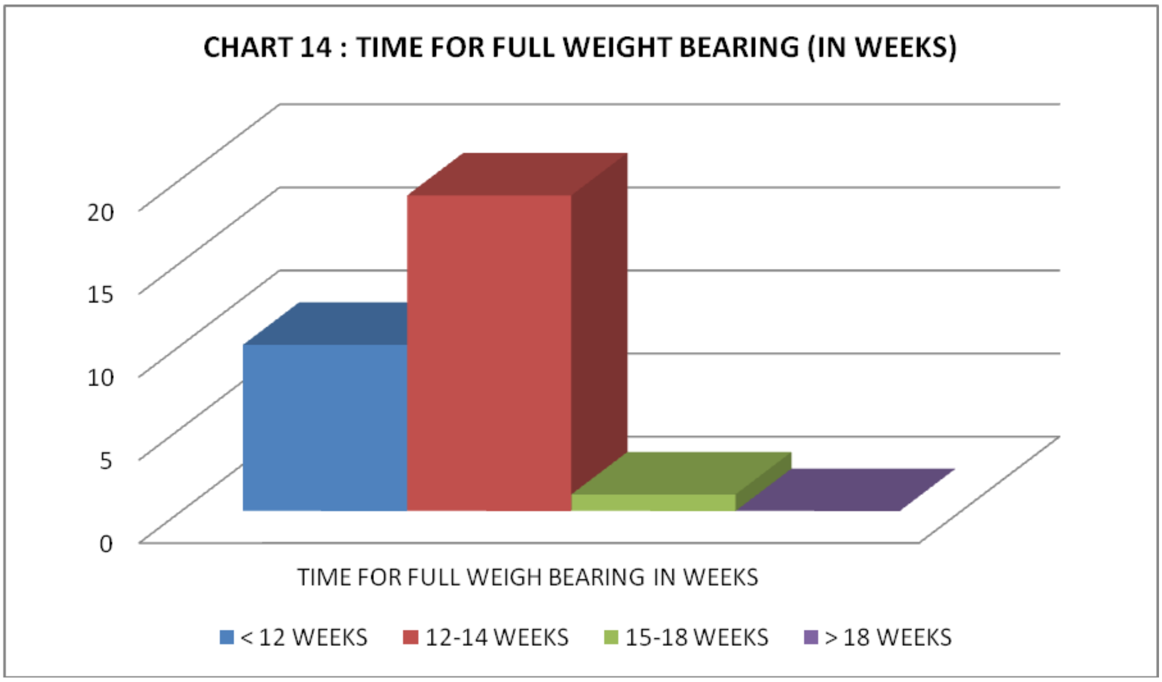
Time for union	**Number of patients**	**%**
< 12 weeks	22	73.33
12 – 14 weeks	7	23.33
15 – 18 weeks	1	3.33
>18 weeks	0	0.0
Total	**30**	**100.0**



14. **Time to full weight bearing :**

TABLE 29: TIME OF FULL WEIGHT BEARING

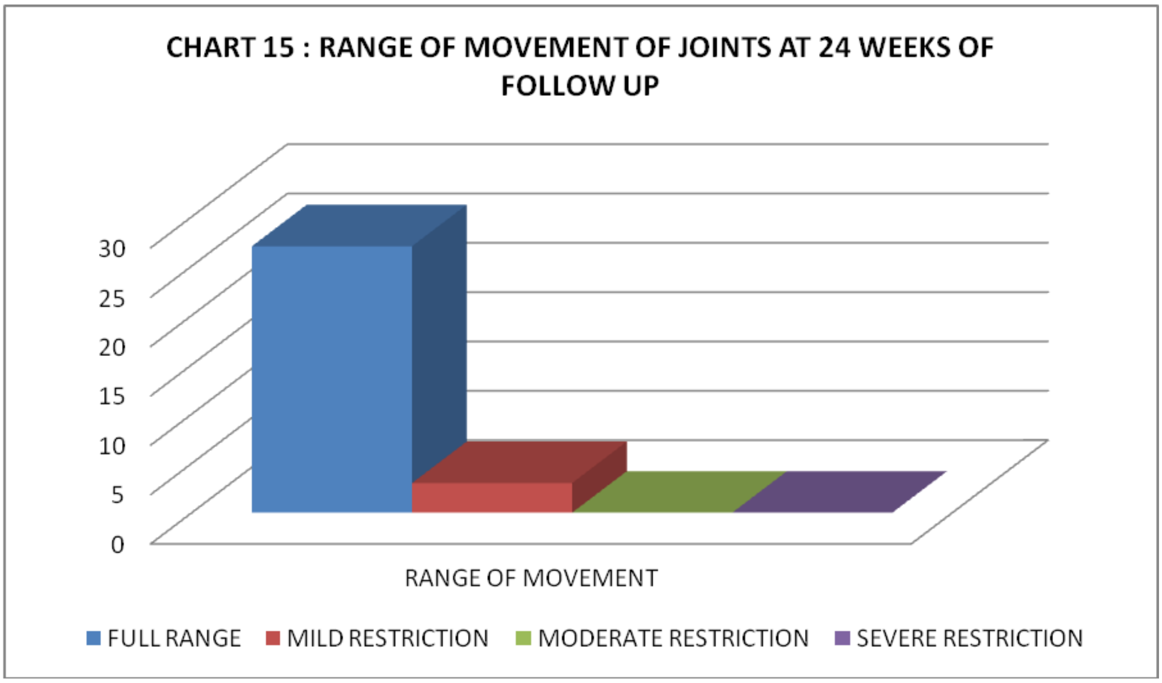
Time for full weight bearing	Number of patients	%
< 12 weeks	10	33.33
12 – 14 weeks	19	63.33
15 – 18 weeks	1	3.33
>18 weeks	0	0.0
Total	**30**	**100.0**



15. **Range of movement** (in degrees) of joints adjacent to the bone fractured achieved by the patient at 24 weeks of follow up following surgery.

TABLE 30: RANGE OF MOVEMENTS AT 24 WEEKS(DEGREES)

Range of movements(degrees)	Number of patients	%
Full range	27	90.0
Mild restriction	3	10.0
Moderate restriction	0	0
Severe restriction	0	0
Total	**30**	**100**



16. **Complication observed** till 24 weeks follow up:

<u>TABLE 31.A : COMPLICATIONS</u>

Complications	Number of patients	percentage
NIL	17	56.66
MINOR	13	43.33
MAJOR	0	0.0
TOTAL	30	100.0

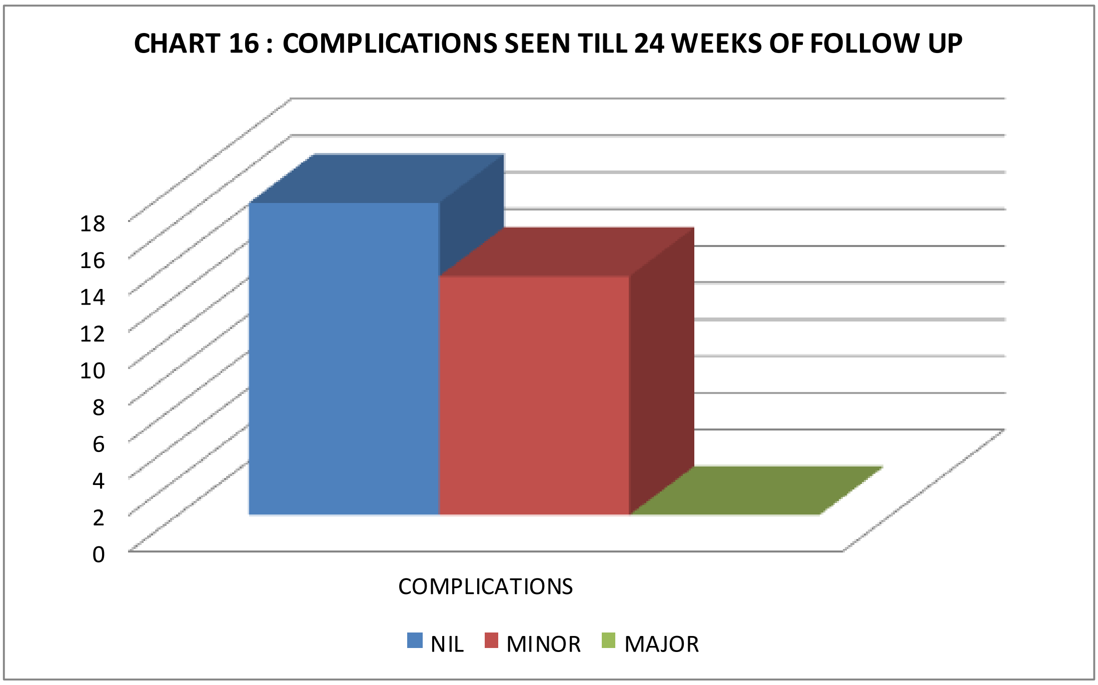
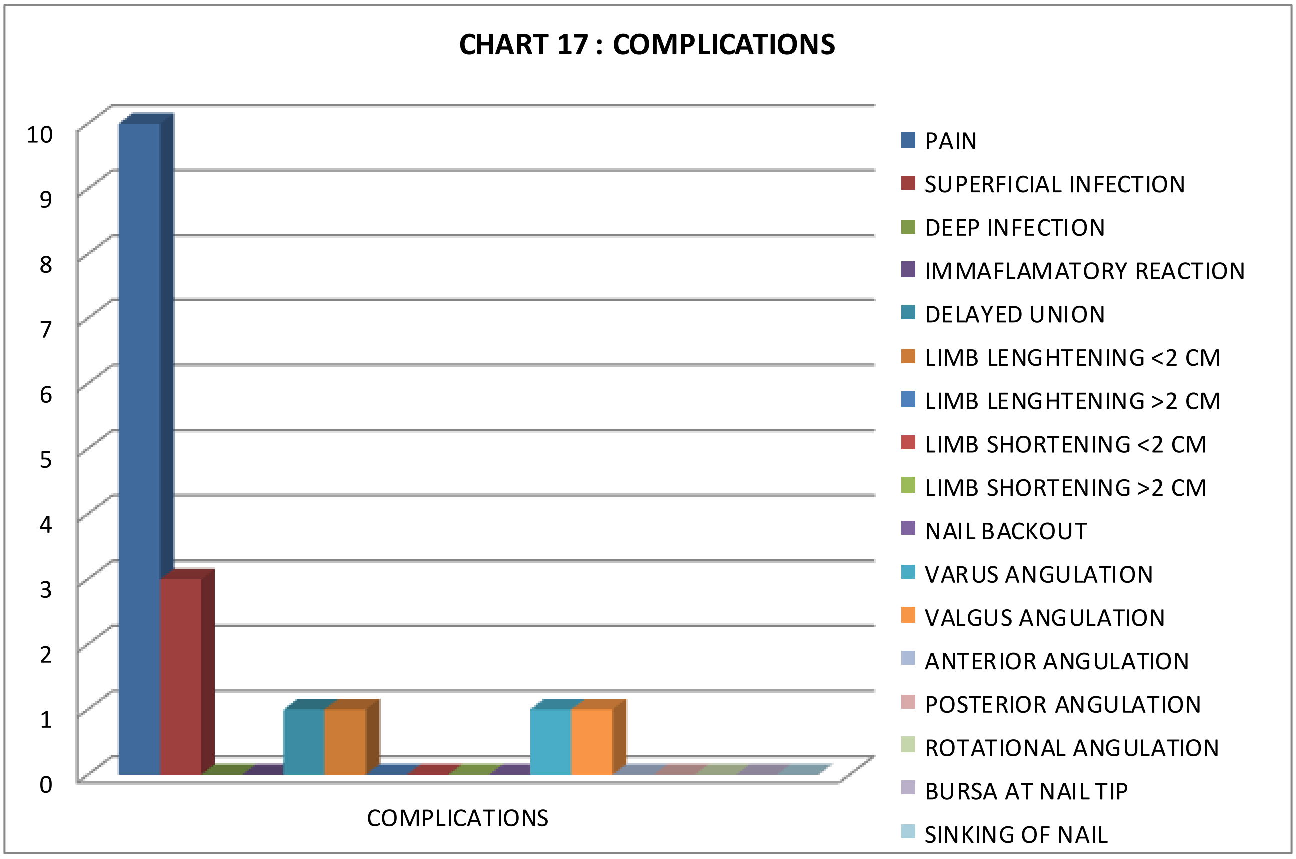


TABLE 31.B. MINOR AND MAJOR COMPLICATIONS

Complications	No. of cases	Percentage
1. Pain	10	33.33
2. Infection		
2.1. Superficial	3	10.0
2.2. Deep	0	0.0
3. Inflammatory reaction	0	0.0
4. Delayed union and non union	1	3.33
5. Limb lengthening		
5.1. < 2 cm	1	3.3
5.2. > 2 cm	0	0
6. Limb shortening		
6.1. < 2 cm	0	0
6.2. > 2 cm	0	0
7. Nail back out	0	0
8. Mal alignment		
8.1. Varus angulation	1	3.3
8.2. Valgus angulation	1	3.3

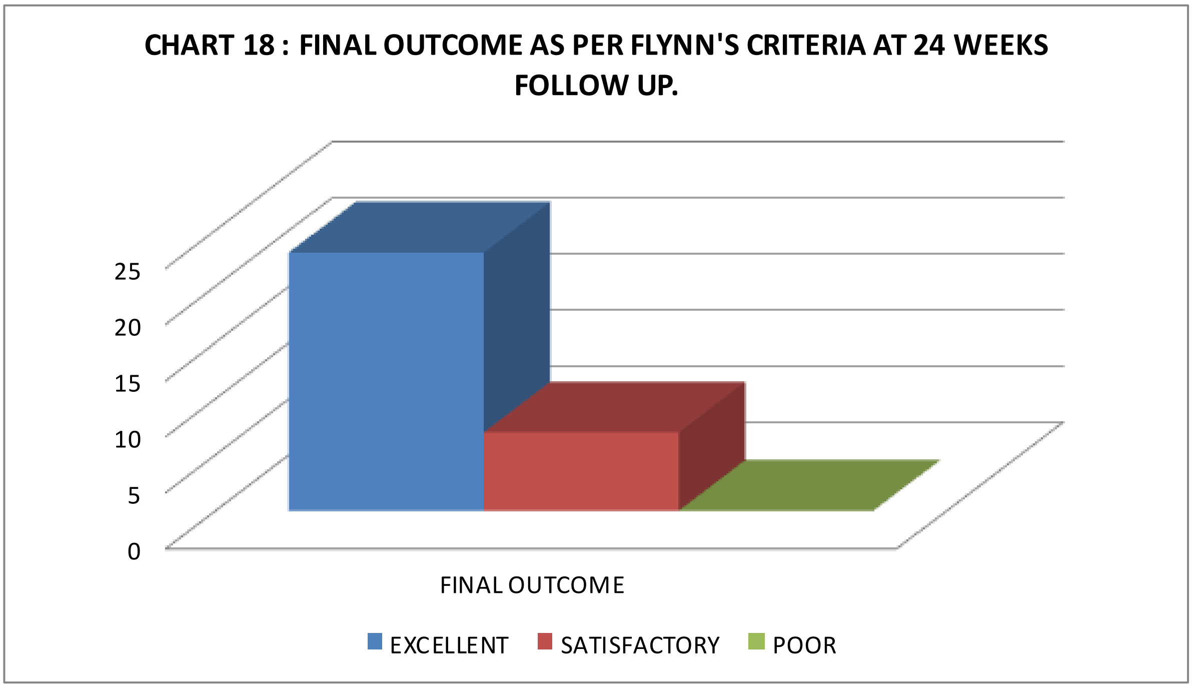
8.3.	Anterior angulation	0	0
8.4.	Posterior angulation	0	0
8.5.	Rotational malalignment	0	0
9.	Bursa at the tip of the nail	0	0
10.	Sinking of the nail into the medullary cavity	0	0



17. **Final outcome as per Flynn's criteria**

TABLE 32: OUTCOMES AS PER FLYNN'S CRITERIA

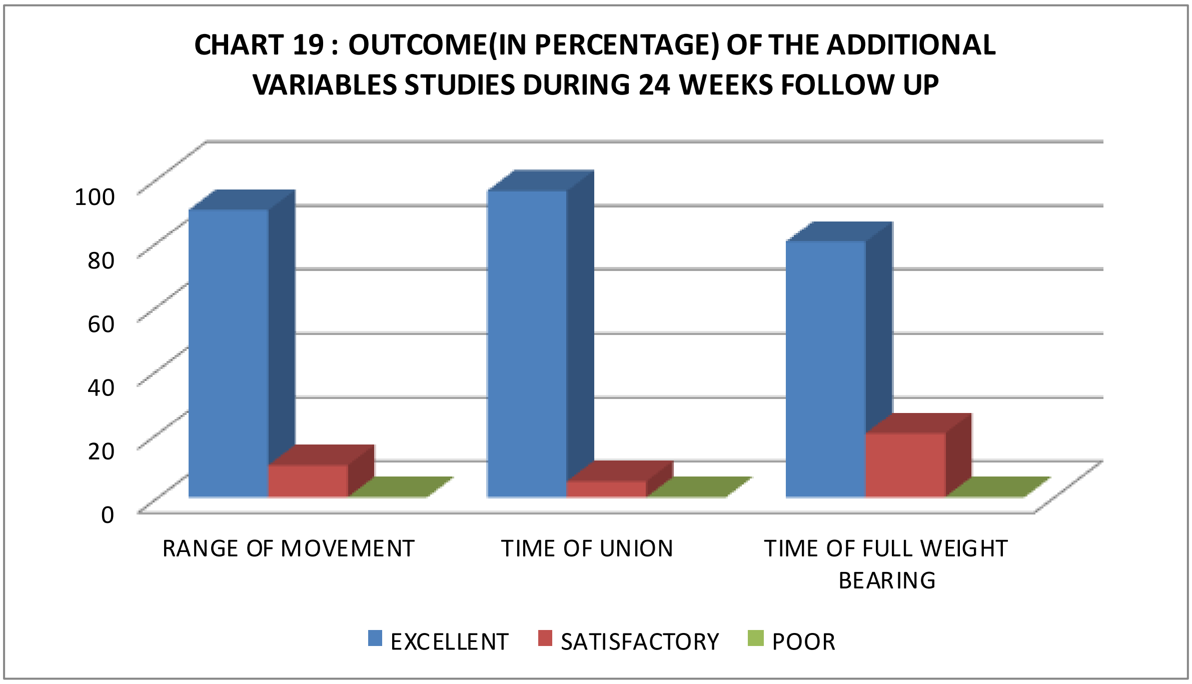
Outcome	Number of patients (n=30)	%
Excellent	23	76.66
Satisfactory	7	23.33
Poor	0	0.0



18. Outcomes of the additional variables studied in our study.

TABLE 33 : OUTCOME FOR ADDITIONAL VARIABLES

OUTCOME / VARIABLES	EXCELLENT (%)	SATISFACTORY (%)	POOR (%)
Range of movements	90.0	10.0	0.0
Time for union	96.67	3.33	0.0
Unsupported weight bearing	80.0	20.0	0.0



19. Relation between the incidence of complications and clinical variables (pre-op) as observed in our study:.

TABLE 34: RELATION BETWEEN CLINICAL VARIABLES AND COMPLICATIONS

Clinical variables	Total number of patients (n=30)	Complications(Minor) Absent (n=13)	Present (n=17)	P value
Age in years				
• 5-8	12(40%)	09(69.2%)	03(17.6%)	
• 9-12	12(40%)	02(15.4%)	10(58.8%)	0.528
• 13-16	06(20%)	02(15.4%)	04(23.5%)	
Gender				
• Male	23(76.6%)	07(53.8%)	16(94.1%)	0.361
• Female	7(23.3%)	06(26.2%)	01(5.9%)	
Mode of Injury				
• RTA	11(36.7%)	04(30.7%)	07(41.1%)	
• Fall	13(47.3%)	09(69.2%)	04(23.5%)	0.489
• Fall from height	6(20%)	00%)	06(35.29%)	
Bone affected				
• Femur	13(43.3%)	03(23.07%)	10(58.8%)	0.721
• Tibia	17(56.7%)	10(76.03%)	07(41.1%)	
Pattern of fracture				
• Transverse	14(46.3%)	03(23.07%)	11(64.7%)	
• Oblique	10(33.3%)	06(26.2%)	04(23.5%)	

• Spiral	3(10%)	3(23.07%)	00(0%)	0.811
• Segmental	0(0%)	0(0%)	00(0%)	
• Communited	3(10%)	03(23.07%)	02(11.76%)	
Time interval between trauma & surgery				
• <10 hours	03(33.3%)	03(23.07%)	00(0%)	0.582
• 10 - 24 hours	19(26.7%)	8(61.53%)	11(64.7%)	
• 25 - 48hours	08(33.3%)	2(15.38%)	06(35.29%)	

The relation between the pre-op clinical variable and complications is not statistically significant, showing that rate of complication does not depend in this study on factors such as age and gender of patient, mode of injury, the bone and side effected as well as the pattern of fracture or the time between trauma and surgery.

RADIOLOGICAL & CLINICAL PHOTOGRAPHS

FIGURE 45 : RADIOLOGICAL AND CLINICAL PICTURES

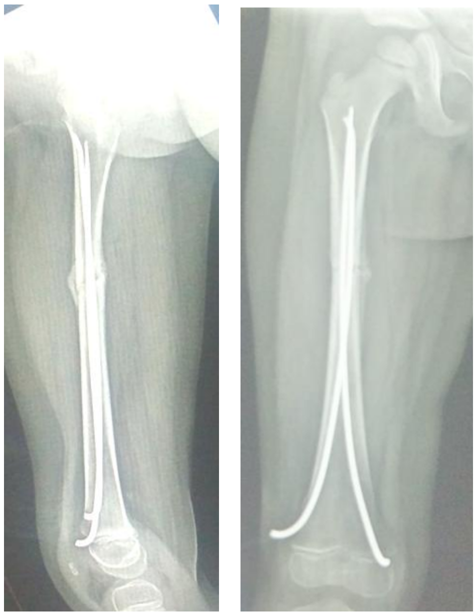
CASE 1

Pre op

Post op

6week follow up

12 weeks follow up

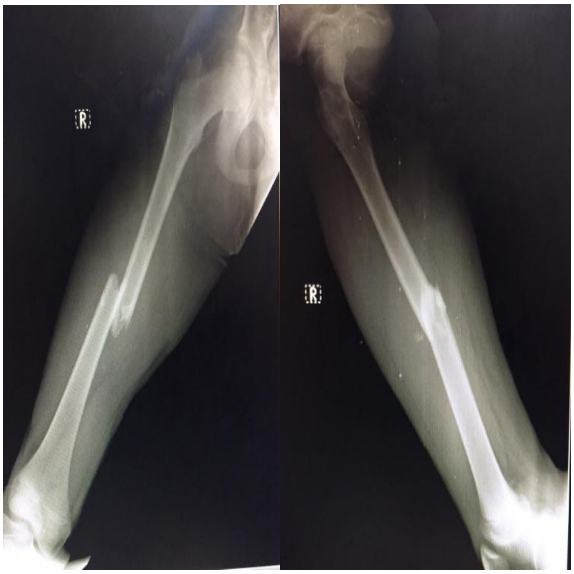


24 week follow up

Clinical pictures

CASE 2

Pre op



post -op

6 weeks follow up

12 weeks follow up

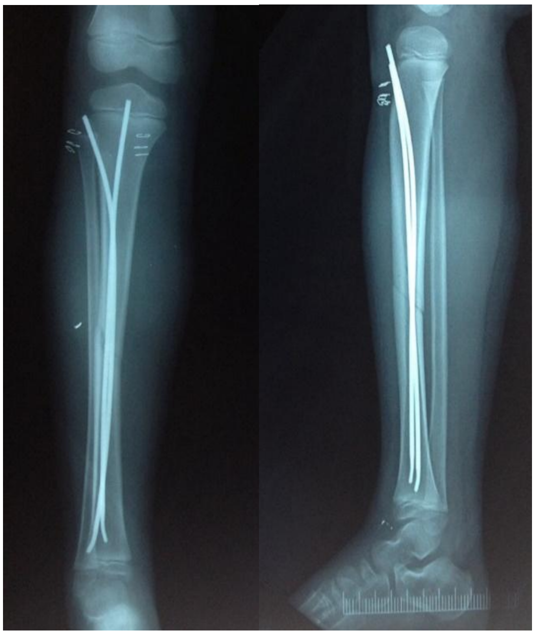
24 week follow up

Clinical pictures

CASE 3

Pre op

post-op



6 weeks follow-up

12 weeks follow-up

24 week follow –up

Post implant removal at 24 weeks

Clinical pictures

CASE 4

Pre op

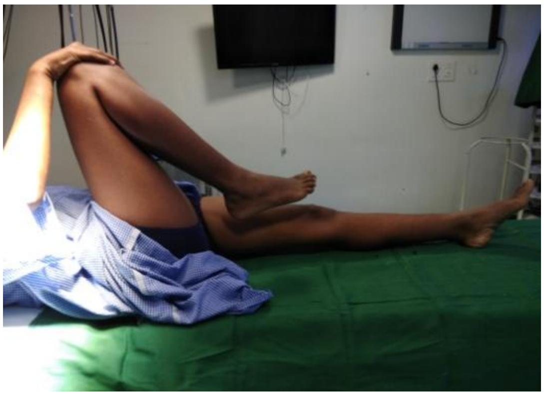
Post -op

6 weeks follow up

12 weeks follow-up

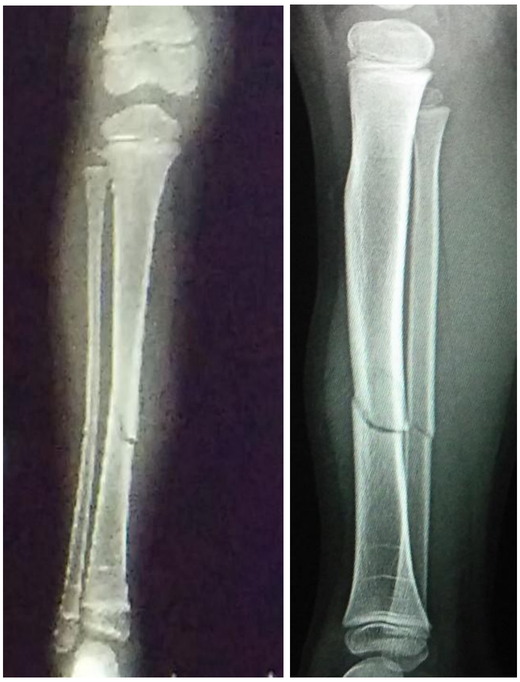
24 weeks follow-up

Clinical pictures

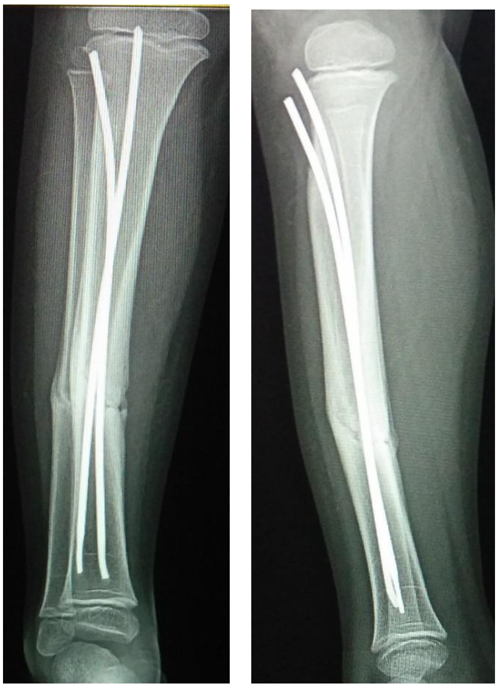


Case 5

Pre op



6 weeks follow -up



12 week follow up

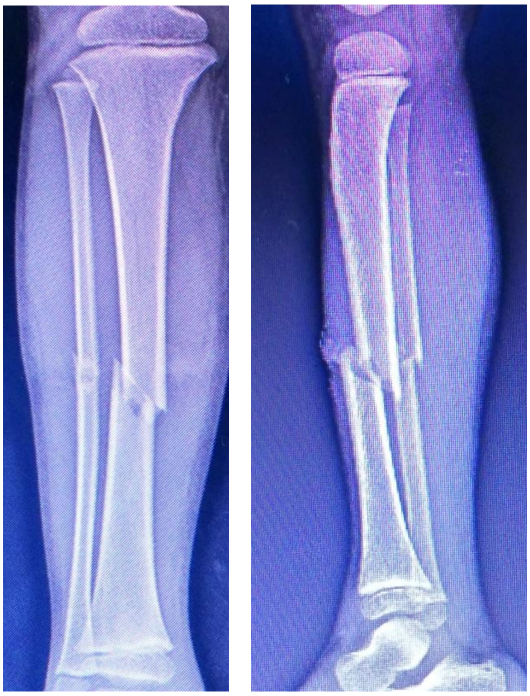
24 weeks follow - up

Post implant removal at 24 weeks

Clinical pictures

CASE 6

Pre op



Post - op

6 weeks follow up

12 weeks follow up

24 week follow up

Clinical pictures :

DISCUSSION

Since past four decades, paediatric orthopedic surgeons have tried a variety of methods to avoid the prolonged immobilization and complications of traction and spica casting for older children with a femur fracture. Spica casting is safe and effective for many cases, it particularly suits children with high-energy trauma, children with head injuries or spasticity[44]. External fixation has also been used successfully but often surgeons face complications like temporary loss of knee motion and pin-track infection and re-fracture after fixator removal which is more troublesome[45]. Solid ante grade IM nailing is better than casting for adolescent femur fractures, but incidences of avascular necrosis of femur head, trochanteric growth arrest and coxa valga has restricted their use in children with open proximal femoral phises[46,47].

Although the majority of tibia shaft fractures in children can be treated with closed reduction and casting, occasionally surgical stabilization is required. Historically, external fixation has been the treatment of choice; however, risks include pin-track infections, nonunion, and refracture[48,49]. Reamed locked intramedullary nails, while shown to be effective in the skeletally mature, pose unnecessary risk to the proximal tibial physis, and have limited indications in those children with growth remaining[21].

ESIN is a reliable stabilization method for long-bone fractures in children, provided that the important biomechanical principles of ESIN are respected. These principles are more important in older and heavier children, especially in the case of fractures in weight-bearing bones. ESIN is predominantly used for stabilization of diaphyseal femoral and less commonly used for diaphyseal tibial fractures. When indications for ESIN are expanded, modifications of the existing technique and strict vigilance are required. Patients and their families must be adequately counseled preoperatively about potential complications related to ESIN[50].

A better understanding of the elastic nailing procedure, overall promising results published in different international journals and patient's demand instilled confidence in our minds to begin this apparently new mode of fixation.

This prospective study was undertaken to critically analyze the outcomes of diaphyseal fractures of femur and tibia in children in age group 5 years to 15 years treated with titanium elastic nails in 30 consecutive patients at our institute catering to vast rural population.

The outcomes were assessed clinically and radiologically at 6 weeks, 12 weeks and 24 weeks follow ups and any complications arising were identified, assessed and reported.

1. **Age distribution :**

   In our study there were 12 patients each in age group 5years to 8 years and 9 years to 12 years. Age group 13years to 15 years had 6 patients. The average age of the patient was 9.2 years.

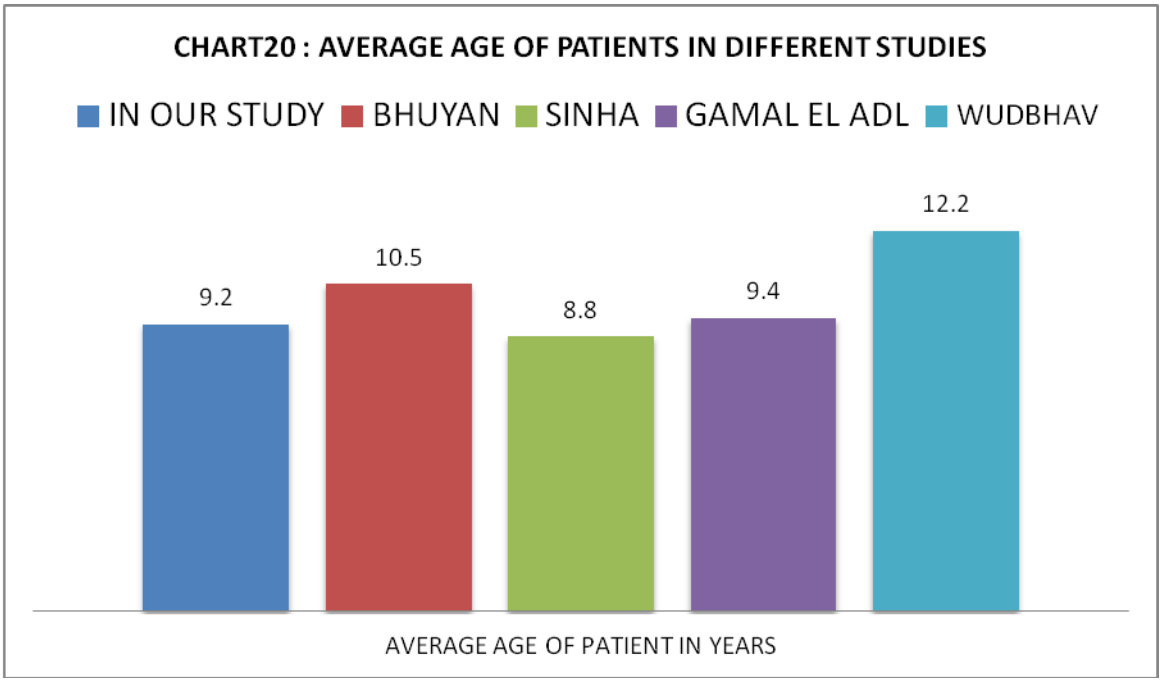
   Bhuyan[51] did a study of 40 femur shaft fractures in patients of age group 5years to 16 years, average age was 10.5 years.

   Similar study performed by Sinha[52] in 2016 on 60 cases had average age of patient 8.8 years.

In a study by Gamal el ald on 66 cases of femur and tibia fracture treated by TENS average age of patient was 9.4 years[6]. Wudbhav N Sankar et al studied children ranged from 7.2-16 years with a mean of 12.2 years[21].

TABLE 35 : COMPARISON OF AVERAGE AGE IN DIFFERENT STUDIES

STUDY	AVERAGE AGE OF PATIENT
IN OUR STUDY	9.2 YEARS
BHUYAN[51]	10.5 YEARS
SINHA[52]	8.8 YEARS
GAMAL EL ALD [6]	9.4YEARS
WUDBHAV[21]	12.2 YEARS



2. **Male / Female distribution :**

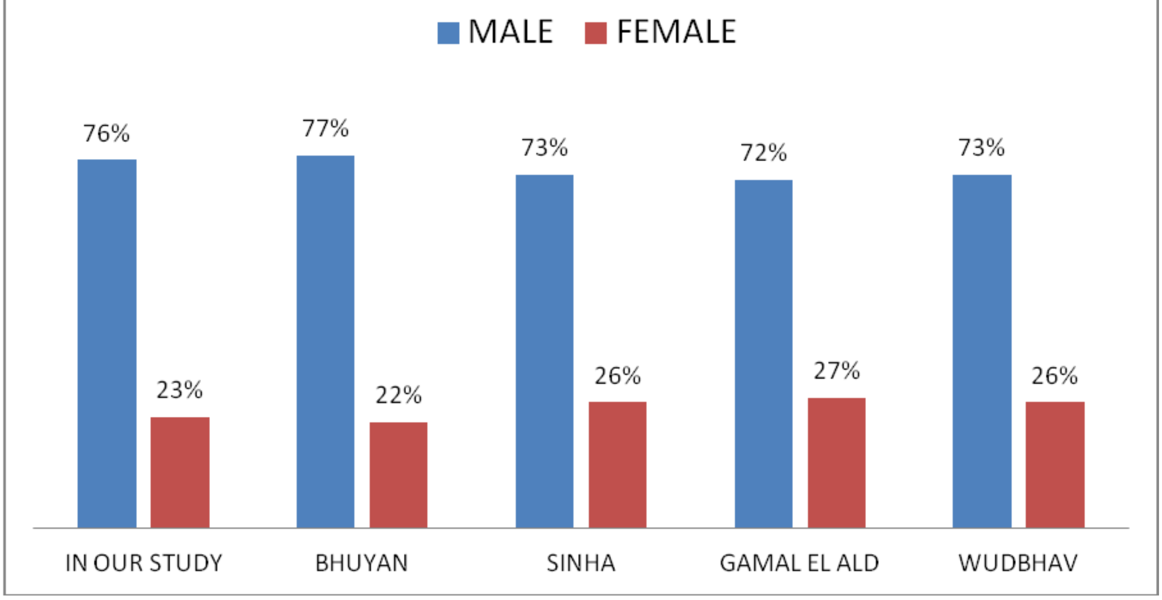
   There were 23 boys(76.6%) and 7 girls(23.3%) in our study.

   Previous studies also show a higher incidence of fracture in boys than girls. In the study by Bhuyan[51] out of 40 cases, 31 were boys (77.5%) and in study by Gamal el ald[6] out of total 66 cases, 48 were boys(72.7%).

TABLE 36: COMPARISON OF GENDER DISTRIBUTION IN DIFFERENT STUDIES

STUDY	NUMBER OF BOYS (%)	NUMBER OF GIRLS(%)
IN OUR STUDY	23(76.6)	7(23.3)
BHUYAN[51]	31(77.5)	9(22.5)
SINHA[52]	39(73.6)	14(26.4)
GAMAL EL ALD [6]	48(72.7)	18(27.3)
WUDBHAV[21]	14(73.6)	5(26.4)

CHART 21 : MALE/FEMALE DISTRIBUTION IN DIFFERENT STUDIES



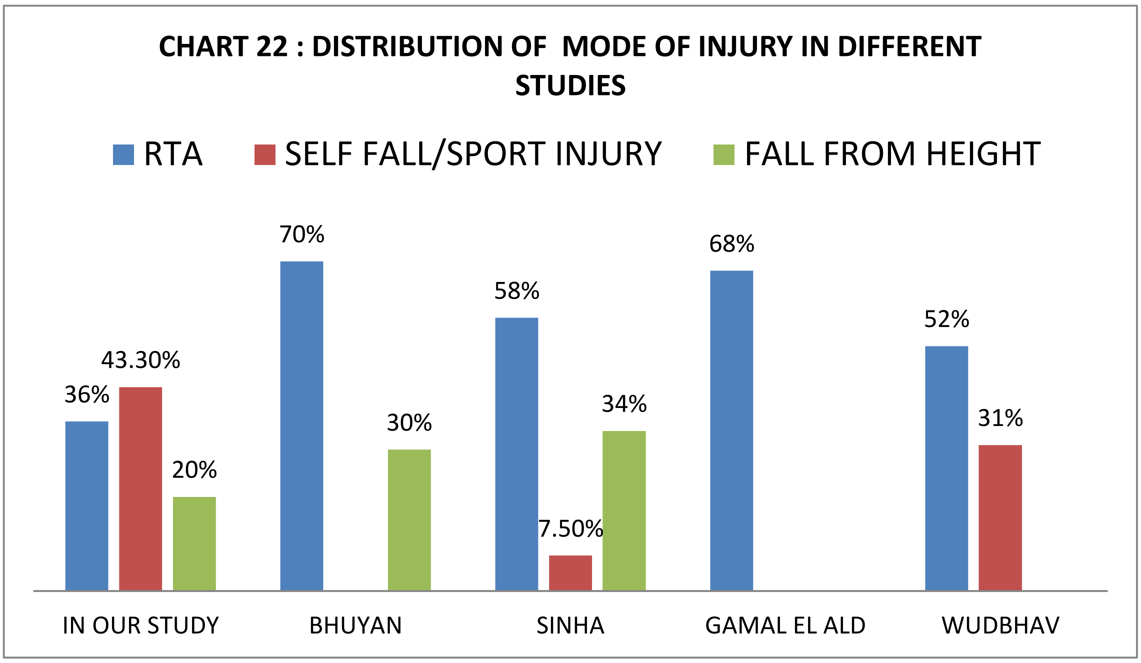
3. Mode of injury

In our study the most common mode of injury was self fall including sports injuries accounting for total of 13 cases (43.3%), closely followed by road traffic accident (RTA) (36.7%) and the least common cause was fall from height accounting for only 20% of cases.

In previously published literature the most common mode of injury was RTA. In study by Bhuyan[51] it was found that RTA was responsible for 70% of injuries and Wudbhav[21] found that RTA accounted for 52.6% of fractures.

TABLE 37: COMPARISON OF MODE OF INJURY IN DIFFERENT STUDIES

STUDY	MODE OF INJURY (IN PERCENTAGE)		
	RTA	SELF FALL/SPORTS INJURIES	FALL FROM HEIGHT
IN OUR STUDY	36.7%	43.3%	20%
BHUYAN[51]	70%	-	30%
SINHA[52]	58.5%	7.5%	34%
GAMAL EL ALD [6]	68.2%	-	-
WUDBHAV[21]	52.6%	31.57%	-



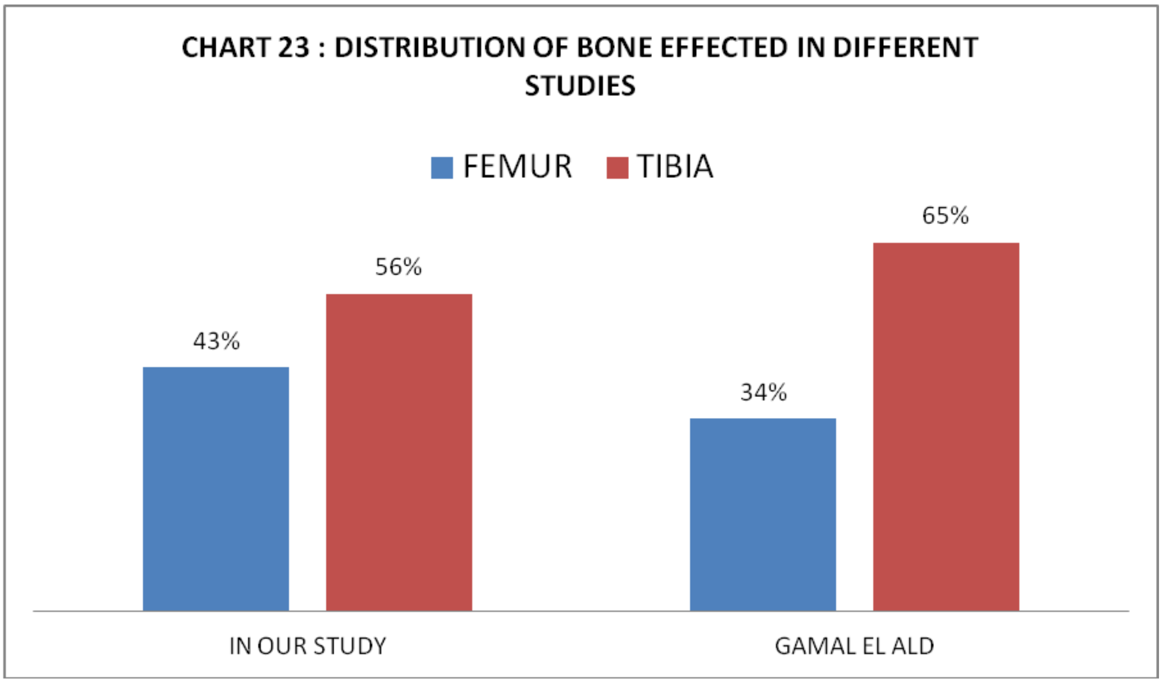
4. Bone effected

In our study there were 13(43.3%) femoral and 17(56.7%) tibial fractures.

In their study, Gamal El-Adl et al. had 48 (65.7%) femoral and 25 (34.3%) tibial fractures[6].

TABLE 38: COMPARISON OF BONE EFFECTED IN DIFFERENT STUDIES

STUDY	BONE EFFECTED	
	FEMUR	TIBIA
IN OUR STUDY	13 (43.3%)	17(56.7%)
GAMAL EL-ADL[6]	25(34.3%)	48(65.7)



5. Pattern of fracture

In our study out of the total 30 cases, most common pattern observed was transverse, seen in 14 cases (46.7%). Oblique was seen in 10(33.33%)cases, spiral in 3(10%) and communited in 3(10%) cases.

In their study Wudbhav[21] had 47.3% transverse and 36.8% oblique fractures. Bhuyan[51] in their study out of the total 40 cases had 11(27.5%) transverse, 15(37.5%) oblique, 9(22.5%) spiral and 5(9.4%) communited fractures.

In previously published literature, in children, transverse pattern of fracture has been noted most commonly and communited as the least common.

TABLE 39: COMPARISON OF MODE OF INJURY IN DIFFERENT STUDIES

STUDY	MODE OF INJURY (IN PERCENTAGE)				
	TRANSVERSE	OBLIQUE	SPIRAL	SEGMENTAL	COMMUNITED
IN OUR STUDY	14(46.7%)	10(33.33%)	3(10%)	0(0.0)	3(10%)
BHUYAN[51]	11(27.5%)	15(37.5%)	9(22.5%)	-	5(12.5%)
SINHA[52]	26(49.1%)	22(41.5%)	-	-	5(9.4%)
GAMAL EL ALD [6]	20(30.30%)	26(39.39%)	14(21.21%)	-	12(18.18%)
WUDBHAV[21]	9(47.3%)	7(36.8%)	2(10.5%)	-	1(5.2%)

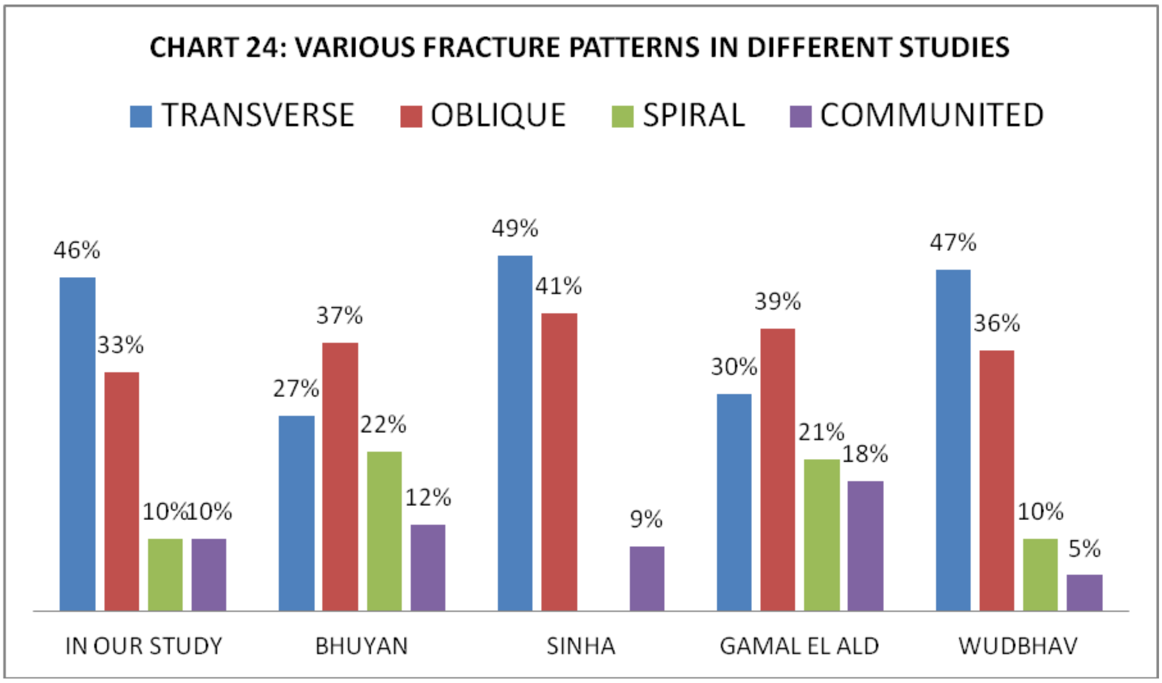


CHART 24: VARIOUS FRACTURE PATTERNS IN DIFFERENT STUDIES
TRANSVERSE
OBLIQUE
SPIRAL
COMMUNITED
46%
33%
10%
10%
27%
37%
22%
12%
49%
41%
9%
30%
39%
21%
18%
47%
36%
10%
5%
IN OUR STUDY
BHUYAN
SINHA
GAMAL EL ALD
WUDBHAV

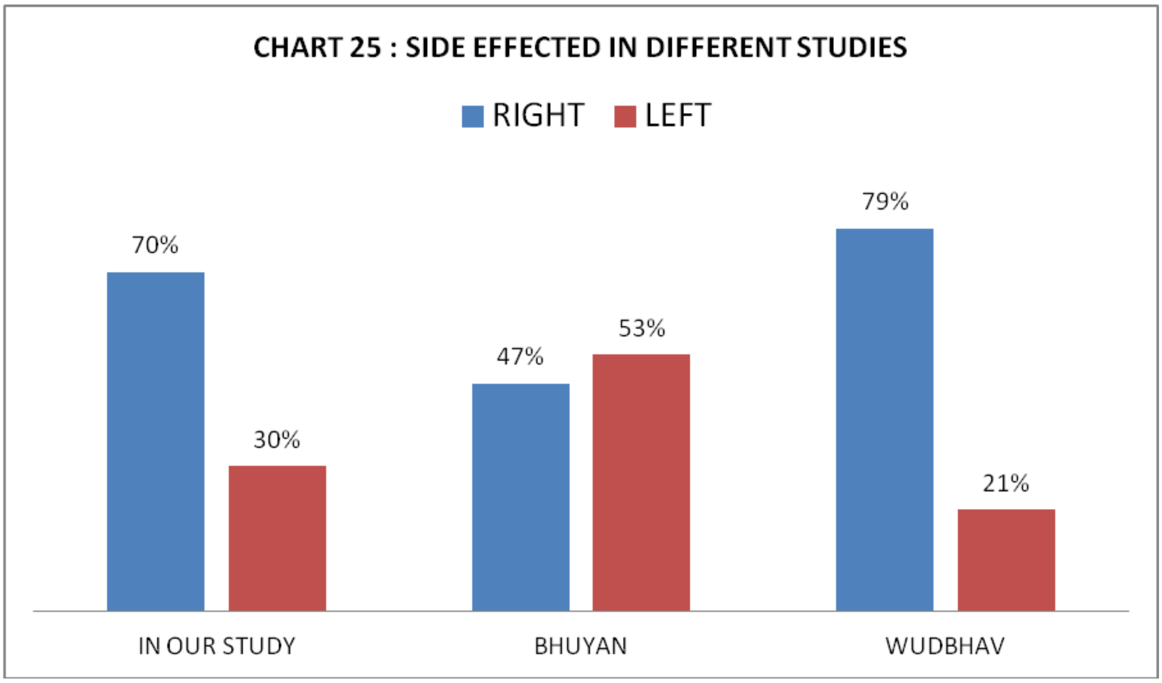
6. **Side effected**

Out of the total 30 cases, 21(70%) fractures were on the right side and 9(30%) were on the left side.

Bhuyan[51] in his study had 19(47.5%) right and 21(52.5%) out of the total 40 cases and Wudbhav[21] had 15(78.94%) right sided fractures.

TABLE 40: COMPARISON OF SIDE EFFECTED IN DIFFERENT STUDIES

STUDY	SIDE EFFECTED	
	RIGHT	LEFT
IN OUR STUDY	21(70%)	9(30%)
BHUYAN[51]	19(47.5%)	21(52.5%)
WUDBHAV[21]	15(78.94%)	4(21.05%)



7. **Level of fracture**

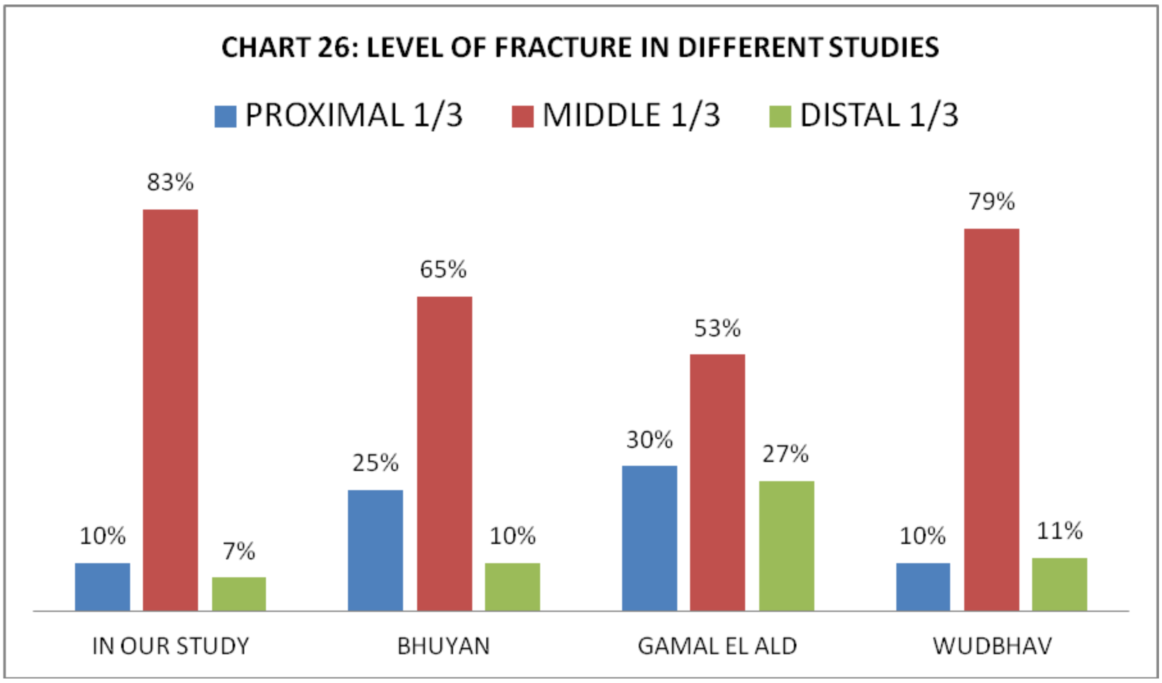
In our study the out of the total 30 cases, most commonly fractures were observed in the middle one-third with 25(83.3%) cases, followed by proximal one-third 10(30.0%) cases and distal one-third 2(6.7%) cases.

Gamal el adl[6] in their study of 66 cases had 20(30.30%) proximal one-third fractures, 35(53.03%) middle one-third and 18(27.27%) distal one-third fractures.

Similar results were seen n study by Bhuyan[51], where 26 out of 40 cases were seen in middle one-third, 10(25%) cases in proximal one-third and 4(10%) caes in distal one –third.

TABLE 41: COMPARISON OF LEVEL OF FRACTURE IN DIFFERENT STUDIES

STUDY	LEVEL EFFECTED		
	PROXIMAL 1/3	MIDDLE1/3	DISTAL1/3
IN OUR STUDY	3(10%)	25(83.3%)	2(6.7%)
BHUYAN[51]	10(25%)	26(65%)	4(10%)
GAMAL EL ALD [6]	20(30.30%)	35(53.03%)	18(27.27%)
WUDBHAV[21]	2(10.5%)	15(78.9%)	2(10.5%)



8. Time interval between trauma and surgery.

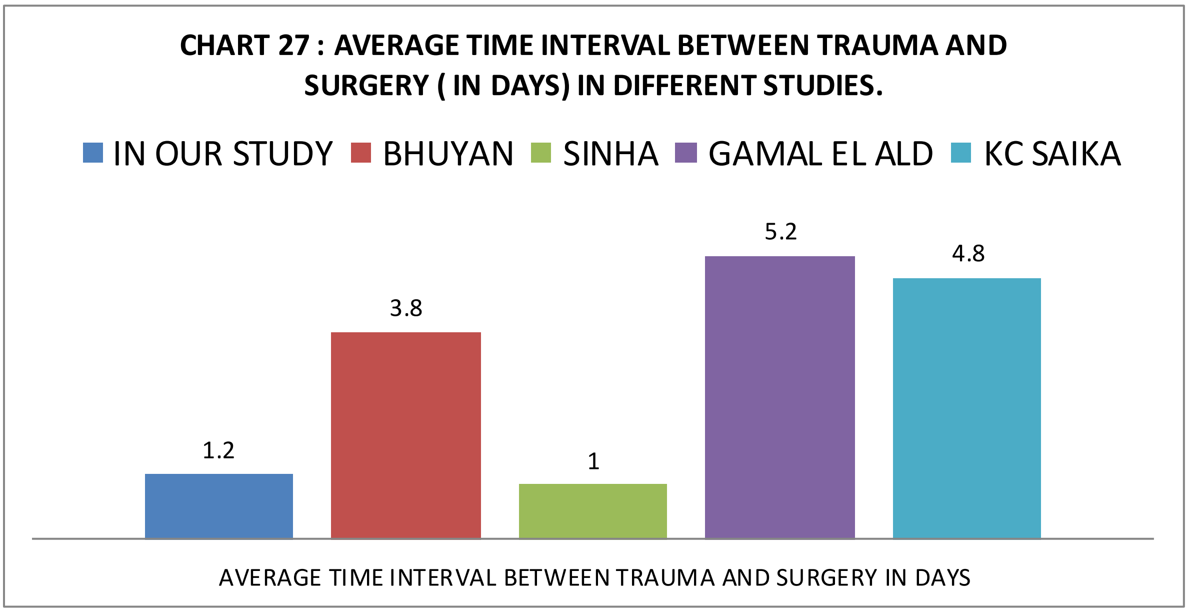
All cases coming to our institute were operated within first 48 hours of trauma. The average time interval between trauma and surgery was a little over one day at 29.1 hours (1.2 days). 22 cases (73.33%) got operated within first 24 hours and 8 cases got operated between 24 to 48 hours.

In study by Sinha SK[52] all cases operated within 24 hours of trauma. The time interval between trauma and surgery in study by Bhuyan[51] was ranging from 1day to 8 days, with average of 3.8 days.

In a study by K C Saika et al., 77.27% patients were operated with-in 7 days of injury[22].

TABLE 42: COMPARISON OF TIME BETWEEN TRAUMA AND SURGERY IN DIFFERENT STUDIES

STUDY	AVERAGE TIME INTERVAL BETWEEN TRAUMA AND SURGERY
IN OUR STUDY	1.2 DAYS (29.1 HOURS)
BHUYAN[51]	3.8 DAYS
SINHA[52]	WITH-IN 24 HOURS
GAMAL EL ALD [6]	5.2 DAYS
KC SAIKA[22]	4.8 DAYS



9. **Duration of surgery**

In our study the total duration of surgery was less than 40 minutes in 7 cases (23.33%) and from 40 minutes to 60 minutes in 23 (76.66%) cases, with average duration of surgery of 49.83 minutes.

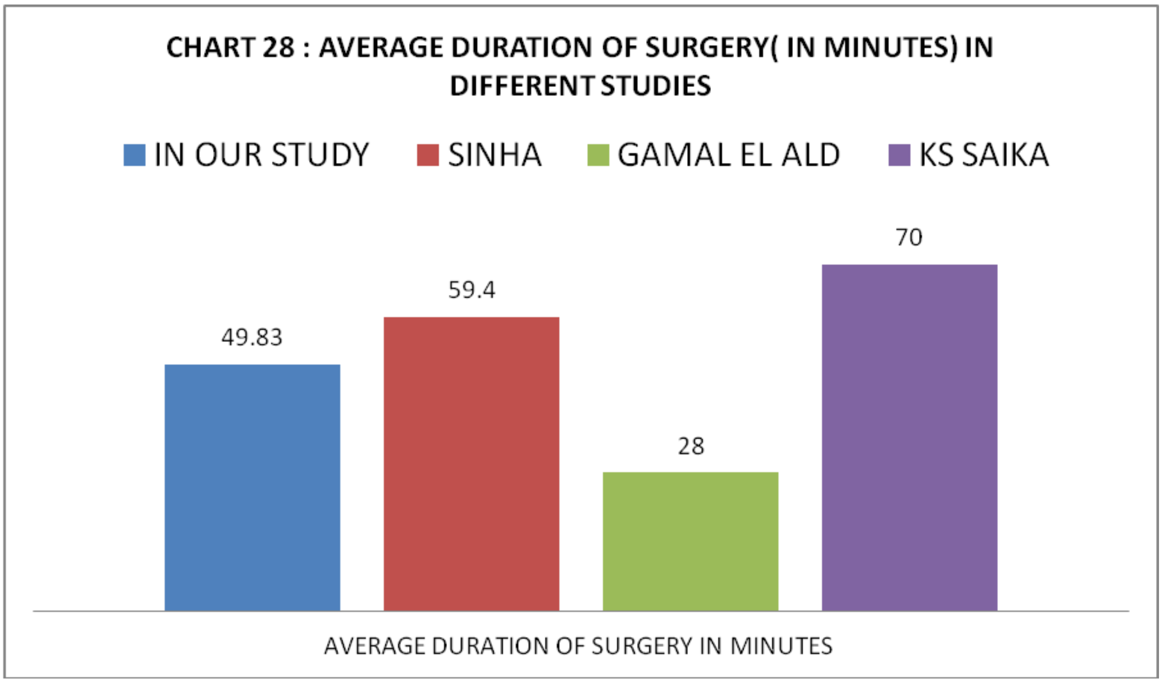
In study by Bhuyan[51] the duration of surgery ranged from 20 to 45 minutes.

Sinha[52] reported an average duration of surgery of 59.4 ± 16.6 minutes.

In study by Gamal El Adl[6] average duration of surgery was 28 minutes, ranging from 15 to 75 minutes.

TABLE 43: COMPARISON OF AVERAGE DURATION OF SURGERY IN DIFFERENT STUDIES

STUDY	AVERAGE DURATION OF SURGERY
IN OUR STUDY	49.83 MINUTES
SINHA[52]	59.4 MINUTES
GAMAL EL ALD [6]	28 MINUTES
KC SAIKA[22]	70 MINUTES



10. Period of post operative immobilization.

In our study the post operative immobilization was based on the fracture pattern and stability of the fixation. Where the operating surgeon deemed necessary the patient was immobilized in high groin POP slab/ long leg cast/ knee immobilizer till patient was started on weight bearing as tolerated.

For cases with-out immobilization quadricep exercises and range of movement were started on post-op day 2-3 and weight bearing as tolerated was started within 1 week post surgery.

A total of 18 (60%) cases required post –op immobilization with an average of 2.23 weeks of which maximum immobilization was for 6 weeks. Cases immobilized for 6 weeks had communited pattern of fracture. After 6 weeks immobilization was removed and mobilization exercises and weight bearing as tolerated were started.

Bhuyan[51] in his study immobilized 7(17.5%) cases due to unstable fracture fixation with hip spica and started non weight bearing ambulation of post-op day 2-3.

Gamal El Ald[6] immobilized 20(33.33%) cases post operatively, most common method of immobilization was knee immobaliser used in 50% cases.

TABLE 44: COMPARISON OF POST-OP IMMOBILIZATION IN DIFFERENT STUDIES

STUDY	POST-OP IMMOBILZATION	
	NUMBER OF CASES	AVERAGE DURATION
IN OUR STUDY	18(60%)	2.23 WEEKS
BHUYAN[51]	33(82.5%)	2 WEEKS
GAMAL EL ALD [6]	20(33.33%)	-
WUDBHAV[21]	19(100%)	6 WEEKS

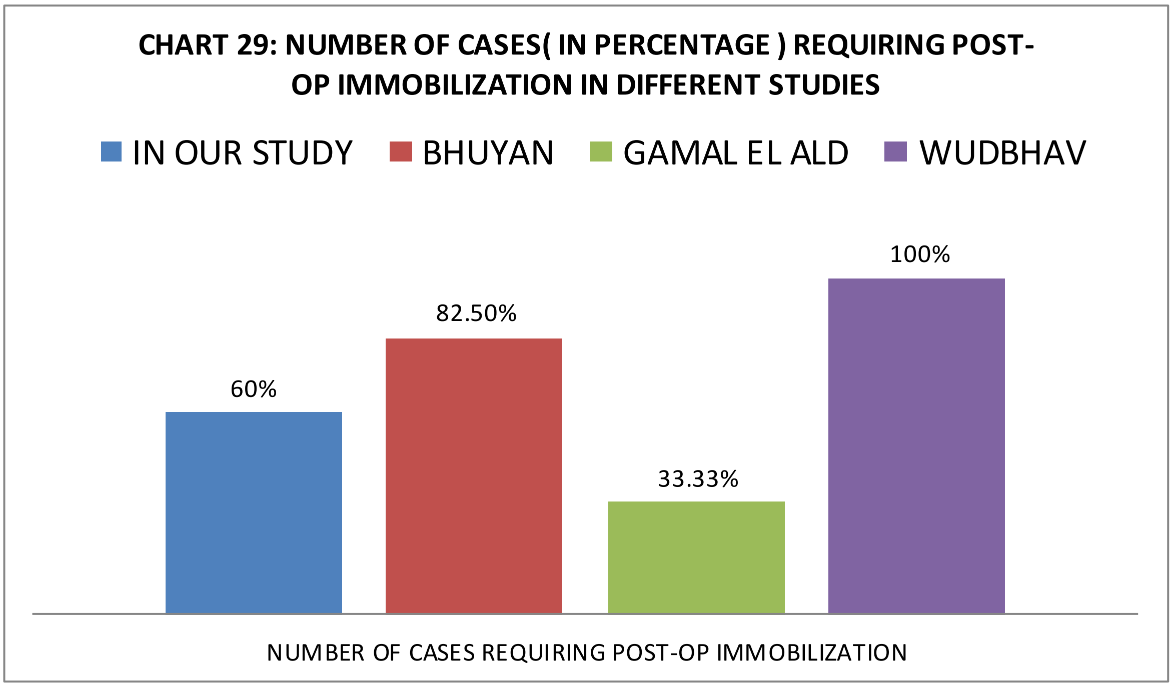


CHART 29: NUMBER OF CASES(IN PERCENTAGE) REQUIRING POST-OP IMMOBILIZATION IN DIFFERENT STUDIES
IN OUR STUDY
BHUYAN
GAMAL EL ALD
WUDBHAV
60%
82.50%
33.33%
100%
NUMBER OF CASES REQUIRING POST-OP IMMOBILIZATION

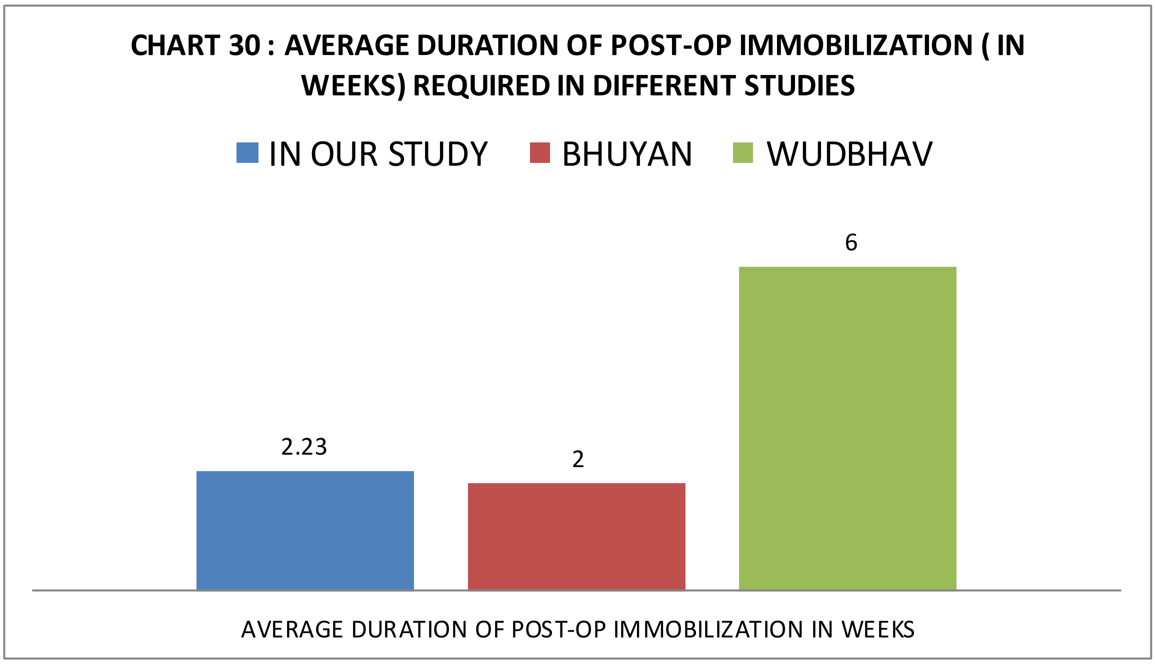


CHART 30 : AVERAGE DURATION OF POST-OP IMMOBILIZATION (IN WEEKS) REQUIRED IN DIFFERENT STUDIES
IN OUR STUDY
BHUYAN
WUDBHAV
2.23
2
6
AVERAGE DURATION OF POST-OP IMMOBILIZATION IN WEEKS

11. Nail sizes used in different studies :

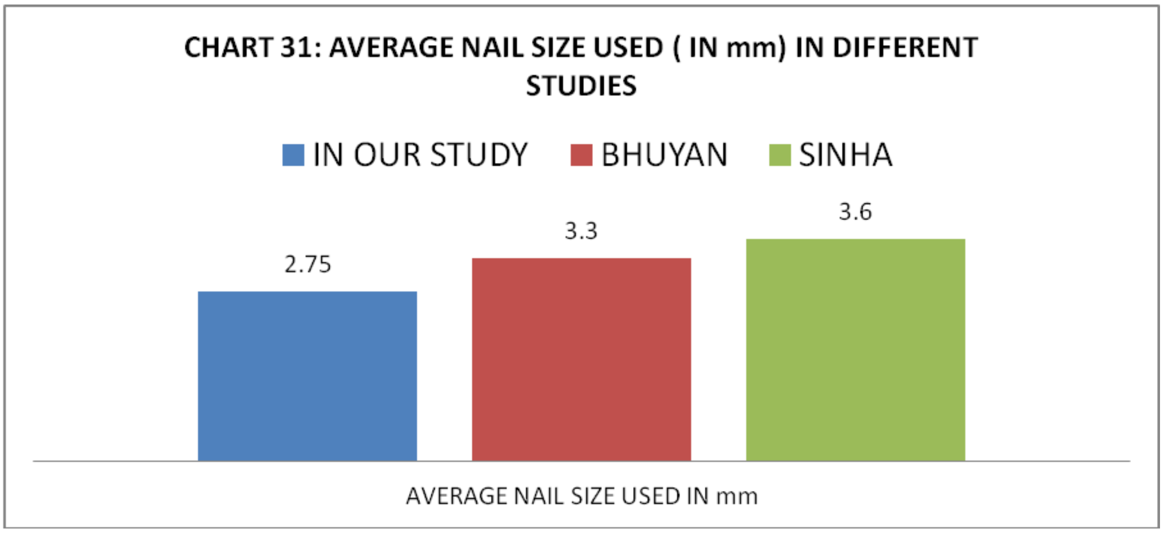
In our study the minimum nail size used was 2 mm and maximum nail size used was 3.5 mm. In study by Bhuyan[51] the nail sizes used varied from 2.5 mm to 4 mm.

The average nail size used by Sinha[52] in their study was 3.6mm ± 0.3 mm.

TABLE 45: COMPARISON OF NAIL SIZES USED IN DIFFERENT STUDIES

NAIL SIZE USED IN OUR STUDY	NUMBER OF PATIENTS
2mm	11(36.67%)
2.5mm	10(33.33%)
3mm	7(23.33%)
3.5mm	2(6.66%)

STUDY	AVERAGE NAIL SIZE USED
IN OUR STUDY	2.75 mm
BHUYAN[51]	3.3 mm
SINHA[52]	3.6 mm



12. Duration of stay in hospital.

The average duration of stay in our study was 8.2 days. Minimum duration was 6 days and maximum was 11 days, for one patient with superficial nail entry site infection for completing antibiotic course.

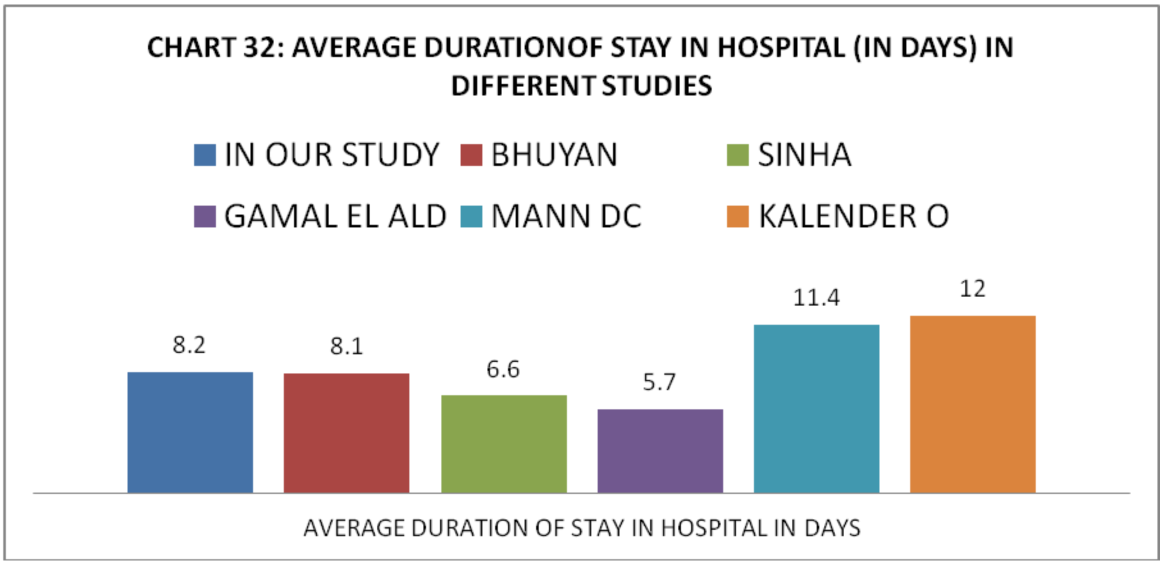
Bhuyan[51] reported a hospital stay ranging from 5 days to 12 days with a mean of 8.1 days.

In study by Sinha[52] a mean hospital stay of 6.6 days was reported where patients were discharged immediately after they were comfortable with physiotherapy.

Mann DC[53] in their study had a hospital stay of 11.4 days.

TABLE 46: **COMPARISON OF AVERAGE HOSPITAL STAY DURATION IN DIFFERENT STUDIES**

STUDY	AVERAGE DURATION OF HOSPITAL STAY
IN OUR STUDY	8.2 DAYS
BHUYAN[51]	8.1 DAY
SINHA[52]	6.6 DAYS
GAMAL EL ALD [6]	5.7 DAYS
MANN DC[53]	11.4 DAY
KALENDER O[54]	12 DAYS



13. Time for union of fracture.

In our study union of fracture was achieved in < 12 weeks in 22 (73.33%) of the patients, between 12-14 weeks in 7 (23.33%) cases and between 15-18 weeks in 1 case (3.33%). Average time to union was 10 weeks.

Bhuyan[51] reported an mean union time of 9 weeks with time for union ranging from 8 to 10 weeks.

Aksoy C, et al compared the results of compression plate fixation and flexible intramedulalry nail insertion. Average time to union was 7.7 (4 to 10) months in the plating group and 4 (3 to 7) months for flexible intramedullary nailing[55]

Oh C.W et al reported average time for union as 10.5 weeks[56].

Wudbhav[21] in their study reported a mean time for union as 9.7 weeks for closed fractures and 13.8 weeks for open fractures .

In two of the cases in the study, both tibia mid shaft fractures, there was complete remodeling of bone seen at 24 weeks and implant was removed at 24 weeks. Both the cases had excellent results(refer clinical pictures case 3 and case 5). Such complete remodeling was not seen in any of the femur fracture cases, hence in none of the femur cases implant was removed with-in 24 weeks post surgery.

TABLE 47 : COMPARISON OF TIME OF UNION IN DIFFERENT STUDIES

STUDY	AVERAGE TIME FOR UNION OF FRACTURE POST-OP
IN OUR STUDY	10 WEEKS
BHUYAN[51]	9 WEEKS
AKSOY C[55]	16 WEEKS
OH CW[56]	10.5 WEEKS
WUDBHAV[21]	11 WEEKS

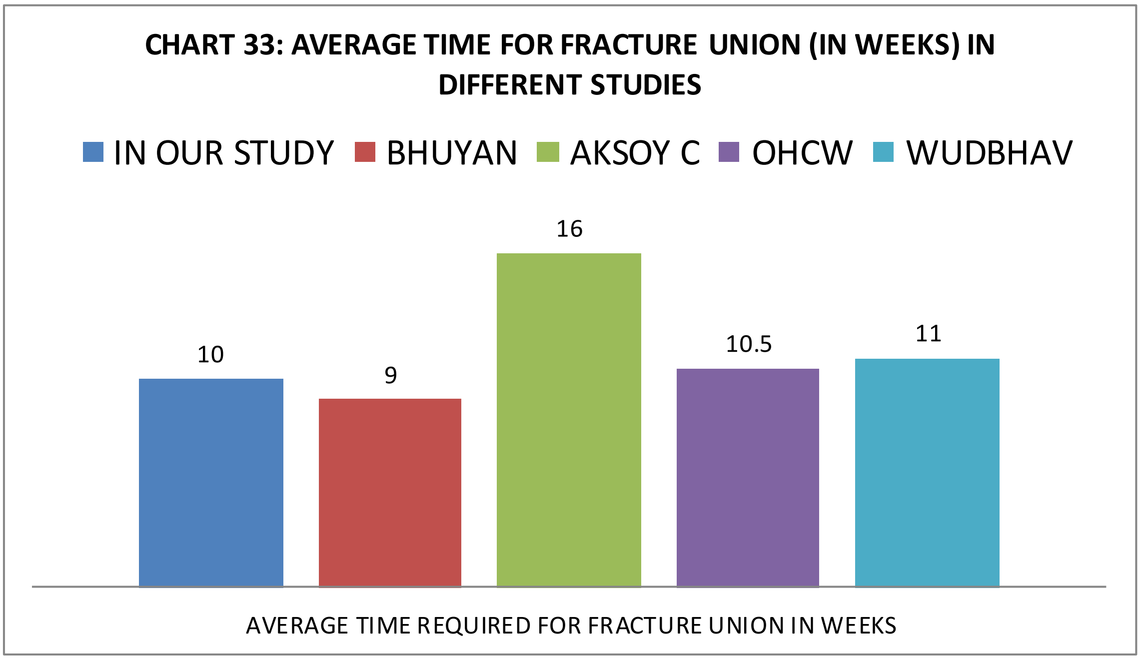


CHART 33: AVERAGE TIME FOR FRACTURE UNION (IN WEEKS) IN DIFFERENT STUDIES
IN OUR STUDY
BHUYAN
AKSOY C
OHCW
WUDBHAV
10
9
16
10.5
11
AVERAGE TIME REQUIRED FOR FRACTURE UNION IN WEEKS

14. Time for full weight bearing .

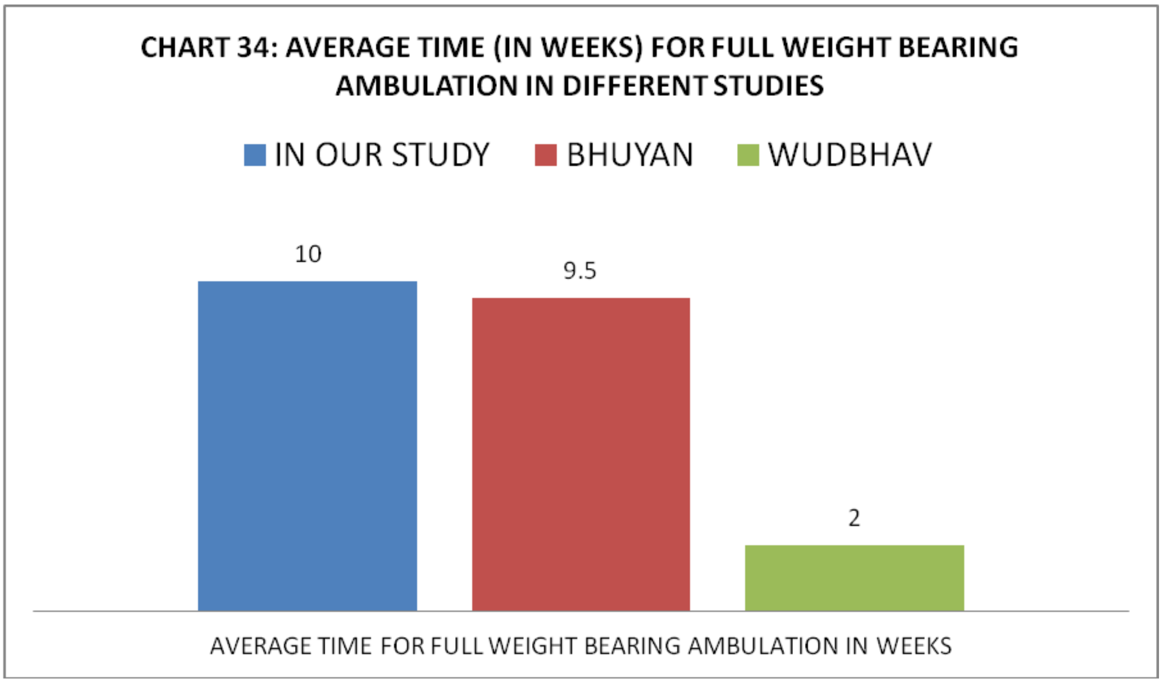
Time for full weight bearing was closely related to the time for fracture union. Most of the cases started full weight bearing ambulation with n a week of fracture union.

Average time for full weight bearing in our study was 10 weeks.

Bhuyan[51] and Wudbhav[21] reported time for full weight bearing as 9.5 weeks and 8.4 weeks respectively.

TABLE 48: COMPARISON OF TIME FOR FULL WEIGHT BEARING IN DIFFERENT STUDIES

STUDY	AVERAGE TIME FOR FULL WEIGHT BEARING AMBULATION
IN OUR STUDY	10 WEEKS
BHUYAN[51]	9.5 WEEKS
WUDBHAV[21]	8.4 WEEKS



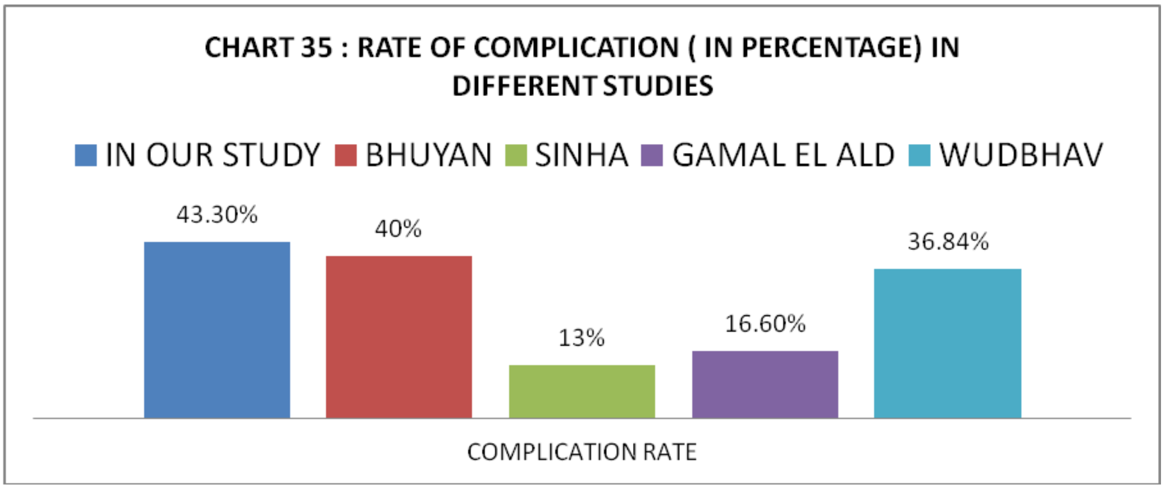
15. Complications

All the patients were followed up for 24 weeks post surgery and any complications arising were keenly observed were meticulously recorded. Out of the total 30 cases, thirteen cases had complications which were seen till the 24 week follow up. All the complications seen in patients were minor complications. The fact that no major complications were seen in our study can be attributed to the fact that we had more stringent inclusion criteria which led us to better outcome and that we strictly followed the surgical technique by careful intra-operative monitoring.

Bhuyan[51] reported complications in 16 of the total 40 cases (40%). Skin irritation at site of entry was the most common complication seen in 7 of the 16 cases of complications (43.75%). Sinha[52] reported a complication rate of 24.5%, Gamal El Ald[6] and Wudbhav[21] had complications rate of 16.6% and 36.84% respectively.

TABLE 49: COMPARISON OF COMPLICATION RATE IN DIFFERENT STUDIES

STUDY	COMPLICATION RATE
IN OUR STUDY	43.3%
BHUYAN[51]	40%
SINHA[52]	13%
WUDBHAV[21]	36.84%



15.a. Nail Prominence and associated complications

The most commonly reported complication related to TENS involves nail prominence and irritation at the nail entry site. Other serious complications which follows are skin breakdown, superficial or deep infection, effusion and stiffness at the adjacent joint, bursitis and reoperation to perform nail trimming or nail advancement.

All these complications prompt for early implant removal with the subsequent risk of re-fracture[50]. The worst complication is osteomyelitis, which can extend to the diaphysis[11].

In published literature the prevalence of nail irritation has been reported to be 3% to 52%, with the femur being the most commonly affected site[50].

In our study 10 cases (33.33%) cases had complaints of nail site irritation making it the most common complication.

Three cases (10%) had superficial infection, which resolved with oral antibiotic course. In all the patients the complaints subsided by 20 weeks of follow up and no reoperations or nail removals were required. No patient had deep infection or bursitits at nail tip.

Narayanan et al[57] in a study of 79 femur fracture cases treated with ESIN reported nail entry site irritation in 41(52%) cases which required reoperation in 6 cases.

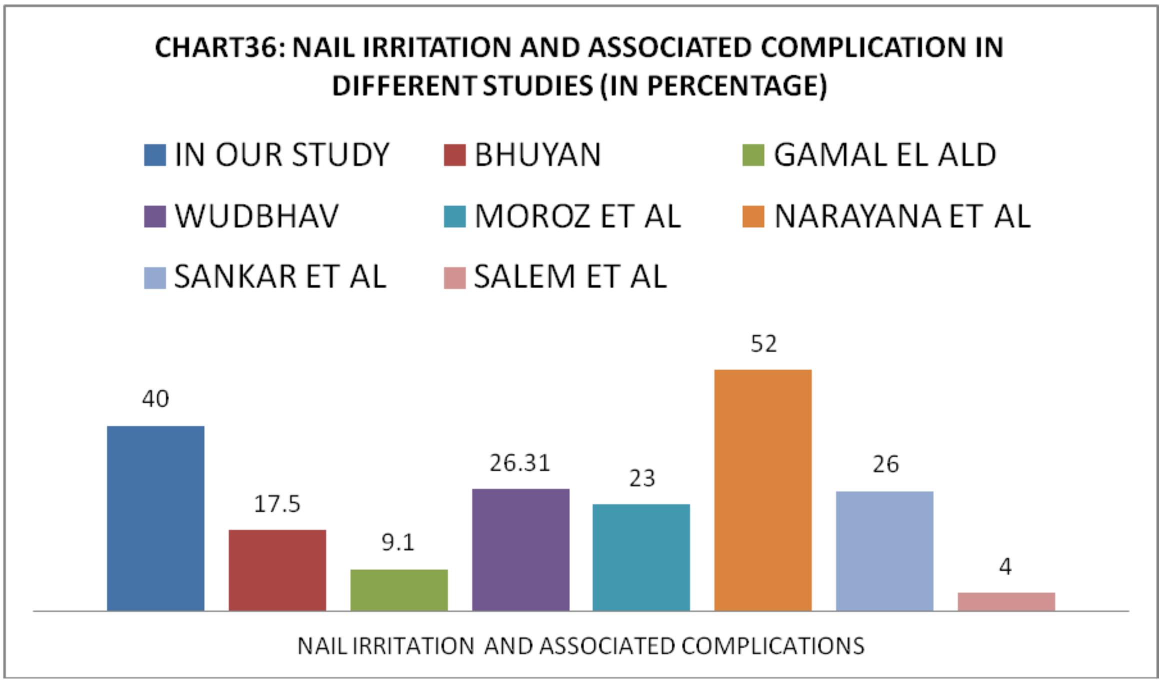
Sankar et al[27] in study of 19 tibia fracture cases reported skin irritation in 5 (26%) cases.

Moroz et al[58] in a comprehensive study of 234 cases reported 49 skin irritation and 4 superficial infection incidences. Six cases required nail trimming.

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[5].

TABLE 50 : COMPARISON OF THE NAIL PROMINENCE RELATED COMPLICATIONS IN DIFFERENT STUDIES.

STUDY	NUMBER OF PATIENTS WITH SKIN IRRITATION AND ASSOCIATED COMPLICATION
IN OUR STUDY	12 (40.0%)
BHUYAN[51]	7 (17.5%)
GAMAL EL ALD [6]	6 (9.1%)
WUDBHAV[21]	5 (26.31%)
MOROZ ET AL[58]	53 (23%)
NARAYANAN ET AL[57]	41(52%)
SANKAR ET AL[27]	5 (26%)
SALEM ET AL[32]	3 (4%)



The originators of the ESIN technique recommended to either bend the nail ends or leave them prominent for easy removal. Many authors have modified this technique overtime to overcome the complications of skin irritation and associated complications. For femoral ESIN Narayanan et al.[57] recommended that nail ends should be left unbent closely opposed to the metaphysis. The length of nail protruding out of bone for femur should be < 25mm as per Luhmann et al.[59] and for tibia ESIN Sankar et al.[27] recommended that <1.5 cm of the nail should be outside the bone, unbent and parallel to the proximal tibial metaphysis. Several studies have recommended postoperative immobilization of the knee joint to prevent soft tissues from rubbing over the nail ends[12,27].

Possible treatments for prominent nails include early removal, trimming of the nail end, advancement of the nail, exchange nailing, or observation[50].

15.b. Loss of reduction and/or malunion.

Angular malunion (valgus, varus, anterior, posterior) and limb-length discrepancy are relatively common, whereas rotational malunion is uncommon[60].

In our study we observed 1(3.33%) case of limb length discrepancy (1cm lengthening in fracture of tibia) and 2 cases (6.66%) of coronal plane deformity, one each varus deformity(femur fracture 5 degrees) and valgus (femur fracture 8 degrees). None of the deformities were major and required any further manipulation or surgery.

No case of sagittal plane deformity and rotational deformity were observed in our study.

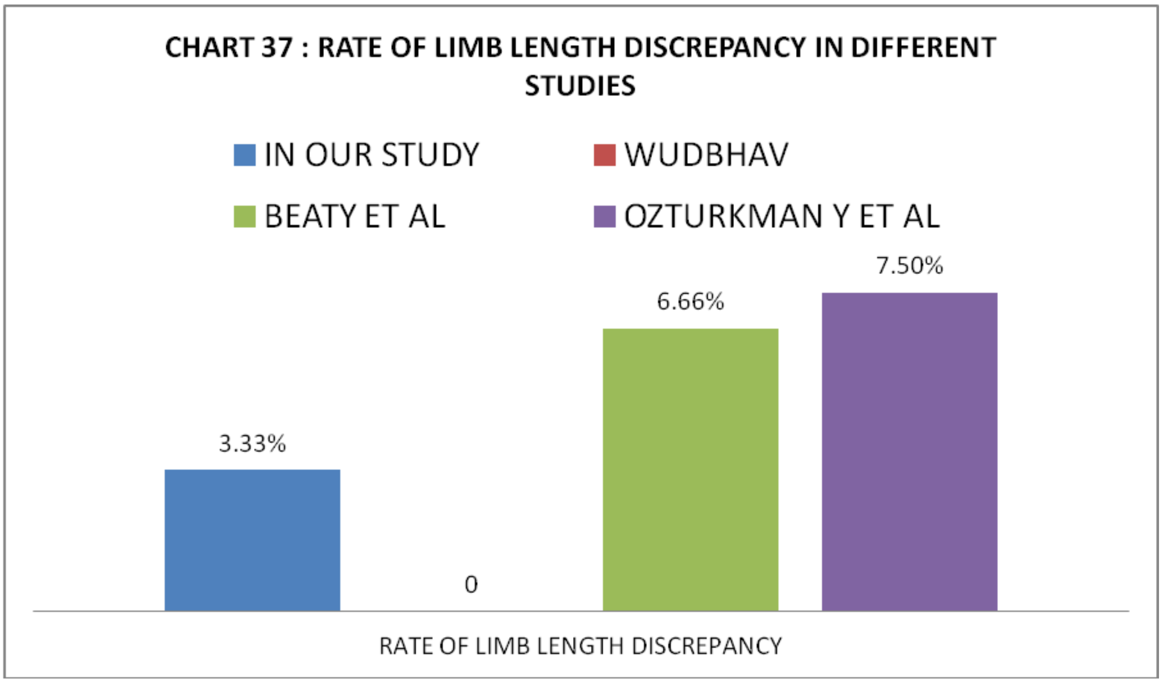
In their study of thirty-one femoral-shaft fractures in 30 patients, Beaty et al.[62] reported, two patients had lengthening of femur of more than 2.5 cm, being a major deformity it required epiphysiodhesis.

Wudbhav[21] in their study of 19 tibial shaft fractures reported no leg length discrepancy.

Ozturkman Y. et al[63] in their study of femur diaphyseal fractures treated with ESIN observed leg lengthening in 4 (5%) patients with a mean lengthening of 7 mm and shortening in 2 (2.5%) patients with a mean shortening of 6mm.

TABLE 51: COMPARISON OF LIMB LENGTH DISCREPANCY IN DIFFERENT STUDIES

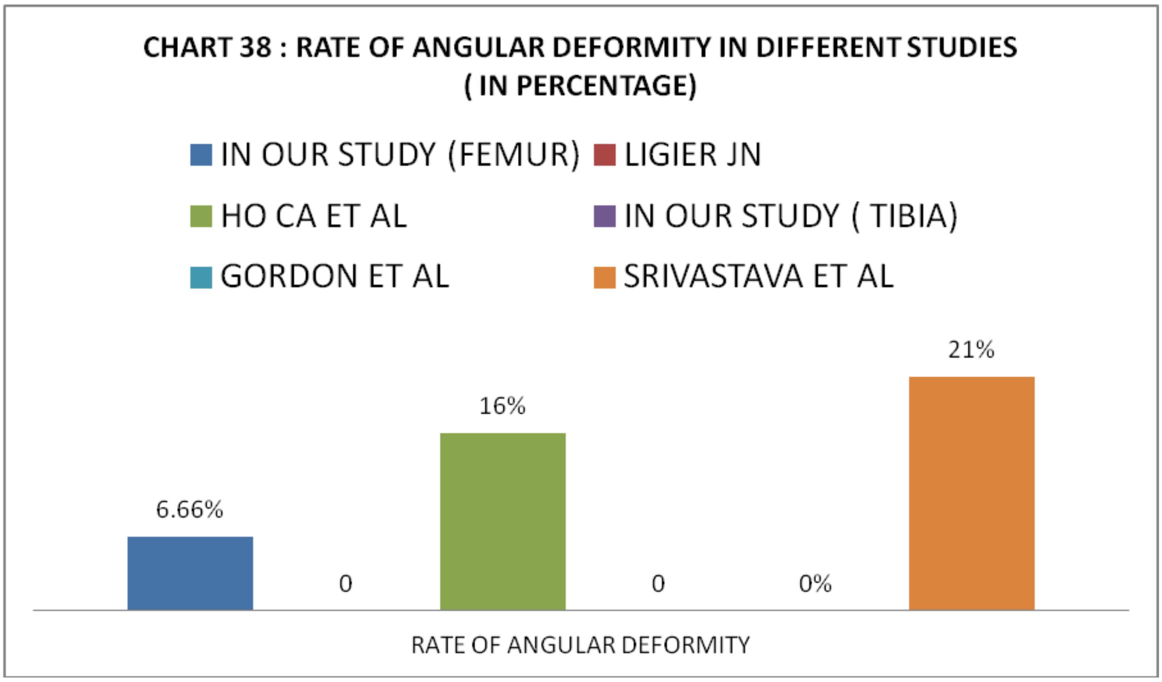
STUDY	NUMBER OF PATIENTS WITH LIMB LENGTH DISCREOENCY
IN OUR STUDY	1 (3.33%)
WUDBHAV[21]	0
BEATY ET AL.[62]	2 (6.66%)
OZTURKMAN Y. ET AL[63]	6 (7.5%)



The reported rate of angular malunion after femoral ESIN varies from 0% as reported in study by Ligier JN[12] to 16% in a study by Ho CA et al[61]. The rate of angular malunion after ESIN of tibia diaphyseal fractures varies from varies from 0% (in a study by Gordon et al[21]) to 21% as observed by Srivastava et al[28] in their study done in 2008

TABLE 52: COMPARISON OF ANGULAR DEFORMITY COMPLICATIONS IN DIFFERENT STUDIES

STUDY	SITE OF FRACTURE	NUMBER OF PATIENTS WITH ANGULAR DEFORMITY
IN OUR STUDY	FEMUR	2 (6.66%)
LIGIER JN[12]	FEMUR	0
HO CA ET AL[61]	FEMUR	15 (16%)
IN OUR STUDY	TIBIA	0
GORDON ET AL[21]	TIBIA	0
SRIVASTAVA ET AL[28]	TIBIA	2 (21%)



Several authors have recommended that ESIN should not be used in older, heavier paediatric patients as rate of malunion increases with ages more than 10 years and patient have poor outcomes[58,61].

No such co-relation was found in our study, as the difference between the complications in different age groups was statistically insignificant.

The biomechanical principles of TENS should be followed to prevent malunion. Mismatched and inappropriate nail size have been implicated as causes of femoral malunion in various studies.

Because of the eccentric location of the tibia in the leg musculature and its triangular cross section, TENS nailing of tibia diaphyseal fractures is more technically demanding and makes it prone to recurvatum deformity[11]. In such instances, the nail tips should be pointing in a posterior direction to counteract the recurvatum force[50].

No anterior or posterior angulation deformity and rotational deformity was observed in present study.

In a study of seventy-eight diaphyseal femur fractures by Heinrich SD et al[1], 8% of the patients had an average anterior or posterior angulation of 8 degrees.

Sagan et al.[64] recommended that at least one nail should be inserted with its tip directed anteriorly to prevent procurvatum, which is the most common sagittal plane malunion.

15.c. Other complications:

In our study restriction of movement was seen in 3 cases(10%). All 3 cases had femur diaphyseal fracture and the restriction was mild restriction of knee joint (active painless flexion of 0 – 120 degrees present, terminal 20 degrees of flexion restricted) at 24 weeks of follow up.

J.M.Flynn et al.[5] in a study of 234 fractures treated with titanium elastic nails reported 2 (0.9%) cases of knee stiffness.

No cases in the present study had complication of nail back out or sinking into medullary cavity. No cases of iatrogenic injuries were observed in present study.

Luhmann et al.[59] reported fracture communition during nail insertion in a patient with a distal femoral fracture.

One case of delayed sciatic neuropraxia secondary to nail protrusion through the femoral neck was reported by Narayanan et al.[57].

16. Assessment of outcome:

In our study for the final outcome assessment Flynn's criteria was used.

Out of the total 30 cases studies, excellent outcomes were seen in 23 patients (76.66%), satisfactory results were seen in 7 patients (23.33%).

Poor outcomes were observed in none.

The outcomes in 7 patients were assessed as satisfactory because of minor complications seen: delayed union in one case of communited middle femur shaft fracture, superficial pain infection at nail entry site in 3 cases, limb lengthening of 1cm in one tibia fracture case and coronal plane deformity (<10 degrees) in 2 cases of femur fracture.

All these complications resolved within 20 weeks of follow up and there was so no lasting morbidity in the patients.

Bhuyan et al.[51] in their study of 40 cases, reported excellent outcomes in 33 (82.5%) cases and satisfactory in 7 cases (17.5%). The reason for satisfactory outcome was complications like limb length discrepancy in 3 cases and angular deformity in 4 cases.

In a study by Sinha et al.[52] where out of 60 cases, 53 cases were followed up till final outcome, they reported excellent outcome in 40 (75.5%) cases, satisfactory in 9 (17.0%) and poor in 4 (7.5%) cases. Poor outcome was due to 2 cases of transient neurological deficit and 2 cases of refracture which needed resurgeries.

Gamal El Adl et al.[6] 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.

Flynn et al.[5] 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.

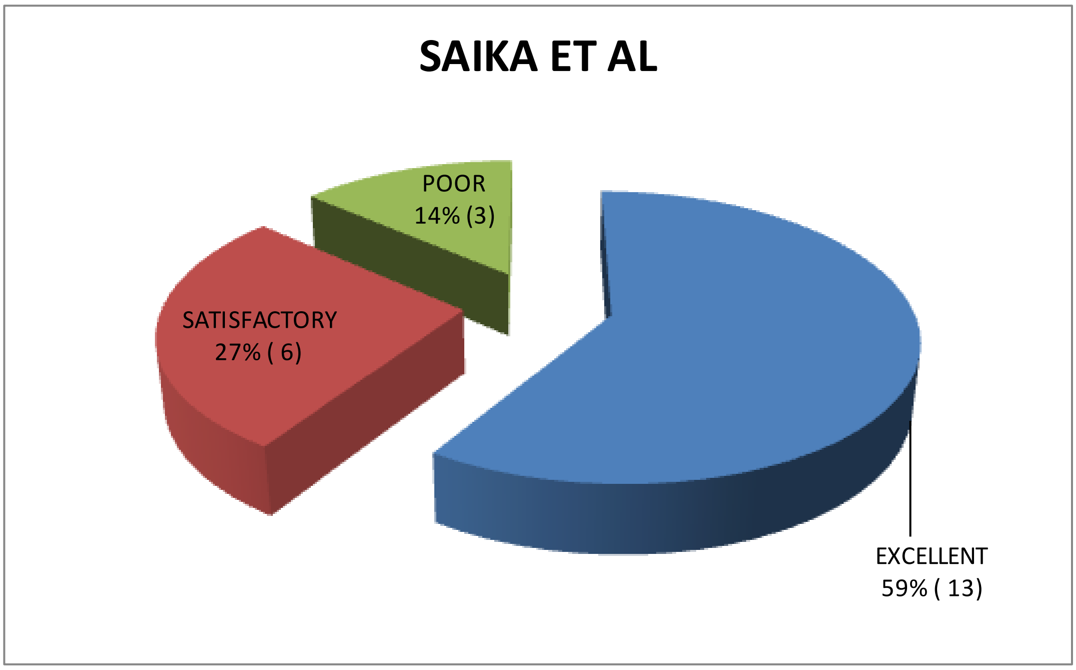
Wudbhav[21] in their study of 19 tibial shaft fractures reported 12 (63.15%) excellent, 6 (31.57%) satisfactory and 1 (5.26%) poor results.

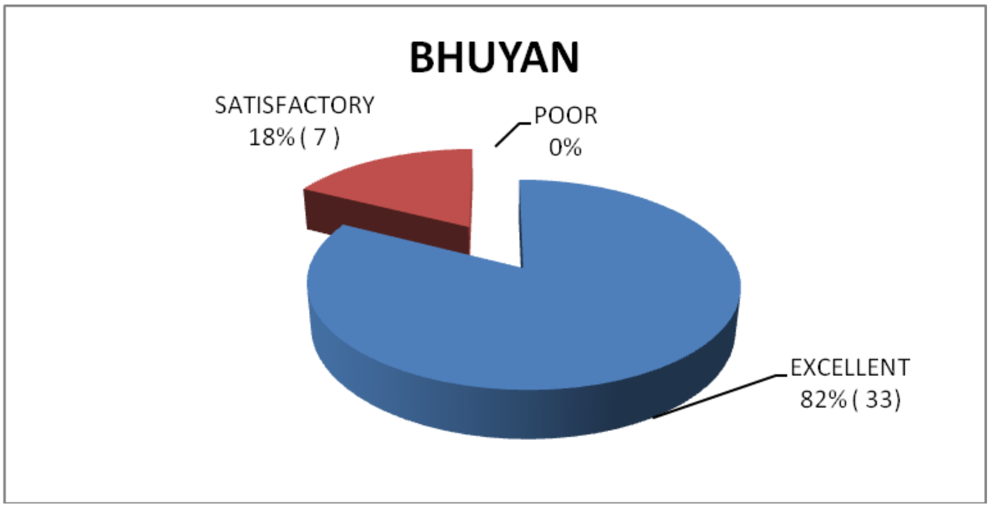
Saikia et al.[22] in their study of 22 children with femoral diaphyseal fractures reported 13 (59%) excellent, 6 (27.2%) satisfactory and 3(13.6%) poor results.

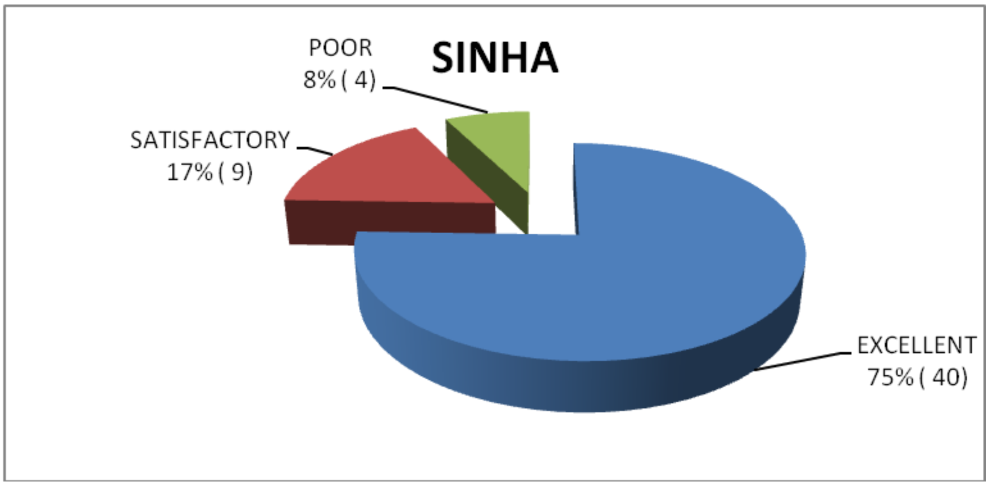
TABLE 53: COMPARISON OF FINAL OUTCOMES IN DIFFERENT STUDIES.

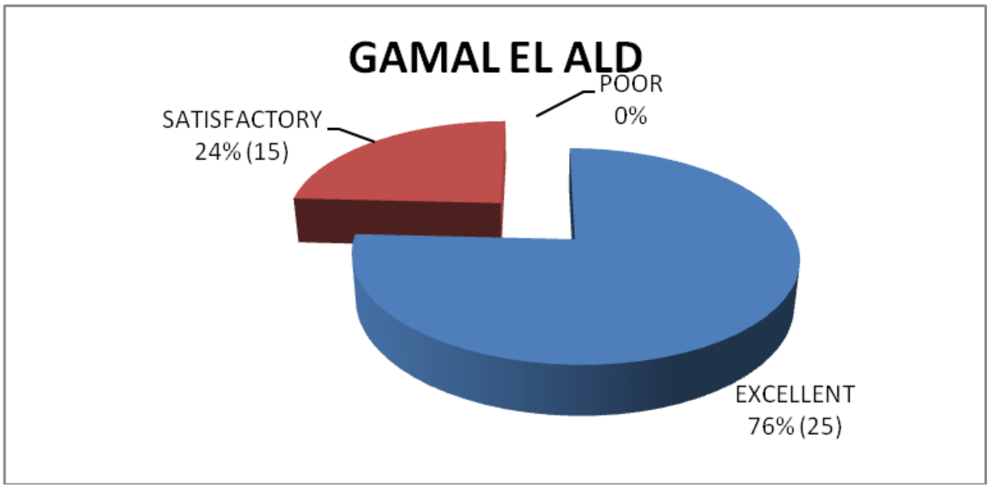
STUDY	FINAL OUTCOME AS PER FLYNN'S CRITERIA		
	EXCELLENT	SATISFACTORY	POOR
IN OUR STUDY	23 (76.66%)	7 (23.33%)	0
BHUYAN[51]	33 (82.5%)	7 (17.5%)	0
SINHA[52]	40 (75.5%)	9 (17.0%)	4 (7.5%)
GAMAL EL ALD [6]	25 (75.8%)	15 (24.2%)	0
FLYNN ET AL[5]	150 (65%)	57 (25%)	23 (10%)
WUDBHAV[21]	12 (63.15%)	6 (31.57%)	1(5.26%)
SAIKA ET AL[22]	13 (59%)	6 (27.2%)	3 (13.6%)

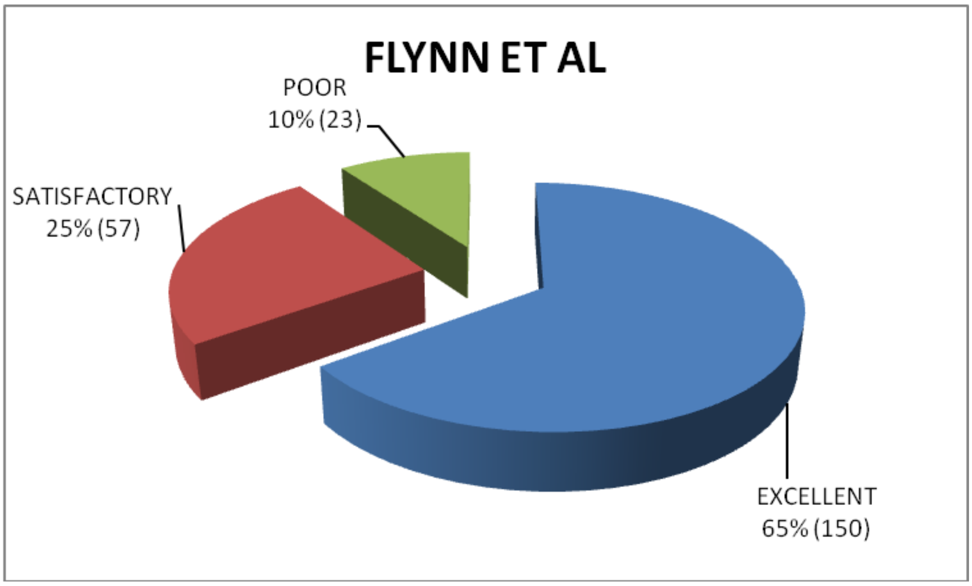
CHART 40: COMPARISON OF FINAL OUT OUTCOMES AS PER FLYNN'S CRITERIA IN DIFFERENT STUDIES.

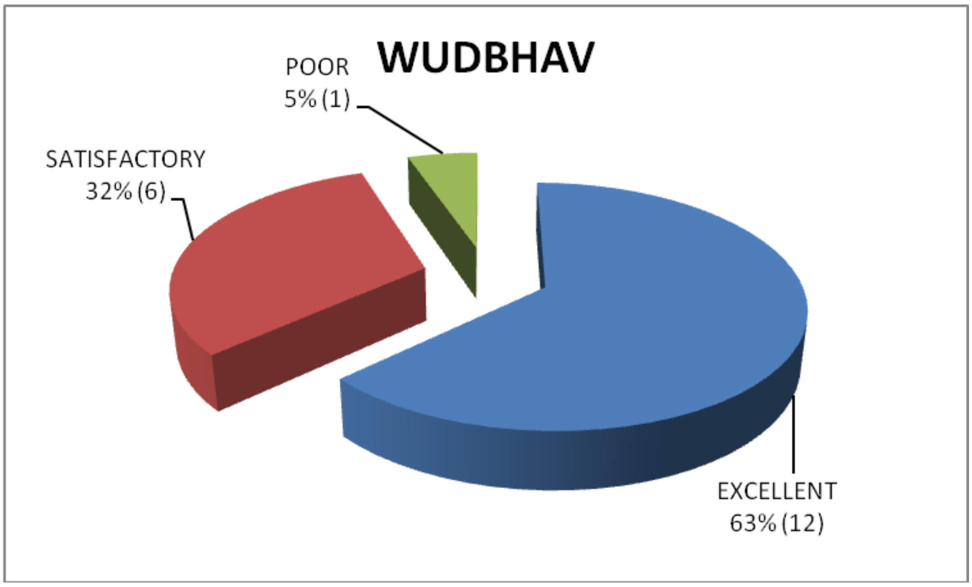


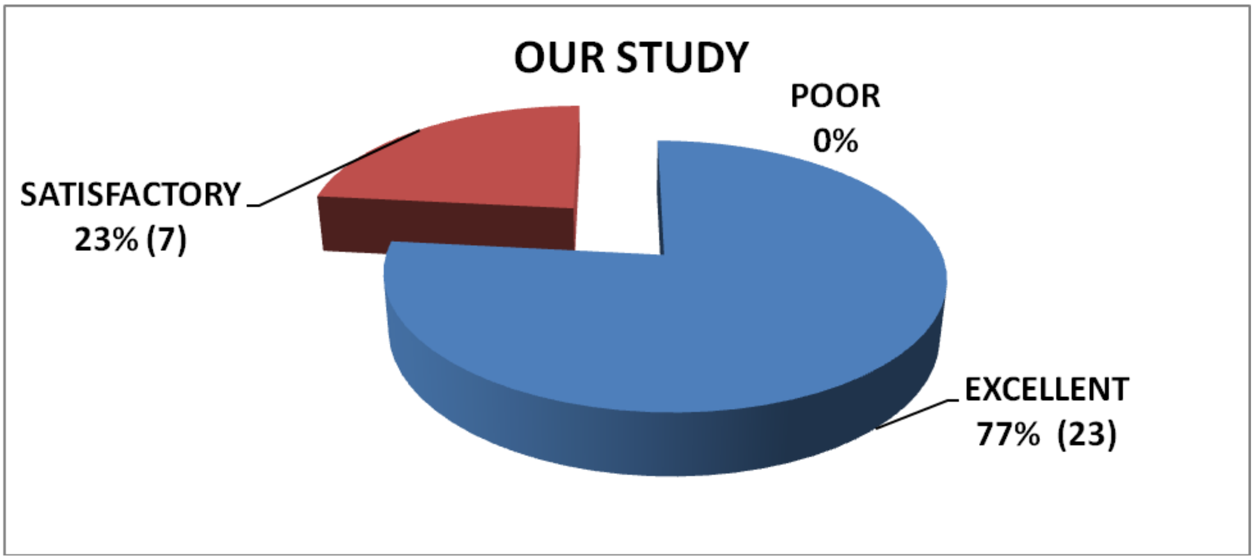

BHUYAN
SATISFACTORY
18% (7)
POOR
0%
EXCELLENT
82% (33)


SINHA
POOR
8% (4)
SATISFACTORY
17% (9)
EXCELLENT
75% (40)


GAMAL EL ALD
POOR
0%
SATISFACTORY
24% (15)
EXCELLENT
76% (25)


FLYNN ET AL
POOR
10% (23)
SATISFACTORY
25% (57)
EXCELLENT
65% (150)


WUDBHAV
POOR
5% (1)
SATISFACTORY
32% (6)
EXCELLENT
63% (12)


OUR STUDY
POOR
0%
SATISFACTORY
23% (7)
EXCELLENT
77% (23)

CONCLUSION:

Based on the experience and results of our study, we conclude that TITANIUM ELASTIC NAIL SYSTEM surgical technique is a safe, simple, reliable and effective method for management of paediatric femoral and tibial diaphyseal fractures between the age of 5 to 15 years.

TITANIUM ELASTIS NAILS gives elastic mobility promoting rapid union at fractures site and stability which is ideal for early mobilization as well as its physeal protective technique and design causes minimal disturbance of bone growth, hence TENS may be considered to be a protective and physiological method of treatment.

TENS has definite advantages in terms of short duration of hospital stay, and early return to activity, acceptable bone healing time, good functional outcome and less incidence of complications.

The surgical technique itself is easy to learn and implement with moderate need of equipment and surgical skills. Minimally invasive approach, shorter operative time, less blood loss, lesser radiation exposure resonates with idea of an ideal surgical technique.

Overall experience in our study shows that TITANIUM ELASTIC NAILING for paediatric femur and tibia diaphyseal fracture is a safe, cost effective, physiological procedure with a relatively easy learning curve resulting in very few short term complications with mostly excellent outcomes irrespective of fracture location and pattern provided that the important biomechanical principles of TENS are followed.

SUMMARY:

This prospective study was started with the objectives to study the functional and radiological outcome following surgical management of diaphyseal fractures of femur and tibia in children aged between 5-15 years by using Titanium Elastic Nailing System at Department of Orthopedic, of R L Jalappa Hospital and Research Center , Kolar, Karnataka.

Thirty consecutive cases which strictly followed inclusion criteria were included in the study after consent of the patient and legal guardian, preferably parents.

Out of the total 30 cases, 23 (76.6.%) were boys and 7(23.3.%) were girls with a mean age of 9.2 years.

Most common mode of injury was self fall/sports injury, accounting for 43.3% of cases, closely followed by RTA (36.7%) and least common was fall from height (20% of cases).

All the cases were closely examined and x-rays were done and findings noted. Femur was effected in 13 cases (43.3%) and tibia in 17 (56.7%) of cases.

The most common pattern of fracture observed was transverse (46.7%), followed by oblique (33.33%), spiral and communited patterns were seen 10% cases each.

Majority of fracture were on right side(70%) and in the middle one-third on the bone (83.3%).

After admission all cases were prepared as per hospital protocols and once patients were fit to undergo surgery they were operated at the earliest strictly following the surgical technique and careful intra-operative monitoring.

All the cases were operated within 48 hours of trauma with an average time interval between trauma and surgery of 29.1 hours.

The average operative time was 49.83 minutes with minimum time 30 minutes and maximum time of 60 minutes.

The minimum nail size used in our study was 2.5mm and maximum size was 3.5mm.

Post-op immobilization was done in 18 cases due to unstable fracture fixation with an average period of 2.23 weeks, non weight bearing ambulation was started on post-op 2^{nd} - 3^{rd} day. Weight bearing as tolerated ambulation was started at the earliest.

Average duration of stay in hospital was 2 weeks, after which patients were followed up at 6weeks, 12 weeks and 24 weeks clinically and with x-rays imaging.

The average time till full weight bearing ambulation was 10 weeks.

Two cases, both tibia mid shaft fracture, had complete bone remodeling seen at 24 weeks, hence implant was removed at 24 weeks.

Time for union for 22 cases (73.33%) was under 12 weeks and the maximum time taken for union was15 weeks for a communited femur midshaft fracture case, the mean time for union was 10 weeks.

With an exception of 3 cases which had mild restriction of movement in knee joint, all the cases had active, full and pain-free range of movement of the adjacent joints.

Minor complications were observed in 13 (43.33%) cases, none of the cases had major complications. Most commonly nail entry site pain/irritation was seen, in 10 (33.33%) cases. Superficial infections were seen in 3 cases which were treated with antibiotic course.

One case of limb length discrepancy was noted with <2 cm lengthening in femur and 2 cases of coronal plane angular deformity were observed with <10 degree of deformity.

None of the cases reported sagittal plane deformity, rotational deformity, nail back out, sinking of nail in medullary cavity, any iatrogenic injuries and any major complications.

The final outcome was evaluated as per Flynn's criteria, 23 (76.66%) cases had an excellent outcome, 7 (23.33 %) had satisfactory and none of the patient had a poor outcome.

At the end of our study it was concluded that TITANIUM ELASTIC NAILING for diaphyseal fracture of femur and tibia in age group 5 years to 15 years old children, is a safe, cost effective, physiological procedure with a relatively easy learning curve resulting in very few short term complications with mostly excellent outcomes irrespective of fracture location and pattern provided that the important biomechanical principles of TENS are followed.

BIBLIOGRAPHY

1. Heinrich SD, Drvaric DM, Darr K et al. The operative stabilization of pediatric diaphyseal femur fractures with flexible intramedullary nails: A prospective analysis. J Pediatr Orthop. 1994; 14(4): 501-7.

2. Stans AA, Morrissy RT, Renwick SE. Femoral shaft fracture treatment in patients age 6 to 16 years. J Pediatr Orthop. 1999; 19(2): 222-8.

3. Clinkscales CM, Peterson HA. Isolated closed diaphyseal fractures of the femur in children: Comparison of effectiveness and cost of several treatment methods. Orthopaedics. 1997; 20(12): 1131-6.

4. Wright JG. The treatment of femoral shaft fractures in children: a systematic overview and critical appraisal of the literature. Can J Surg. 2000; 43(3): 180-9.

5. Flynn JM, Hresko T, Reynolds RA, et al. Titanium elastic nails for Pediatric femur fractures: A multicenter study of early results with analysis of complications. J Pediatr Orthop. 2001; 21(1): 4-8.

6. Gamal El-Adl, Mohamed F. Mostafa, Mohamed A. Khalil, Ahmed Enan. Titanium elastic nail fixation for paediatric femoral and tibial fractures. Acta Orthop. Belg 2009; 75: 512-520.

7. Galano GJ, Vitale MA, Kessler MW, Hyman JE, Vitale MG. The most frequent traumatic orthopaedic injuries from a national pediatric inpatient population. J Pediatr Orthop. 2005;25(1):39-44

8. Metaizeau JP. Stable elastic nailing for fractures of the femur in children.Bone Joint Surg Br 2004;86:954-957.

9. Hassam MK. Titanium Flexible intramedullary nailing of Paediatric Femoral shaft fractures. KASR:EL AIN1 Medical Journal.2003; 13(3): 45 -50.

10. Huber RI, Keller HW, Huber PM, et al. Flexible intramedullary nailing as fracture treatment in children. J Pediatr Orthop. 1996;16:602–605.

11. Lascombes, Pierre. Flexible intramedullary nailing in children: the Nancy University Manual. Springer, 2009

12. Ligier J.N., Métaizeau J.P., Prévot J. and Lascombes P., Flexible Intramedullary Nailing of femoral shaft fractures in children, J Bone Joint Surg. 1988:70B:74–7

13. Lascombes P., Prevot J., Ligier, J.N., Metaizeau J. and Poncelet T., Elastic stable intramedullary nailing in forearm shaft fractures in children: 85 cases. J Pediatr Orthop. 1990;10:167–171

14. Dietz H.G., Schmittenbecher P.P., Slongo,T., and Wilkins K. E., "AO manual of fracture management." ESIN in children(2006).

15. Metaizeau JP. Osteosynthese chez l'enfant. Embrochage centro-medullaire elastique stable. Montpellier: Sauramps, 1988.

16. Ligier JN, Metaizeau JP, Prevot J. Closed flexible medullary nailing in paediatric traumatology. Chir Pediatr 1983;24:383-5.

17. Flynn JM, Skaggs DL, Sponseller PD, Ganley TJ, Kay RM, Kellie Leitch KK. The operative management of pediatric fractures of the lower extremity. J Bone Joint Surg Am 2002;84:288-300.

18. Hassan Al-Sayed et al. Titanium elastic nail fixation for Paediatric femoral shaft fractures Pan Arab J. Orth. Trauma 2006; 10:7-15

19. Kubiak EN, Egol KA, Scher D, Wasserman B, Feldman D, Koval KJ. Operative treatment of tibial shaft fractures in children: are elastic stable intramedullary nails an improvement over external fixation? J Bone Joint Surg Am 2005; 87:1761–1768.

20. Vallamshetla VR, De Silva U, Bache CE, Gibbons PJ. Flexible intramedullary nails for unstable fractures of the tibia in children : An eight-year experience. J Bone Joint Surg 2006 ; 88-B : 536-540.

21. Wudbhav N. Sankar, Kristofer J. Jones, B. David Horn, and Lawrence Wells. Titanium elastic nails for pediatric tibial shaft fractures. J Child Orthop 2007 November; 1(5):281-286

22. Saikia K, Bhuvan S, Bhattacharya T, Saikia S. Titanium elastic nailing in femoral diaphyseal fractures of children in 6-16 years of age. Indian J Orthop. 2007;41(4):381-5.

23. Mark G. Swindells and R. A. Rajan. Elastic intramedullary nailing in unstable fractures of the paediatric tibial diaphysis: a systematic review J Child Orthop 2010 February; 4(1): 45–51

24. Goodwin RC, Gaynor T, Mahar A, Oka R, Lalonde FD (2005) Intramedullary flexible nail fixation of unstable pediatric tibial diaphyseal fractures. J Pediatr Orthop 25(5):570–576 7.

25. Gordon JE, Gregush RV, Schoenecker PL, Dobbs MB, Luhmann SJ (2007) Complications after titanium elastic nailing of pediatric tibial fractures. J Pediatr Orthop 27(4):442–446 8.

26. O'Brien T, Weisman DS, Ronchetti P, Piller CP, Maloney M (2004) Flexible titanium nailing for the treatment of the unstable pediatric tibial fracture. J Pediatr Orthop 24(6):601–609 10.

27. Sankar WN, Jones KJ, David Horn B, Wells L (2007) Titanium elastic nails for pediatric tibial shaft fractures. J Child Orthop 1:281–286

28. Srivastava AK, Mehlman CT, Wall EJ, Do TT (2008) Elastic stable intramedullary nailing of tibial shaft fractures in children. J Pediatr Orthop 28(2):152–158.

29. Furlan D et al. Elastic stable intramedullary nailing for pediatric long bone fractures: experience with 175 fractures. . Scandinavian Journal of Surgery 100: 208–215, 2011

30. Ahmed Labib Zarad. Flexible intramedullary nails for unstable fractures of the tibia in children: a retrospective evaluation of effectiveness. Egyptian Orthopedic Journal 2014, 49:281–285.

31. Sreenivasulu P.S.B, Biju Ravindran , Tirumala Chaitanya K. Evaluation of Outcome of Paediatric Long Bone ShaftFractures by Titanium Elastic Nailing. Asian Pac. J. Health Sci., 2015; 2(1): 1-9.

32. Salem K, Lindemann I, Keppler P. Flexible intramedullary nailing in pediatric lower limb fractures. J Pediatr Orthop 2006; 26(4):505–509.

33. Heffernan MJ et al. Treatment of Femur Fractures in Young Children: A Multicenter Comparison of Flexible Intramedullary Nails to Spica Casting in Young Children Aged 2 to 6 Years. J Pediatr Orthop 2015;35:126–129.

34. Bauer J, Hirzinger C, Metzger R. Quadruple ESIN (Elastic Stable Intramedullary Nailing). J Pediatr Orthop 2017;37(2).

35. Kaiser et al. Modification of elastic stable intramedullary nailing with a 3rd nail in a femoral spiral fracture model – results of biomechanical testing and a prospective clinical study. BMC Musculoskeletal Disorders 2014 15:3.

36. Newton PO, Mubarak SJ. Financial aspects of femoral shaft fracture treatment in children and adolescents. J Pediatr Orthop 1994;14(4):508-512.

37. Dameron, Thomas B. Jr.; Thompson, Hugh A. Femoral-Shaft Fractures in Children: Treatment by Closed Reduction and Double Spica Cast Immobilization. J Bone Joint Surg 1959; 41(7) :1201-1212.

38. Beaty, James H.; Kasser, James R.. “Femoral Shaft Fractures.” *Rockwood and Wilkins Fractures in Children*, 7th ed., Lippincott Williams & Wilkins, 2010, pp. 904–950.

39. Beaty, James H.; Kasser, James R.. “Fractures of the Shaft of the Tibia and Fibula” *Rockwood and Wilkins Fractures in Children,* 7th ed., Lippincott Williams & Wilkins, 2010, pp.1048-1087

40. Ender J, Simon-Weidner R (1970) Die Fixierung der trochanteren Brücke mit runden, elastischen Condylenägeln. *Acta Chir Aust;* 1:40–42.

41. Hunter JB. The principles of elastic stable intramedullary nailing in children. Int. J. Care Injured (2005) 36, S-A20—S-A24

42. McKibbin B (1978) The biology of fracture healing in long bones. *J Bone Joint Surg Br;* 60-B(2):150–162.

43. Perkins G (1958) *Fractures and dislocations.* London, The Athlone Press, University of London.

44. Ziv I, Rang M. Treatment of femoral fractures in the child with head injury. *J Bone Joint Surg Br* 1983;65:276–8.

45. Probe R, Lindsey RW, Hadley NA, et al. Refracture of adolescent femoral shaft fractures: a complication of external fixation: a report of two cases. *J Pediatr Orthop* 1993;13:102–5.

46. Beaty JH. Aseptic necrosis of the femoral head following antegrade nailing of femoral fractures in adolescents. Tech Orthop 1998;13:96–9.

47. Raney EM, Ogden JA, Grogan DP. Premature greater trochanteric epiphysiodesis secondary to intramedullary femoral rodding. J Pediatr Orthop 1993;13:516–20.

48. Siegmeth A, Wruhs O, Vecsei V (1998) External fixation of lower limb fractures in children. Eur J Pediatr Surg 8:35–41

49. Tolo VT (1983) External skeletal fixation in children’s fractures.J Pediatr Orthop 3:435–442

50. Parikh SN, Jain VV, Denning J et al.Complications of Elastic Stable Intramedullary Nailing in Pediatric Fracture Management. J Bone Joint Surg Am. 2012;94:e184(1-14)
51. Bhuyan BK, Singh SM.Titanium elastic nailing in pediatric femoral diaphyseal fractures in the age group of 5-16 years -A short term study. JCOT 2014;5:203-10.
52. Sinha SK, Kumar V, Singh A. Outcomes of fracture shaft femur in pediatric population managed at emergency. JCOT 2016.
53. Mann DC, Weddington J, Davenport K. Closed elastic nailing of femoral shaft fractures in adolescents. J Pediatr Orthop 1986; 6 (6): 651-5.
54. Kalenderer O., Agus H, Sanli C. Open reduction and intramedullary fixation through minimal incision with ender nails in femoral fractures of children aged 6 to 16 years. Acta Orthop Traumatol Jure 2002; 36 (4): 303-9.
55. Aksoy C et al. Pediatric femoral fractures: A comparison of compression plate fixation and flexible intramedullary nailfixation. J Bone & Joint Surg (Br) 2003; 85-B: Supp III: 263pp.
56. Oh CW. Et al. Retrograde flexible intramedullary nailing in children's femoral fractures. Int Orthop 2002; 26 (1): 52- 5.
57. Narayanan UG, Hyman JE, Wainwright AM, Rang M, Alman BA. Complications of elastic stable intramedullary nail fixation of pediatric femoral fractures, and how to avoid them. J Pediatr Orthop. 2004 Jul-Aug;24(4):363-9.
58. Moroz LA, Launay F, Kocher MS, Newton PO, Frick SL, Sponseller PD, Flynn JM. Titanium elastic nailing of fractures of the femur in children. Predictors of complications and poor outcome. J Bone Joint Surg Br. 2006 Oct;88(10):1361-6.
59. Luhmann SJ, Schootman M, Schoenecker PL, Dobbs MB, Gordon JE. Complications of titanium elastic nails for pediatric femoral shaft fractures. J Pediatr Orthop. 2003 Jul-Aug;23(4):443-7.

60. Houshian S, Gothgen CB, Pedersen NW, Harving S. Femoral shaft fractures in children: elastic stable intramedullary nailing in 31 cases. Acta Orthop Scand. 2004 Jun;75(3):249-51.

61. Ho CA, Skaggs DL, Tang CW, Kay RM. Use of flexible intramedullary nails in pediatric femur fractures. J Pediatr Orthop. 2006 Jul-Aug;26(4):497-504.

62. Beaty JH., Austin SM., Warner WC, et al. Interlocking intramedullarynailing of femoral shaft fractures in adolescents: preliminary results and complications. J Pediatr Orthop 1994; 14: 178-183.

63. Ozturkman Y. Dogrul C, Balioglu MB. and Karli M. Intramedullarystabilization of pediatric diaphyseal femur fracture with elastic intramedullary nails.Acta Orthop Traumatol Jure 2002; 36 (3): 220- 7.

64. Sagan ML, Datta JC, Olney BW, Lansford TJ, McIff TE. Residual deformity after treatment of pediatric femur fractures with flexible titanium nails. J Pediatr Orthop. 2010 Oct-Nov;30(7):638-43.

TENS FOR TIBIA AND FEMUR DIAPHYSEAL FRACUTRES IN CHILDREN

PROFORMA

NAME : I.P.NUMBER :

AGE : DOA:

SEX : DOS:

ADDRESS : DOD:

OCCUPTION :

INFORMANT :

<u>HISTORY</u>

- PRESENTING COMPLAINTS

  1. PAIN
  2. SWELLING
  3. DEFORMITY
  4. RESTRICTION OF MOVEMENTS

- MODE OF INJURY .

  RTA

  SELF FALL

  FALL FROM HEIGHT

- ASSOCIATED INJURIES
- PAST HISTORY
- FAMILY HISTOY

- PERSONAL HISTORY

SOCIO ECONOMIC
STATUS DIET

APPETITE SLEEP

BOWEL/BLADDER

EXAMINATION

- GPE

1.BUILT

2.NOURISHMENT WELL MODERATE POOR

3. WEIGHT

4. P E N C I L

5. PR - BP - RR - TEMP. - GCS

- SYSTEMIC EXAMINATION

CVS :

RS :

PA :

CNS :

- LOCAL EXAMINATION

1. ATTITUDE
2. SWELLING R L

THEIGH

LEG

3. DEFORMITY R L

THEIGH

LEG

4. TENDERNESS AND CREPITUS

THEIGH	R	L
Proximal 1/3rd		
Middle 1/3rd		
Distal 1/3rd		

LEG	R	L
Proximal 1/3rd		
Middle 1/3rd		
Distal 1/3rd		

5. RESTRICTION OF MOVEMENTS

	R	L
HIP		
KNEE		
ANKLE		

6. SHORTENING

	R	L
THEIGH		
LEG		

7. DISTAL NEUROLOGICAL DEFICITS YES NO

8. DISTAL VASCULAR DEFICITS YES NO

INVESTIAGATIONS

- Blood : Haemoglobin TC

  ESR DC

  RBS Blood urea

  S.creatinine HIV

  HbsAg sodium

  Potassium

- Urine : Alubmin Sugar
- ECG
- X – ray full length – theigh with hip and knee - - AP and lateral views

  OR

  X – ray full length – leg with knee and ankle - - AP and lateral views

-SIDE AFFECTED R L

-SITE OF FRACTURE PROXIMAL 1/3rd MIDDLE 1/3rd DISTAL 1/3rd

-TYPE OF FRACTURE

TRANSVERSE OBLIQUE SPIRAL SEGMENTAL COMMMUNITED

DIAGNOSIS

MANAGEMEMT

A. PRELIMINARY IMMOBILIZATION

THOMAS SPLINT

ABOVE KNEE POP SLAB

B.SURGICAL MANAGEMENT

- DURATION BETWEEN TRAUMA AND SURGERY :
- ANAESTHESIA : SPINAL
- GENERAL PROCEDURE :
- DURATION OF SURGERY :

C. SIZE OF THE NAIL

MEDIAL

LATERAL

D. POST OPERATIVE MANAGEMENT

a)ANTIBIOTICS INTRAVENOUS ORAL

b)WOUND INSPECTION AND DRESSING

c)DATE OF SUTURE REMOVAL

ASSESSMENT TYPE	CLINICAL PARAMETERS	DURATION IN WEEKS		
		6	**12**	**24**
CLINICAL ASSESSMENT	PAIN			
	RANGE OF MOVEMENTS HIP KNEE ANKLE			
	TIME OF WEIGHT BEARING			
RADIOLOGICAL ASSESSMENT	ALLINGMENT SAGGITAL CORONAL			
	CALLOYUS FORMATION			
	VISIBILITY OF FRACTURE LINE			
COMPLICATIONS	MAJOR			
	MINOR			

-

PATIENT INFORMATION SHEET AND CONSENT FORM FOR SURGERY AND STUDY

ಸಮ್ಮತಿ ಪತ್ರ / ಮಾಹಿತಿ ಪತ್ರ

CONSENT FORM FOR SURGERY AND STUDY

....*ಹೆಸರಿನವನಾದ ನಾನು/ನಾವು* ....
ಹೆಸರಿನ........... *ವರ್ಷ ವಯಸ್ಸಿನವನಾದ ಯು.ಹೆಚ್.ಐ.ಡಿ ಹೊಂದಿದ ರೋಗಿಯ ಪೋಷಕರು/ ಸಂಬಂಧಿಕರು /ರಕ್ಷಕರು ಆಗಿದ್ದು* ,
ನಮಗೆ ರೋಗಿಯ ಸ್ಥಿತಿ
....
ಕುರಿತು ವಿವರಿಸಲಾಗಿದೆ.

I / we…………………………….. the patient parent(s)/relative(s)/attender(s) of the patient named……………………, aged…………., hospital number…………………….. have been told about the patients condition i.e.
……………………………………………………………………………………………………
…………………………….

ಹಾಗು ಮೇಲಿನ ಸ್ಥಿತಿಗೆ ಲಭ್ಯವಿರುವ ವಿವಿಧ ಚಿಕಿತ್ಸಾ ವಿಧಾನಗಳಾದ:

-ಟೈಟಾನಿಯಂ ಎಲಾಸ್ಟಿಕ್ ನೈಲಿಂಗ್ ವ್ಯವಸ್ಥೆ ಬಳಸಿ ಶಸ್ತ್ರಚಿಕಿತ್ಸೆಯಿಂದ ಜೋಡಣೆ

-ಬೇರೆ ರೀತಿಯ ಕಂಬಿ (ಉದಾಹರಣೆಗೆ - ರಶ್ ನೇಲ್ ,ಕೆ ವೈರ್) ಬಳಸಿ ಶಸ್ತ್ರಚಿಕಿತ್ಸೆಯಿಂದ ಜೋಡಣೆ

-ಮುಲಾಮು ಪಟ್ಟಿ ಬಳಸಿ ಚಿಕಿತ್ಸೆ

And the treatment options available for it, which are as follows :

1. Surgical treatment with TITANIUM ELASTIC NAILING SYSTEM (TENS)
2. Surgical treatment using other types of implants e.g. rush nail, K-wires etc.
3. Non surgical treatment with cast application.

ಮೇಲಿನ ಚಿಕಿತ್ಸಾ ವಿಧಾನಗಳ ಕುರಿತು ವೈದ್ಯರು ಹೇಳಿದ ಆಗು ಹೋಗುಗಳ ಕುರಿತು ತಿಳಿದುಕೊಂಡು ನಾವು **ಟೈಟಾನಿಯಂ ಎಲಾಸ್ಟಿಕ್ ನೈಲಿಂಗ್ ವ್ಯವಸ್ಥೆ ಬಳಸಿ ಶಸ್ತ್ರಚಿಕಿತ್ಸೆಯಿಂದ ಜೋಡಣೆಗೆ** ಆದ್ಯತೆ ನೀಡುತ್ತಿದ್ದೇವೆ.

After understanding all the advantages and disadvantages for each of the above mentioned treatment options, I/ we choose to undergo surgical treatment using TENS.

ನಮಗೆ ಈ ಚಿಕಿತ್ಸೆಯ ಅಪಾಯಕಾರಿ ಅಂಶಗಳು, ಸಾಧ್ಯವಿರುವ (ಶಾಸ್ತ್ರಚಿಕಿತ್ಸೆಗಿಂತ ಮುಂಚಿನ/ ಸಮಯದ / ನಂತರದ) ತೊಡಕು ಪರಿಣಾಮಗಳ ಕುರಿತು ವಿವರಿಸಲಾಗಿದೆ.

I / we have explained about all the risk factors, possible complication of the treatment pre-, intra- and post –op and we give our full consent to perform the surgery .

ಈ ಅಧ್ಯಯನದ ವಿವಿಧ ಅಂಶಗಳ ಬಗ್ಗೆ ಪ್ರಶ್ನೆಗಳನ್ನು ಕೇಳುವ ಅವಕಾಶವನ್ನು ನನಗೆ ನೀಡಲಾಗಿದೆ ಮತ್ತು ನನ್ನ ಪ್ರಶ್ನೆಗಳಿಗೆ ತೃಪ್ತಿಕರವಾದ ಉತ್ತರಗಳು ದೊರೆತಿರುತ್ತವೆ.

I have been given chance to ask doubts regarding the study and I have got satisfactory answers for my questions.

ಮೇಲೆ ತಿಳಿಸಿರುವ ಅಧ್ಯಯನದ ಕಾರ್ಯ ವಿಧಾನಗಳು ಮತ್ತು ಅಹಿತಕರ ಪರಿಣಾಮಗಳನ್ನು ಅರಿತು ಮುಚ್ಚುಮರೆ ಇಲ್ಲದೆ ನನ್ನ ಪರಿಪೂರ್ಣ ವಿವೇಚನೆಯಲ್ಲಿ ಅಧ್ಯಯನದಲ್ಲಿ ಭಗವಹಿಸಲು ಹಾಗು ನನ್ನ ಹೆಸರು ಮತ್ತು ಪರೀಕ್ಷಾ ವರದಿಗಳನ್ನು ಸಂಶೋಧನೆಯಲ್ಲಿಬಳಸಿಕೊಳ್ಳಲು ಒಪ್ಪಿಗೆ ನೀಡುತಿದ್ದೇನೆ.

I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).

I understand that the medical information produced by this study will become part of institutional record and will be kept confidential by the said institute.

ಈ ಅಧ್ಯಯನದಿಂದ ಯಾವುದೇ ಸಂದರ್ಭದಲ್ಲಿ ಹಿಂದೆ ಸರಿಯುವ ಸ್ವಾತಂತ್ರ್ಯ ನನಗಿದೆ ಎಂಬುದನ್ನು, ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಪಾಲ್ಗೊಳ್ಳುವುದರಿಂದ ನನಗೆ ಯಾವುದೇ ಹೆಚ್ಚುವರಿ ವೆಚ್ಚ ತಗಲುವುದಿಲ್ಲವೆಂಬುದನ್ನು ತಿಳಿದಿರುತ್ತೇನೆ.

I understand that my participation is voluntary and may refuse to participate or may withdraw my consent and discontinue participation at any time without prejudice to my present or future care at this institution.

ಈ ಅಧ್ಯಯನದ ಯಾವುದೇ ಅಹಿತಕರ ಪರಿಣಾಮಗಳಿಗೆ ಚಿಕಿತ್ಸೆ ನೀಡುತ್ತಿರುವ ವೈದ್ಯರು,ಶುಶ್ರೂಷಾ ಸಿಬ್ಬಂದಿ ಹಾಗೂ ಆಸ್ಪತ್ರೆಯ ವ್ಯವಸ್ಥಾಪಕರನ್ನು ಹೊಣೆಗಾರರನ್ನಾಗಿ ಮಾಡುವುದಿಲ್ಲವೆಂದು ತಿಳಿಸುತ್ತಾ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸಲು ಒಪ್ಪಿರುತ್ತೇನೆ.

ಪರೀಕ್ಷಾರ್ಥಿ: ಸಹಿ - .... ಹೆಸರು - ....

ಸಾಕ್ಷಿ : 1) ಸಹಿ - .... ಹೆಸರು - ....

2) ಸಹಿ - .... ಹೆಸರು - ....

ಸಹಿ ತೆಗೆದುಕೊಂಡ ದಿನಾಂಕ: ....

ಸಂದರ್ಶಕರ ಸಹಿ ಪ್ರಧಾನ ಪರೀಕ್ಷಕರ ಸಹಿ

ದಿನಾಂಕ: ದಿನಾಂಕ:

COMMENTS :	
DR. VAIBHAV MITTAL (INVESTIGATOR)	
DR. SIDDARAM . N. PATIL (GUIDE FOR STUDY)	

MASTER CHART KEYS

Mode of injury		
SERIAL NUMBER	DETAILS	CODE

1	Road traffic accident	1
2	Self fall/sports injury/weight fall	2
3	Fall from height	3

SIDE EFFECTED		
SERIAL NUMBER	DETAILS	CODE
1	Right	1
2	Left	2

PATTERN OF FRACTURE		
SERIAL NUMBER	DETAIL	CODE
1	Transverse	1
2	Oblique	2
3	Spiral	3
4	Segmental	4
5	Communited	5

LEVEL OF FRACTURE		
SERIAL NUMBER	DETAILS	CODE
1	Proximal 1/3	1
2	Middle1/3	2
3	Distal 1/3	3

RANGE OF MOVIMENT OF HIP/KNEE/ANKLE AT 24 WEEKS(REFER TABLE 2)		
SERIAL NUMBER	DETAILS	CODE
1	Full	1
2	Mild restriction	2
3	Moderate restriction	3
4	Severe restriction	4

MINOR COMPLICATIONS		
SERIAL NUMBER	DETAILS	CODE
1	Pain at the site of nail insertion	1
2	Minor angulation	2
3	Minor leg length discrepancy	3
4	Inflammatory reaction to nails	4
5	Superficial infection at site of nail insertion	5
6	Delayed union	6

MAJOR COMPLICATIONS		
SERIAL NUMBER	DETAILS	CODE
1	Angulation exceeding the guidelines	1
2	Leg length discrepancy exceeding the guidelines	2
3	Deep infection	3
4	Loss of reduction requiring revision surgery	4
5	Surgery to revise nail placement	5
6	Compartment syndrome requiring surgery	6
7	Neurological damage after nailing	7
8	Delayed or nonunion leading to revision surgery.	8

Final outcome as per Flynn’s criteria

SERIAL NUMBER	DETAILS	CODE
1	Excellent	1
2	Satisfactory	2
3	Poor	3

SERIAL NUMBER	NAME	AGE	GENDER	HOSPITAL NUMBER	ADDRESS	MODE OF INJURY	BONE EFFECTED	SIDE EFFECTED	PATTERN OF FRACTURE	LEVEL OF FRACTURE	TIME BETWEEN TRAUMA AND SURGERY (IN HOURS)	DURATION OF SURGERY (IN MINUTES)	NAIL SIZES (IN mm)	POST-OPERATIVE IMMOBILIZATION(IN WEEKS)	POST - OPERATIVE STAY IN HOSPITAL (IN DAYS)	PARTIAL WEIGHT BEARING (IN WEEKS)	TIME FOR UNION (IN WEEKS)	FULL WEIGHT BEARING (IN WEEKS)	RANGE OF MOVEMENTS AT 24 WEEKS	HIP	KNEE	ANKLE	COMPLICATIONS	MAJOR	MINOR	OUTCOME
1	DHILIPA	15	MALE	172747	KOLAR	1	FEMUR	1	2	2	48	60	3;3	0	8	4	10	10		1	2			0	1	1
2	ABDUL MAJEED	14	MALE	177185	KOLAR	1	TIBIA	1	5	1	24	45	2;2	6	7	6	12	14			1	1		0	0	1
3	VISHNUVARDHAN	6	MALE	189220	CHINTAMANI	2	TIBIA	1	1	2	48	60	2;2	0	9	2	10	10			1	1		0	0	1
4	JYOTISH	8	MALE	212004	MALUR	2	TIBIA	1	2	2	48	60	2;2	4	8	4	9	10			1	1		0	0	1
5	ANAND	11	MALE	234507	MULABAGAL	1	TIBIA	1	2	2	48	50	2.5;2.5	0	7	3	11	12			1	1		0	1	1
6	KARTHIK	12	MALE	250054	BANGALORE	1	FEMUR	2	3	2	24	60	3;3	4	7	4	10	10		1	1			0	0	1
7	RAJESH	15	MALE	258630	CHINTAMANI	1	FEMUR	1	5	2	24	50	3;3	6	10	6	15	15		1	2			0	6	2
8	A. KUMAR	11	MALE	234507	MULABAGAL	1	TIBIA	2	2	2	48	40	2.5;2.5	0	8	3	11	12			1	1		0	1	1
9	SHASHIDHAR	7	MALE	281460	KOLAR	2	TIBIA	2	2	2	24	40	2;2	1	6	2	12	14			1	1		0	0	1
10	AKSHAY KUMAR	10	MALE	286585	KOLAR	2	TIBIA	1	2	2	24	45	2;2	0	10	3	11	12			1	1		0	5	2
11	SADIQ	10	MALE	290904	MULABAGAL	1	TIBIA	2	1	2	48	45	2;2	0	8	4	10	11			1	1		0	0	1
12	SHIVAMANI	10	MALE	293314	MALUR	3	TIBIA	1	1	2	48	55	2.5;2.5	0	7	2	12	12			1	1		0	1,3	2
13	ANKITA	5	FEMALE	297874	KOLAR	2	TIBIA	2	2	2	24	40	2;2	3	8	5	10	10			1	1		0	0	1
14	YESHESH	5	MALE	227051	KOLAR	2	TIBIA	1	1	2	24	30	2;2	0	8	2	11	12			1	1		0	0	1
15	S.YAKUB	10	MALE	290904	MULABAGAL	1	FEMUR	2	1	2	48	60	2.5;2.5	6	7	6	12	13		1	1			0	1	1
16	ALLENA SADIYA	5	FEMALE	301914	NARSAPURA	2	FEMUR	1	1	1	10	50	2.5;2.5	5	8	5	10	12		1	1			0	0	1
17	UMASHREE	5	FEMALE	317696	CHINTAMANI	2	FEMUR	1	1	2	24	40	2;2	2	9	4	11	11		1	1			0	0	1
18	KARTHIK	14	MALE	358619	DEVARAJSAMUDRA	1	FEMUR	1	5	2	24	50	3;3	6	8	6	12	12		1	2			0	0	1
19	VAISHNAVI	5	FEMALE	369573	KOLAR	2	TIBIA	1	1	2	24	40	2;2	0	8	2	11	12			1	1		0	1	1
20	VIJAY	14	MALE	403432	MULABAGAL	3	TIBIA	1	3	2	24	45	2.5;2.5	1	9	2	12	12			1	1		0	0	1
21	HARSHIT GOWDA	10	MALE	418394	CHINTAMANI	3	TIBIA	1	3	2	24	55	3;3	0	10	3	11	12			1	1		0	5	2
22	ROHIT	6	MALE	419322	KOLAR	2	TIBIA	1	2	2	12	50	2.5;2.5	2	8	3	10	13			1	1		0	0	1
23	SACHIN	6	MALE	419742	MALUR	3	FEMUR	2	1	2	24	60	2;2	3	8	5	11	13		1	1			0	1	1
24	DARSHAN	9	MALE	420593	KOLAR	3	FEMUR	1	1	2	12	60	2.5;2.5	2	11	6	10	11		1	1			0	1,5	2
25	SHYLAJA	6	FEMALE	442740	KOLAR	2	FEMUR	1	2	3	24	40	2.5;2.5	6	8	6	11	12		1	1			0	0	1
26	TEJAS	9	MALE	446179	MALUR	1	FEMUR	1	1	2	24	50	3;3	0	9	3	10	11		1	1			0	0	1
27	HUZAIF	13	MALE	451261	KOLAR	1	FEMUR	2	1	2	24	45	3;3	2	8	4	12	12		1	1			0	1,2	2
28	DEEKSHA	10	FEMALE	453887	NARSAPURA	2	TIBIA	1	1	3	24	60	3;3	0	8	1	11	12			1	1		0	0	1
29	VIJAY	7	MALE	467301	MALUR	2	FEMUR	2	1	1	24	60	2;2	2	9	4	10	12		1	1			0	1,2	2
30	RaAMYA	9	FEMALE	424428	KOLAR	3	TIBIA	1	2	2	24	50	2.5;2.5	6	7	6	11	11			1	1		0	0	1