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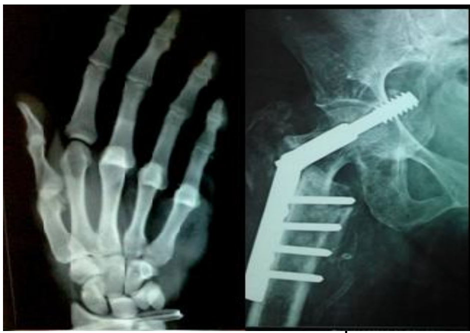

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Surgical outcome of fracture shaft femur in children using flexible intramedullary nailing

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Abstract

Background and Objective: Femoral shaft fractures account for 1.6% of all paediatric bony injuries. Angulation, malrotation and shortening are not always corrected effectively by conservative methods. Fixation of femur fractures in children & adolescents by flexible intramedullary nailing is becoming widely accepted because of the lower chance of iatrogenic infection and prohibitive cost of in hospital traction and Spica cast care.

The objective of our prospective study was to study the various aspects of Managing diaphyseal fractures of femur in children aged between 5-15 years by using Titanium Elastic Nailing System& Ender nailing. Subjective and objective study of clinical parameters like pain, comfort to the patients, early mobilization, operative technique, radiological evaluation for union, stages of weight bearing till complete recovery and any associated complications by using the above mentioned methods.

Method: Children and adolescents between the age group of 5-15 years with femoral shaft fractures who were admitted Adichunchanagiri Institute of Medical Sciences meeting the inclusion criteria were selected.

All patients underwent titanium elastic nailing & Enders nailing fixation for the femur fracture.

Patients were followed up for a period of 6 months at 4,8,12 and 24 weeks after surgery. 50 such cases were studied.

Result: The outcome is excellent in 38 (76%) cases, satisfactory in 12 (24%) cases and there were no cases of poor outcome.

Conclusion: Flexible intramedullary nail leads to rapid fracture union by preservation of fracture hematoma and limited soft tissue exposure. It also helps in preventing damage to the physis.

Our study confers all the advantages which the previous studies have shown at various institutes and is fairly a simple, reliable technique with a shorter learning curve imparting lot of advantages over other intramedullary techniques or other methods followed for management of pediatric diaphyseal femur fractures.

Keywords: Femoral shaft fractures Diaphyseal fracture Titanium Elastic Nailing System Ender nailing

Introduction

Femoral shaft fractures account for 1.6% of all paediatric bony injuries. Treatment of long bones fractures in children continues to improve as newer techniques evolve. Previously most of the fractures were effectively managed conservatively & only unstable and displaced fractures were taken up for fixation. Although a number of other intramedullary devices like rush nail or enders nail are available for treatment of paediatric long bone fractures, yet these have poor elasticity, rotational stability and require multiple nails to achieve fracture stability [1].

There is little controversy over the treatment of adult femoral shaft fractures with intramedullary nail fixation. Similarly, there is little controversy over the treatment of infants and toddlers with femoral shaft fractures by using spica casting, but the treatment of paediatric and adolescent (age 5 to 15 years) femur fractures remains controversial. Hence there was an evolution in treatment options for this age group for optimum treatment of fractures. Treatment of paediatric fractures dramatically changed in 1982 when Metaizeau and the team from Nancy, France, developed the technique of elastic stable intramedullary nailing.

In last three decades there was an increased interest in the operative treatment of paediatric fractures, although debate persisted over its indication. There is little disagreement concerning the management of long bone fractures in children less than 6 years i.e. pop casting, and adolescents over16 years with intramedullary nailing [2]. Differences of opinion about treatment are greatest for patients who are too old for early spica casting and yet too young for adult type of treatment with a reamed IM nailing. Current treatment options include early spica casting, traction, external fixation, ORIF with plating, flexible intramedullary nails and reamed intramedullary nails. The two major drawbacks with various types of traction and plaster cast immobilization are prolonged bed rest leading to separation of the child from routine activities and the expenditure incurred on the treatment during the stay in the hospital and parental non acceptance.

Over a period of time, with experience, clinicians have shown that children with diaphyseal femur fracture do not always recover with conservative treatment. Angulation, malrotation and shortening are not corrected effectively. Whatever the method of treatment, the goals should be to stabilize the fracture, to control the length and alignment, to promote bone healing and to minimize the morbidity and complications for the child and family [2].

The management of paediatric femoral shaft fractures has gradually shifted towards operative approach in the past decade. Plating of femoral shaft fracture offers rigid fixation but it requires a larger exposure with the potential for increased blood loss and scarring. It is a load bearing device and re-fracture is a risk and it can cause growth disturbance also. The now favoured Elastic internal fixation in the form of flexible intra medullary nailing & enders nail provides a healthy environment for fracture healing with some motion leading to increased callus formation. This method avoids physeal damage, minimally invasive with relatively reduced hospital stay and high acceptance by parents after a short learning curve.

Aims and Objective of the Study

To study and evaluate the clinical outcome of surgical treatment of fracture shaft femur in children by elastic nailing & ender nailing. A femoral shaft fracture is the most common major paediatric injury that most orthopaedic surgeons will treat routinely.

Objectives of the study

1. For early mobilization of the patient
2. To prevent prolonged immobilization with traction & plastering
3. To prevent post-op limb length discrepancy
4. To prevent hip Spica associated problems such as shortening, angulation of fracture, toileting, formation of sores.
5. Avoiding plate osteosynthesis which have more deleterious effect on paediatric age group like scar, immobilization, joint stiffness& plate removal.

Anatomy of Femur [3, 4]

The femur or thigh bone is the longest and strongest bone in the body. Its shaft is almost cylindrical in cross section in most of its length and bowed with a forward convexity. Its upper extremity has a rounded articular head, projecting medially on short neck of bone formed by the medial inclination of the upper part of the shaft. The distal or inferior extremity is more massive being in the form of a condyle articulating with the tibia.

The upper end of the femur comprises a head, neck, a greater and a lesser trochanter. The head of the femur is more than half sphere. It is directed upwards, medially and slightly forwards to articulate with the acetabulum. It has an anteversion of 15°. The neck of the femur which is about 5 cms long connects the head and the shaft, with which it forms an angle of about 125°(110-140). The anterior surface of the neck is flattened and at its junction with the shaft is marked by a prominent rough ridge termed intertrochanteric line, the posterior surface of the neck at its junction with the shaft is termed the intertrochanteric crest.

The most prominent feature of the femur is the anterior bowing. In its middle third region, the shaft possesses three surfaces and three border. The shaft is thickly covered with muscles and cannot be felt through the skin. Its anterior and lateral surfaces provide attachment in their three fourths for the vastus intermedius. The lower portion of the lateral surface is covered by vastuslateralis. The medial surface is covered by vastus medialis. In addition to the attachments already described, the linea aspera receives adductor longus, the inter muscular septa and the short head of biceps femoris. The perforating arteries cross the linea aspera from medial to lateral side under the tendinous arches in the adductor magnus and short head of biceps femoris. The foramina for nutrient arteries are situated close to the linea aspera.

The lower end of femur

Is widely expanded and thus provides a load bearing surface for the transmission of the weight of the body to the tibia. It consists of two prominent masses of bones, the condyles, which are partially covered by large articular surfaces.

Paediatric bones have greater flexibility and reduced tensile strength, the child's fracture differs from that seen in adults. Open femoral fractures are seldom seen in infants and young children, the bone tends to bend before it breaks, and since the edge of the fracture fragments are not so sharp, penetration of the soft tissue occurs less frequently. Because of the abundant blood supply union is rapid and consistent. Furthermore restoration of bone mass occurs rapidly after healing and nutritional supplement are unnecessary. The thick periosteum aids in protecting the adjacent soft tissues and facilitates rapid union. Undisplaced fractures occur and is due in part to the thick periosteal sleeve.

Ossification of femur [5]

A. The femur is the second long bone in the body to start ossifying. The primary center appears in the shaft during the fetal 7th week. It may be noted that the neck of femur ossifies from the primary center.
B. Three secondary centers appear at the upper end of the bone, one each for the head (first year), the greater trochanter (4th year) and the lesser trochanter (around the 12th year). Each center fuses independently with the shaft in the reverse order of appearance, the lesser trochanter about 13 years, the greater trochanter at about 14 years and the head around 16 years.
C. One center appears for the distal end. This center appears before birth in the 9th month of fetal life. It fuses with the shaft between the 16th and 18th years.

Blood supply of femur

4 main arterial systems supplying femur are periosteal, diaphyseal, metaphyseal and epiphyseal. Diaphyseal or nutrient arteries of the femur are 2 in number and enter the shaft at linea aspera. In children the superior artery passes downwards and the inferior upwards. No major artery entered the lower third of the femur. A fracture at the upper and the

middle third would deprive blood to the upper end of the lower fragment and a fracture at the junction of lower and middle third will certainly result in decreased blood supply of lower end of upper fragment. If there is periosteal stripping or muscles attached to linea aspera are detached, fracture healing will be delayed. Haemorrhage in children following femoral shaft fracture is usually limited and less serious than in adults, vascular injuries are uncommon because the vessels are flexible and resistant to perforation because of thick periosteal sleeve [4].

Mechanism of Injury

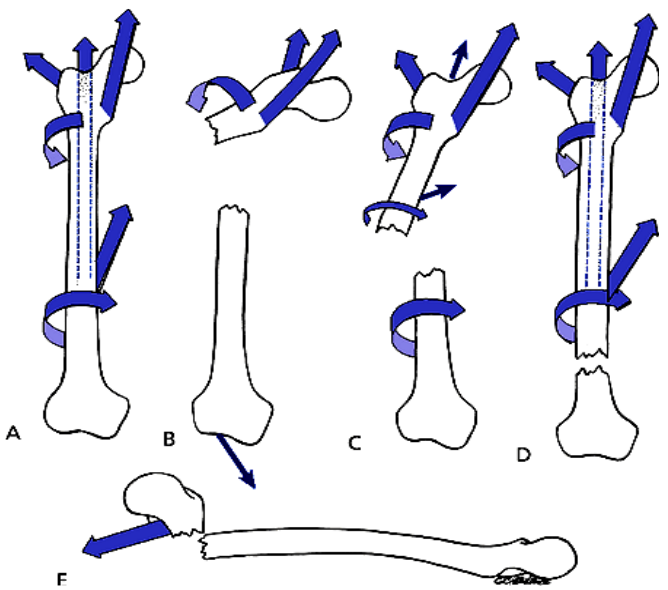
The etiology of femoral fracture in children varies with the age of the child. In children less than walking age (2 years) up to 80% of femoral fractures may be caused by abuse [5]. In children under 4 years of age, up to 30% of femoral fractures may be caused by abuse. In older children, femoral fractures are most likely to be caused by high velocity injuries, such as motor vehicle accidents which account for over 90% of femoral fracture in this age group [5, 6]

Gunshot wounds are an increasingly common cause of femoral fractures. Pathological fractures are relatively rare in children, but they may occur because of generalized osteopenia in infants or young children with rickets, osteogenesis imperfect [7].

A femoral fracture in a young child with no history suggestive of abuse or significant trauma should suggest the possibility of osteogenesis imperfecta. Generalized osteopenia may also accompany neurologic diseases, such as cerebral palsy or myelomeningocele, leading to fracture with minor trauma [8]

Stress fractures may occur in any location of the femoral shaft. Most occur in adolescents involved in sports activity such as football and track [5].

Relationship of Fracture Fragments



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).

C. In mid-shaft fractures the effect is less extreme because there is compensation by the adductors and extensor attachments on the proximal fragment.

D. Distal shaft fractures produce little alteration in the proximal fragment position because most muscles are attached to the same fragment, providing balance.

E. Supracondylar fractures often assume a position of hyperextension of the distal fragment due to the pull of the gastrocnemius

Classification of Fractures of Femoral Shaft

The AO/Orthopaedic [5] Trauma Association classification is based largely on the fracture morphology and includes the fracture location as well as the degree and type of communition.

Type A fractures are considered simple and include spiral, oblique, and transverse patterns.

Type B fractures are wedge fractures and include spiral wedge, bending wedge, and segmental wedge patterns.

Type C fractures are considered complex patterns that have no predicted cortical contact between the major proximal and distal fractures. These fractures are divided on the basis of the same characteristics described for B fractures.

Treatment of Fracture Shaft of Femur

Treatment of femoral shaft fracture in children is age dependent, with considerable overlap between age groups. The child's size and bone age also must be considered, as well as the cause of the injury. Whether the femoral fracture is an isolated injury or part of polytrauma influences treatment choices. Especially in older children, the disadvantages of non-operative treatment by traction or a cast, economic or social impact on the family must be usefully weighed against the potential complications of a surgical procedure like infection, refracture after removal of fixation, neurovascular injury, limb shortening or over growth, and avascular necrosis of the femoral head.

- In infants, new born to 6 months of age, femoral fractures usually are reasonably stable because of thick periosteum. For stable proximal or mid shaft fractures, simple splinting or a pavlik harness is all that is required. For unstable fracture in infancy, a pavlik harness with a wrap around the thigh is beneficial. For fractures with excessive shortening (more than 1 to 2 cm) or angulation (more than 30%), spica casting may be required.
- In children 6 months to 6 years of age, immediate or early spica casting is the treatment of choice for femoral fractures with less than 2 cm of initial shortening. Femoral fractures with more than 2 cm of initial shortening or marked instability and those fractures that cannot be reduced with immediate spica casting require 3 to 10 days of skin or skeletal traction. Skeletal stabilization by external fixation generally is reserved for children with open or a multiple trauma. Intramedullary nail is used in children with metabolic bone disease that predisposes to fracture or after multiple fractures, such as in osteogenesis imperfecta. Larger children in whom reduction cannot be maintained with a spica cast. Occasionally may benefit from flexible intramedullary nail.
- Treatment of femoral fractures in children 6 to 11 years of age is highly controversial. For stable minimally displaced fracture, immediate spica casting usually produces satisfactory results. However, in large children with unstable communited fractures, traction followed by application of a cast brace or spica cast may be necessary. Enthusiasm for treatment that decreases hospital stay has led to the use of external fixation and flexible intramedullary nails in children from 6 years of age through maturity. Compression plating has been re-introduced as a technique with low risks and significant benefit in the management of paediatric femoral fractures.

- In older children and adolescents, antegrade nailing has been recommended as a standard procedure, but the recognized risks of avascular necrosis and growth disturbance has led to limited use of this as a standard technique.

Immediate spica casting

It is indicated for isolated femoral shaft fractures in children under 6 years of age unless
a. Shortening of > 2cm present
b. Massive swelling of the thigh is noted or
c. Associated injuries are present.
Advantages are - simplicity, low cost, and generally good results based on leg length equality, healing time and motion. Problems encountered were transportation, cast intolerance by the child, keeping the child clean and loss of alignment.

Technique

Child is taken to a plaster room and anaesthesia or sedation is given. A short leg cast is applied with the foot in neutral rotation. The cast is then extended to a long leg cast with the knee in 90° flexion. Patient is then placed on a spica table, supporting the weight of the legs with manual traction, and the remainder of the cast is applied with the hips in 90° of flexion and 30° of abduction, holding the fracture out to length and the leg should be placed in 15° of external rotation. Generally the spica cast is worn for 4 to 8 weeks.

Traction and casting

The indications for skin or skeletal traction include,

a. Unstable femoral fracture in a child under 6 years of age with more than 2 to 3 cm of shortening.
b. Femoral fracture that fails to maintain proper length and alignment in a spica cast in a child under 6 years of age.
c. Femoral fracture in a child 6 to 11 years of age, without multiple fractures, head trauma or severe soft tissue or vascular injuries, who is able to cooperate with a period of bed rest and spica immobilization and whose family prefers no surgery. Traction is applied for 3 weeks and then hip spica is applied.

Acceptable Angulation [5]

Age	Varus / valgus (degree)	Anterior/posterior (degrees)	Shortening (mm)
Birth to 2 year	30	30	15
2-5 years	15	20	20
6-10 years	10	15	15
11 years to maturity	5	10	10

External Fixation

It is the method of choice when severe soft tissue injury is present and maybe considered in any patient where traditional closed method of management are not appropriate. External fixation is performed using a unilateral or cantilever type system. The stability of the fixation is increased if the two pins on each side of the fracture are spread widely with one pin close to the fracture and one quite distant from it. A second longitudinal rod can be added to this system to increase its rigidity. The pins are placed through predrilled holes to avoid thermal necrosis of bone. Sharp drills should be used. At least two pins should be placed proximally and two distally.

Intramedullary fixation

a. Flexible intramedullary nail fixation

- The benefit of elastic internal fixation is that a healthy environment for fracture healing with some motion leads to increased callus formation.
- Nails can be inserted either antegrade or retrograde
- Antegrade insertion is usually indicated in distal 1/3rd fractures.
- An entry point is made below the trochanteric epiphysis on the lateral cortex.
- One C-shaped nail and one S-shaped nail are introduced into the medullary canal. The fracture is reduced and the nails are hammered in to the distal fragment.
- Retrograde insertion is a routinely employed method. It is indicated in proximal 1/3rd and middle 1/3rd fractures.

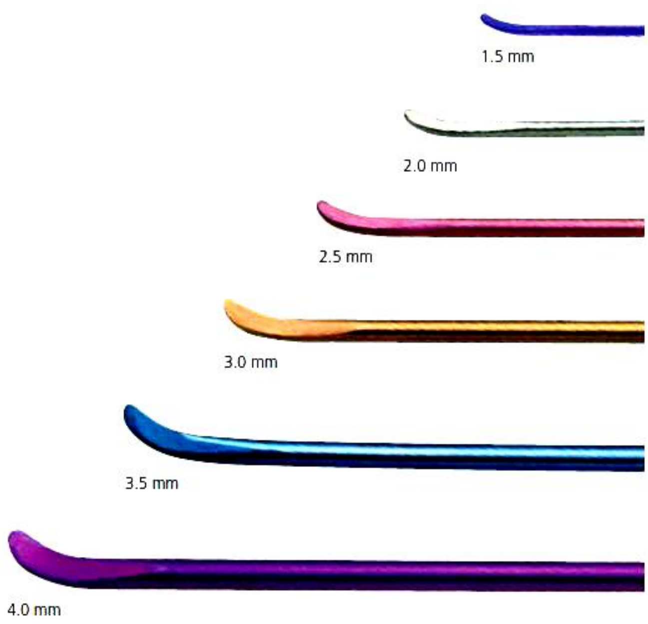
b. Rigid intramedullary nail fixation:

Problems with angular malalignment and maintenance of length can be avoided with the use of rigid intramedullary fixation.

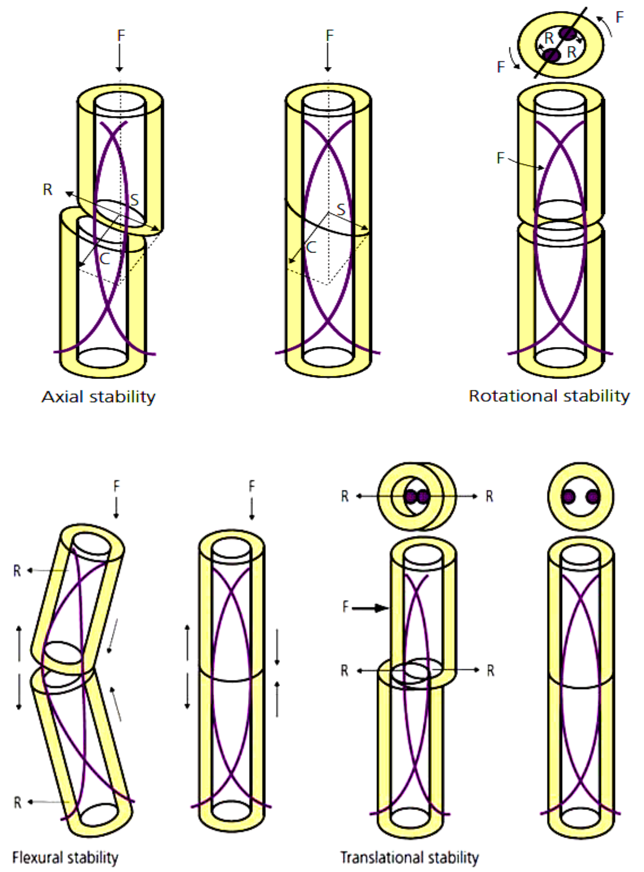
c. ORIF with Plate and Screws

Plate fixation offers the advantages of anatomic reduction, ease of insertion, simplified nailing care.

Titanium Elastic Nailing System (Tens) Nails



It was first tried and practiced by Rush and Enders. They tried this procedure to stabilize long bone # in femoral shaft and trochanteric fractures. It works on the basic principle of three point fixation, provided by symmetrical bracing action of two elastic nails inserted into the metaphysis, each of which rests against the inner bone at three points. This produces following four properties: flexural, axial, translational and rotational stability [5, 6] All four are essential for achieving optimal result.



Bio Mechanics of Flexible nailing [9]

F - force acting R - restoring force of the nail

S - shear force C - compressive force

The ends of nails are anchored firstly in their entry points, secondly in the metaphysis at the other end of bone. The curvature of nail is achieved by bending it beyond its elastic limit from this new position of stability, it resists the tendency to be straightened out (thus creating some tension within intramedullary canal) as well as a tendency to be further bent, thus minimizing the risk of deformation. Three nail into single bone is unnecessary because this unbalances the bipolar matched construct.

Once inserted into the medullary canal, the nail resists angular, compressive and rotational forces by virtue of elastic quality of material and balanced insertional construct. Titanium alloy has a modular elasticity and handling characteristic very suitable to a child's diaphysis. It allows stable reduction, maintainance of reduction and early mobilization [5].

It aims to develop early bridging callus and contributes to rapid restoration of bone continuity. Titanium elastic nail is advantageous over other surgical methods particularly in this age group because it is simple, is a load sharing internal splint that doesn't violate open physis, allows early mobilization and maintains alignment [5].

Micro-motion conferred by the elasticity of the fixation promotes faster external bridging callus formation. The periosteum is not disturbed and being a closed procedure there is no disturbance of fracture hematoma, there by less risk ofinfection [6].

All the current available elastic nails have beaked or hooked ends to allow satisfactory sliding down on insertion along inner surface of diaphysis without impacting on opposite cortex. 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 is to be fixed with ESIN, the entry points must be at opposite ends of bone. The incorrect insertion points can have various negative effects like internal tension and imbalance of fracture stability and fixation. 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. 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.

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- the corkscrew phenomenon. In such cases it is rotationally and axially unstable.

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.

Materials and Methods

Source of Data

Patients having history of pain& deformity over thigh with x ray showing fracture shaft of femur, aged between 1-15 years who are admitted in Adichunchanagiri Institute Of Medical Sciences will be taken for study after obtaining their consent.

Inclusion Criteria

1. The patient with fracture shaft femur unilaterally or bilaterally.
2. Aged between 1- 15 years.

Exclusion Criteria

1. Patients aged above 15 years.
2. Patients with open fractures.
3. Patients with pathological fractures

Admitted patients are evaluated by paediatrician for fitness, routine pre anaesthetic check-up will be done and informed written consent will be taken before surgery.

- Intra operatively - Position of the Patient, bony land mark and surgical incision for the nail Insertion,reduction modalities under image intensifier, time needed for surgery, blood loss and any other difficulties faced during the procedure is carefully noted, including sizing and suitability of titanium elastic nails as per A.O. guidance
- 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
- Between 8 to 10 days - wound inspection and suture/staple removal
- Patient is called for periodic follow up at 4 weeks, 8 weeks, 12 weeks and at 6 months clinical and radiological assessment will be done
- Clinical evaluation for - pain, range of movements (hip and knee), limb length and time of weight bearing (partial/complete) is done.
- Radiological evaluation for – position of the nail, coronal and sagittal alignment, loss of reduction / deformity and delayed/non-union is done.

Complications – minor and major were noted.
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.

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

Flynn's criteria [9]

Results Variables at 24 weeks	Excellent	Satisfactory	Poor
Limb-length equality	< 1.0 cm	1.0-2.0 cm	>2.0 cm
Malalignment	5 degrees	10 degrees	>10 degrees
Unresolved pain	Absent	Absent	Present
Complications	None	Minor and resolved	Major and lasting Morbidity

Excellent: when there was anatomical or near anatomical alignment, no leg length discrepancy with no perioperative problems.

Satisfactory: when there was acceptable alignment and leg length with resolution of perioperative problems.

Poor: in the presence of unacceptable alignment or leg length with unresolved perioperative problems.

Preoperative Planning
Nail Size and Nail Width: The diameter of the individual nail is selected as per

1) Flynn *et al*'s formula [9]
Diameter of nail= width of the narrowest point of the medullary canal on AP and Lateral view X 0.4mm

2) Intra operative assessment
Diameter of the nail is chosen so that each nail occupies atleast 1/3rd -40% of the medullary cavity.

Age in years	Nail size in mm
6-8	3.0
9-11	3.5
12-14	4.0

Select two nails of the same diameter so that opposing bending forces are equal, avoiding malalignment.

Nail length: Lay one of the selected nails over the thigh, and determine that it is of the appropriate length by fluoroscopy. The nail should extend from the level of the distal femoral physis to a point approximately 2 cm distal to the capital femoral physis and1 cm distal to the greater trochanteric physis.

Operative Procedure
Procedure for Tens & Ender Nailing Of Diaphyseal Fracture of Femur Retrograde Fixation
General / Spinal anaesthesia is administered, and patient is placed in supine on a radiolucent table. The operative extremity is then prepared and draped free. Identify the physis by fluoroscopy, and mark its location on the skin.
A 2 to 2.5 cm longitudinal skin incision was made over the medial and lateral surface of the distal femur, starting 2 cm proximal to the distal femoral epiphysis, a haemostat was used to split the soft tissue down to the bone, following which a 3.2 mm drill bit/bone awl was used at a point 2.5 cm proximal to the distal femoral growth plate to open the cortex at a right angle; the drill/bone awl was then inclined 100-450 to the distal femoral cortex. A nail was introduced with an introducer by rotatory movements.
Under image intensifier control, the nail was passed with rotatory movement or with an introducer to the fracture site which was aligned to anatomical or near anatomical position with proper attention to limb rotation and length. Fracture was reduced under C-arm guidance with longitudinal traction to the limb. By rotation movements of the T-handle with or without limb manipulation with or without use of F tool for reduction of fracture, the nail was directed to the proximal fragment which was pushed into better alignment by the nail. 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, and 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. The construct should be in a symmetrical alignment face to face with the maximum curvature of the nails at the level of the fracture.
Distally the nails were cut leaving only 0.5 - 1 cm outside the cortex. The extra osseous portion of the nails was kept as it was or slightly bent away from the bone to facilitate removal later on. In all cases care was taken to use nails with same diameters, to use the largest possible diameter, and to use the double C construct to ensure 3-point fixation. In our study no end caps were used.

Minor Complications
1. Pain at the site of nail insertion
2. Minor angulation at final follow-up
3. Superficial infection at site of nail insertion
4. Delayed union
5. Loss of knee movement more than 2 months after removal

Major Complications
1. Angulation exceeding the guidelines at final follow-up
2. Loss of reduction requiring new reduction or surgery
3. Surgery to revise nail placement
4. Leg length discrepancy exceeding the guidelines at final follow-up
5. Deep infection
6. Delayed or non-union leading to revision

Radiological Assessment
X-ray thigh full length with hip and knee joints – AP and LATERAL views
1) Alignment- sagittal/coronal
2) Callus formation

Operative Photos

Tens Nailing

Operative Procedure Showing Initial Bone Entry Step Being Assisted By C-Arm Imaging

Tens Entry Using Introducer

Both TENS introduced into the femur

TENS bent to bury it inside soft tissue

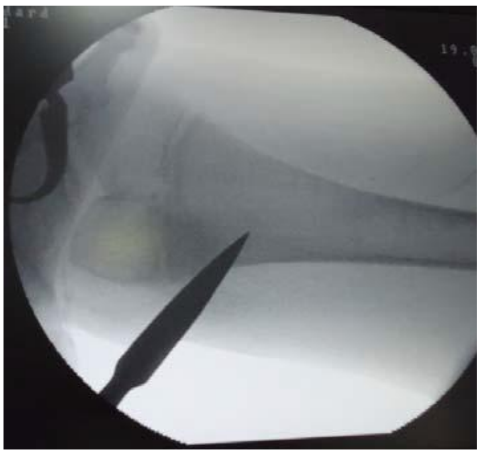
The bent TENS being cut

Ender's Nailing

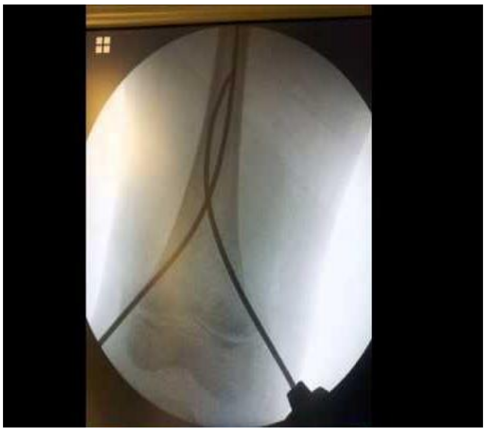
Bone entry site for Ender's nail

Ender's nail being introduced

C-ARM PHOTOS

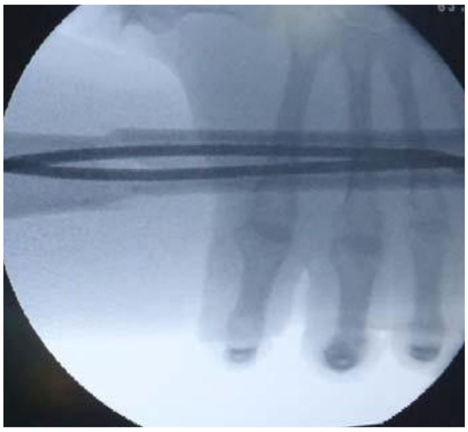


Entry Using Bone Awl



Second Nail Entry

Nails Crossing Fracture Site



Double C Construct

Observation and Results

Table 1: Age Incidence

Age in years	No. of Cases	Percentage
5 – 8	23	46
9 -12	18	36
13 -15	11	22

Table 2: Sex Incidence

Sex	No. of cases	Percentage
Male	28	56
Female	22	44

Table 3: Mode of Injury

Mode of Injury	No. of cases	Percentage
RTA	33	66
Self-fall	14	28
Fall from height	3	06

Table 4: Side affected

Side affected	No. of cases	Percentage
Right	32	64
Left	18	36

Table 5: Pattern of Fracture

Pattern of Fracture	No. of cases	Percentage
Transverse	15	30
Oblique	22	44
Spiral	08	16
Segmental	00	0
Communited	05	10

Table 6: Level of the Fracture

Level of fracture	No. of cases	Percentage
Proximal 1/3rd	17	34
Middle 1/3rd	26	52
Distal 1/3rd	07	14

Table 7: Time interval between trauma and surgery

Duration In Days	No. of Cases	Percentage
<2days	19	38
3-4 days	22	44
5-7 days	07	14
>7 days	02	04

Table 8: Duration of Surgery

Duration	No. of cases	Percentage
< 45 mins	10	20
45 mins – 75mins	28	56
76mins – 90 mins	12	24

Table 9: Duration of Stay in Hospital

Duration (days)	No. of cases	Percentage
0-7	14	28
8-10	31	62
11-13	05	10

Table 10: Complications

Complications	No. of cases	Percentage
Pain at the Site of Nail Insertion	11	22
Infection	04	08
Limb shortening <1cm	02	04
Limb lengthening <1cm	01	02

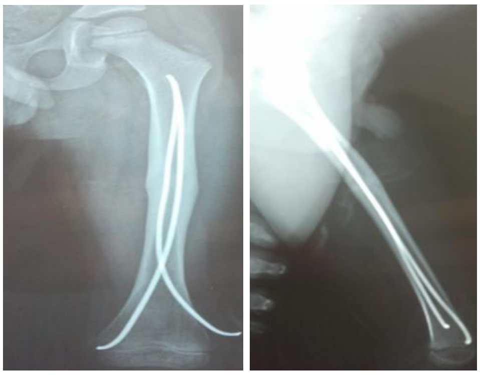
Table 11: Outcome

Outcome	No.of cases	Percentage
Excellent	38	76
Satisfactory	12	24
Poor	0	0

Radiological and Clinical Photographs Case Series – 01

Pre Op Xrays

Post Op at 4 Weeks



post op x-rays at 10 weeks

Flexion

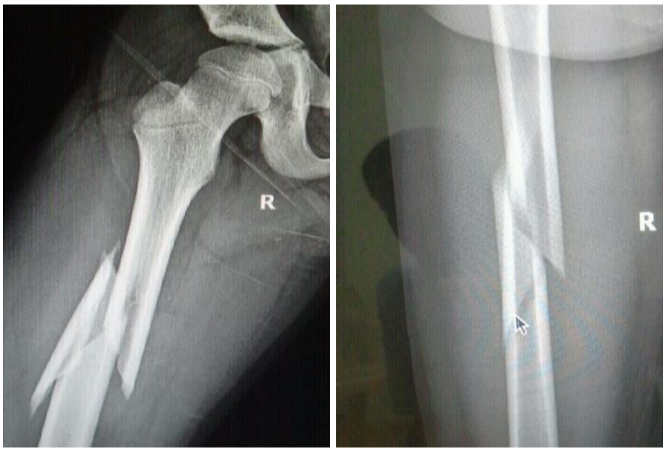
Abduction

Cross Legged

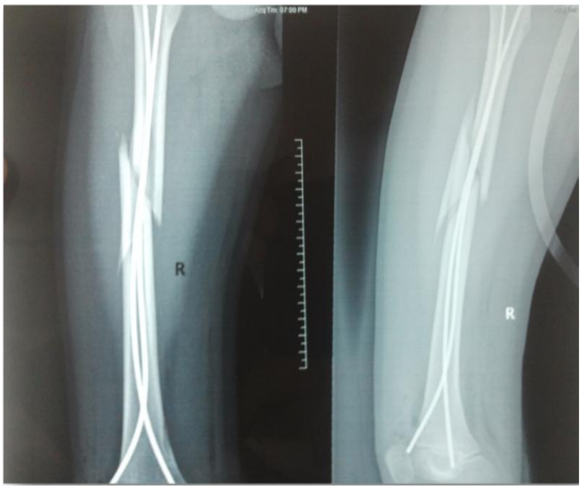
Squatting

Limb Length

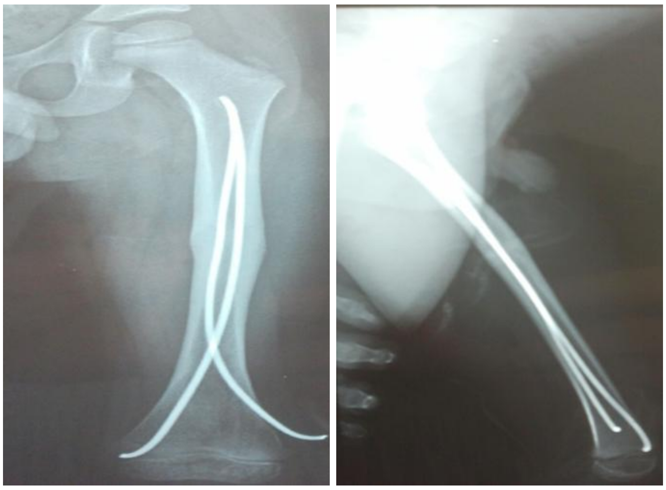
Full Weight Bearing After 12 Weekscase Series -02



Pre-Op X-Rays



Post Op Xray At 4 Weeks



Post Op Xray At 10 Weeks

Flexion

Abduction

Adduction

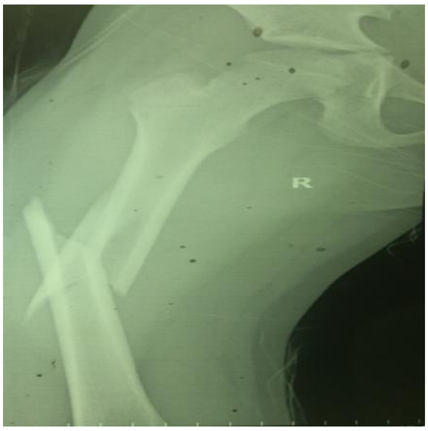
Sitting Cross Legged

Squatting

Full Weight Bearing At 10 Weeks

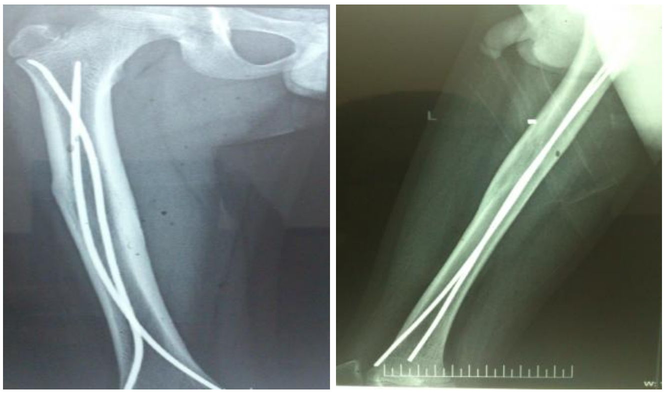
Case Series - 03

Pre Op: Ap View



Pre Op: Lateral View

Post Op Xray At 4 Weeks



Post Op At Xray 12 Weeks Ap & Lateral View

Flexion

Limb Length

Adduction

Abduction

Sitting Cross Legged

Squatting

Discussion

Age incidence

In the present study 23(46%) of the patients were 5-8 years, 18 (36%) were 9 to 12 years and 11(22%) were 13 to 15 years age group with the average age being 9.03 years.

J. N. Ligier *et al* studied children ranged from 5-15 years with a mean of 10.2 years [10]

Studies	Age Incidence (Average) In Years
Present study	9.03
J.N.Ligier *et al*. [10]	10.2

Sex incidence

There were 28(56%) boys and 22 (44%) girls in the present study. The sex incidence is comparable to other studies in the literature.

In their study J. N. Ligier *et al*. out of 118 cases, had 80 (67.7%) boys and 38(32.3%) girls [10].

In their study, Gamal El-Adl *et al*. out of 66 patients, there were 48 (72.7%) male and 18 (27.3%) females [11].

Studies	Male %	Female %
Present study	56	44
J.N. Ligier *et al* [10]	67.7	32.3
Gamal El-Adletal [11]	72.7	27.3

Mode of injury

In the present study RTA was the most common mode of injury accounting for 33 (66%) cases, self-fall accounted for 14 (28%) cases and fall from height accounted for 03 (06%) of the cases.

J. M. Flynn *et al*, in their study assessing 234 cases, 136(58.1%) were following RTAs, 46(19.6%) were following self fall and remaining43(28.8%) were as a result of fall from height [7].

Mechanism of injury(%)	Rta	Self Fall	Fall From Height
Present Study	66	28	06
J.M.Flynn *et al* [7]	58.1	19.6	28.8

Pattern of Facture

In our study, transverse fractures accounted for 15 (30%) cases, oblique fractures 22(44%), spiral fractures 08(16%), communited fractures 05(10%) and there were no segmental fractures.

In their study J. N. Ligier *et al* out of 123 femoral fractures studied (38.2%) were transverse fractures, oblique fractures 7(23.3%), spiral fractures19 (15.4%) and 4 (3.2%) were segmental fractures [10].

Studies	Transverse %	Oblique %	Spiral %	Segmental %	Communited %
Present study	30	44	16	0	10
J. N. Ligier *et al* [10]	38.2	23.3	15.4	3.2	25.4

Level of Fracture

Fractures involving the middle l/3rd accounted for 26 (52%) cases, proximal 1/3rd 17(34%) and distal l/3rd 07 (14%) of cases in our study.

In their study J. N. Ligier *et al* among 123 femoral shaft fractures 42were in proximal 1/3rd, 45 in the middle 1/3rd, 36 were in the distal 1/3rd [10].

Studies	Proximal l/3rd %	Middle l/3rd %	Distal l/3rd %
Present Study	34	52	14
J. N. Ligier *et al* [10]	34.1	36.5	29.2

Time interval between trauma and surgery

In the present series, 19 (38%) patients underwent surgery within 2 days after trauma, 22(44%) in 3 - 4 days, 07 (14%) in 5 - 7 days and 02(04%) patients in 7-10 days. Average duration between trauma and surgery was 3.8 days.

In the study Gamal El-Adl *et al* operated 56.1% of cases between 3-4days after injury, 21.2% cases between 3 -4 days and 22.7% cases after 7days [11].

K C Saikia *et al*. operated 77.27% patients within 7 days of injury [12]

Studies	Time Interval Between Trauma And Surgery (In Days) (%)				AVERAGE (in days)
	<2	3-4	5-7	>7	
Present study	38	44	14	04	3.8
Gamal El-Adl *et al* [11]	0	56.1	21.2	22.7	5.2
K C Saikia *et al* [12]	77.27			22.23	4.8

Duration of surgery in minutes

In the present study, duration of surgery was < 45mins in 10 (20%) cases, 45- 75 minutes in 28 (56%) cases, 76-90 minutes in another 12(24%) cases. The average duration of surgery in our study was 69 minutes.

In Khurram Barlas *et al*. study, the average duration of surgery was 70mins [13]. In a study by K C Saikia *et al*., the duration of surgery ranged from 50- 120mins with a median of 70 minutes [12]

Studies	Average Duration Of Surgery (In Mins)
Present Study	69
Khurram Barlas *et al* [13]	70
K C Saikia *et al* [12]	70

Duration of stay in the hospital

The duration of stay in the hospital < 7 days for 14 (28%) patients, 8-10 day: for 31 (62%), 11-13 days for 05 (10%). The average duration of stay in the hospital in our study was 8.8 days

The mean hospital stay was 12 days in Kalenderer O *et al* study [14]. Average hospitalization time was 11.4 days in the study conducted by Mann et a1 [15].

Studies	Average Duration Of Stay In Hospital (In Days)
Present study	8.8
Kalenderer O *et al* [14]	12
Mann *et a1* [15]	11.4

Gross RH, *et al* conducted a study on cast brace management of the femoral shaft fractures in children and young adults. The average length of hospitalization in their study was 18.7 days [16] Compared to the above studies conducted on conservative methods and cast bracing, the average duration of hospital stay was less in our study i.e.8.8days. The reduced hospital stay in our series is because of proper selection of patients, stable fixation and less incidence of complications.

Time for union

In our study union was achieved in <3 months in all 50 (100%) cases.

Average time to union was 11.1 weeks.

Oh C.W *et al* reported average time for union as 10.5 weeks [17] Aksoy C, *et al* compared the results of compression plate fixation and flexible intramedullary nail insertion [18]. 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.

Studies	Time Of Union (In Weeks)
Present study	11.1
Oh C.W, *et al* [17]	10.5
Aksoy C, *et al* [18]	16

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

Time of partial weight bearing

Type of fracture	Time (in weeks)
Transverse	3
Oblique	4
Spiral	4
Communited	5

Time of full weight bearing

In the present study, unsupported full weight bearing walking was started in <12 weeks for 30(100%) of the patients. The average time of full weight bearing was 11 weeks.

Time of union

Type of fracture	Time of union(in weeks)
Transverse	10.6
Oblique	10.9
Spiral	11.1
Communited	11.8

Complications

Pain at the site of nail insertion

In the present study, 11(22%) patients had developed pain at site of nail insertion during initial follow up evaluation which resolved completely in all of them by the end of twenty four weeks.

J.M. Flynn *et al*. reported 38 (16.2%) cases of pain at site of nail insertion out of 234 fractures treated with titanium elastic nails [7]

Infection

Superficial infection was seen in 04(8%) case in our study which was controlled by antibiotics & regular dressings on alternate days within a week.

J.M. Flynn *et al*. reported 4 (1.7%) cases of superficial infection at the site of nail insertion out of 234 fractures treated with titanium elastic nails [7].

Pin tract infection is a major disadvantage of external fixation. Bar-on E, *et al* reported 2 cases of deep pin tract infection in their patients treated with external fixation.

Range of motion

All patients had full range of hip and knee motion by 10 weeks in the present study. J.M. Flynn *et al*. reported 2 (0.9%) cases of knee stiffness out of 234fractures treated with titanium elastic nails [7].

Limb length discrepancy

This is the most common sequelae after femoral shaft fractures in children and adolescents. 02(4%) patient had shortening of femur and 01(2%) had lengthening of femur. No

patient in our study had major limb length discrepancy (i.e. > ± 2cm).

Beaty *et al*. reported, two patients had overgrowth of more than 2.5 cm necessitating epiphysiodesis, after conservative treatment [19].

Ozturkman Y. *et al* observed mean leg lengthening of 7mm in 4 (5%) patients and mean shortening of 6mm in 2 (2.5%) children [20].

Cramer KE, *et al* noted average limb lengthening of 7mm (range l-19mm) in their study. Clinically significant limb discrepancy (> 2cm) did not occur in any patient in their study [21].

John Ferguson *et al* noted more than 2cm shortening in 4 children after spica treatment of paediatric femoral shaft fracture [22]. In the present study, limb length discrepancy of less than 10mm was present in 2 (10%) cases.

Comparing to limb length discrepancy in conservative methods, limb length discrepancy in our study was within the acceptable limits.

Nail back out
In the present series, nail back out was not seen in any of the cases. Carrey T.P. *et al* out of 38 cases, noted nail back out in one case in their study, which necessitated early removal.

Malalignment
Some degree of angular deformity is frequent after femoral shaft fractures in children, but this usually remodels after growth. In our study no cases had varus or valgus mal alignment. J.M. Flynn *et al*. reported 10 (4.3%) cases of minor angulation out of 234 fractures treated with titanium elastic nails [7]. Heinrich SD, *et al* reported 5° of varus angulation in one child in their study and 11 % of fractures had an average varus or valgus mal alignment of 6^0 [23].
Herndon WA, *et al* compared the results of femoral shaft fractures by spica casting and intramedullary nailing in adolescents. They noticed varus angulation ranging from 7 to 25° in 4 patients treated with spica casting and no varus angulation in surgical group [24].

Antero posterior angulation
In the present study, no patients had anteroposterior angulation. Ozturkman Y, *et al* noted an anterior angulation of 7° and a posterior angulation of 6° in 2 patients respectively. Herndon WA, *et al* noticed anterior angulation ranging from 8° to350inpatients treated with traction and spica casting [24]. 8% of the patients had an average anterior or posterior angulation of 80 in Heinrich SD *et al*, study [23].

Rotational deformities
A difference of more than 10° has been the criterion of significant deformity. No patient in our study had significant rotational deformity.
Heinrich SD *et al*, out of 183 fractures studied, reported 8° out toeing in four children and two children with 5° in toeing following flexible intramedullary nailing [23]. No patient in our study had significant rotational deformity.

Assessment of Outcome
In the present study, the final outcome was excellent in 38(76%) cases, satisfactory in 12(24%) cases and there were no poor outcome cases.
J.M. Flynn *et al*. treated 234 femoral shaft fractures and the outcome was excellent in 150(65%) cases, satisfactory in 57 (25%) cases and poor in 23(10%) of cases [7] Hossam M kandil, treated thirty-two children, age 4.9–13.2 years, with femoral shaft fractures, the outcome scoring to evaluate functional results showed excellent results in twenty-six patients (81.25%), satisfactory results in six patients (18.75%), and no poor results [25] In K.C. Saikia *et al* in their study of 22 children with femoral shaft fractures 13 (59%) excellent, in 6 (27.2%) satisfactory and 3(13.6%) poor results [12].

Studies	Outcome (%)		
	Excellent	Satisfactory	POOR
Present Study	76	24	-
J.M.Flynn *et al* [7]	65	25	10
Hossam M Kandil [25]	81.25	18.75	-
K.C.Saikia *et al* [12]	59	27.2	13.6

Conclusion
Based on our experience and results, we conclude that Titanium Elastic Nailing System & Ender nailing is an ideal method for treatment of paediatric femoral fractures. It gives elastic mobility promoting rapid union at fracture site and stability which is ideal for early mobilization with lower complication rate, good outcome when compared with other methods of treatment.
It is a simple, easy, rapid, reliable and effective method for management of paediatric femoral fractures between the age of 5 to 15 years, with shorter operative time, lesser blood loss, lesser radiation exposure, shorter hospital stay, and reasonable time to bone healing.
Because of early weight bearing, rapid healing and minimal disturbance of bone growth, intramedullary fixation by TENS & Ender nails may be considered to be a physiological method of treatment.
Use of Ender nails &TENS for definitive stabilization of femoral shaft fractures in children are considered a reliable, minimally invasive, and more importantly a physeal protective treatment method.
Our study confers all the advantages which the previous studies have shown at various institutes and is fairly a simple, reliable technique with a shorter learning curve imparting lot of advantages over other methods followed for management of paediatric diaphyseal femur fractures.

Summary
Thirty patients with diaphyseal fractures of the femur were treated with Titanium elastic nailing & Ender nailing between May 2013 to December 2016 at Adichunchanagiri Institute of Medical Sciences, B.G. Nagar, Mandya.

- Children and adolescents aged between 5 to 15 years were included in the study. 23(46%) of patients were between 5-8 years, 18(36%) were between 9 to 12 years and 11(22%) were between 13 to 15 years age group with the average age being 9.03 years.
- 28(56%) of the patients were boys and 22(44%) were girls.
- RTA was the most common mode of injury accounting for 33(66%) cases followed by self-fall 14 (28%) and fall from height 3(6%).
- Transverse fractures accounted for 15(30%) cases, oblique fractures 22(44%), spiral fractures 08(16%) & communited fractures 05(10%).
- Fractures involving the middle l/3rd accounted for 26 (52%), upper1/3^rd^ 17(34%) and lower 1/3rd 07(14%) cases.
- The average duration between trauma and surgery was 3.8 days with 19 (38%)patients undergoing surgery within 2 days, 22 (44%) patients between 3 to 4days, 07 (14%) between 5 to 7 days and 2 (4%) between 8 to 10days.
- All the patients were prepared and operated as early as possible once the general condition was stable and the patient was fit for surgery.
- Duration of surgery for 10 cases <45minutes, 28 cases 45 to 75 minutes and 12 cases 76 to 90 minutes. The average duration of surgery is 69 minutes.
- Average duration of stay in hospital was 8.8 days with 14 patients getting discharged within a week, 31 patients within 10 days & rest within 2 weeks.
- Union was achieved in <3 months in 50 (100%) of the patients with average time to union being 11.1 weeks.
- Unsupported full weight bearing walking was started in < 3 months for 50(100%) of the patients.
- All patients had full range of hip and knee motion by 12weeks in the present study.
- 11(22%) patients had developed pain at site of nail

insertion during followup evaluation, all of which resolved by the end of 24 weeks follow up.

- Superficial infection was seen in 04(8%) cases.
- 02(04%) patient had shortening of femur (0.6 & 0.8)cm and 1(2%) patient had lengthening of femur (0.9cm).
- No patient in our study had major limb length discrepancy (i.e. > ± 2cm). Nail back out was not seen in any of the cases.
- No patients had angular or rotational mal alignment.
- The TENS & Ender's nail fixation for treatment of paediatric femur fractures are simple, safe technique as it avoids any growth disturbance by preserving the epiphyseal growth plate and it avoids bone damage or weakening through the elasticity of construct, which works as a load sharing biocompatible internal splint.

Reference

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