

PROSTHESIS IN UNSTABLE INTERTROCHANTERIC FRACTURES IN ELDERLY PATIENTS IN A RURAL

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Under the Guidance of

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LIST OF ABBREVIATIONS USED

AO	Association for osteosynthesis
OTA	Orthopedic Trauma Association
IT	Intertrochanteric fractures
ORIF	Open reduction and internal fixation
CRIF	Closed reduction and internal fixation
DHS	Dynamic Hip screw
PCCP	Percutaneous compression plate system
CHS	Compression Hip Screw
FRS	Functional Recovery Score
THR	Total Hip Replacement
THA	Total Hip Arthroplasty
HHS	Harris Hip Score
GT	Greater Trochanter
LT	Lesser Trochanter
ITL	Intertrochanteric Line
ITC	Intertrochanteric Crest
NSA	Neck Shaft Angle
CCD	Caput Collum Diaphyseal angle
PFL	Pubo femoral ligament
IFL	Ischiofemoral ligament
ILFL	Iliofemoral ligament
AIIS	Anterior inferior iliac spine
ADL	Activities of daily living
DSIF	Dual fluoroscopic imaging system
BW	Body weight
CG	Centre of gravity
HAF	Hip abductor force

JRF	Joint reaction force
CF	Cane force
STS	Sit to Stand
CT	Computerized tomography
HPWE	High molecular weight polyethylene
PMMA	Polymethyl Methacrylate
NSAID	Non steroidal anti-inflammatory drugs
TT	Tetanus toxoid
PSIS	Posterior superior iliac spine
ITB	Iliotibial band
DVT	Deep vein thrombosis
RTA	Road traffic accident
IHD	Ischemic heart disease
LLD	Limb length discrepancy
SSI	Surgical site infection

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ABSTRACT

Back ground and objectives:

Intertrochanteric (IT) femur fractures are among the most common fractures in elderly patients constituting nearly 45% of all fractures in elderly.¹ They are also associated with an increased mortality of 20% and form a major cause of death and disability in elderly.² Treatment for most proximal femur including IT fractures before the advent of fixation devices was conservative with prolonged traction and immobilisation resulting in high morbidity and mortality.^{6, 7} The current modality of treatment for intertrochanteric fractures remains popular with internal fixation with sliding hip screw, however they frequently have complications such as lag screw cut out, excessive collapse and loss of fixation especially in unstable intertrochanteric fractures.⁹⁻¹² The development of internal Proximal femoral nail to address the shortcomings for DHS lead to some improvements however the complications in unstable fractures remained high and patients continued to be recumbent for prolonged durations.^{6, 8, 13, 14} Endoprosthesis are suggested as a good alternative for treatment of unstable intertrochanteric fractures with osteoporosis and severe

comminution in elderly patients, achieving early rehabilitation of the patient and good long term results. Return to pre injury levels of activity are hastened with the use of prosthesis and thus obviate various recumbency related complications.^{9-12, 14-16}

Methods:

30 patients from November 2016 to October 2018 with unstable IT fractures and meeting the inclusion criteria presenting to the Orthopedic Department of R. L. Jalappa hospital were included in the study and underwent cemented modular bipolar hemiarthroplasty. They were followed up for 6 months and assessed using Harris hip score.

Result:

Among 30 patients treated with The functional assessment according to the Harris hip score (HHS) showed good to excellent results in 20 patients (69%) while 9 patients had fair results (31%) at the final follow-up. The average HHS after 1 month and three months after surgery were 76.7 and 79.2, which are good results, while the score at final followup at 6 months was 81.4 which is an excellent result. 3 patients developed abductor weakness and no implant related complications were noted.

Conclusion:

According to the results observed in our study, we are of the opinion that treatment with hemiarthroplasty may be considered as the first choice of treatment in elderly patients with unstable inter trochanteric fractures which allows early mobilization and hence avoiding serious complications of prolonged immobilization

Key words: intertrochanteric fracture, unstable, hemiarthroplasty, modular bipolar, primary arthroplasty, harris hip score, elderly, geriatric, osteoporotic, cemented, endoprosthesis

INTRODUCTION

Intertrochanteric (IT) femur fractures are among the most commonly occurring fractures in elderly patients constituting nearly 45% of all fractures in elderly populace.¹ They are also associated with an increased mortality of 20% in unstable IT fractures and form a major cause of death and disability in elderly.² Their more common occurrence in females compared to males can be attributed to the similar higher incidence of osteoporosis in female population.³

The incidence of hip fractures is expected to double over the next 50 years as the geriatric population increases owing to better health care and increasing life expectancies.¹ Post-menopausal and senile osteoporosis makes treating fractures in the elderly populace more challenging which are not major complications of similar fractures in young adults. The fragile nature of the patients due to increasing comorbid conditions associated with old age pose grave contests in the fracture management in elderly patients.³

Intertrochanteric fracture (IT) of femur is defined as “fracture extending from the extra-capsular basilar neck region to region along the lesser trochanter before medullary canal development.”⁴ Unstable IT fractures are difficult to treat even in the present age and have to be carefully managed due to the higher incidence of failure. Unstable IT fractures which also have comminution in the

posteromedial cortex of proximal femur pose significant complications in majority of elderly patients. The commonest cause for IT fracture is a trivial fall in elderly and high energy traumatic injuries in younger patients commonly encounter in motor vehicle accidents.⁵

Treatment for most proximal femur including IT fractures before the advent of fixation devices was conservative with prolonged traction and immobilisation. The patients ended up with a myriad of complications resulting in high morbidity and mortality.^{6, 7}

As new fixation devices and hardware were conceived along with the progress of better imaging techniques and accessibility to roentgenogram there has been considerable improvement in the patients care with marked decrease in moribund conditions.⁶ Improved understanding of the fracture configurations and response to treatments led to further improvements in implant device and there has been a continuous downward trend in the complications of such fracture which were previously deemed to be fatal or severely incapacitating.⁸

The current modality of treatment for intertrochanteric fractures remains popular with internal fixation. The sliding hip screw is predominant fixation method at present; however they frequently have complications such as lag screw cut out, excessive collapse and loss of fixation especially in unstable intertrochanteric fractures. The poor bone quality also predisposes to non-union,

femoral head perforation of the hardware and implant failure. Also excessive sliding in these devices can lead to unacceptable limb shortening along with deformity (lateral rotation of the limb).⁹⁻¹²

The development of internal Proximal femoral nail to address the shortcomings for dynamic hip screw lead to some improvements in treatment of hip fractures. However the complications in unstable fractures remained high and patients continued to be recumbent for prolonged durations.^{6, 8, 13, 14}

Compliance for partial weight bearing in elderly is poor and when allowed to fully weight bear will limit complete loading on the injured or treated limb voluntarily. The prolonged period of rest required as such predisposes these elderly patients to various other health complications further adding to morbidity and also mortality.^{15, 16}

Endoprosthesis are suggested as a good alternative for treatment of unstable intertrochanteric fractures with osteoporosis and severe comminution in elderly patients, achieving early rehabilitation of the patient and good long term results. Return to pre injury levels of activity are hastened with the use of prosthesis and thus obviate various recumbency related complications. Prosthetic replacement for intertrochanteric fractures is not employed frequently and remains a controversial modality of treatment, requiring further long term studies.^{9-12, 14-16}

Over the years there has been a lot of development in the design of prosthesis used for hemiarthroplasty of hip with many current and old designs still available.¹⁸ Bipolar prosthesis with a low friction dual bearing surface provides good results in comparison to unipolar prosthesis. Early pain relief, rehabilitation and stability provide good functional results while reducing hospital stay and complications in elderly.^{16, 17}

The challenges posed by the current internal fixation devices with poor results for unstable intertrochanteric fractures has also led to development of new designs addressing the instability and attempting to better treat them while reducing complications.^{4, 19, 20}

This study evaluates the role of primary hemiarthroplasty with cemented modular bipolar prosthesis in the treatment of unstable intertrochanteric fracture in elderly patients.

AIM AND OBJECTIVES OF THE STUDY

- The aim of this study is to assess the role of primary hemiarthroplasty in the management of unstable intertrochanteric fractures in elderly patients.
- The objective of this study is to assess the clinical and functional outcome of elderly geriatric patients with unstable IT fractures who have been primarily treated with modular cemented bipolar prosthesis using Harris hip score.

REVIEW OF LITERATURE

HISTORICAL REVIEW

The fractures of the hip were known to mankind since the earliest days, with its descriptions in many of the ancient civilization scriptures. The Aztecs and Egyptians have hieroglyphics describing the use of crutches and splints made of bark or branches.⁶ Sushruta, an Indian surgeon in 5th century AD divided fractures and dislocations into various types and devised treatment methods.²¹ The Greeks employed use of traction to reduce dislocations and splint fractures, with many of the techniques described by Hippocrates which were elaborately compiled in the medical and surgical treatise “Corpus Hippocraticum”.^{6, 22}

The earliest description for the use of sustained traction for fracture reduction was recorded by Italian surgeon, Guglielmo de Saliceto (1210-1277) with the use of weights and pulleys. A French surgeon, Guy de Chauliac (1298–1368) also advocated the idea of isotonic traction for the use of femoral fracture reduction. Many modifications were made by different surgeons for the next few centuries improving upon the previous designs, using gravity assisted counter traction and traction.^{22, 23}

Sir Astley Cooper, in his book, “A treatise on dislocations and on fractures of the joints, 1825”, was able to accurately describe and classify proximal femur fractures into extracapsular and intracapsular hip fractures, even before the advent of various imaging techniques which explained the differences in the prognosis of proximal femur fractures based on the fracture classification.²⁴

In 1825, the introduction of plaster of paris bandage by a Flemish surgeon, Antonius Mathijssen, was an important milestone in the management of fractures to act as external supports supplanting many splints and braces.⁷

In 1867, Hugh Owen Thomas (‘father of British Orthopaedics’), hailing from a family of bone setter went on to become a foremost British Orthopaedician and developed the Thomas Splint, which is still in vogue today. Initially used as treatment for tuberculosis of knee joint to transmit weight from ischial tuberosity to the ground. The principal of sustained uninterrupted immobilisation was an important teaching of H O Thomas.^{7, 23}

In 1895, the discovery of X-rays or Rontgen rays by Wilhelm Conrad Röntgen and its subsequent application in the medical field radically changed and advanced the diagnosis and treatment of fractures.

Improvements in the method of applying traction were made with the introduction of Steinmann pins by a Swiss surgeon, Dr Fritz Steinmann in 1907

and Kirschner wire by a German surgeon, Dr Martin Kirschner in 1909. The Balkan frame designed by the Dutch in the Balkan wars of 1903 was revolutionary in treatment by suspension and traction.^{6, 7}

After the discovery of Rontgen rays, the initial classification systems were based on anatomical pattern of fractures. With the advancements in surgical techniques, imaging modalities and better fixation implants, the classification of intertrochanteric fractures were made.

In 1949, Boyd and Griffin classified the fracture based on instability in coronal and sagittal planes.²⁶ In 1951, Mervyn Evans divided them into stable and unstable groups giving emphasis for deciding the line of treatment based on stability of fracture and improving outcome. The importance of posteromedial cortex continuation contributing to stability was emphasised and these classification systems were widely adopted and continue to be relevant.²⁷

The AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture classification was introduced in 1996 to be used as a comprehensive and standardised classification system including intertrochanteric fractures, which is widely used in clinical practice and research to present day.²⁸

Further classification systems were developed and expanded upon previous classifications such as Tronzo classification in 1973, based on Boyd

and Griffin and later Kyle and Jensen modification of the Evans classification and numerous others but remain rarely used in daily practice.^{29, 30}

ADVENT OF OPERATIVE MANAGEMENT

Till the 1900s the treatment of intertrochanteric fractures had conventionally been conservative with various traction apparatus. The advent of the 20th century saw a shift towards operative management of IT fractures with the concurrent development of the field of radiology. The benefits of operative treatment swiftly gained traction and their associated with better functional outcomes came to be recognised.^{6, 7, 8}

The progress in implant designs were primarily aimed to address intracapsular femur fractures treatment which had a considerably high rate of treatment failure. These implant gradually were used or modified to be used in other fractures and thus intertrochanteric fractures saw favour with operative treatment.⁸

The invention of tri-flanged internal fixation device by Marius Nygaard Smith Petersen for femur fractures 1925 was a major breakthrough, allowing surgical fixation of intertrochanteric fractures and greatly reducing mortality and morbidity. Thus began the modern era of internal fixation.³¹

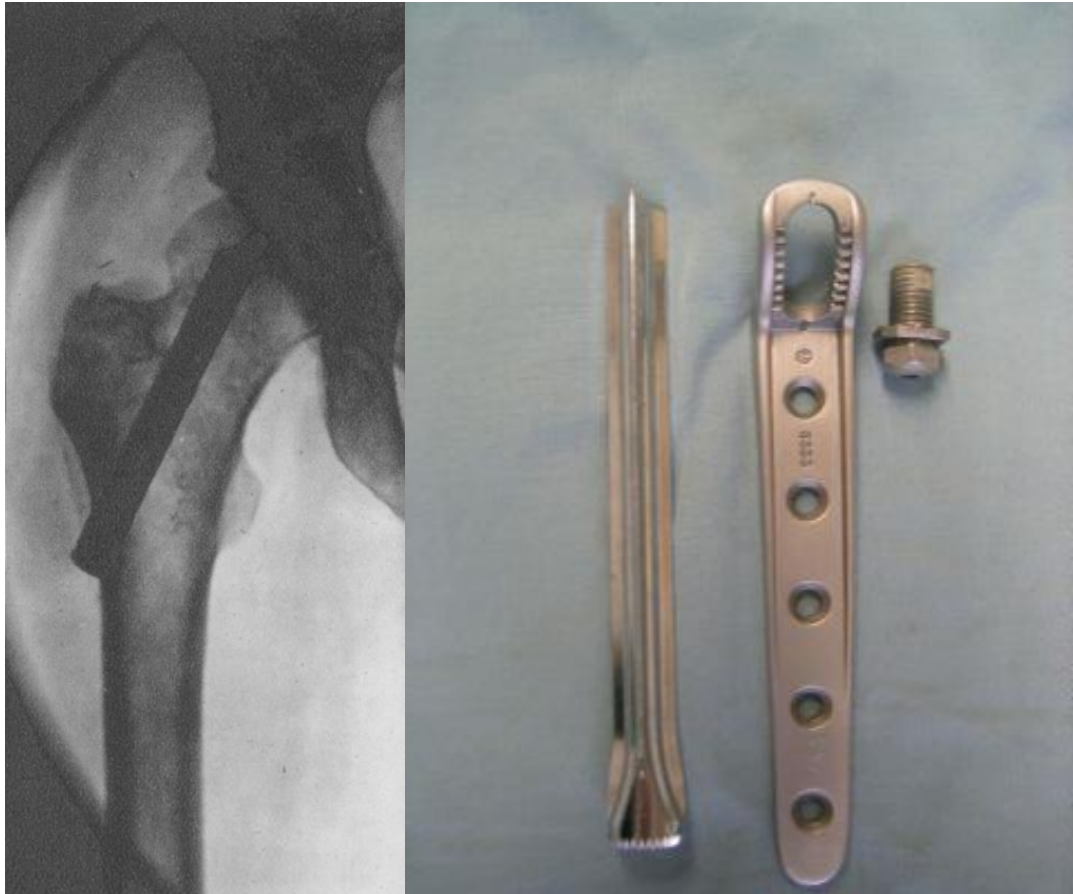


Figure 1: SMITH PETERSON NAIL

Figure 2: SMITH PETERSON NAIL WITH McLAUGHLIN PLATE

In 1937, Lawson Thornton made another modification with the addition of a side plate to the the Smith Peterson nail making it possible to use this implant for trochanteric fractures of femur while McLaughlin added a multiple angle side plate which was adopted in further designs.³²

In 1941, Eugene L Jewett combined the use of Smith Peterson nail with Hawley bone plate welding them together to create a one piece flanged nail

plate or Jewett nail which conferred greater stability to the fragments. The Jewett nail gained popularity and was widely used till the associated drawbacks of a rigid fixation were recognised, prompting new designs.³³

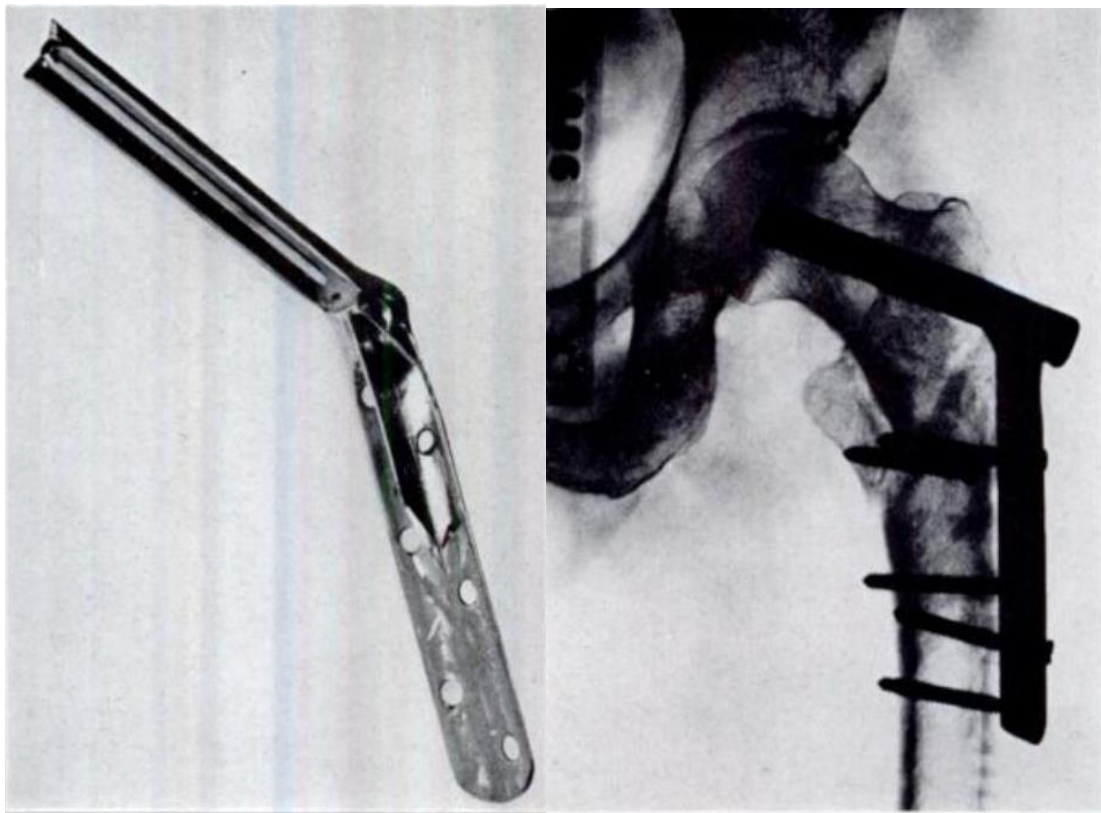


Figure 3: JEWETT NAIL

SLIDING HIP SCREW

The principal of rigid fixation of fractures as was advocated by the AO foundation continued to influence the way the fixation devices were designed. They started to show their limitations with a high failure rate and complications in proximal femur fractures. Ernst Pohl, a German designer in Kiel, developed the first gliding screw plate which allowed for telescoping of the fracture fragments and led to the advent of biological fixation of proximal femur fractures. The popular implants in use today, the dynamic hip screw (DHS) and intramedullary hip nail devices are all based on modifications of Ernst Pohl's design.³⁴

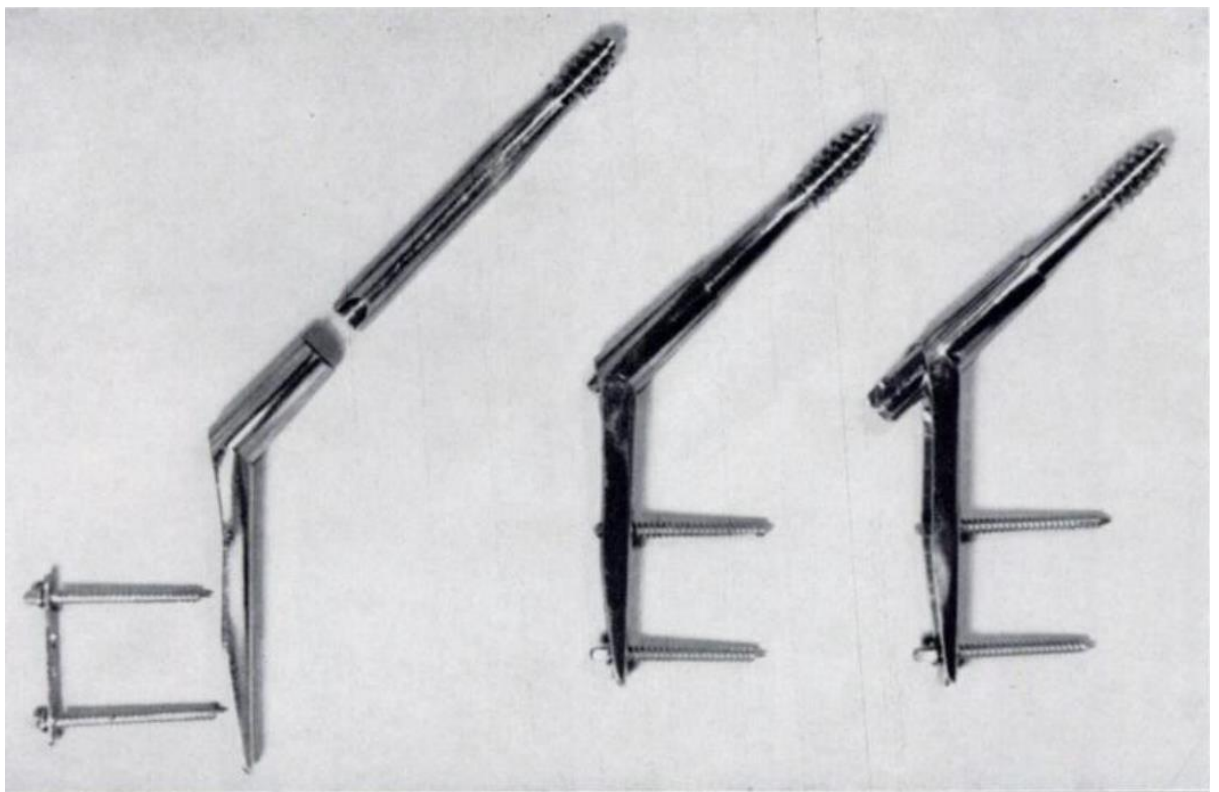


Figure 4: SLIDING HIP SCREW

In 1955, W Schumpelick described the use of sliding screw in his study for treating twenty eight patients with better comparable results.³⁵ Further modifications of this device were made by Callender and introduced in the United States in 1967, where it was used in a series of unstable intertrochanteric fractures by Harrington and Johnston in 1973. The improvements of designs in the sliding mechanism made by Kay Clawson became the standard treatment for IT fractures with the development of the Richard's compression hip screw.^{8, 36}

The development of the sliding screw further led to designs with bidirectional sliding with the aim to maximise fracture impaction. The same proximal lag screw telescopes within the plate and the plate itself axially along the shaft of femur. This was done with the addition of slotted screw holes (instead of round screw holes) in Egger's plate. In 1992, the Medoff plate was developed with a coupled internal sliding component in the plate along with the sliding screw allows for biaxial dynamization. Other types of plate screw mechanisms were developed like the Percutaneous compression plate system PCCP by Gotfried, Intertan CHS and hybrid locking and trochanteric buttress plates.^{19, 37, 38}

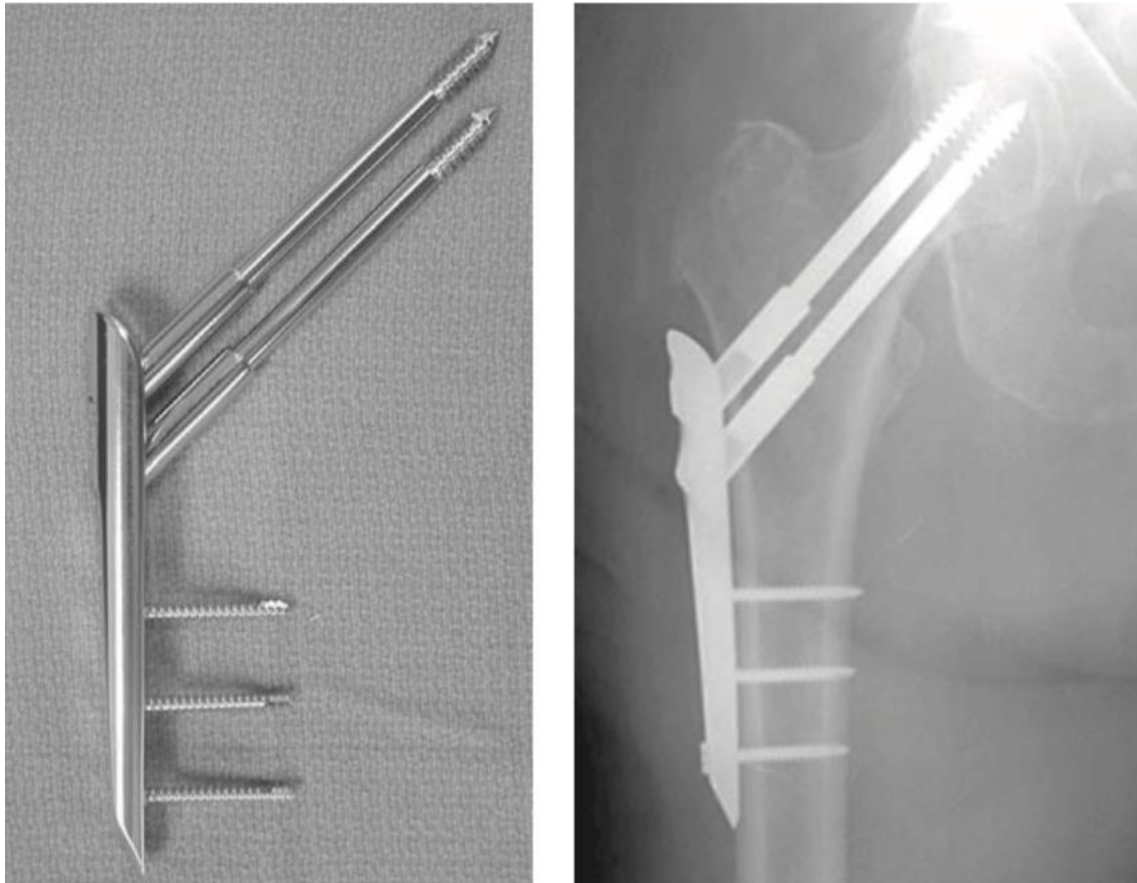


Figure 5: Percutaneous Compression Plate (PCCP)



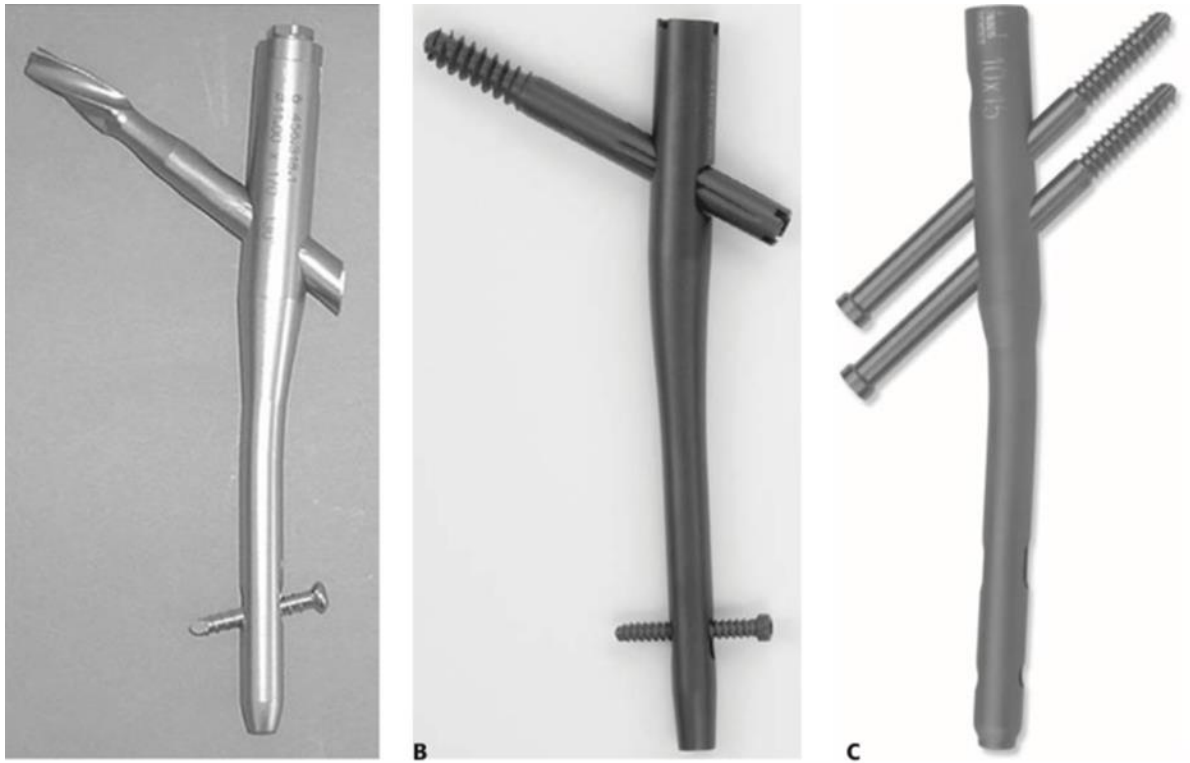
Figure 6: MEDOFF PLATE

CEPHALOMEDULLARY NAILS

The cephalomedullary nails as the name suggest were inserted into the proximal femur through a closed technique. They provided good results due to being closer to the biomechanical axis of femur and providing greater support while eccentric loading on single cortex.³⁸

They were devised in the earliest form as Y nail by Kuntscher in 1953. Further iterations and modifications were Zickel nail and titanium trochanteric fixation nail. The dynamic compression or gamma class nails were developed later and introduced by S C Halder in 1992, consisting of a single lag screw with dynamic compression and pioneered by Grosse and Kempf.³⁹

In 1984, Reconstruction nails with two screw head components were developed by Russell and Taylor which were primarily used for subtrochanteric fractures and pathological fractures. The current versions of the device such as Targon PF nail have better load bearing properties. However their use in unstable IT fractures still poses severe complications. The InterTAN series of implants made of titanium alloy are the most recent development in this class of implants developed by Russell and Sanders.^{38, 40}



**Figure 7: (A) Short trochanteric fixation nail TFN
(B) Short gamma 3 cephalomedullary nail
(C) Short trochanteric antegrade nail**

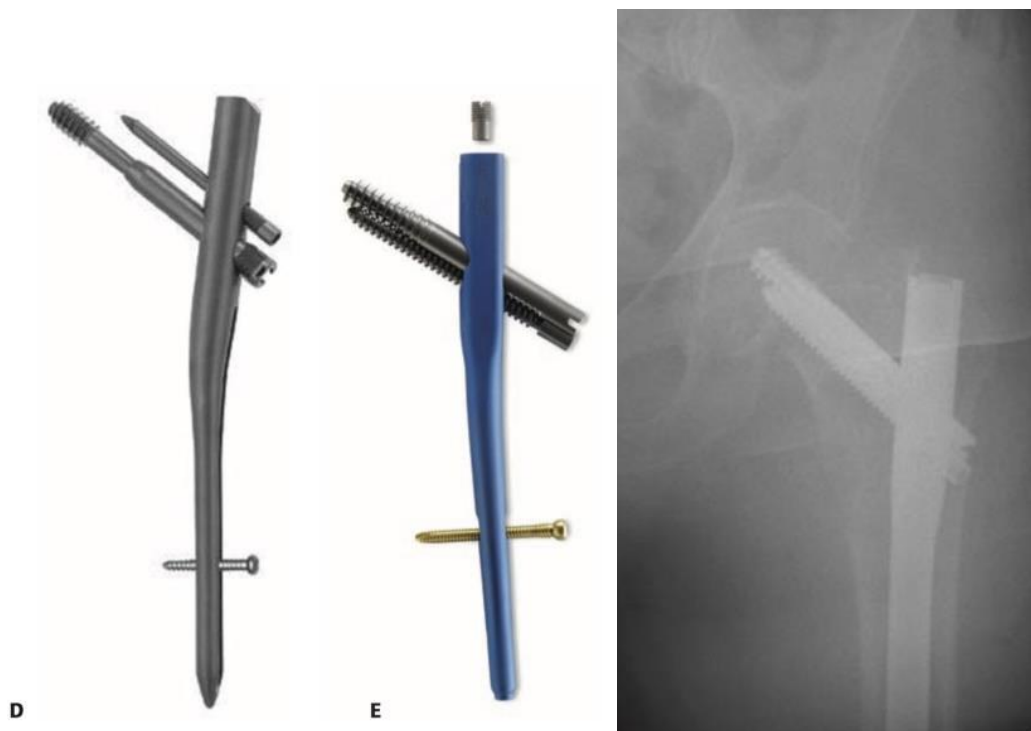


Figure 8: (D) Targon PFN (E) Short interTAN cephalomedullary nail

ARTHROPLASTY

In the early 20th century the high incidence of complications after internal fixation led to ideas to replace the fractured femoral head and create a new joint by interposing it with a durable substance between the bone ends. Many materials were tried like ivory, gold, silver, steel, tin and synthetic materials like acrylic, plastic and high density polyethylene. Hey-Groves in 1927 used ivory prosthesis for femoral head and reported four years later that patient led an active life.⁴¹

In 1932, Charles Scott Venable and W G Stuck introduced vitallium in orthopaedic fracture fixation after much research for a biocompatible inert metal.^{42, 43}

Smith Petersen worked on various materials for mould arthroplasty starting with glass, Bakelite and plastic materials for bearing surface without much success and finally settled on vitallium after 15 years of research and developed vitallium cup arthroplasty along with Nathaniel Allison which was used in 1938 for a case of bony ankylosis of rheumatoid arthritis.⁴¹⁻⁴³

Harold Bohlman in 1939 developed the first vitallium based femoral prosthesis with a short stem and a year later performed the first hip joint replacement using his device.⁴⁴



Figure 9: VITALLIUM BOHLMAN HEMIARTHROPLASTY WITH SHORT STEM

Jean and Robert Judet, developed a short-stemmed acrylic coated prosthesis which had excellent initial results but started experiencing loosening of hardware and was subsequently abandoned.^{41, 42}

Austin T Moore and Bohlman in 1940 developed a custom made long stemmed metal prosthesis to replace proximal femur of a patient with recurrent giant cell tumour with good outcome.⁴⁴ They observed that the bone growth took place through the holes in the prosthesis thus refining their future design to incorporate a fenestrated stem to allow for bone ingrowth.^{41, 45}

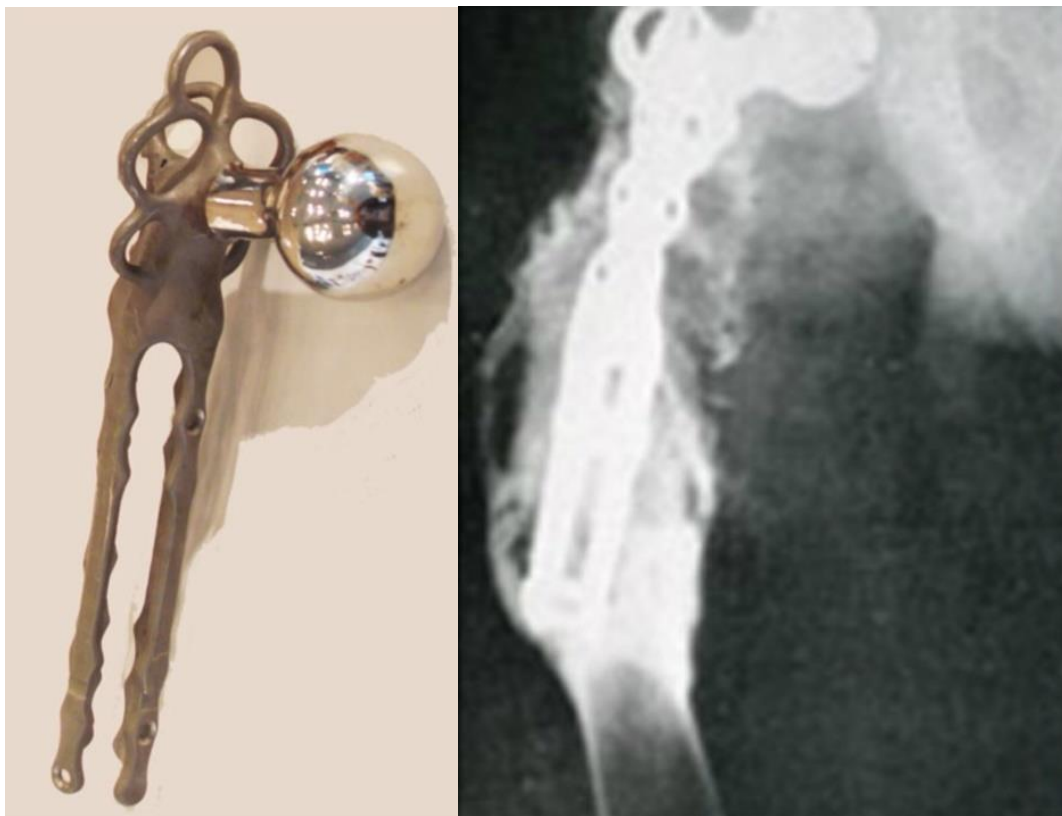


Figure 10: CUSTOM LONG STEMMED PROXIMAL FEMORAL PROSTHESIS

The long stemmed prosthesis designed separately by Frederick R Thompson and Austin T Moore were widely used and remained popular for several decades.^{45, 46} Austin-Moore prosthesis was later incorporated into the McKee Farrar total hip design.^{43, 47}



Figure 11: AUSTIN-MOORE PROSTHESIS
Figure 12: THOMPSON PROSTHESIS

Tronzo claimed to be the first to use endoprosthesis for the primary treatment of intertrochanteric fracture. In 1973, Rosenfeld et al used a head neck replacement prosthesis for treating unstable IT fractures in 72 geriatric patients with 33 excellent results, 21 good and 11 fair results. 33 patients had poor results while 5 deaths were reported. The author concluded that in elderly frail patients hemiarthroplasty aided in swifter ambulation and also reducing complications.^{48, 49}

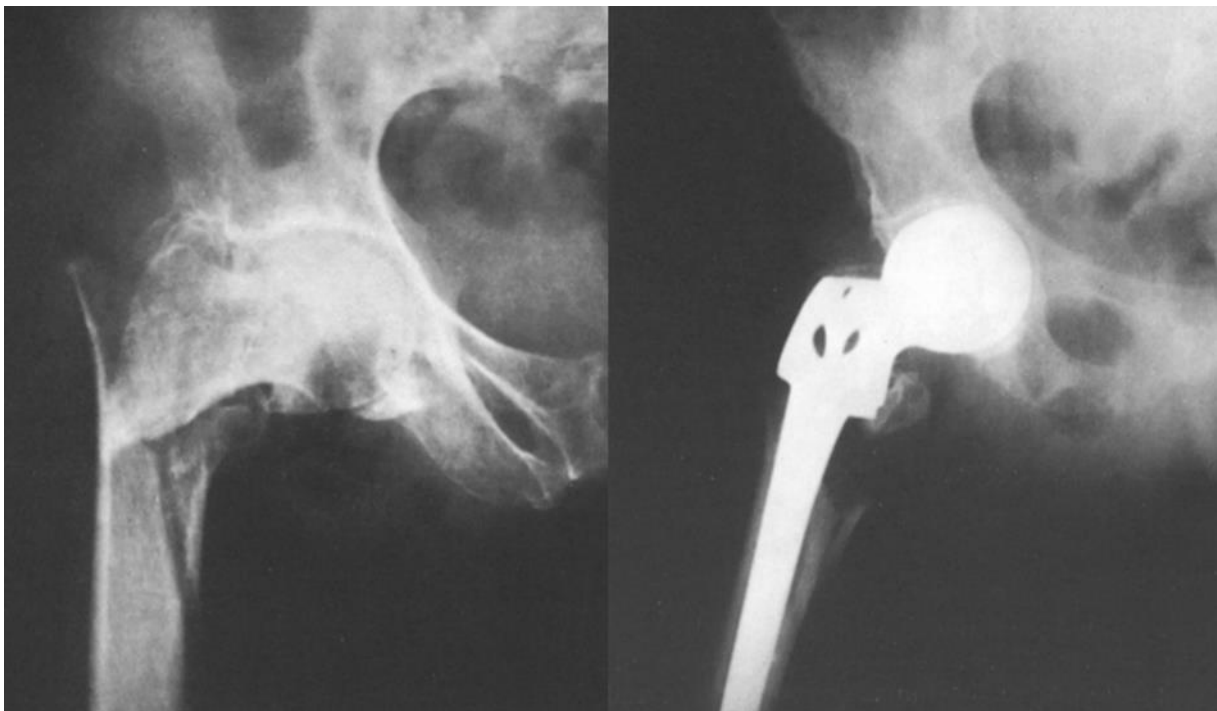


Figure 13: LEINBACH PROSTHESIS

BIPOLAR LITERATURE

In 1974, an Orthopaedician, Dr James Ennis Bateman along with a bio-engineer, Averill, were the first to design multiple-bearing endoprosthesis with an interposing free riding cup with the rationale to lessen the frictional forces between the femoral head and the acetabular cartilage to address the issues with the unipolar prosthesis of the time which was used in the same year by J E Bateman and Gilbert in their study. Previous attempts made to develop a bipolar prosthesis using Teflon resulted in poor mechanical and biological properties. A multitude of bipolar designs have appeared since by Devas and Hinves (1983), Gilberty (1983), Berberane (1983); Leyshon and Matthews (1984), Hastings bipolar prosthesis, Talwalkar's bipolar endoprosthesis.^{8, 18, 50}



Figure 14: LEINBACH BIPOLAR PROSTHESIS (early design)

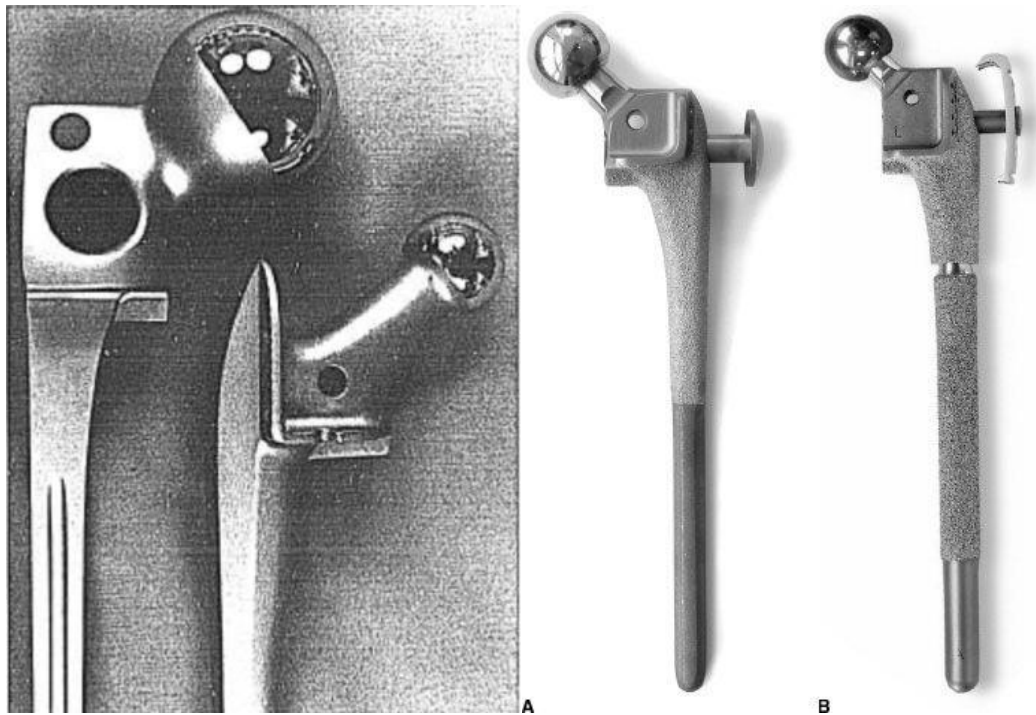
In 1977, a study by Stern et al, on 29 intertrochanteric fracture cases treated primarily or secondarily with the use of a leinbach prosthesis showed eighty six percent of the patients returning to full weight bearing ambulation within 5 to 10 days. The authors concluded that the use of leinbach bipolar prosthesis in debilitating geriatric patients was an effective way of treating unstable IT fractures with an attempt to achieve early ambulation and decrease associated complications.⁵¹



Figure 15 LEINBACH BIPOLAR PROSTHESIS

In a 1987 study by Green S et al, 20 elderly (average age 82.2 years) unstable IT fracture patients were treated with bipolar head neck replacement of which seventeen patients received primary hemiarthroplasty and three for salvage of failed internal fixation. The patients achieved unrestricted weight bearing ambulation after average of 5 days post-surgery. The bipolar design

permits conversion to a total hip arthroplasty with the reusability of the femoral component, and thus reducing the risk of acetabular cartilage damage and thus the authors recommend its use for rapid rehabilitation for elderly patients.⁵²



**Figure 16: Leinbach prosthesis (left), bipolar head neck replacement prosthesis with outer head removed (right)
A (monoblock) & B (Modular) Mallory head neck replacement prosthesis**

In 1989, a three year study by Hantjens P et al, primary bipolar arthroplasty was performed on 37 elderly (mean age 75 years) unstable IT fracture patients. The functional results were excellent in 75 % of the patients according to the Merle d'Aubigné scale. The authors concluded that rehabilitation of the patient was faster and easier with decreased incidence of pressure sores, atelectasis and pulmonary infection compared to internal

fixation. The major contributing factor to these results was the early weight bearing made possible by the bipolar endoprosthesis.⁵³

In 1994, a 10 year study by A C Vahl et al used an endoprosthesis for the treatment of seventeen unstable intertrochanteric and five subtrochanteric fractures with severe comminution and osteoporosis. Ten patients each had cardio-pulmonary disorders and central nervous system disease. 77% of the patients achieved full weight bearing mobilisation while 23% patients never walked again with mortality of two patients in the first month. The study concluded that for elderly and debilitated patients, hemiarthroplasty was an acceptable alternative to osteosynthesis in unstable intertrochanteric fractures.⁵⁴

In 2000, Casey C K a series of 55 standard cemented hemiarthroplasties for IT fractures patient (average age of 84.2 years) were reviewed. During folloup, 12 patients died within 6 months, 19 patients maintained the same walking category as before fracture and 8 of those had no increase in dependency on walking aides. The authors of this study think that the use of standard cemented hemiarthroplasty is a viable alternative to a sliding screw device for the treatment of intertrochanteric fractures in the geriatric patients.⁵⁵

In a 2002 study by Lin W C et al, 50 patients underwent salvage procedure for failed compression hip screw fixation of intertrochanteric fractures with 16 patients undergoing bipolar hemiarthroplasty, 5 Austin Moore hemiarthroplasty

and 9 total hip arthroplasty. Total hip and bipolar group showed better functional outcomes compared to internal fixation which had a 9.7% failure incidence.⁵⁶

In a 2002 study by Rodop O et al, 54 elderly patients were treated with primary hemiarthroplasty using a modular leinbach hemiprosthesis with an average of 22 months followup in complications of aseptic loosening, deep infection and acetabular erosion were encountered. 17 excellent and 14 good results were seen after 12 months based on Harris hip score and showed good short term results. The study observed that the inner motion of the bipolar head had decreased over long durations.⁵⁷

In 2003, Haidukewych G J et al, in a 12 year study treated sixty elderly patients with hip arthroplasty after failed osteosynthesis of intertrochanteric fracture of which thirty two patients underwent total hip arthroplasty, twenty seven with bipolar hemiarthroplasty and one unipolar hemiarthroplasty. During the followup period ten patients died within 2 years; 40 patients could walk, 26 with one arm support or less. The authors concluded that arthroplasty of hip was an effective salvage procedure in the failed treatment of intertrochanteric fractures in an elderly patients with most patients having good pain relief and functional improvement.⁵⁸

In a 2007 study conducted by Florian Geiger et al., the clinical records and radiographs of trochanteric femoral fracture of elderly patients were

studied. Out of a total of 283 patients, 132 patients received primary arthroplasty, 109 patients with dynamic hip screw and 42 were treated with proximal femoral nail. The main focus of the study was on the survival rate after one year and complications requiring treatment in the same period with parameters such as age, gender and comorbidities reduced by multivariate logistic regression analysis. The study concluded that treatment by primary hip arthroplasty had low risk of one year mortality and rate of complications in comparison to osteosynthesis.⁵⁹

In a 2005 study by Chris Grimsrud et al, 39 unstable 3 and 4 part intertrochanteric hip fracture patients underwent cemented bipolar hip arthroplasty with a standard length femoral component along with cerclage fixation of trochanteric bone fragments with retention of femoral calcar. On one year followup all trochanters healed with no loosening of femur components with complications of one dislocation and one deep infection reported. The authors advocated hemiarthroplasty with cerclage cabling of trochanters to treat unstable 3 and 4 part fractures, which reduced rate of complications and achieved early weight bearing with this technique.⁶⁰

In 2008, a study five year study by Gui-shan G U et al., included 48 patients with unstable intertrochanteric fractures (Evans type III in 11 cases, Evans type IV in 25 cases and Evans type V in 22 cases) of whom 17 patients were treated with cemented bipolar hemiarthroplasty. Post-operative protocol

involved patients encouraged on day 3 to 4; partial weight bearing on 5 to 7 days and allowed to walk with walker after day 10. Evaluation with Zuckerman functional recovery score (FRS) after 30 days postoperatively was 78.7. The authors consistently achieved satisfactory results and emphasised on strict preoperative risk assessment, strict indication for patient selection and systematic postoperative rehabilitation.⁶¹

In 2010 a study reviewing a 23 randomised control trials was undertaken by Parker M J et al., including 2861 elderly proximal femoral fractures patients by searching MEDLINE, Cochrane group specialised register (2009), CENTRAL (Cochrane library 2009), EMBASY and trial registers (2009), and articles reference list comparing different arthroplasties. The authors inferred less pain and improved mobility after one year period with cemented prosthesis compared to uncemented prosthesis, with no significant differences in surgical complications. No difference was noted in 220 participants comparing hydroxyapatite coat and cemented prosthesis. No difference was found between unipolar and bipolar hemiarthroplasty in 863 fractures. Total hip arthroplasty was noted to have more dislocations compared to hemiarthroplasty but better functional outcome scores in 734 participants. In conclusion the authors suggested that THR had better functional outcome compared to hemiarthroplasty and cementing prosthesis reduces post-operative pain and lead to better mobility.⁶²

CURRENT REVIEW

In a 2010 study by Sancheti K H et al., retrospective analysis of 37 (averaging 77 years) patients who underwent primary hemiarthroplasty for unstable intertrochanteric fractures was undertaken and followed for 24 months. Patients average time to walk was postoperative 3 days and complications such as superficial skin infection and pressure sore were encountered. Functional outcome results based on HHS showed 32 patients had excellent to fair and 2 patients had poor results. The conclusion drawn was that primary hemiarthroplasty provides a pain free, mobile and stable joint with acceptable complications.⁶³

In 2012 Ahmed Elmorsy et al., prospectively evaluated 41 patients who underwent bipolar hemiarthroplasty for unstable IT fractures. Using the Harris hip score the last followup measures were found to be excelled in 4 cases, good in 16, fair in 16 and poor in 5 patients. Thus the author concluded that the bipolar hemiarthroplasty for unstable IT fractures should be considered as one of the treatment modalities especially in case of fragility fractures as they have good early clinical outcomes in geriatric patients.⁶⁴

In 2013, Dr Atul Patil et al., operated 126 geriatric (avg 65.5 years) osteoporotic patients with comminuted IT fractures who were treated with cemented bipolar hemiarthroplasty along with tension band wiring for GT

Greater trochanter). The average HHS 80.76 in the last followup at a mean of 3 years was a significant improvement when compared to pre surgery scores.⁶⁵

In 2014, a 7 year study by P K Raju V et al., bipolar hemiarthroplasty was done for twenty elderly with 3 week old unstable IT fractures. Functional results with HSS at 6 month followup was fair (78.2) and 24 months was good (83.25). The authors concluded that bipolar hemiarthroplasty was a viable option for the treatment of unstable intertrochanteric fracture in a geriatric population.⁶⁶

In 2018, Sivabalan T et al published a study on 60 elderly unstable intertrochanteric fractures patients treated with cemented hemiarthroplasty with medial calcar augmentation with bone graft and followup for a total period of 2 years. Functional results with HHS showed 28% had excellent outcome, 43% good and 23% fair outcome. A 3.3% in-hospital mortality was noted with 85% survival rate at the end of one year. It was concluded that cemented bipolar hemiarthroplasty with medial calcar augmentation is a good option for unstable intertrochanteric fractures in elderly with osteoporotic bones and other comorbidities.⁶⁷

In 2018, Tyler A Luthringer et al reviewed six studies with 188 patients, comparing hemiarthroplasty and total hip arthroplasty outcomes for failed IT fracture osteosynthesis of whom 100 underwent THA and 88 hemiarthroplasty. The author concluded that THA had more improvement in HHS compared to hemiarthroplasty group but there was no significant difference in post-operative fractures, dislocation, infection or stem subsidence.⁶⁸

ANATOMY

HIP JOINT

The hip joint is a synovial multiaxial spheroidal ball and socket joint. It is formation of the articulation between the “ball” or spherical femur head and “cup”, a concave socket or lunate surface of the acetabulum. It connects the axial skeleton with the lower extremity through the articulation of the pelvis with femur and is designed for weight bearing and stability while sacrificing some mobility.^{69,70}

ACETABULUM

The os coxae or hip bone in adults is formed by the convergence of different bones i.e. ilium, ischium and pubis (fusion around end of adolescence)

The acetabular articular surface is reminiscent of a horseshoe like surface or an incomplete ring with a deficient centre and a notch directed inferiorly.^{69,70}

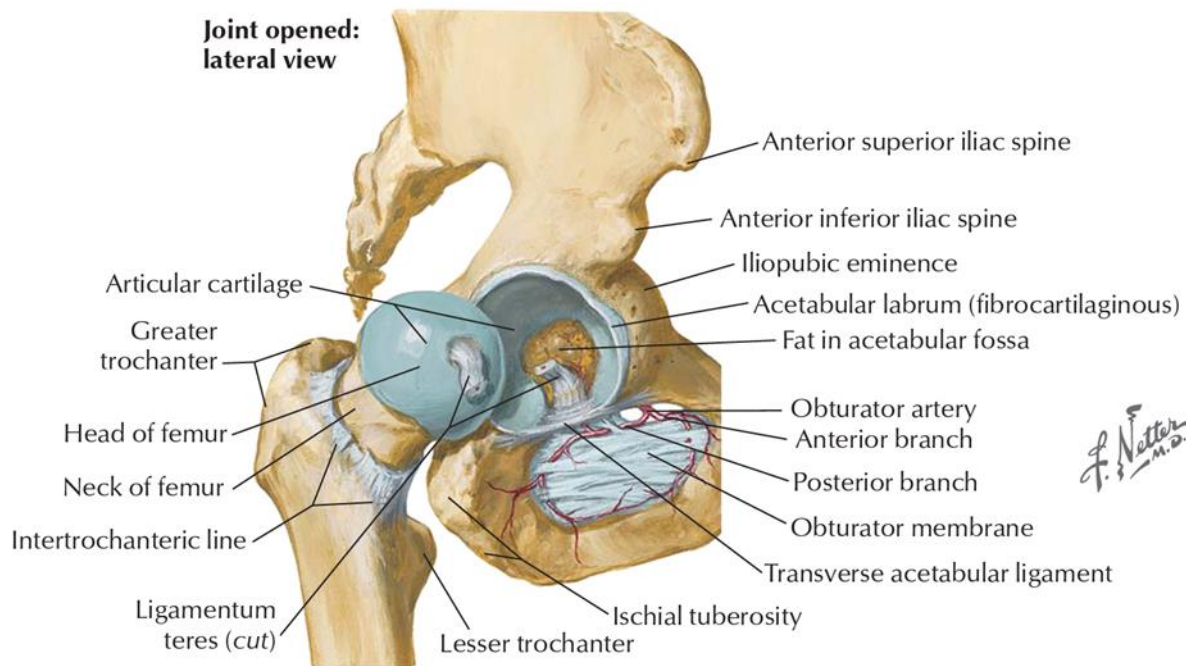


Figure 17: ACETABULUM (lateral view)

It is broad in the superior aspect to accommodate for the pressures associated with the weight transmission during erect posture and flattens slightly during stance phase to increase contact area. The acetabular fossa doesn't contain any cartilage but is occupied by the pulvinar which is a synovium covered cushion of fibroelastic fat. The transverse acetabular ligament bridges the labrum inferiorly. The acetabulum covers roughly two fifths of the femoral head, almost entirely encompassing it. Articular cartilage lining the acetabulum and femur are thick in the peripheries while thin in the centre. The articular opposing surfaces curve reciprocally. ^{69,70}

It is orientated 45 degrees caudal & 15 degrees anteriorly ^{18,69,70}

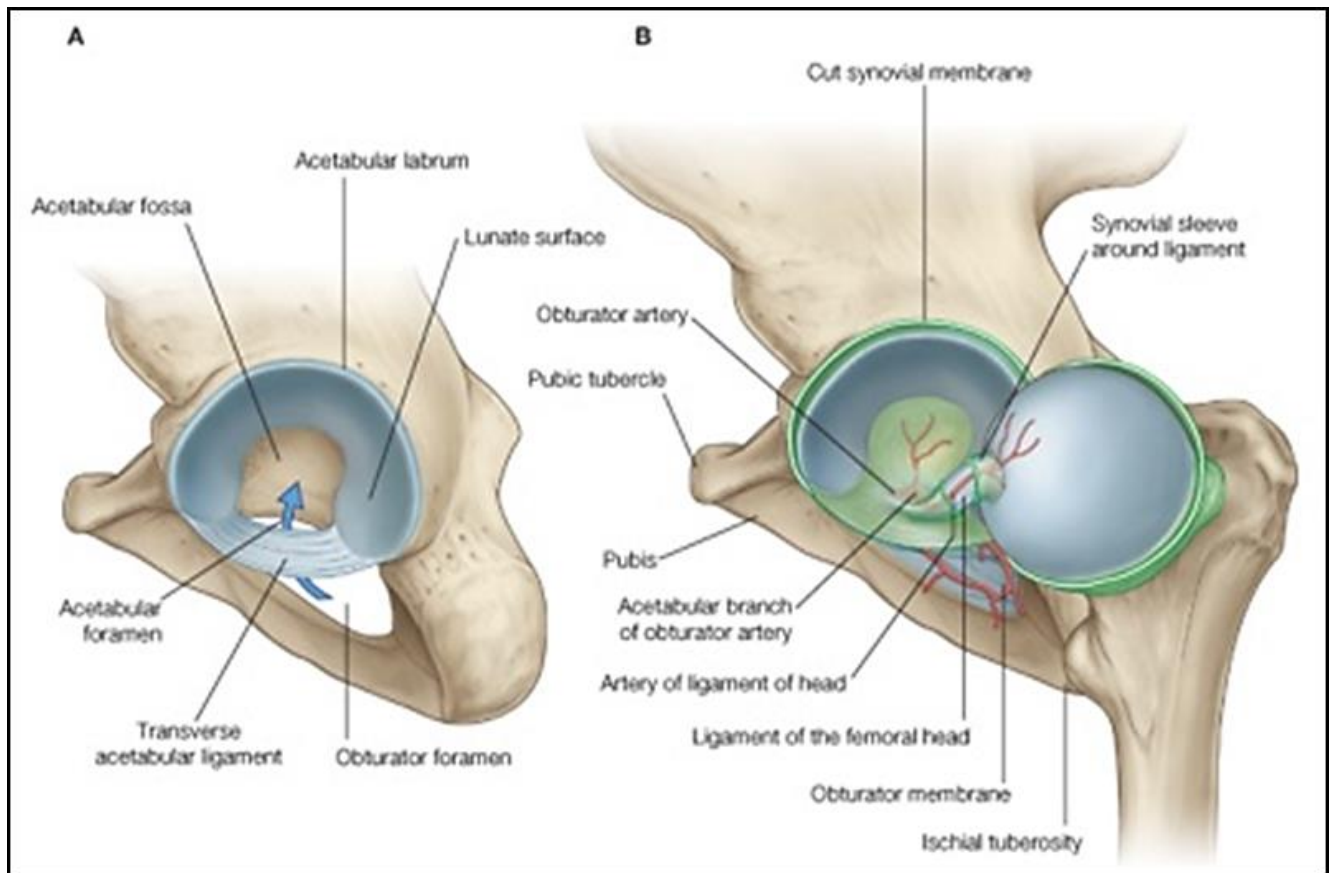


Figure 18: ACETABULUM AND PROXIMAL FEMUR

FEMUR^{69,70}

It is the longest and strongest bone in the human body consists of a shaft and two ends, articulating with the hip bone at the upper end and with the patella and tibia at the lower end.

It contains anterior and lateral bowing in the mid portion with an anteversion of neck and proximal metaphysis of approximately 15 degrees

The upper end or proximal part of femur of femur includes the head, neck, greater trochanter (GT), lesser trochanter (LT), intertrochanteric line (ITL) and intertrochanteric crest (ITC).

HEAD OF THE FEMUR^{69,70}

It articulates with the acetabulum to form the hip joint and forms more than half of a sphere being directed medially, upwards and slightly forward

It also contains the fovea which is a roughened pit present below & behind the centre. It gives attachment to the ligament of head of femur (also called the round ligament or ligamentum teres)

NECK OF THE FEMUR^{18,69,70}

It is about 5 cm long on average and connects the femur head to shaft forming an angle of about 125° and anteversion of $15-20^{\circ}$ (adults). The neck shaft angle (NSA) or caput-collum-diaphyseal (CCD) angle is less in females as a result of a wider pelvis.

The neck is strengthened by calcar femorale in its concave surface

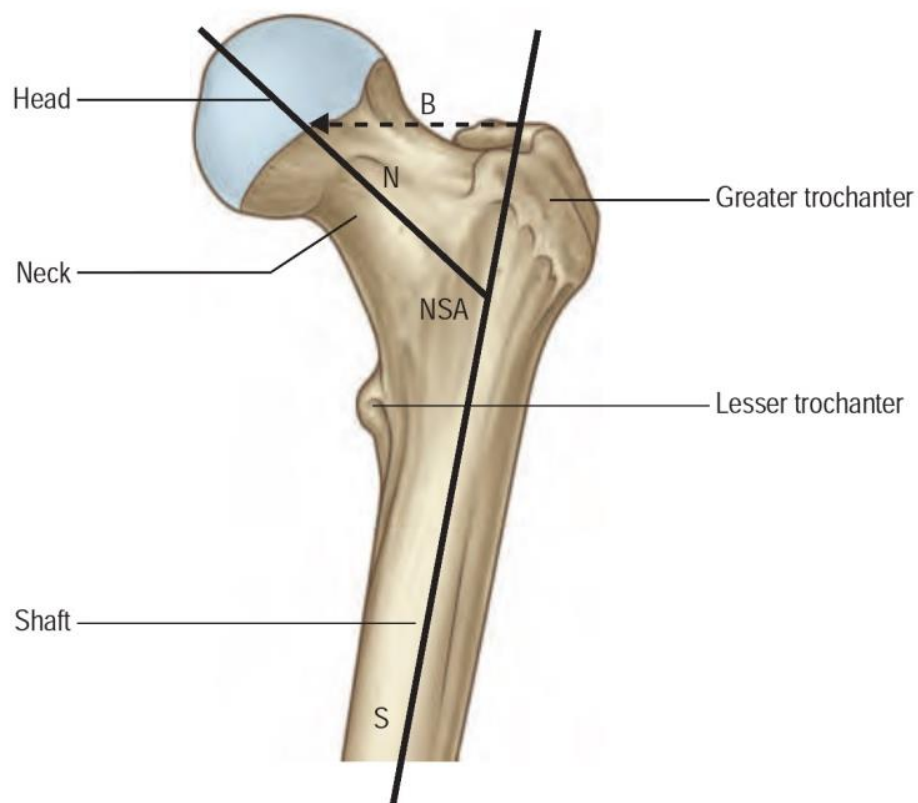


Figure19: NSA: Neck shaft angle

GREATER TROCHANTER

It is large, quadrangular, laterally positioned and irregular and gives attachment for most of the muscles of the gluteal region.

Its apex is the posteriorly in-turned in its upper border and provides insertion to the piriformis muscle

- It has three surfaces : 1) Anterior 2) medial and 3) lateral
 1. Anterior surface : Rough (laterally) for insertion of the gluteus minimus.
 2. Medial surface :
 - Upper rough impression - Insertion to the common tendon of Obturator internus and the Gemelli muscles.
 - Trochanteric fossa - insertion of Obturator.
 3. Lateral surface - crossed by an oblique ridge directed downwards and forwards
 - Insertion - Gluteus medius.
 - Trochanteric bursa of gluteus medius in front of the ridge
 - Trochanteric bursa of gluteus maximus behind the ridge

LESSER TROCHANTER

- Conical eminence at junction of neck and shaft femur
- Directed medially and backwards
- Psoas major muscle - inserted on the apex and medial aspect of the rough anterior surface
- Iliacus muscle - inserted on the anterior surface of the base of LT and the area below it.
- Smooth posterior surface - Covered by a bursa - Due to the upper horizontal fibers of adductor magnus

INTERTROCHANTERIC LINE (ITL)

- Junction : Anterior surface of neck and shaft of femur
- Begins superiorly at the antero-superior angle of the GT and is continuous below with the spiral line in front of the lesser trochanter.
- Provides attachment for:
 1. Capsular ligament of the hip joint
 2. Upper part ITL : Upper band of ilio femoral ligament
 3. Lower part ITL : Lower band of ilio femoral ligament
 4. Upper end ITL : Origin to the highest fibers of the vastus lateralis
 5. Lower end ITL : Origin of the highest fibers of vastus medialis

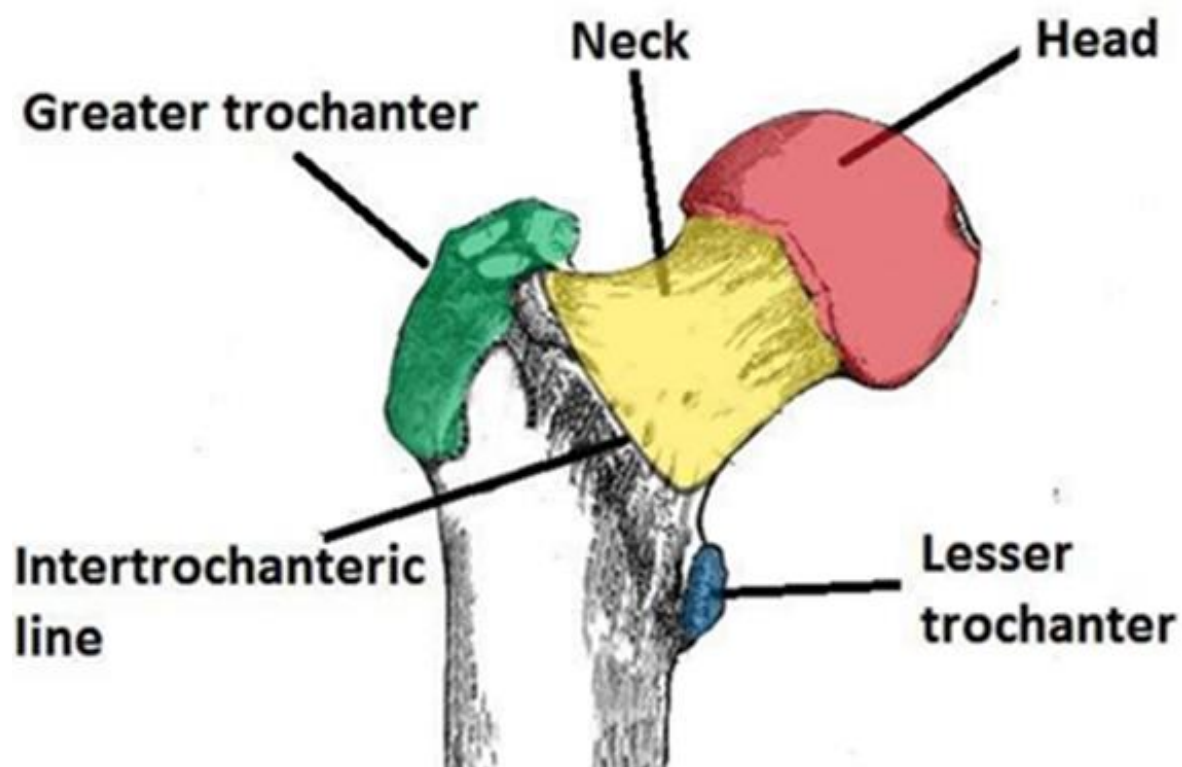


Figure 20: PROXIMAL FEMUR (anterior view)

INTERTROCHANTERIC CREST (ITC)

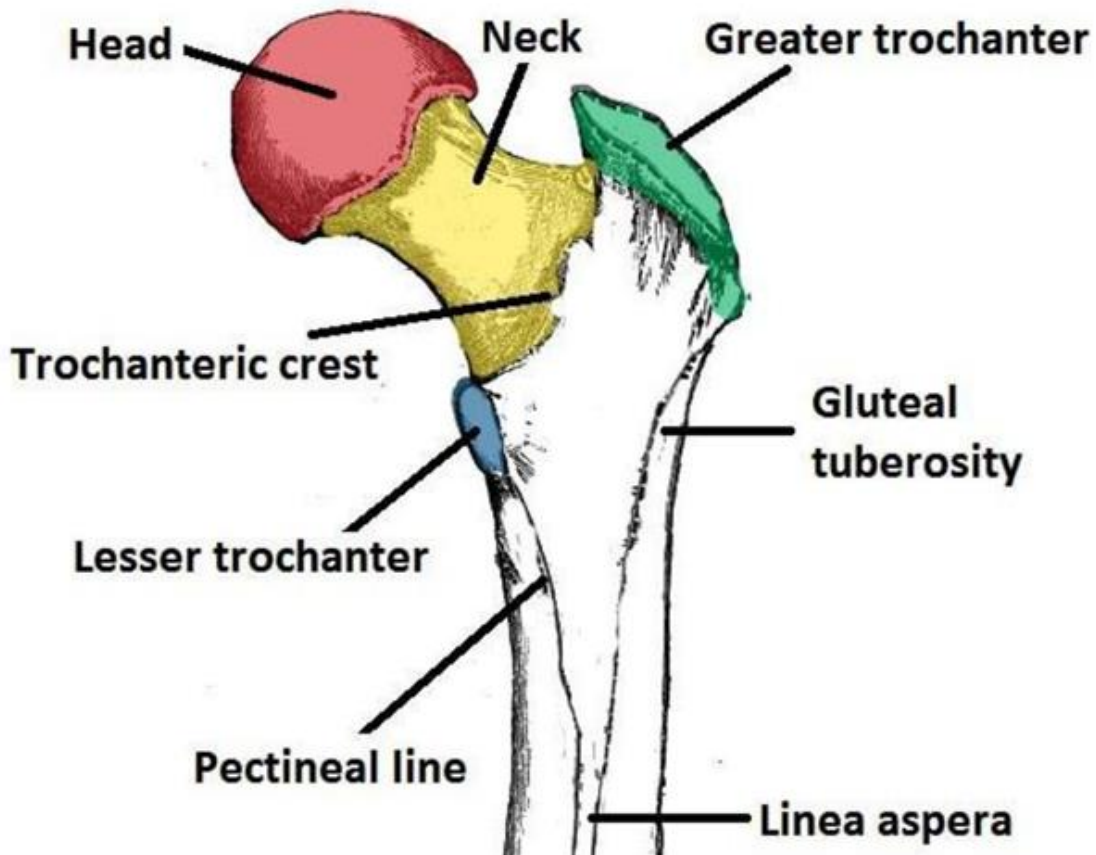


Figure 21: PROXIMAL FEMUR (Posterior view)

- Junction : Posterior part of neck and shaft of femur
- Begins superiorly at the postero-superior angle of greater trochanter and ends at the lesser trochanter
- Quadrate tubercle : Rounded elevation in the middle of ITC
 - Insertion to quadrates femoris

CALCAR FEMORALE

In 1957, Harley and Griffin clarified the definition of the calcar femorale as a vertical plate of dense bone that projects from the posteromedial cortex of the femur deep to the lesser trochanter and proximally blends with the posterior cortex of the femoral neck. It is continuation of the cylindrical cortex of the shaft and its function is to strengthen the proximal femur around lesser trochanter.⁷²

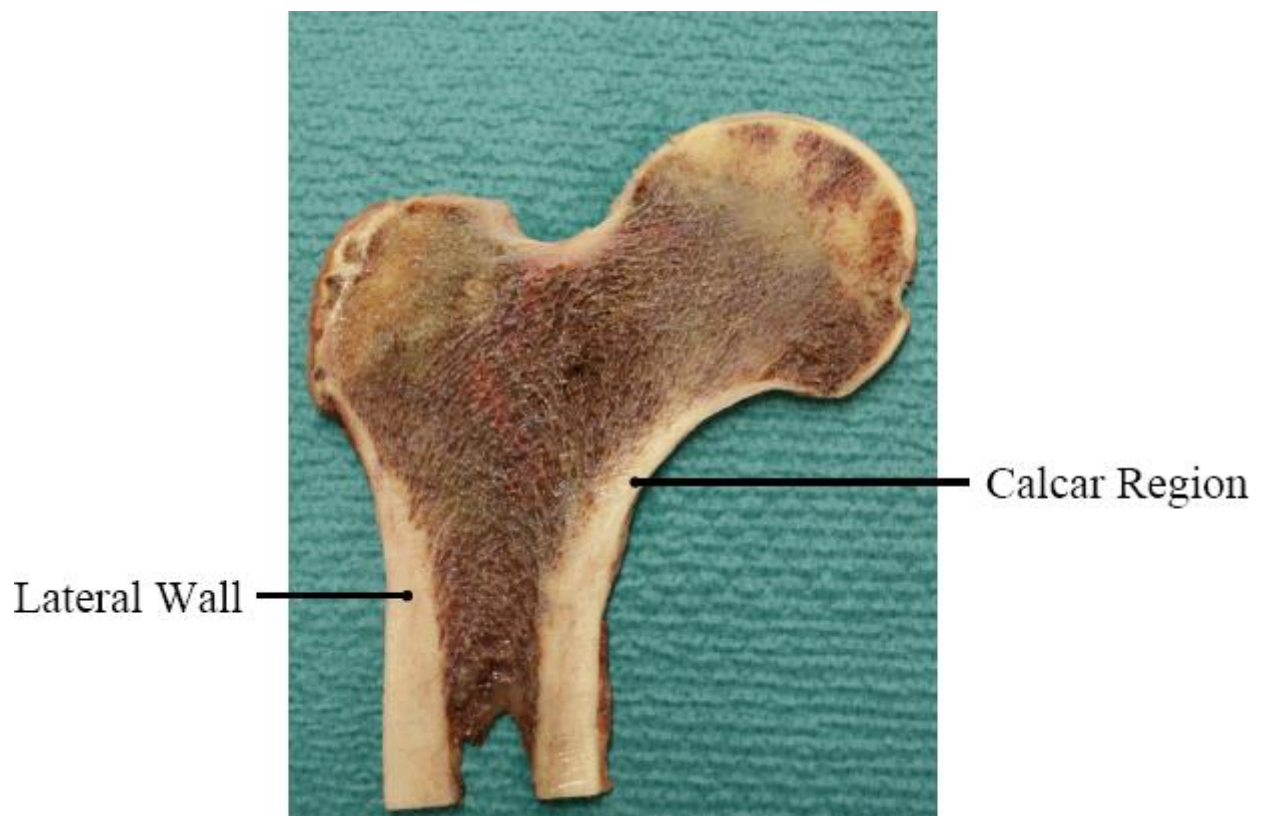


Figure 22: CALCAR FEMORALE

SYNOVIAL MEMBRANE

It forms a tubular covering around the ligament of the femur head, lines fibrous membrane of joint and attaches to the articular margins of femur and acetabulum. It also covers the neck of femur and reflects back to the fibrous membrane, which encloses the hip joint.

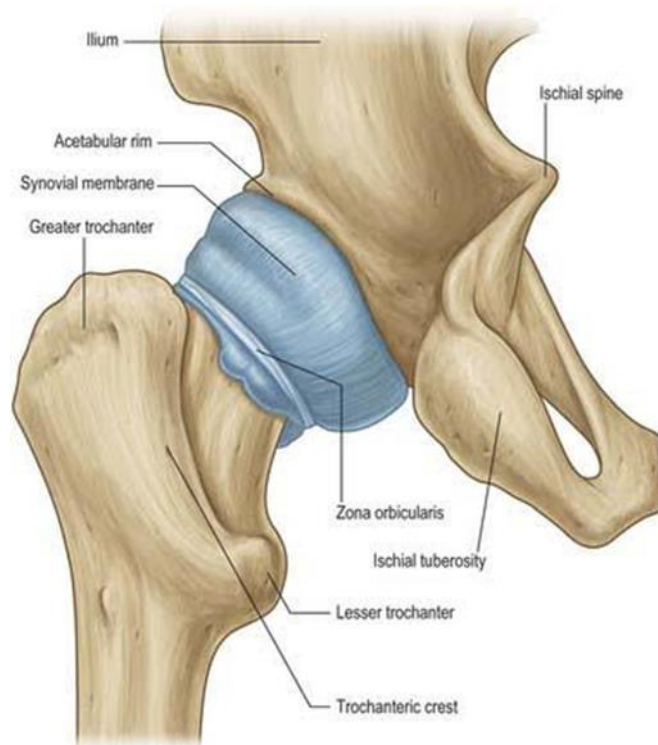


Figure23: SYNOVIAL MEMBRANE HIP JOINT

FIBROUS CAPSULE^{69,70}

It is a dense and strong structure which is attached medially to the acetabulum, transverse acetabular ligament and the obturator foramen margin. It surrounds the femoral neck and is attached laterally on anterior aspect to ITL on femur above base of femoral neck and posteriorly around 15mm proximal to the ITC to the neck of femur.

The capsule is thickest antero-superiorly, which bears the maximum stress during standing with extension of hip. Postero-inferior aspect it is thin and also loosely attached. The capsule is formed of two layers – ‘Zona Orbicularis’ the inner circular layer, which is formed around the femoral neck. It blends with pubofemoral (PFL) and ischiofemoral (IFL) ligaments; outer longitudinal layer which are reinforced by iliofemoral (ILFL) ligament anterosuperiorly. The circular layer is not directly attached to bone

LIGAMENTS^{69-71,73-76}

The ligaments impart great deal of stability to the hip joint and allow for motion in a defined arc.

ILIOFEMORAL LIGAMENT (Y-shaped ligament ILFL of Bigelow):

- It is present anterior to the joint and confers greatest stability to hip joint with a tensile strength of 350 N and stiffness of 100 N/mm
- Emanates as two distinct bands; apex is attached from a small interval between anterior inferior iliac spine (AIIS) and antero superior acetabular rim and its base is attached along ITL
- Key static stabilizer during stance phase; primarily resisting hyperextension which allows for erect posture to be maintained without constant muscular action
- Tighten during external rotation, adduction and anterior femoral head translation

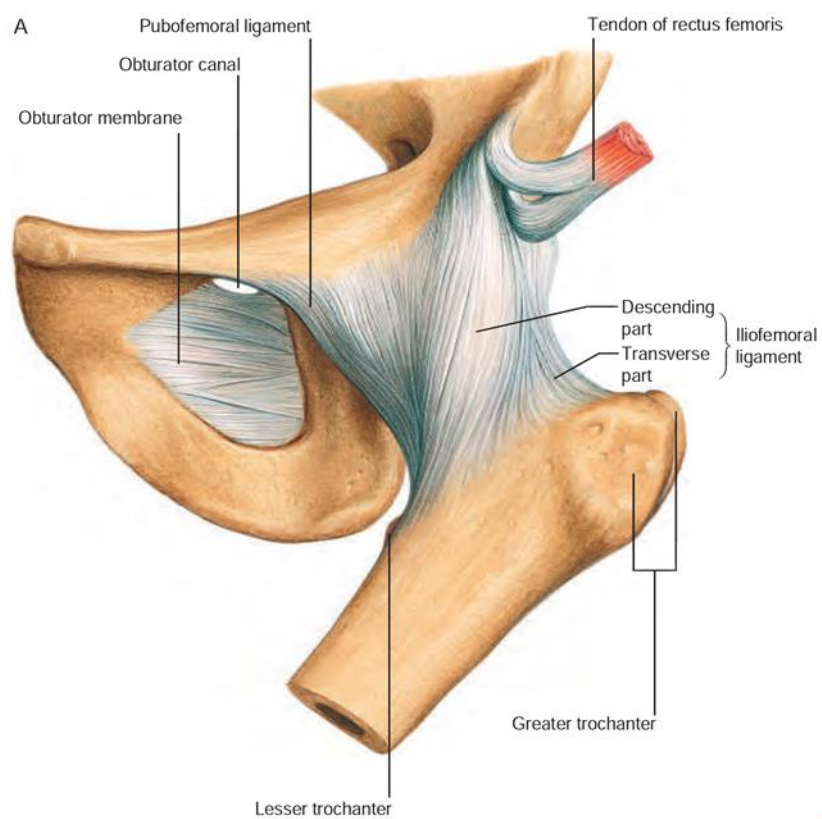
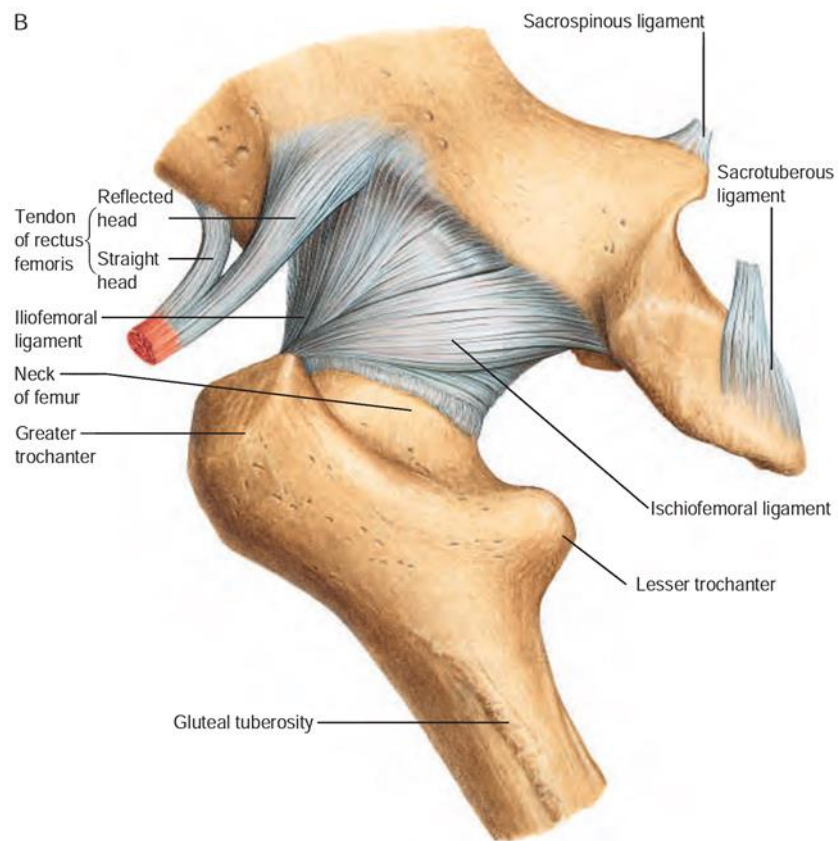


Figure 24: LIGAMENTS OF HIP

PUBOFEMORAL LIGAMENT:

It is anteroinferior to joint capsule and triangular shaped

Its originates from a wide base along the anterior aspect of superior pubic ramus and anterior obturator crest projecting towards the anterior inferior intertrochanteric ridge laterally blending with fibrous membrane and iliofemoral ligament

It resists lateral translation, excessive abduction and external rotation

ISCHIOFEMORAL LIGAMENT:

It is the main posterior ligamentous thickening of the capsule

It is attached to entirety of postero-superior acetabular rim, medially to ischium, laterally to medial aspect of anterosuperior greater trochanter

At the base of femur neck they become confluent with the deep arcuate fibers of zona orbicularis; second fibrous band from ischium to posteromedial base of intertrochanteric ridge

They resist internal rotation throughout hip motion, superior bands act as static stabilizer to adduction with hip in flexion

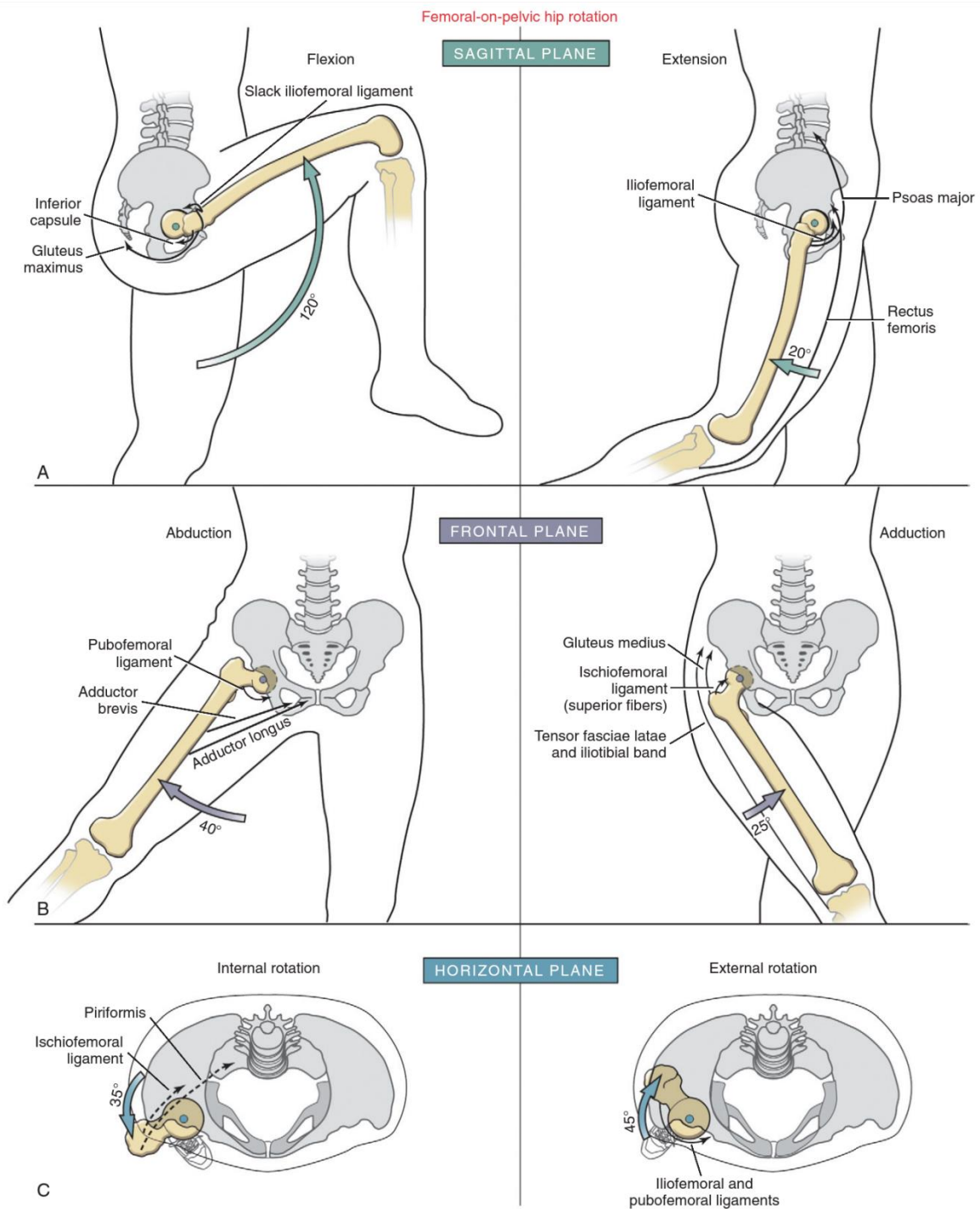


Figure 25: FEMORAL-ON-PELVIC NEAR MAXIMAL RANGE OF HIP MOTION IN (A) SAGGITAL PLANE; (B) FRONTAL PLANE; (C) HORIZONTAL PLANE.

Tissues being elongated or taut are indicated in black or dashed black arrows. Slackened tissue indicated by wavy black arrow.

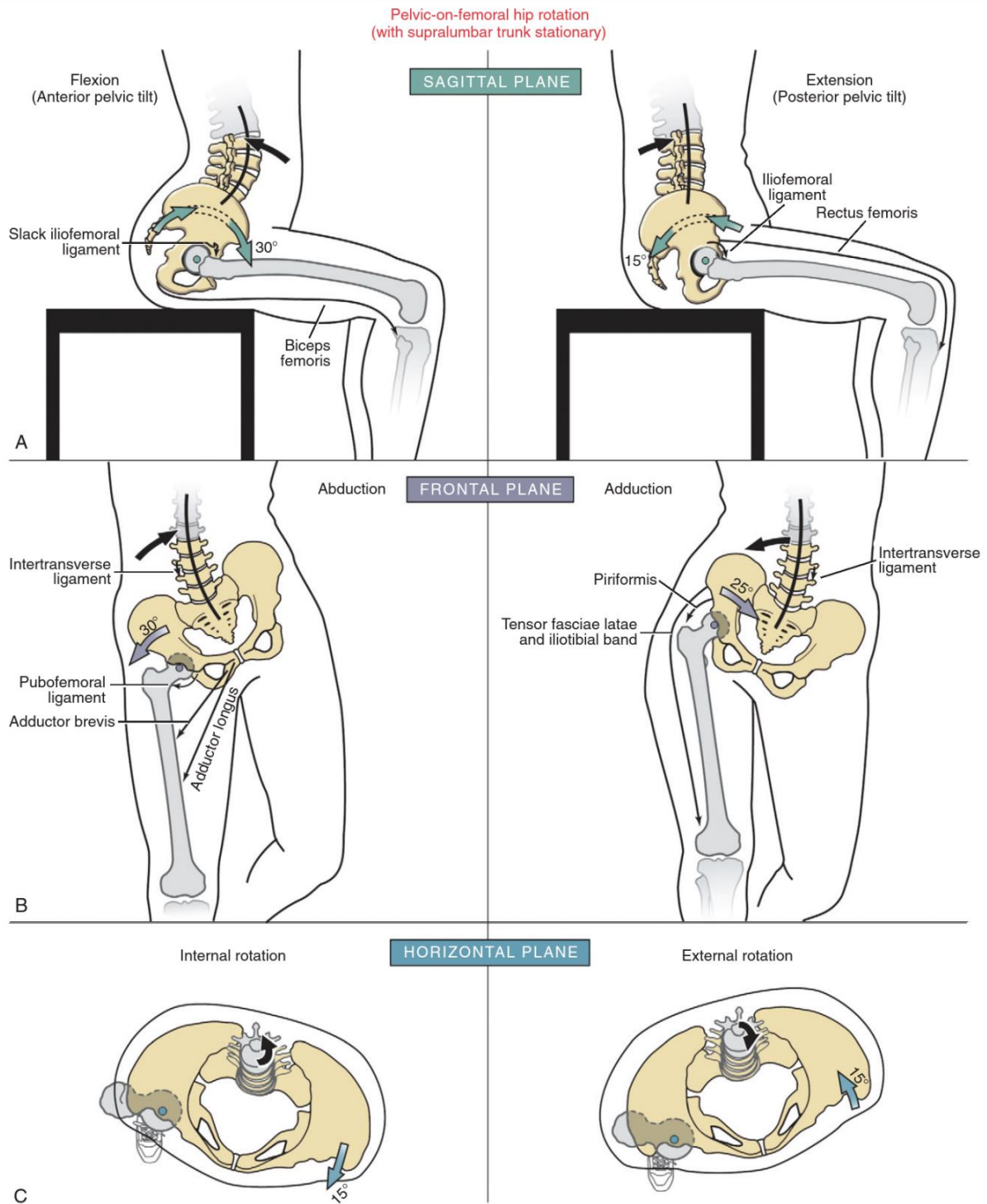


Figure 17 : PELVIC-ON-FEMORAL NEAR MAXIMAL RANGE OF HIP MOTION IN
(A) SAGGITAL PLANE;
(B) FRONTAL PLANE;
(C) HORIZONAL PLANE.

Coloured and black arrows depict pelvic rotation and associated offsetting lumbar motion. Tissues being elongated or taut are indicated in black or dashed black arrows. Slackened tissue indicated by wavy black arrow

ARCUATE LIGAMENT:

They are deep arch of fibers, bolstering the posterior capsule, that run transversely along the base of the femoral neck and do not cross the joint

Interconnect superomedial aspect of greater trochanter and the superior rim of posterior lesser trochanter

It is a part of the annular structure – zona orbicularis that encircles the entire femoral neck base

This retaining ring resists extremes of flexion, extension and distraction forces

TRANSVERSE ACETABULAR LIGAMENT:

It crosses the acetabular notch, forms a foramen giving passage to vessels and nerves to enter the joint

LIGAMENTUM TERES:

It is a flat band which is triangular in shape and attached to a pit on head of femur. It is attached to base on the sides of the acetabular notch. It also varies in length and is sometimes only represented by the synovial sheath.

It is tense in adduction with semi-flexion of hip. It is relaxed in thigh abduction.

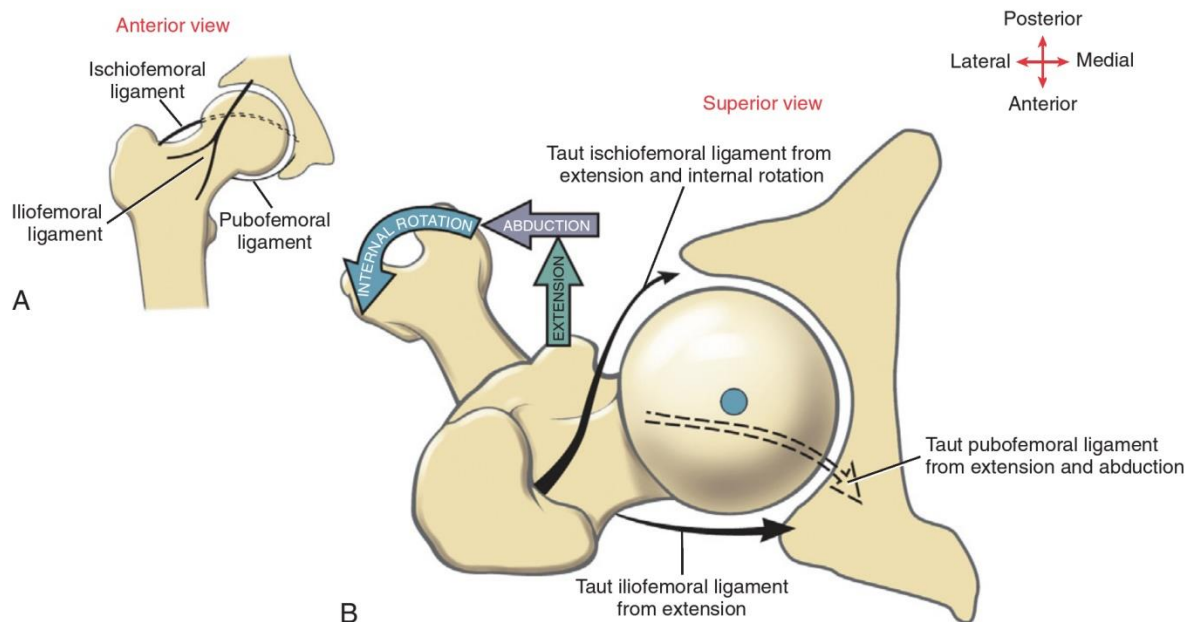


Figure 27: (A) Hip in neutral position; (B) Superior view of hip in full extension, slight abduction and internal rotation. Close-packed position elongates components of all three capsular ligaments

SENSORY SUPPLY^{69,70}

The hip joint derives sensation from the obturator, femoral, sciatic, and superior gluteal nerves.

Sensory supply - Hip joint

Location	Nerve supply
Anteromedial	Obturator nerve
Anterior capsule	Femoral nerve
Posterior aspect	Sciatic nerve
Posterolateral capsule	Gluteal nerve

MUSCULAR ANATOMY⁶⁹⁻⁷⁶

- Muscles around the hip take advantage to arise from a large surface areas to provide adequate stability and rotational motion in all direction and operate as a closed kinematic chain system
- 22 muscles act on the hip joint providing both stability and forces required for hip movement
- Musculature of hip is invested in fascia lata a fibrous layer which is a continuous fibrous sheath enveloping the thigh
- The fascia late increases efficiency of muscle contractions and limits the bulging of thigh muscles
- The muscles also prevents undue bending stresses and protects the femur

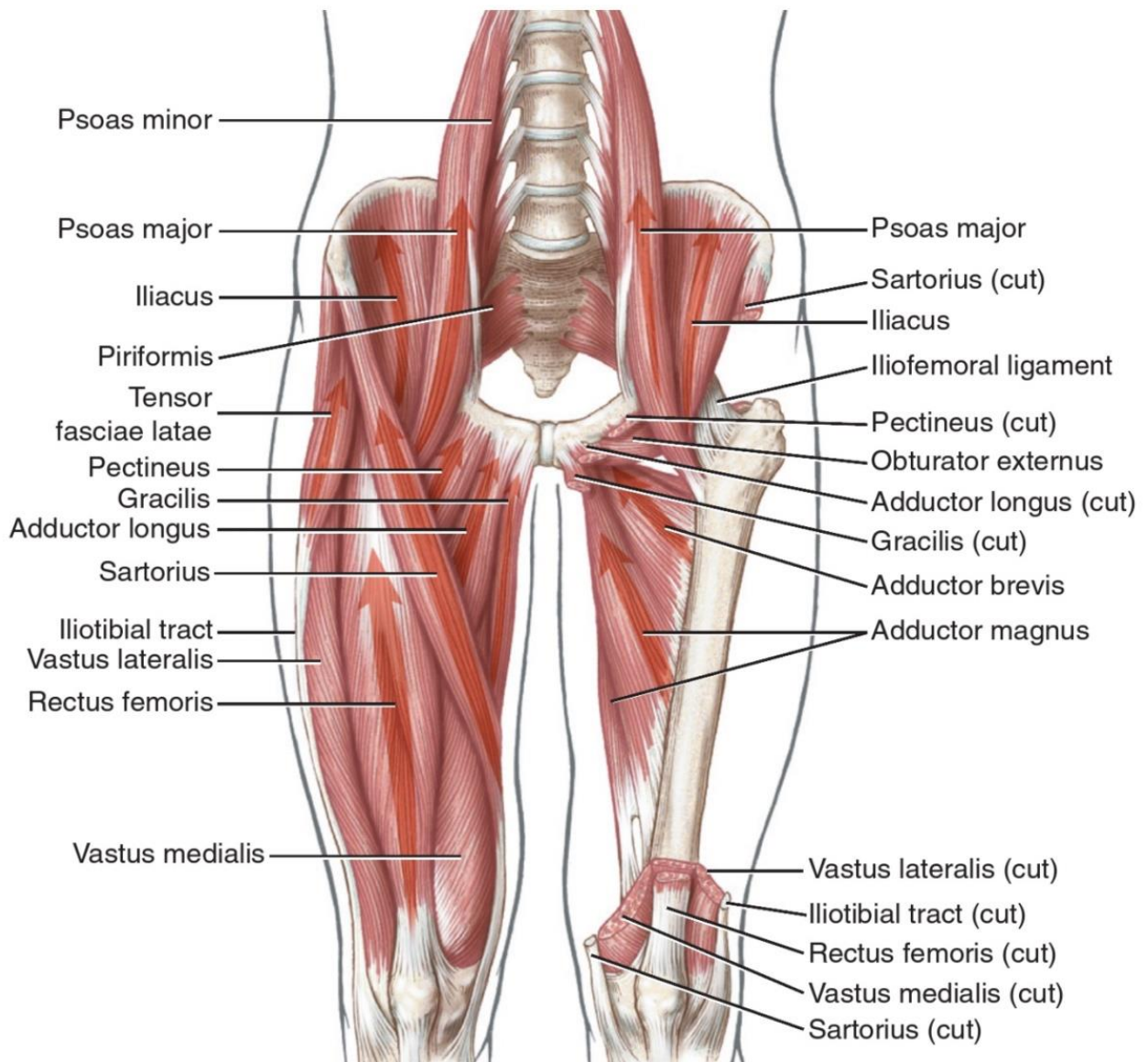


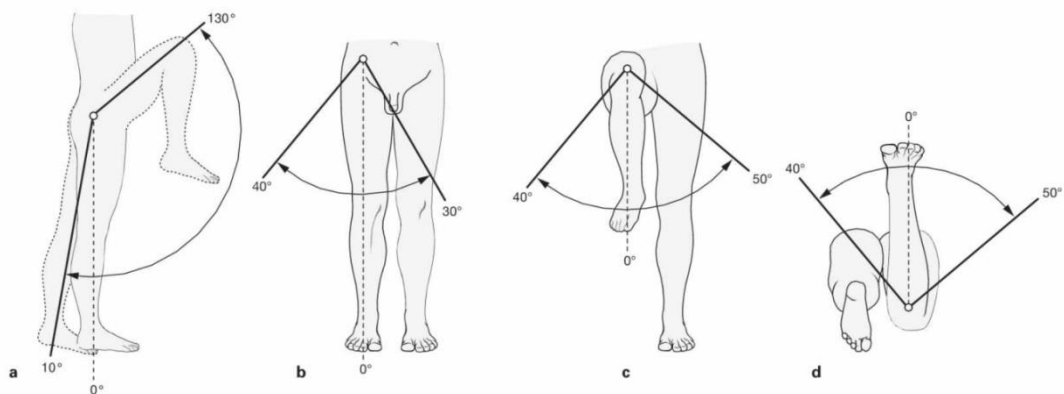
Figure 28: MUSCLES OF HIP AND THIGH

MOVEMENT	MUSCLES	
	Primary	Secondary
Flexion	Iliopsoas Rectus femoris Sartorius	Tensor fasciae lata Pectineus Adductor longus Adductor brevis Adductor magnus Gluteus medius Gluteus minimus
Extension	Gluteus maximus Biceps femoris (long head) Semitendinosus Semimembranosus	Adductor magnus (ischiocondylar fibers)
Abduction	Gluteus medius Gluteus minimus	Tensor fasciae lata Gluteus maximus (upper part)
Adduction	Adductors longus Adductor brevis Adductor magnus Gracilis Pectineus	

Internal Rotation	Tensor fasciae latae	Semitendinosus
	Anterior fibers of	Semimembranosus
	Gluteus medius and	Pectineus
	minimus	Adductor magnus (posterior part)
External rotation	Quadratus femoris	Gluteus maximus
	Pyriformis	Gluteus medium
	Obturator externus	Biceps femoris
	Obturator internus	Adductor magnus
	Superior and inferior	Sartorius
	Gemelli	Iliopsoas

RANGE OF MOVEMENT

Flexion	120° to 130°
Extension	10° to 20°
Abduction	40° to 50°
Adduction	30° to 40°
Medial rotation	30° to 40°
Lateral rotation	40° to 50°



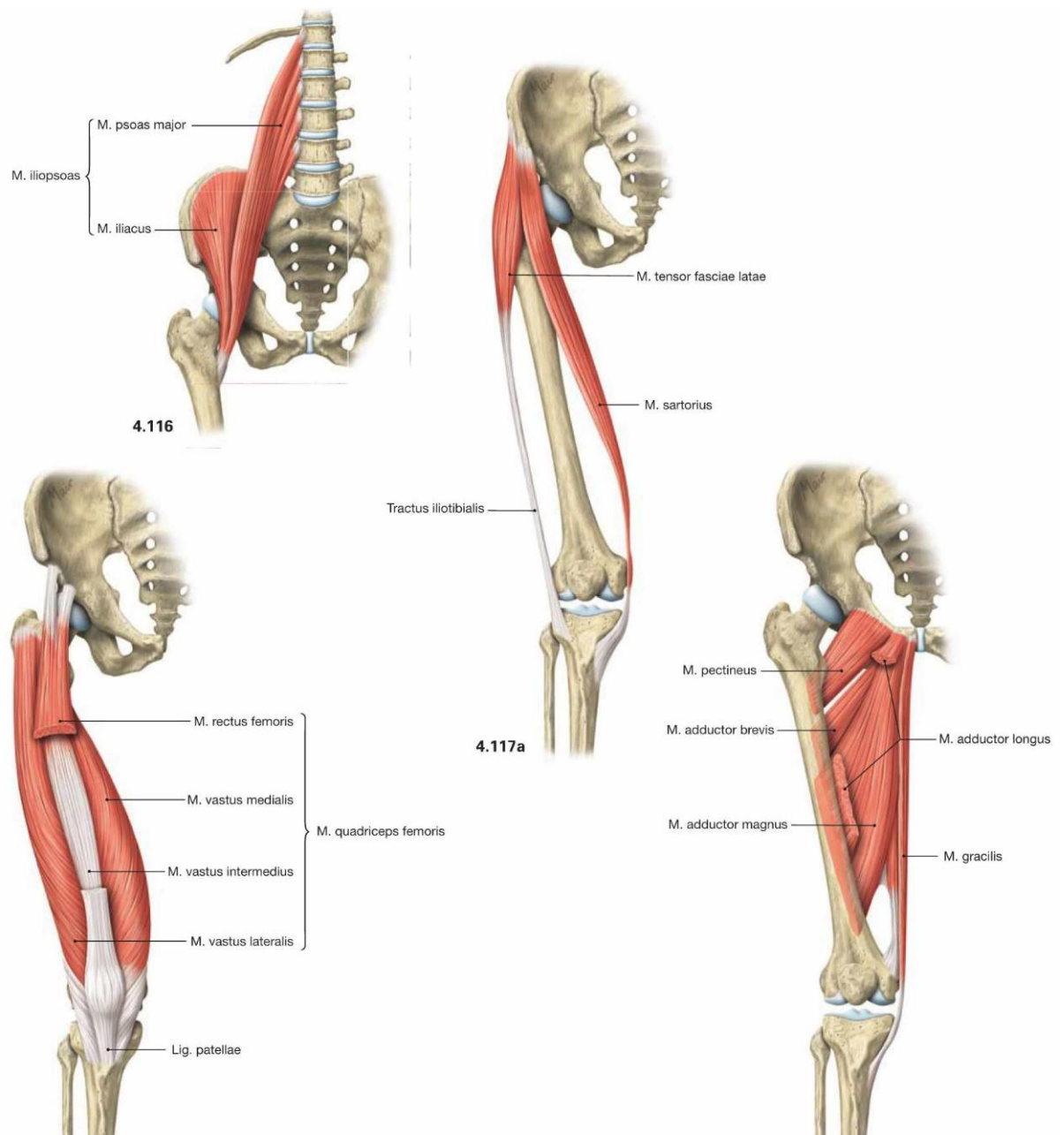


Figure 30: PRIMARY & SECONDARY HIP FLEXORS

- Muscles of the hip joint contribute to movements in several planes depending on the position of the hip
- Line of action of muscle and the hips axis of rotation (inversion of muscle action) changes contribute to this phenomenon
- Gluteus medius and minimus act as abductors in extension of hip and act as internal rotators when hip is flexed
- Adductor longus acts as a flexor at 50° of hip flexion but as an extensor at 70°

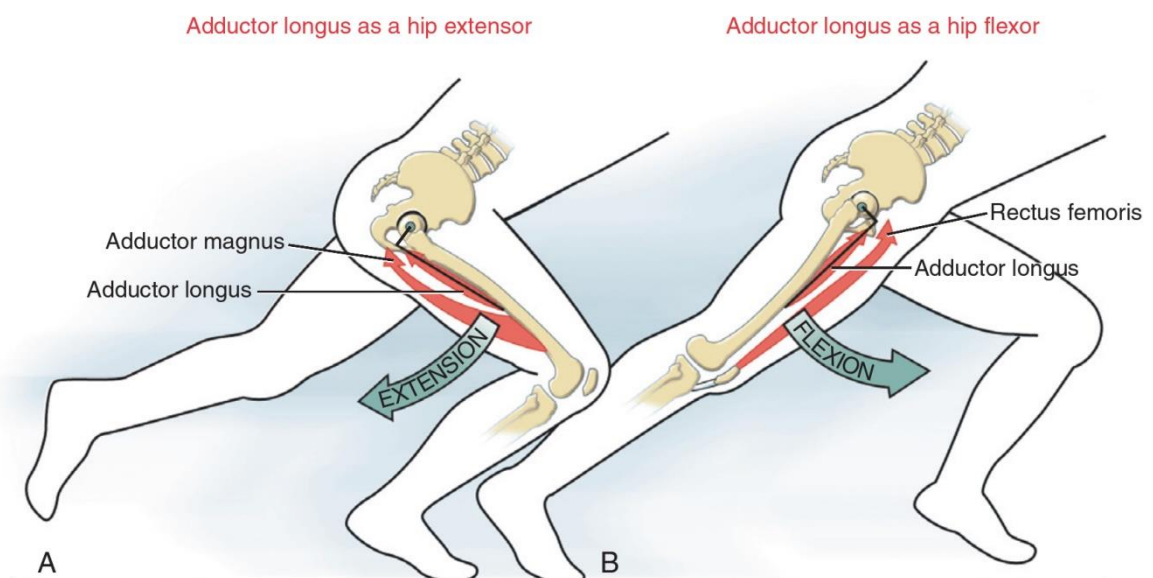


Figure 31: DUAL SAGGITAL PLANE ACTION OF ADDUCTOR LONGUS MUSCLE

A) HIP IN FLEXION, ADDUCTOR LONGUS ACTS TO EXTEND THE HIP ALONG WITH ADDUCTOR MAGNUS

B) HIP IN EXTENSION, ADDUCTOR LONGUS ACTS AS A FLEXOR OF HIP WITH RECTUS FEMORIS

ABDUCTORS⁶⁹⁻⁷⁵

- The main abductor muscle is the gluteus which stabilizes the pelvis in the transverse direction. Other abductors are gluteus minimus, tensor fasciae latae and upper part of gluteus maximus.

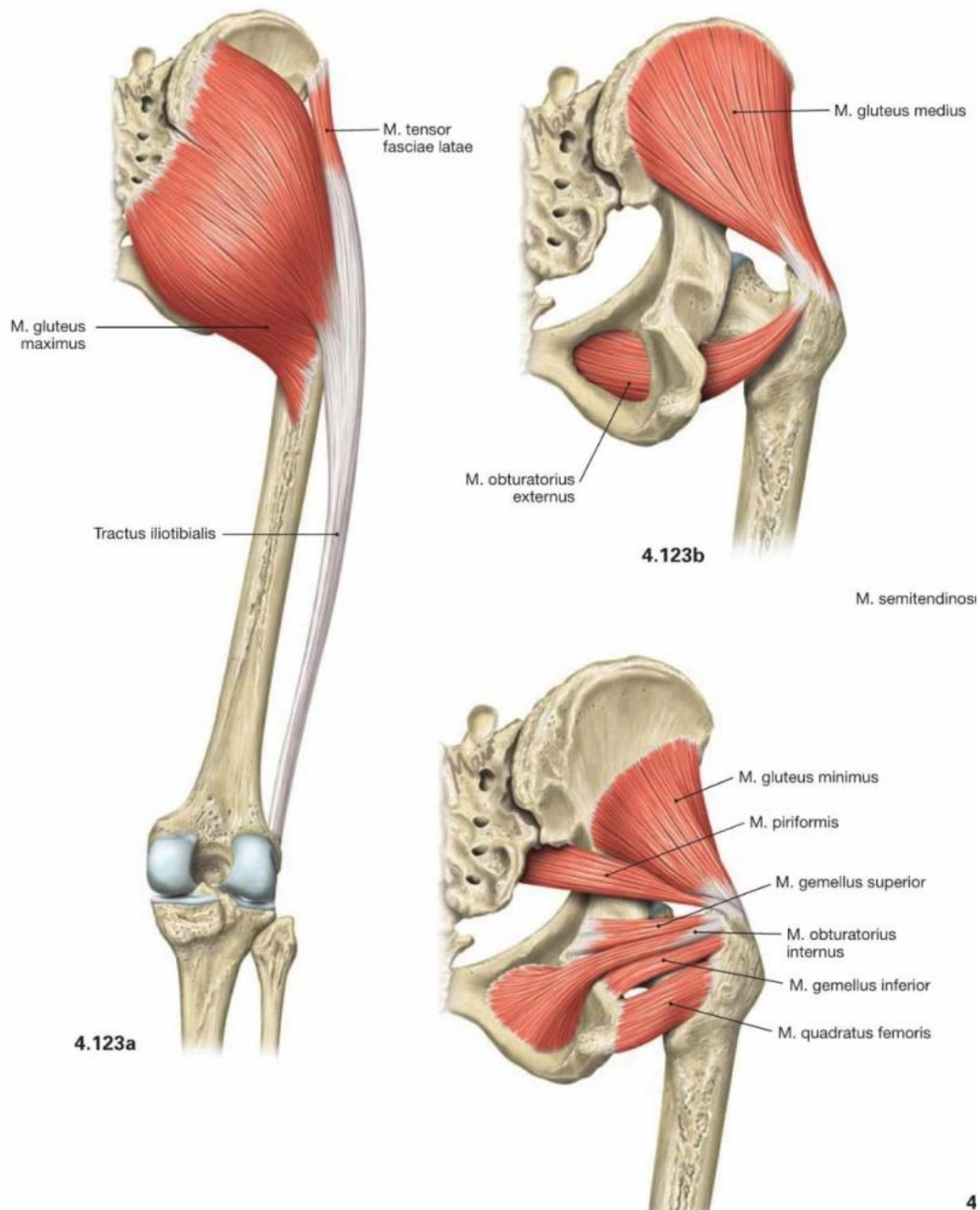


Figure 32: PRIMARY & SECONDARY HIP ABDUCTORS

- Standing on one limb, strong action of the gluteus medius, powerfully assisted by gluteus minimus, tensor fasciae latae and upper part of gluteus maximus, keeps the pelvis horizontal.
- This stabilization of the pelvis is essential for normal walking. In mild or moderate weakness of these muscles, the characteristic sign of Duchenne–Trendelenburg syndrome is demonstrated, i.e. the patient is unable to keep the pelvis horizontal, which is tilted to the opposite side.
- In gross weakness an excessive movement of the trunk towards the affected side compensates the paralysed hip abductors (‘abduction lurch’)

VASCULAR ANATOMY^{69-71,75,76}

The description for vascular supply of adult hip is based on the contributions by Trueta and Harnington (1953). The vascular pattern that is established during the growth phase is not altered at maturity and perseveres throughout life. Even after the growth plate has disappeared, the anastomic arrangement around the upper femur is contributed by an epiphyseal and metaphyseal circulation. The description by Corck of the proximal end of the femur blood supply divides it into three major groups:

1. Capsular vessels
2. Intramedullary vessels
3. Contribution from the ligamentum teres

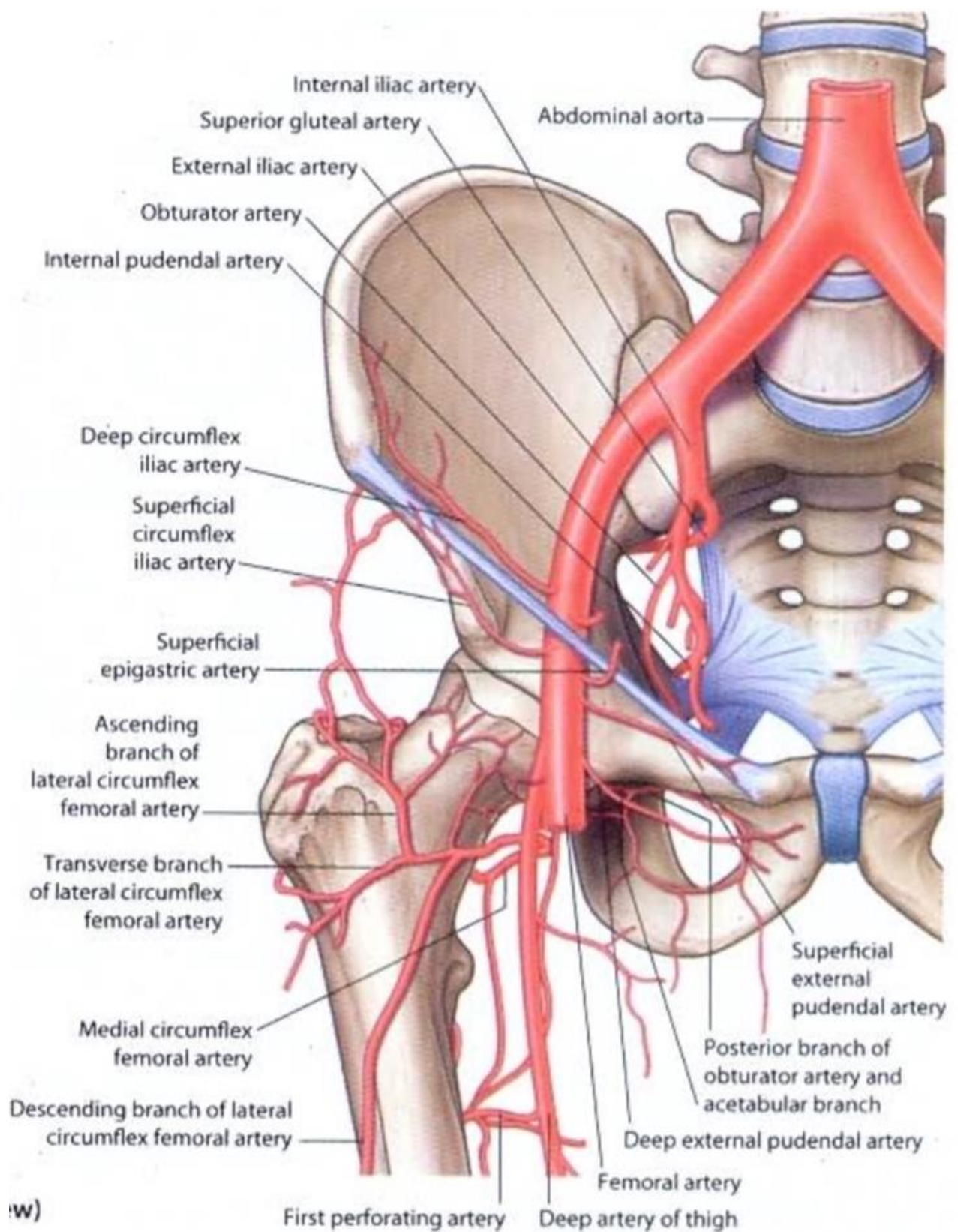


Figure 33: BLOOD SUPPLY OF HIP JOINT

Contribution	Lateral femoral circumflex artery (anteriorly)
	Medial femoral circumflex artery (posteriorly)
Location	Base of femoral neck
Branches	Ascending cervical capsular vessels
Course	Penetrate anterior capsule at base of neck at level of ITL

Extracapsular arterial circular anastomosis :

Contribution: Lateral femoral circumflex arteries (anteriorly)

 Medial femoral circumflex artery (posteriorly)

Location: Base of the femoral neck

Branches: Ascending cervical capsular vessels

Course : Penetrate the anterior capsule

 (at the base neck at the level of ITL)

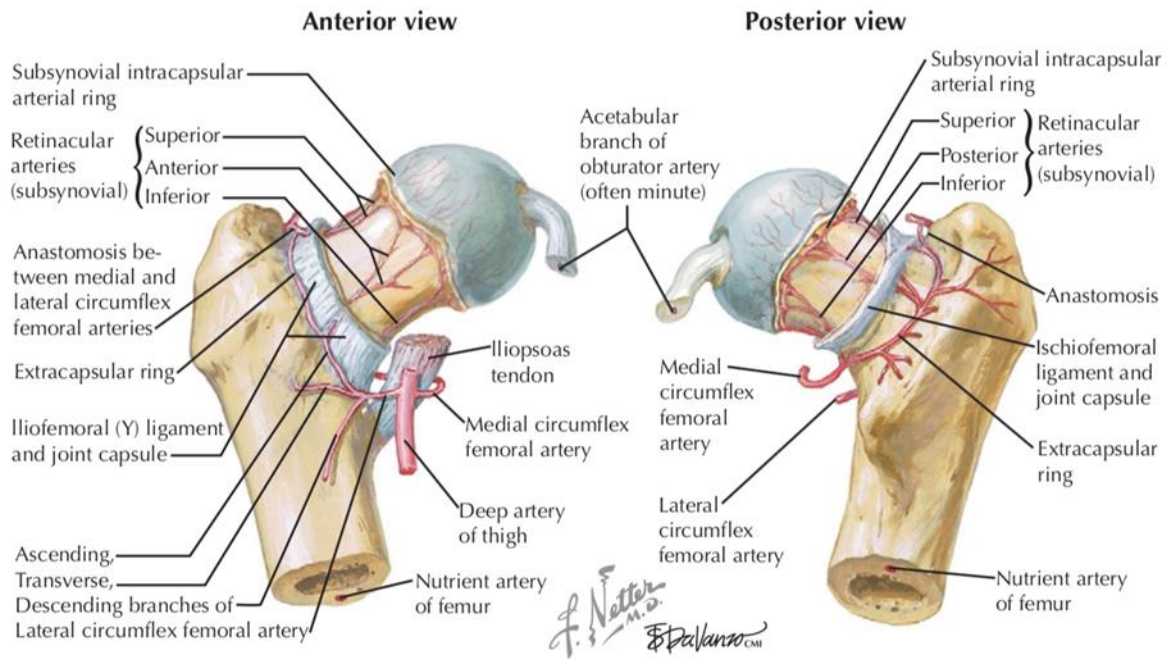


Figure 34: ANASTOMOSIS AROUND THE FEMORAL NECK AND HEAD

CAPSULAR VESSELS: Once they enter the capsule they run along the neck (posterior aspect) beneath orbicular fibers of the capsule to run up the neck under the synovial reflection to reach the articular surface.

RETINACULAR VESSELS: Continuation of the capsular vessels within the capsule are referred to as the retinacular vessels

- Four main groups (anterior, medial, lateral, and posterior)
- Lateral group - largest contribution of blood supply to femoral head
- Most important retinacular vessels - arise from the deep branch of the medial femoral circumflex artery

- Supply the main load-bearing area of the femoral head.

SUBSYNOVIAL INTRA-ARTICULAR RING :

- Second ring anastomosis at head neck junction of femur
- Medial femoral circumflex (deep branch) terminal arteries penetrates and supplies the femoral head

LIGAMENTUM TERES VESSELS:

- Supply femoral head
- Contribution insufficient to maintain vascularity of entire head

NUTRIENT ARTERY

- Arises from second perforating artery
- Replaced by two nutrient arteries - from I and III perforating arteries if absent
- Location : medial side of linea aspera – nutrient foramen. Directed upwards

TRABECULAR PATTERN^{71,73,76-79}

The trabecular architecture of the proximal femur form along the lines of stresses that it is subjected to and they can be traced to be continuous with the acetabular trabecular lines. The trabecular architecture of the proximal end of femur comprises of 5 distinct groups along lines of maximum compression and tension stresses.

Based on the principals of Wolff's law which states that bony structure orient themselves in form and mass to best resist extrinsic forces.⁷⁷

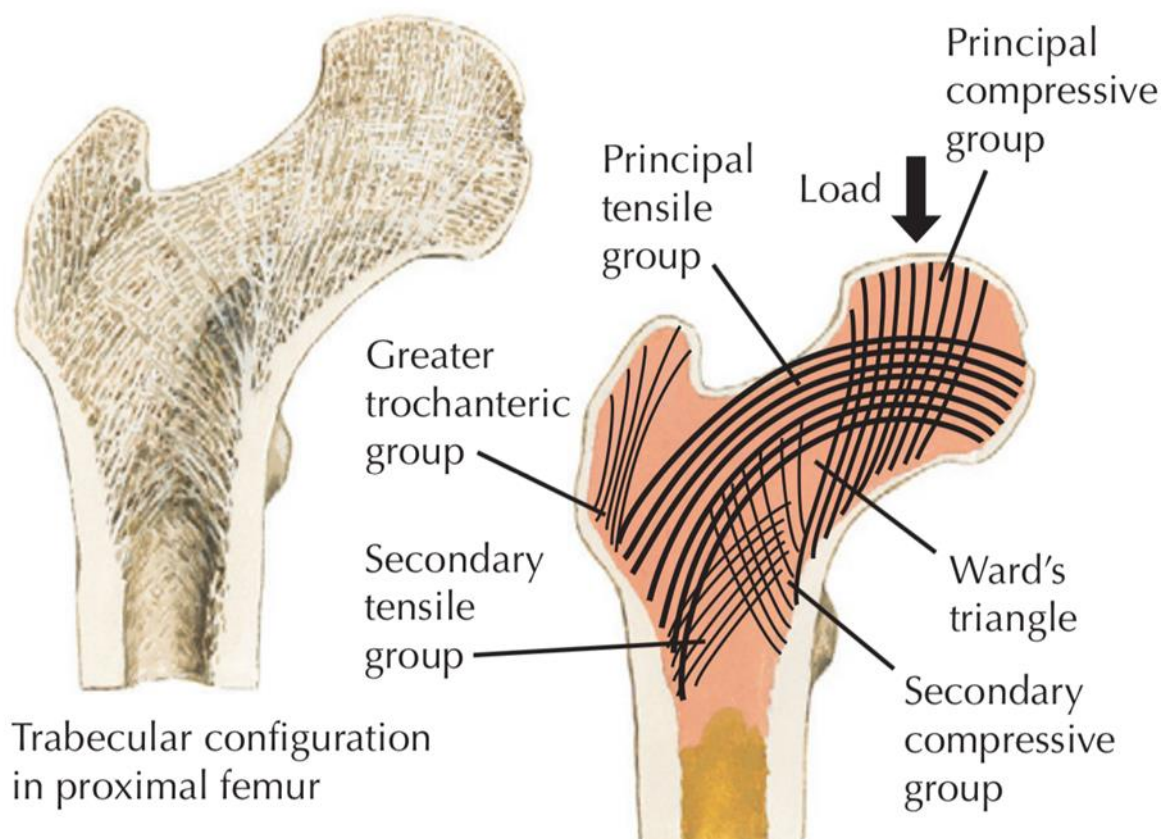


Figure 35: TRABECULAR PATTERN PROXIMAL FEMUR

1. **Principal compressive trabeculae:** They run from the weight bearing upper portion of the femoral head to the region of the calcar femoris and the medial cortex of shaft
2. **Secondary compressive trabeculae:** Arise below principal compressile group curving upwards and laterally towards GT and upper portion of neck
3. **Greater trochanter group:** arise from lateral cortex and end in the superior surface of GT
4. **Principal tensile trabeculae:** they begin in the inferior portion of the head and arch across the superior portion, terminating in the lateral cortex
5. **Seconday tensile group:** Arise from lateral cortex below the principal tensile group and arch upwards and medially across upper end of femur and end crossing the midline

The primary tensile and compression trabeculae, resist tensile and compression stress respectively. Trabecular bone is concentrated as thin layer deep to the subchondral bone. In the neck of femur the primary compressive, the secondary compressive and the tensile trabeculae enclose an area containing a structurally weak area called Ward's Triangle.

SINGHS INDEX⁷⁸

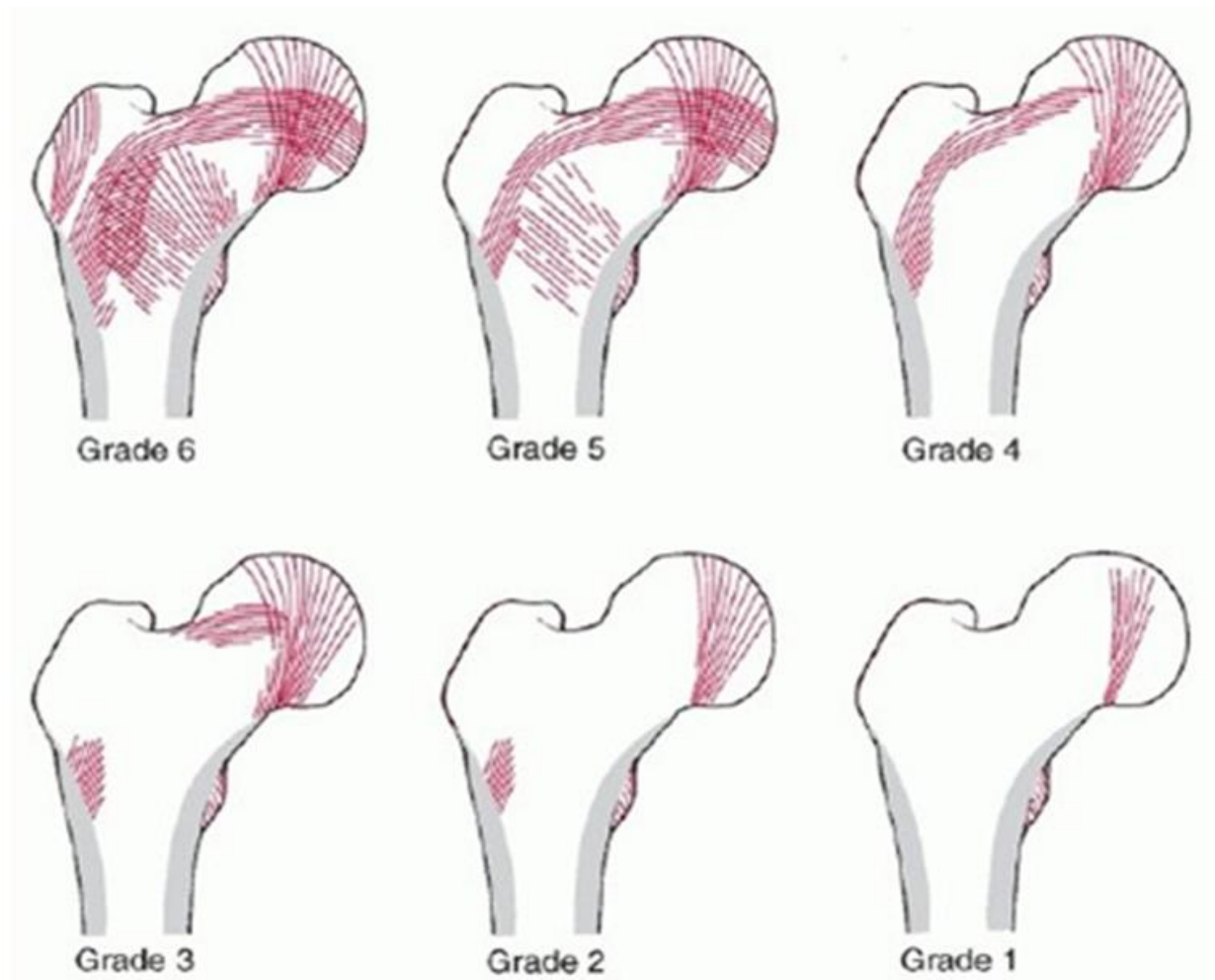


Figure 36: SINGH'S INDEX GRADING

The degree of osteopenia can be noted by the deficient trabecular pattern according to the Singh and Maini's index of osteoporosis, which is graded from grade I to grade VI, grade VI being normal.

GRADES OF SINGH'S INDEX⁷⁸

Grade I: Even the principal compressive trabeculae are markedly reduced in number and are no longer prominent.

Grade II: Only the principle compressive trabeculae stand out prominently. The others have more or less completely reabsorbed

Grade III: There is break in the continuity of the principle tensile trabeculae opposite the trochanter

Grade IV: Principle tensile trabeculae are markedly reduced but can still be traced from the lateral cortex to the upper part of the femoral head

Grade V: The structure of principle tensile and principle compressive trabeculae are accentuated. Wards triangle appears prominent

Grade VI: All the normal trabecular groups are visible and the upper end of the femur seems to be complete occupied by cancellous bone.

OSTEOPOROSIS RISK FACTORS⁷⁹

General factors	Female sex Caucasian or Asian ethnicity Advanced age Early menopause Slender habitus Lack of exercise Smoking Family history Excess alcohol Poor nutrition (low calcium or high protein)
Drug products	Corticosteroids Heparin Cyclosporin Cytotoxic drugs
Diseases • Endocrine disease • Joint disease • Other diseases	Cushing's syndrome Hyperparathyroidism Hypogonadism Acromegaly Type I diabetes mellitus Rheumatoid arthritis Chronic renal failure Chronic liver disease Mastocytosis Anorexia nervosa Inflammatory bowel disease Coeliac disease

BIOMECHANICS OF THE HUMAN HIP⁸⁰⁻⁸⁵

Human beings are quite unique in the use of a bipedal gait for locomotion, a trait shared only with birds in the entire animal kingdom. Even other primates and mammals still use quadripedal mode of ambulation for most of their activities.

As the primary link between the trunk and the lower limb, the hip joint plays an important role in the generation and transmission of forces during routine activities of daily living and athletic activities alike.

This joint is characterized by an extraordinary amount of inherent bony stability, with differences in osseous anatomy significantly impacting the biomechanical properties of the human hip. The hip joint should be imagined as a pivot upon which the entire body is balanced by the various muscular forces to maintain balance and stability in gait with the bone and soft tissues interacting in both static and dynamic situations generating movement.

ANALYSIS OF HIP BIOMECHANICS⁸⁰⁻⁸⁶

Due to the various functions of hip and its dynamic forces involved the analysis of hip has been made in the different states of its utility

A) GAIT ANALYSIS: Gait has been used as the primary activity to analyse kinematics of the hip joint. Most of the literature on biomechanics of hip focuses exclusively on hip joint forces during gait with a wide range of data available.⁸⁰⁻⁹¹

B) ACTIVITIES OF DAILY LIVING (ADL): The hip joint is subjected to wide ranges of motion when performing common day to day activities which were not an important consideration during previous biomechanical studies. The studies involving hemi and total hip replacement have highlighted functional demand as an important outcome measure for patient satisfaction and as such recent biomechanical studies have focused on ADL.⁸⁵

C) SPORTS ACTIVITIES: The hip joint is subjected to much higher and abnormal stresses in athletes than in general population which required specialised analysis. Due to the complexities of motion associated with cutting and pivoting sports, the calculations are difficult and incredibly complex with most of the calculation based on mathematical models.⁸⁶

METHODOLOGY⁸⁰⁻⁹¹

The methods employed for the analysis of biomechanics of human gait and activities has evolved over time giving us a better understanding of the forces involved by employing both in vitro and in vivo studies

1. IN VITRO STUDIES

Studies are done in laboratory conditions which exclude minor contributions from antagonistic muscles, elastic tension of the muscles, tendons and joint capsule. Almost all biomechanical studies are based on in vitro models.

The initial studies involved 2D static analysis using free body diagrams for gait analysis and forces across hip joint in single leg stance. They are a simplified version of the actual hip biomechanics, with the assumption that the hip joint represents a uniform ball and socket joint with a single centre of rotation and spherical head.⁸²⁻⁸⁶

Static analysis criteria: Bones are rigid bars of a lever which can transmit force without deformation, joint are frictionless hinges and ignore rotational and translational movements, muscles are the only force producing tissues, all forces are to be taken as point loads. This oversimplifies the measurements but allows for better understanding the complex biomechanical interactions in joints.⁸⁷

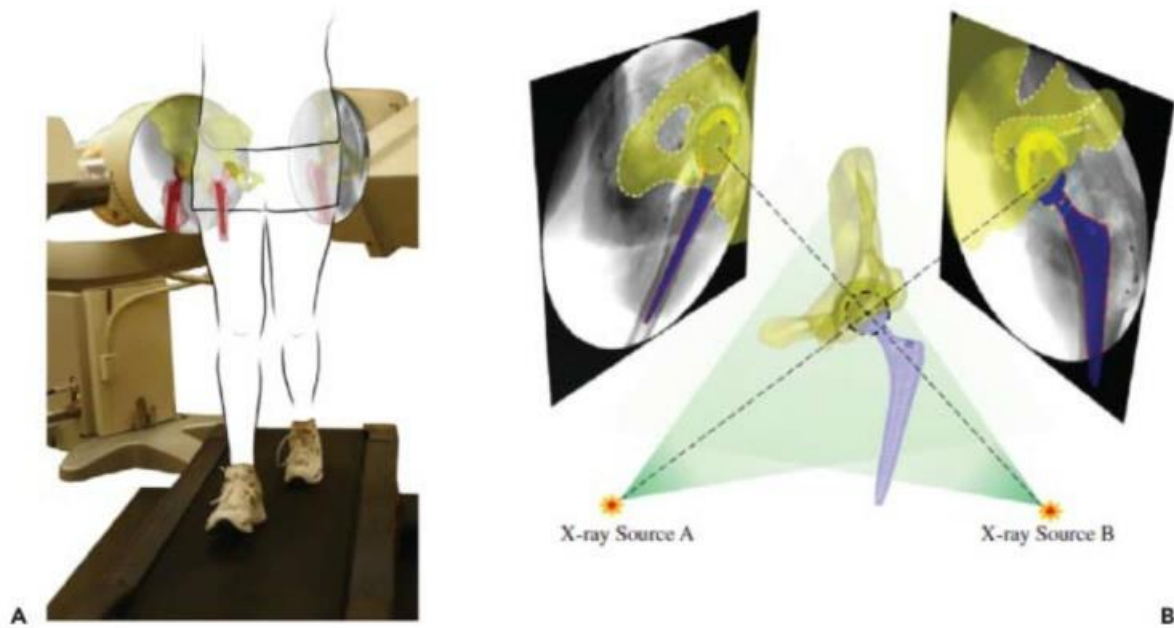


Figure 37: DUAL FLUOROSCOPIC IMAGING SYSTEM (DSIF); (A) Patient walking on treadmill using DSIF; (B) THA kinematics being determined using DSIF

Computational joint contact force models that utilise multi-body inverse dynamics have been done using software simulation to improve upon the calculations. Motion capture in laboratory with infrared cameras capture movement and force plates to measure ground reaction forces have allowed for comprehensive analysis of gait. The results of these studies are difficult to validate but comparable to in vivo studies of Bergmann et al. The advantage of software simulation is that they are less invasive and allow for a fairly rapid acquisition of data, thus facilitating large datasets for a better statistical representation of variation within a given population.⁸⁵

2. IN VIVO MEASUREMENTS

In vivo studies have the advantage of measuring all forces acting on the hip by direct measurement of the hip joint forces including minor contributions from antagonistic muscles, elastic tension of the muscles, tendons and joint capsule.

Theoretically, direct measurements of hip joint forces with surgical insertion of a force transducer will provide the most accurate data but it is fairly impractical. Bergmann et al, characterized the forces acting on a prosthetic joint after conducted a series of measurements obtained during different activities, by implanting pressure transducers into total hip arthroplasty components.⁸³

Other studies for direct measurements of joint pressure at the articular surface have been done but faced many difficulties.

Ruschfelt et al measured articular pressure using an ultrasound probe at the implant-cartilage interface after hemiarthroplasty in hip specimens but due to subtle differences between the socket and prosthesis diameter, they were unable to make any generalizations regarding pressure measurements in the natural joint.⁸⁸

Brown and Shaw used the pressure transducers mounted in cadaveric femoral heads to measure articular contact pressures, but found a random distribution of the maximal point of pressures.⁸⁹

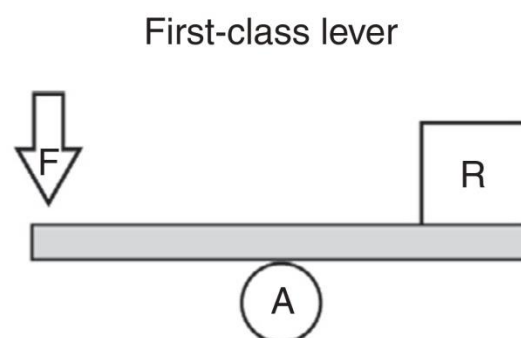
Few limitations of in vivo measurements as stated by Brinckmann were :

1. Femoral head was only loaded in the orientation of the load vector and not allowed to move freely

2. Mismatch between the stiffness of the transducer material, the articular cartilage and subchondral bone, affecting the measurements when the system was loaded.⁹⁹

BIOMECHANICS PRINCIPLE⁸⁷

The hip joint functions on the bio-engineering principle of moment of force with a fulcrum, lever arm and power arm.



Hip joint with the hemi-spherical femoral head articulating in the acetabular cup with abductor muscles acting at one end, the body weight on the

other, and the joint itself being the fulcrum can be compared to a first order lever.

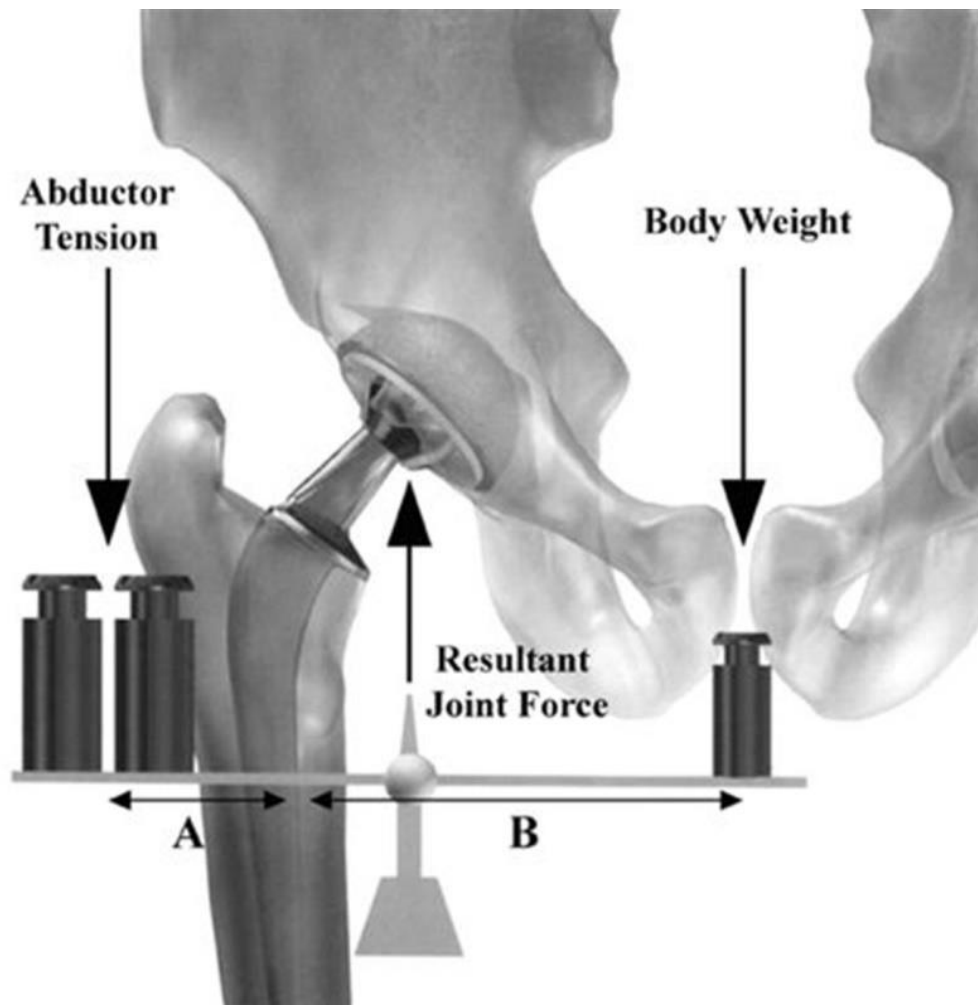


Figure 39: BIOMECHANICAL FORCES OVER PROSTHETIC HIP JOINT

To describe the force acting on the hip joint, the body weight can be depicted as a load applied to a lever arm extending from the body's center of gravity to the center of the femoral head. The abductor musculature, acting on a lever arm extending from the lateral aspect of greater trochanter to the centre of

the femoral head, must exert an equal moment to hold the pelvis level when in a one-legged stance, and a greater moment to tilt the pelvis to the same side when walking or running.

LEVER ARM RATIO

The ratio between the two lever arms of the fulcrum i.e. ratio between body weight moment arm “ D_1 ” and abductor muscle moment arm “ D ”

$$\text{LEVER ARM RATIO} = D_1 : D$$

Typically this ratio corresponds to a ratio of 2.5. The abductor muscles have to exert a force that is three to four times the effective body weight on the hip joint in single leg stance. Variations exist in the lever arm ratio and this is not a fixed value.⁸⁴

GAIT ANALYSIS⁸⁰⁻⁹¹

One single cycle of gait is normalised to begin with heel strike and ending the next time same heel makes contact with the ground with toe off event at 60% of gait cycle. Latest measurements are based on in vitro studies using computational motion capture software.

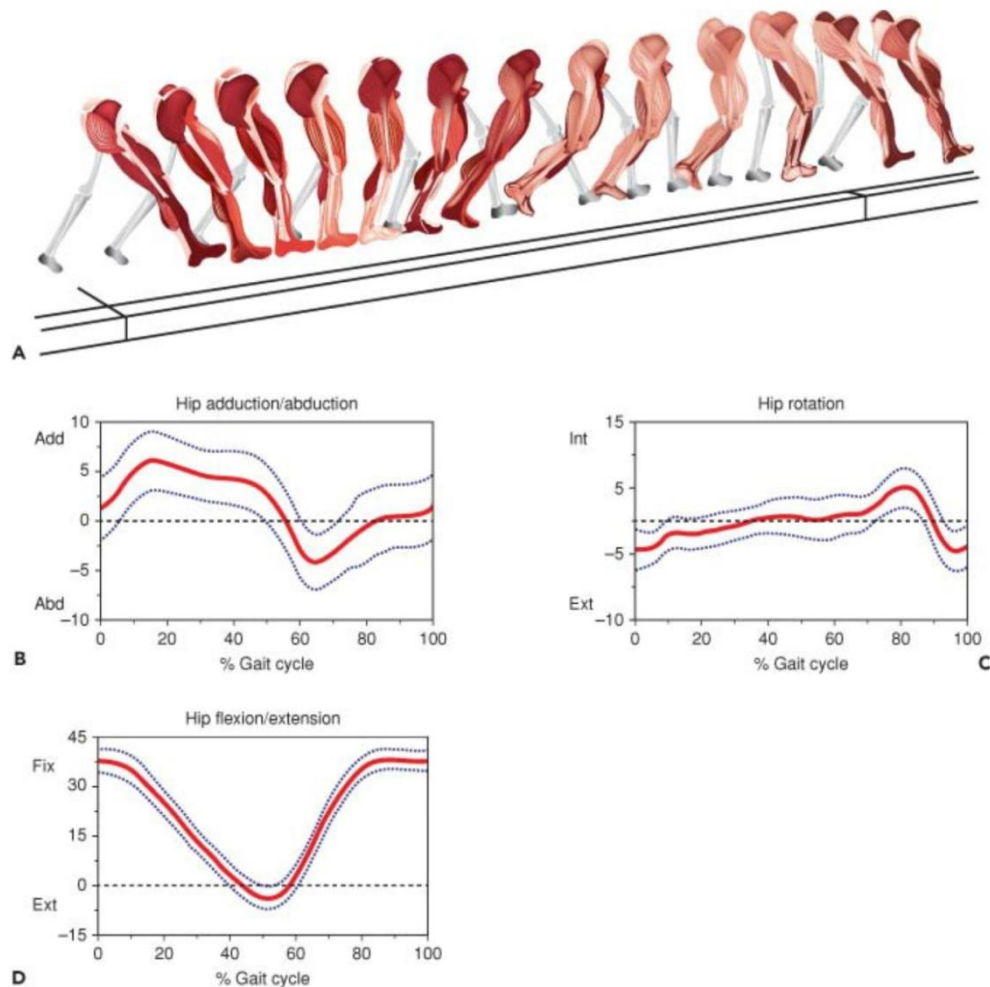


Figure 40: Human gait cycle contributions to hip rotation is all three axes
A) hip motion throughout gait cycle with muscles concentrically contracted (dark) versus muscles eccentrically contracted (light)
B,C,D) in vivo measurement of hip motion during gait cycle

COMPUTER MODEL ESTIMATE OF HIP JOINT COMPRESSION FORCE DURING GAIT CYCLE

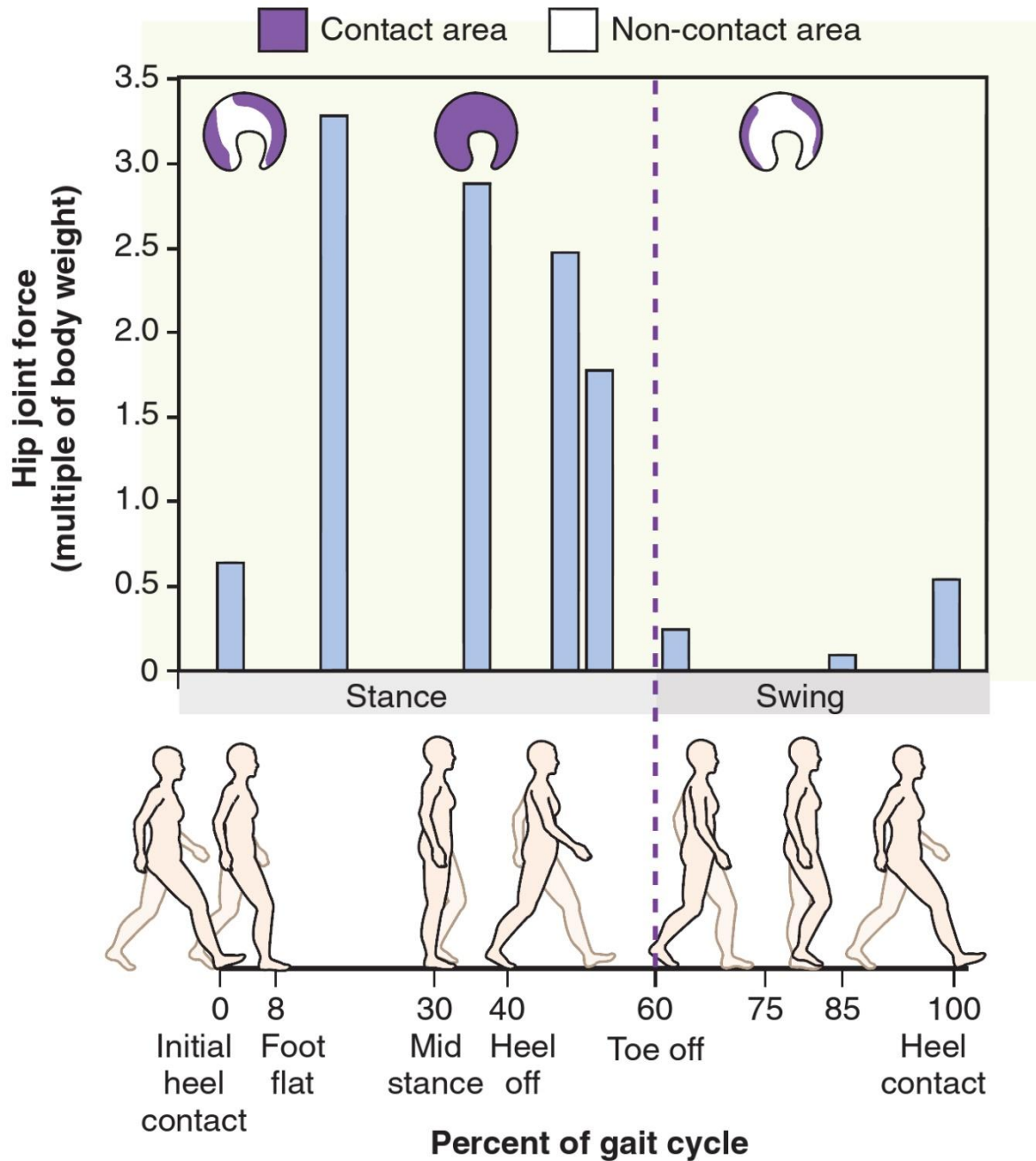


Figure 41: GAIT CYCLE WITH HIP JOINT FORCE MEASUREMENT

Gait can be divided into stance and swing phase starting with heel strike followed by flat foot, mid stance, heel off and toe off to next heel contact and measurements have been made to decipher the stresses on hip at each level of ambulation to better implant design. Stance phase is between 0% to 60% of gait cycle and swing phase is from 60% to 100%.⁸⁵

PHASES OF HIP MOTION DURING GAIT CYCLE

Phase of Gait	Hip Position	Active Muscles	Occurrence During Cycle (%)
Stance			
Initial contact	30 degrees of flexion	Hamstrings and gluteus maximus	0-2
Loading response	30 degrees of flexion 5 to 10 degrees of adduction 5 to 10 degrees internal rotation	Hamstrings and gluteus maximus	0-10
Mid-stance	0 degrees of flexion-extension	Gluteus medius, gluteus minimus, and tensor fascia lata	10-30
Terminal stance	Neutral abduction-adduction		
Pre-swing	10 degrees of extension 0 degrees of flexion-extension	Iliacus Iliacus and adductor longus	30-50 50-60
Swing			
Initial swing	20 degrees of flexion	iliopsoas, rectus femoris, gracilis, and sartorius	60-73
Midswing	5 degrees of abduction 20 to 30 degrees of flexion	iliopsoas, gracilis, and sartorius	73-87
Terminal swing	30 degrees of flexion	Hamstrings and gluteus maximus	87-100

Brinckmann et al, in a summary of the work by various authors calculating the biomechanics of hip in different states of motion and the loads transmission on the hip joint.⁹⁰ Following are the stress values calculated for straight line sprinting on a level surface:-

1. Slow walking: 300% BW after heel strike and 400% just before toe off

2. Speed walking: Increasing the speed of walking the initial peak joint load increases to 400% BW with less increase seen before toe off

3. Running: Forces increase by 700 to 800% BW during heel strike and slightly more during toe off

IN VIVO MEASUREMENTS OF HIP JOINT FORCES⁸³

Bergmann et al, conducted a series of measurements during different activities by using implant pressure transducers into total hip arthroplasty components. The results were helpful in confirming or improving previous ex vivo measurement of hip joint forces. The study observed the following increases in joint forces:

- 300% body weight during slow walking
- 350 to 400% body weight during quick walking
- 500% body weight during quick walking
- 800% body weight stumbling
- The study also interestingly showed the two legged stance measurement of 80 to 100% of body weight

SYMMETRICAL STANDING / BOTH LEG STANCE

In the human body, the centre of gravity (CG), in the resting standing state lies, in midline in front of the second sacral vertebrae in the coronal plane and is posterior to the axis of the joint in the sagittal plane.^{80,81}

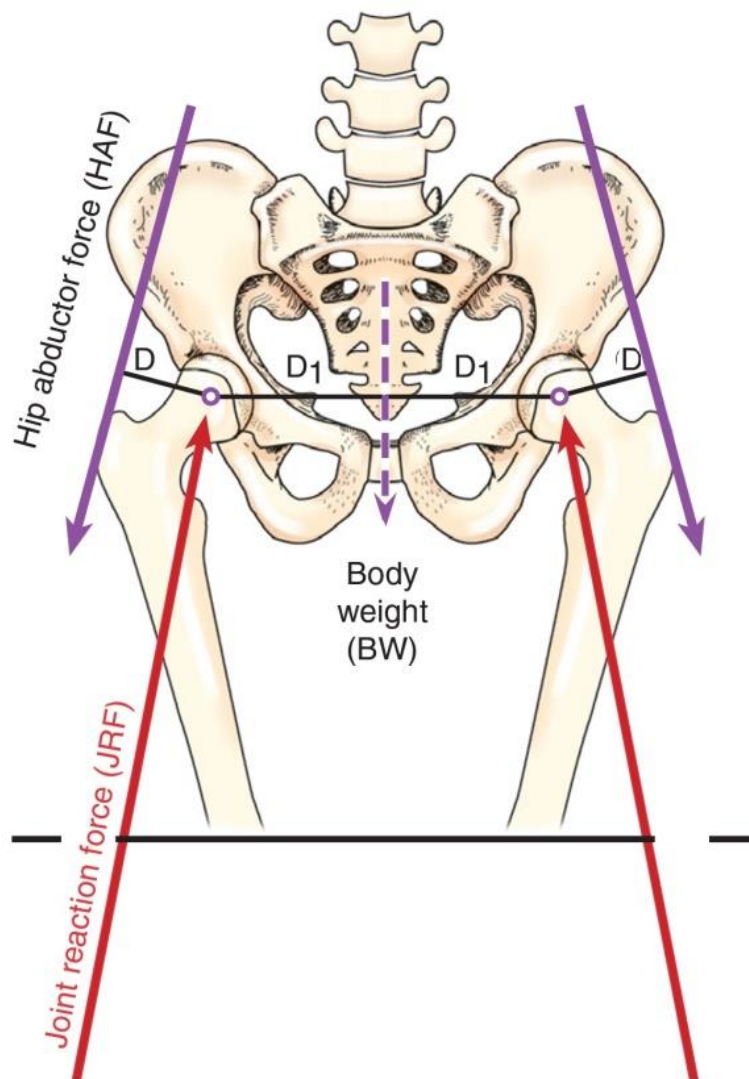


Figure 42: DOUBLE LEG STANCE

Based on in vitro studies, in this state the combined static and dynamic forces are exerted equally on both hips with the weight of the body minus the weight of both legs equally divided between them (femoral head) with the force vector directed vertically downwards towards the ground along the biomechanical axis of femur and lower limb. This equates to a compressive forces acting on each femoral head to be approximately one-third of total body weight i.e. 33%. No muscular forces required to maintain equilibrium position (in erect standing posture) with minimal muscle forces required for maintaining balance in static analysis.⁸⁰⁻⁸⁷

In a study by Bergmann et al, the in vivo measured forces for two legged stance was approximately 80% to 100%, much more than anticipated (33% to 50%). This can be attributed to the persistent muscle tension that is required to maintain and erect two legged stance which are not measured in in vitro studies.⁸³

SINGLE LEG STANCE

When a person stands on one lower limb, either during standing or during the stance phase of gait cycle, the hip joint experiences forces not only due to weight of the body but also muscle forces trying to maintain erect posture, equilibrium and correct for shift in the changing centre of gravity. Although static forces are considered in most studies, the effects of motion and varying loads acting on the hip based on kinetic and kinematic data of the entire limb are more accurate but their complexity of calculations is a major challenge.⁸⁵

When standing on a single limb, the mass of the unsupported leg to is added to the body mass acting on the weight bearing hip. Only the mass of the supported leg below the femoral head is not acting upon the femoral head in this scenario. This causes the centre of gravity to move away from the midline towards the unsupported leg and also distally based on the position of the unsupported limb. The in vitro calculations estimate 270% body weight acts upon the hip joint in single leg stance.⁸⁵

The supporting leg is eccentric to the line of action of centre of gravity. This also results in a rotatory force along the centre of the supported femoral head i.e. the body tries to fall on to the side of the unsupported limb due to gravity but this action is counteracted by pulling the entire trunk and levelling

the pelvis (to horizontal plane) by the strong action of the hip abductor muscles, mainly gluteus medius and minimus.⁸⁰⁻⁹¹

CALCULATION FOR MEASURING HIP JOINT FORCES IN SINGLE LEG STANCE

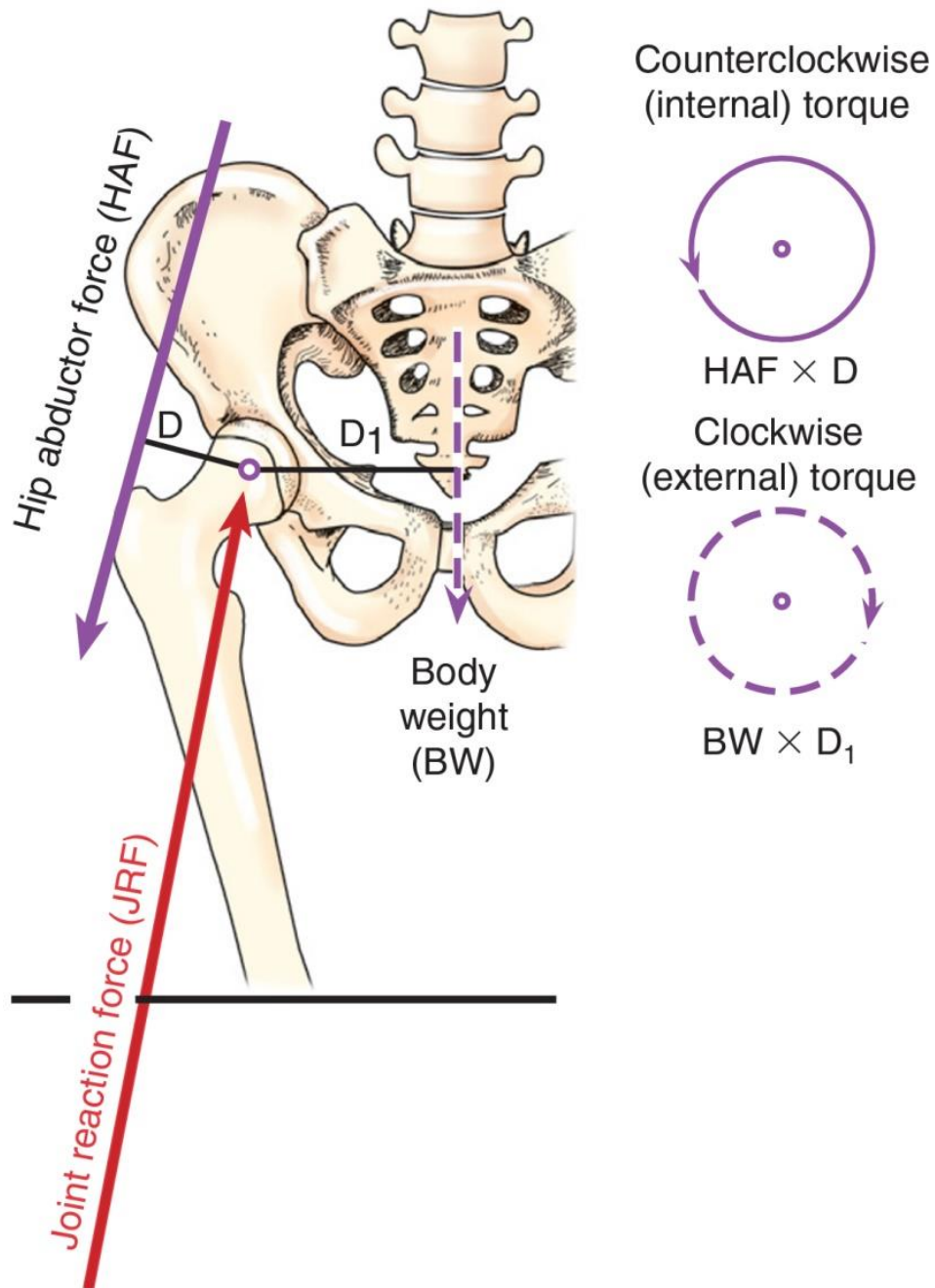


Figure 43: SINGLE LEG STANCE BIOMECHANICS

In vitro calculations based on free body diagrams during single leg stance rely on frontal plane forces. Although limited in their design they help demonstrate the subtle changes in body position or hip anatomy can have on changes in forces across hip joint.⁸²

The static loading of the hip joint can be analysed in the frontal plane with a simplified two dimensional approach:

In the single leg stance the hip joint experiences a rotatory turning force (acting over the centre of the femoral head of supported leg) by the body weight (BW) on one side and its opposing counterpart forces offered by the combined abductor muscles action (HAF)⁸⁰

The rotational torque experience by the hip joint can be calculated by $BW \times D_1$ which is a counter clockwise torque. This necessitates the production of a counter force by the hip abductor muscles which is $HAF \times D$ a clockwise external torque. In a healthy individual these forces balance each other out and the pelvis and trunk remain levelled.⁸⁰

The total stress over the joint is a combination of both the forces acting in opposing directions as mentioned above and is calculated by adding $HAF + BW$ and is called the joint reaction force (JRF). Since the supported leg below hip joint is equal to $1/6^{th}$ BW it does not produce any effects of gravity over the hip joint. Thus JRF is equal to $HAF + 5/6^{th}$ of body weight and acts exactly parallel

to the trabecular pattern of the femoral head and neck with an approximate orientation of 16° from vertical axis, oblique laterally and distally.⁸⁰⁻⁸⁵

The moment arm of the abductor muscles “D” is considerably shorted that the body weight effective lever arm “D₁” this means that the hip abductor muscles have to produce a considerably higher magnitude of force than the body weight which translates roughly 250 to 280% BW.

Example of JRF calculation during single leg stance⁸⁰

Sample Data

D = 4.39 cm, D₁ = 8.64 cm

Total body weight (BW) = 760.6 N (171 lb)

Torque Equilibrium Equation

$\Sigma T = 0$ (counterclockwise torque = clockwise torque)

$(HAF \times D) = (5/6 BW \times D_1)$

$(HAF \times 4.39 \text{ cm}) = (631.3 \text{ N} \times 8.64 \text{ cm})$

$HAF = 5454.43 \text{ Ncm} / 4.39 \text{ cm}$

$HAF = 1242.5 \text{ N (279.3 lb)}$; directed downward

Force Equilibrium Equation

$\Sigma F = 0$ (upward directed forces = downward directed forces)

$JRF = HAF + 5/6 BW$

$JRF = 1242.5 \text{ N} + 631.3 \text{ N}$

$JRF = 1873.8 \text{ N (421.3 lb)}$; directed upward

*excludes the weight of the right lower extremity

APPLIED ASPECTS

Various injuries and diseases can damage the tissues involved in the hip joint causing deformations associated with loading to be painful. The knowledge of the principals involved in the joint forces are to be used to management of various painful hip conditions aimed at reducing the joint reaction force (JRF).

The factors influencing magnitude and direction of compressive forces over femoral head are

- 1) Magnitude of body weight
- 2) Abductor lever arm (function of the neck-shaft angle)
- 3) Position of the centre of gravity

Reduction in total body weight (BW) reduces the overall mass effects of gravity thus reducing both the effective weight over the hip joint and the abductor power necessary to counter it bring in an overall reduction in JRF. Patients should be encouraged to reduce overall weight by means of diet modification and exercise if possible. It is also beneficial in the long term for protection of other joint apart from the pathological symptomatic joint.^{82,84,85}

LEVER ARM RATIO^{80,81}

Any parameter that changes the lever arm ratio will change the abductor muscle force. A shorter abductor lever arm as seen in coxa valga or excessive femoral anterversion will lead to excessive abductor demand. This adds to the increase joint loading or force with the abductor muscles being eventually overpowered. This will cause the pelvis and trunk to dip on the opposite unsupported limb and can be tested by Trendelenburg sign with the patient eventually developing a Trendelenburg gait i.e. pelvic tilting or gluteus medius lurch.

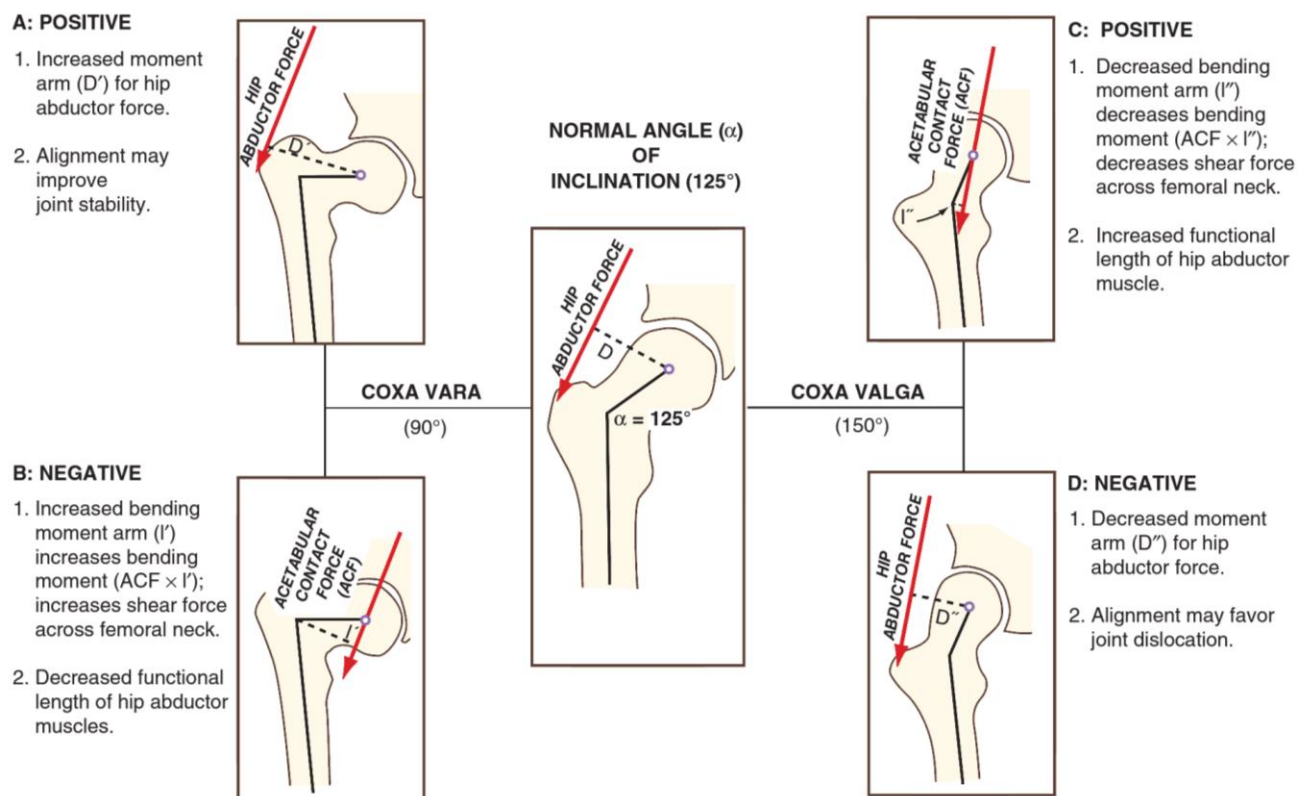
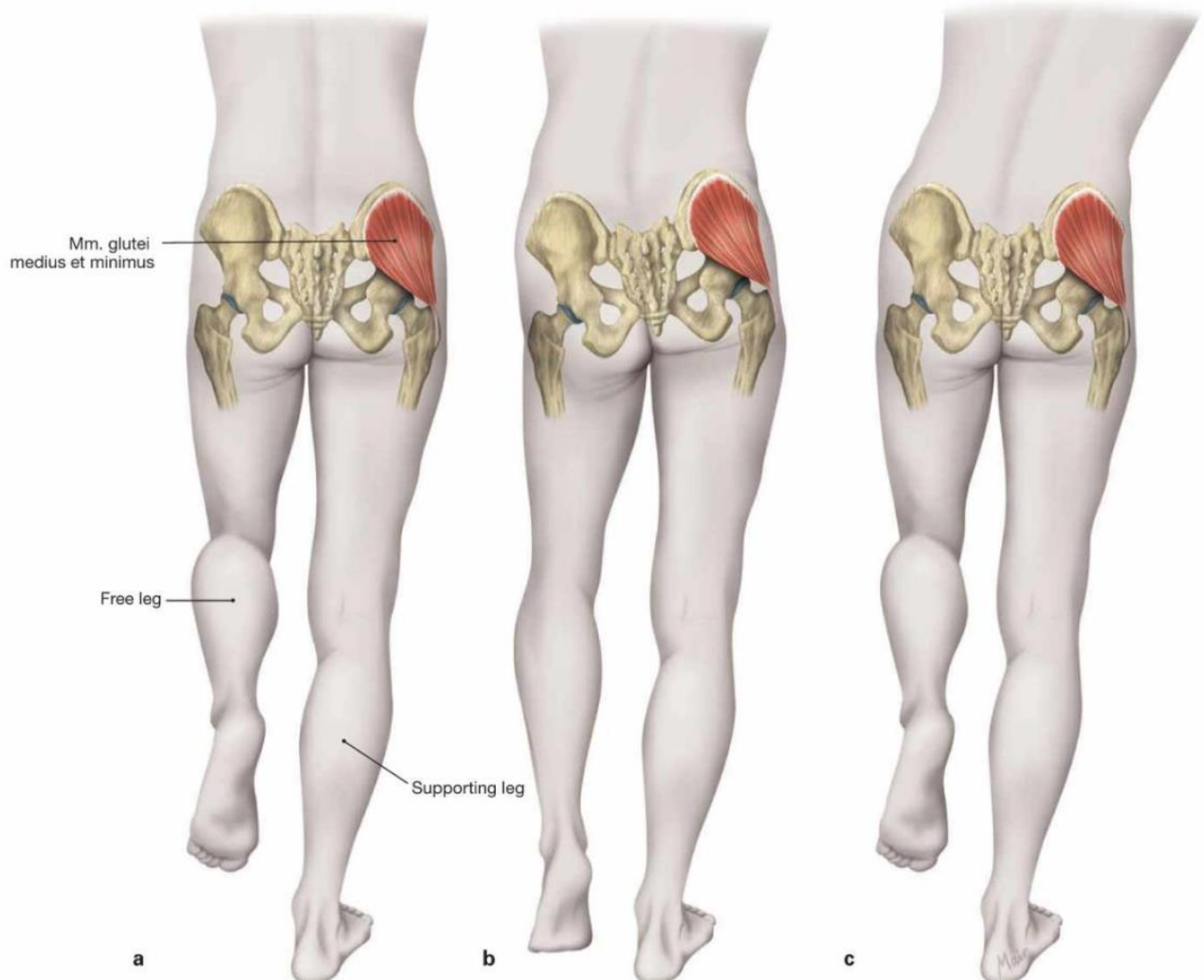


Figure 44: BIOMECHANICAL EFFECTS OF COXA VARA AND COXA VALGA

TRENDELENBURG GAIT⁸⁰⁻⁸⁵

A Trendelenburg gait is observed when a patient bends in the coronal plane during the stance phase of walking, such that a greater proportion of his weight is centred over the standing leg.



**Figure 45: (a) Single leg stance with pelvis levelled showing good abductor function; (b) Trendelenburg sign positive with the pelvis dropping towards the unsupported limb
c) Lurch towards affected hip to bring the centre of gravity closed to supporting hip joint axis and level pelvis**

This is frequently seen in patients with hip pain, and is often thought to be representative of underlying hip pathology or abductor muscle weakness.

Although pure abductor weakness may be a rare clinical finding, an understanding of basic hip biomechanics helps explain why such a gait technique is advantageous in the setting of a painful hip. As the individual's weight is shifted over the standing leg and closer to the hip centre of rotation, the moment arm of the gravitational force " D_1 " is reduced, thus decreasing the force that must be generated by the abductor musculature to counteract the force of gravity on the pelvis. This results in an overall decrease in JRF, with the reduction being proportional to the extent of reduction in the moment arm of the gravitational force. In other words, the worse the Trendelenburg "lurch," the greater reduction in load across the hip joint.^{80,81}

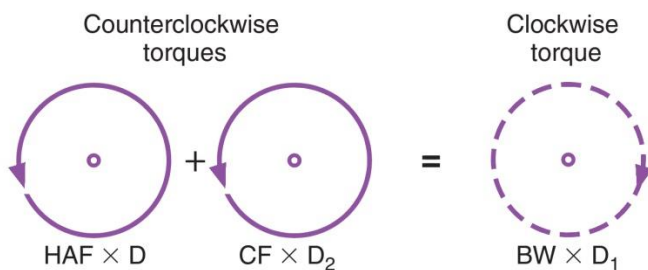
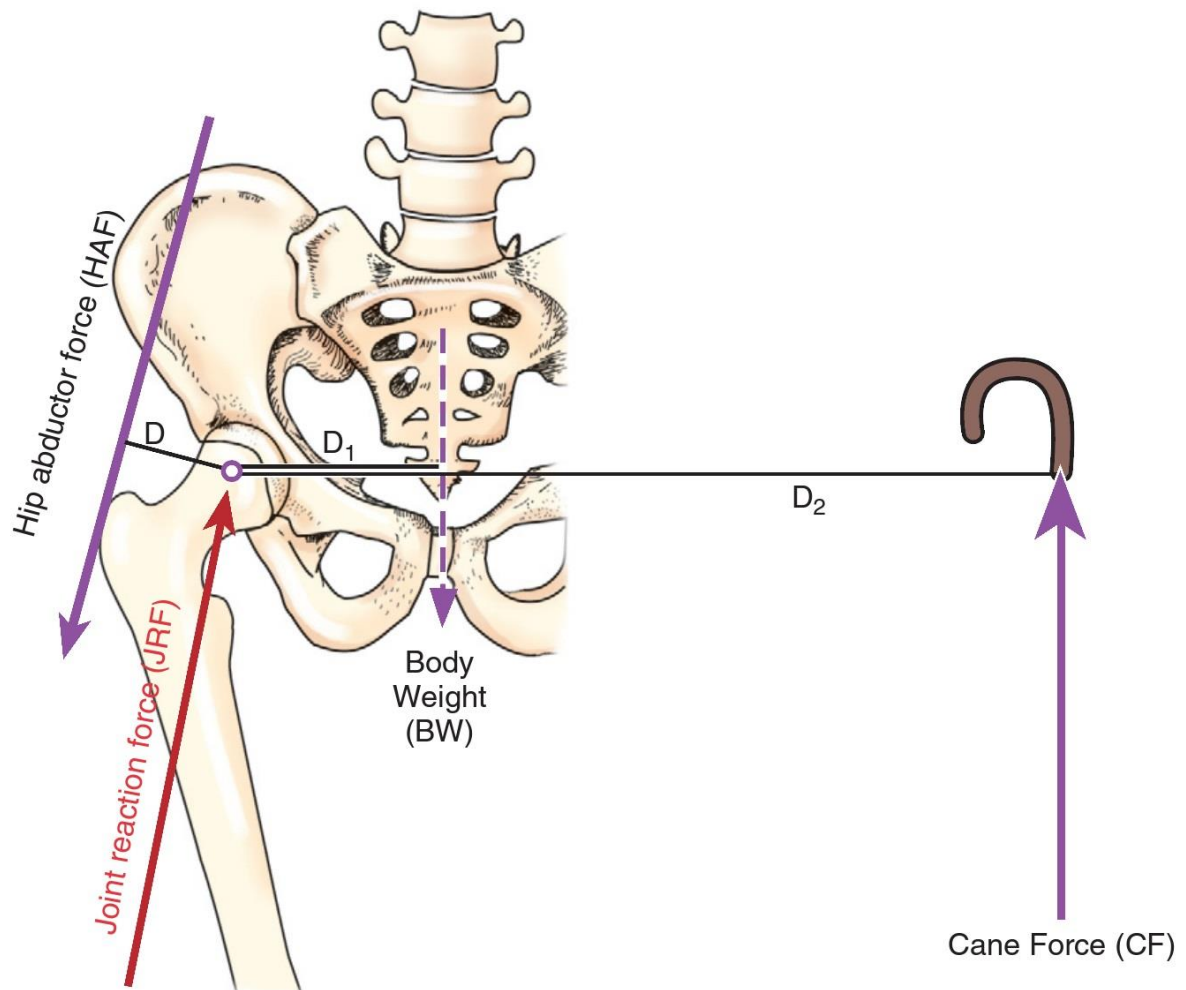
Compensation for Trendelenburg lurch can lead to contralateral knee going into a valgus position which is a risk of injury of knee and predisposes to arthritis due to excessive shear forces acting on the knee joint. Hence maintaining balance of the pelvis is an important consideration for protecting other joint along with the affected joint.⁸⁵

LIMPING^{80,81,87}

One of the natural compensatory mechanisms to alleviate pain is by limping. Patient leans towards the painful hip with lateral movements to reduce the body weight moment arm “ D_1 ” by bringing the CG closer to femoral head centre and reducing the abductor muscle force required which is desirable.

However the cycle of lateral acceleration of the body mass and its deceleration (stance phase) and re-acceleration to other side (opposite leg stance) requires excessive energy consumption and also increased hip joint forces which is undesirable and prolonged limping can aggravate the pain

WALKING AID⁸⁰⁻⁹¹



One of the simplest ways to alleviate pain and reduce compression forces over hip is the use of a walking stick or cane held in the hand opposite to the affected hip. This reduces the JRF caused by activating the hip abductor muscles.^{80,91}

The transfer of force to the walking aid reduces the effective load of body weight and produces a torque about the opposite hip in the same rotatory direction as the overlying hip abductor muscles thus substituting for part of the force and reducing abductor demand.

The cane force (CF) also acts over a large moment arm D_2 as compared to the normal CG moment arm D_1 thus even a small transfer of load to the cane can greatly reduce the combined JRF and this has been calculated to be 20% JRF reduction by some studies with as much as 42% when maximising efforts to use cane. The reprieve brought by use of a cane is thus similar to about 20 to 42% weight loss.^{80,81,91}

CALCULATION FOR A CANE ASSISTED SINGLE LEG STANCE

Sample Data

$D = 4.39$ cm, $D_1 = 8.64$ cm

Total body weight (BW) = 760.6 N (171 lb)

Cane force (CF) = 75.6 N (17 lbs), $D_2 = 35$ cm

Torque Equilibrium Equation

$\Sigma T = 0$ (counterclockwise torques = clockwise torques)

$$(HAF \times D) + (CF \times D_2) = (5/6BW^* \times D_1)$$

$$(HAF \times 4.39 \text{ cm}) + (75.6 \text{ N} \times 35 \text{ cm}) =$$

$$(631.3 \text{ N} \times 8.64 \text{ cm})$$

$$(HAF \times 4.39 \text{ cm}) + 2646.00 \text{ Ncm} = 5454.43 \text{ Ncm}$$

$$HAF = 2808.43 \text{ Ncm} / 4.39 \text{ cm}$$

$$HAF = 639.7 \text{ N (143.8 lb); directed downward}$$

Force Equilibrium Equation

$\Sigma F = 0$ (upward directed forces = downward directed forces)

$$JRF + CF = HAF + 5/6BW$$

$$JRF + 75.6 \text{ N} = 639.7 \text{ N} + 631.3 \text{ N}$$

$$JRF = 1195.4 \text{ N (268.8 lb); directed upward}$$

*excludes the weight of the right lower extremity

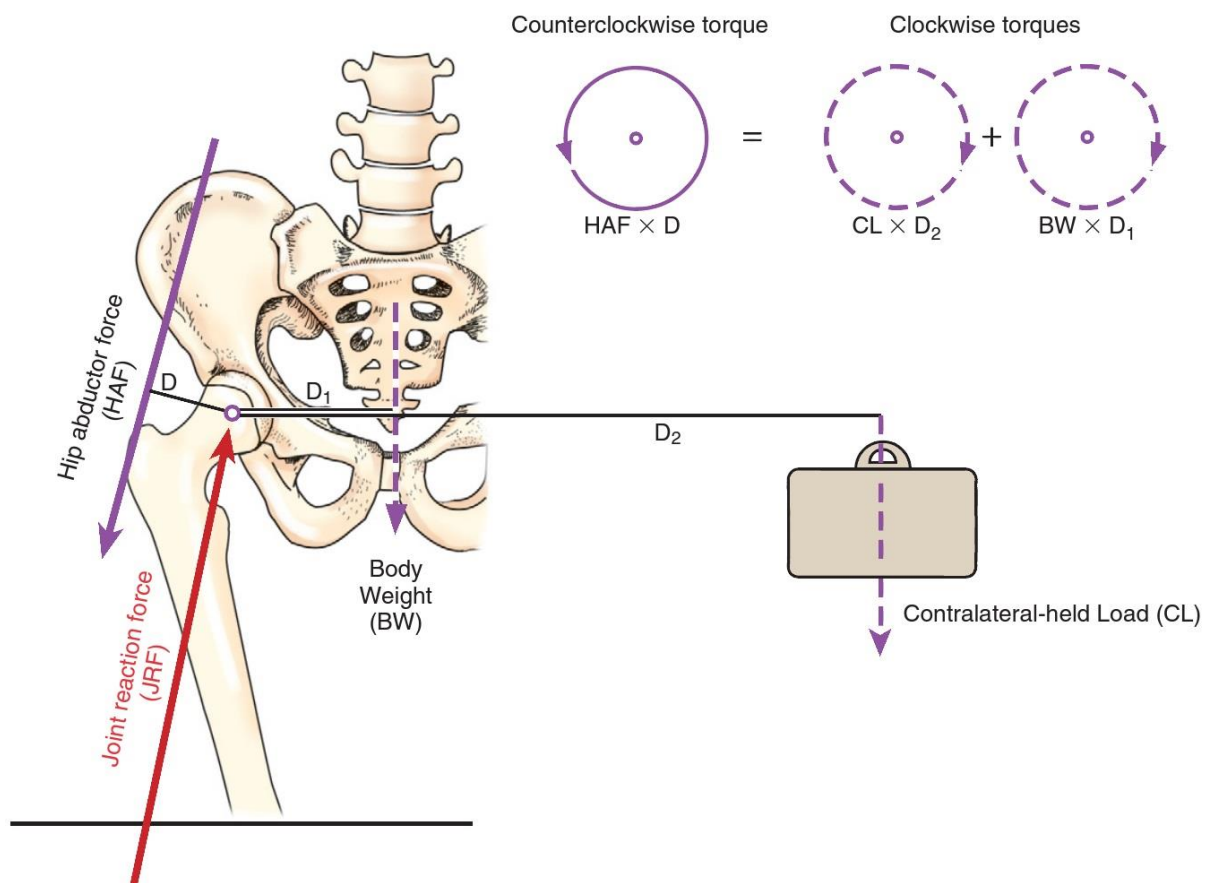
The use of a walking aid in post-operative patients, improves rehabilitation by significantly reducing pain, prevent sideways limping and improving compliance for physiotherapy.

The aspect of loading of the proximal femur takes on particular importance for femoral stem design

- Anteriorly applied loads will produce a twisting strain on the stem within the medullary canal
- Vertical loading of the femoral component will produce compressive load on the medial side of the femoral stem and tension loads on the lateral side of the stem
- Anterior loading will produce shear stresses at the prosthesis-bone-cement interfaces
- Since smooth stems are capable of transmitting load only in compression, this latter mode of loading is an argument for fixation that has the capability of transmitting all three mechanisms of stress: compressive, tensile, and shear.
- It also implies that it is inadequate to analyze the validity of femoral stem design by only simulating vertical load and that the resistance to twisting moments within the femoral canal also requires analysis.

METHODS OF CARRYING EXTERNAL LOAD^{80,81}

Patients with painful, unstable or surgically replaced hip have to be cautioned about carrying heavy hand held loads on the contralateral hip opposite to the affected hip.



The contralateral hip has a very large moment arm D_2 which create a substantial rotatory torque over the affected hip which must be counteracted by the torque produced by the hip abductor muscles. Due to the small moment arm available to the abductors “ D ” a large force is required to counteract the weight.

Patients with unstable or painful hip should be advised to avoid or limit carrying external loads and if require should be carried on the ipsilateral side or backpack.

Summarising the above findings the combined use of a cane in the contralateral hand and load carried on the ipsilateral hand vastly reduces the hip abductor demand than when either method is implemented separately.

Caution should however be exercised that the reduced abductor demand in these patients by above mentioned methods may lead to perpetual weakness in the hip abductor muscles and lead to gait deviations. A balance needs to be achieved between protecting a vulnerable hip from excessive and damaging forces from hip abductors while simultaneously increasing endurance of these muscles. Signs and symptoms such as excessive pain, marked gait deviation, generalised hip instability and abnormal positioning of lower limb should be observed and corrected at the earliest.

ACTIVITIES OF DAILY LIVING⁸⁵

Gait has been used as the primary activity to analyse kinematics of the hip joint. Studies involving total hip replacement have highlighted functional demand as an important outcome measure for patient satisfaction.

There has been growing interest in activities of daily living (ADLs) to obtain a true representation of how the hip moves on a day to day basis. The ADLs which are analysed are often more demanding than gait by requiring increases in ranges of motion and/or joint moments.

The typical activities of daily living which are often analysed are :

- Increased walking speed
- A sit to stand task
- Ascending and descending stairs

The sit-to-stand (STS) task is performed up to 60 times a day by healthy adults and as an activity of daily living is unusual in its movement. Most activities which are performed during daily living are performed in a unilateral pattern whereas the STS task is performed identically bilaterally. The high degree of flexion at the hip at the start of a STS task makes the movement challenging both for maintaining balance and for producing the force needed to complete the movement. Following joint replacement, completion of this task

represents the mechanical efficiency of the quadriceps muscle and how well the associated moment arms have been reconstructed.

Stair ascending creates a greater demand on the muscles compared to descending which is much more about control of the movement than force production. These increases in demand can be seen when considering the increased flexion angle achieved during the sit-to-stand and stair ascent tasks compared to normal walking (34° and 66° respectively)

MEAN VALUES OF HIP MOTION DURING DAILY ACTIVITIES⁸⁵

Activity	Plane of Motion	Recorded Value (Degrees)
Tying shoe with foot on floor	Sagittal	124
	Frontal	19
	Transverse	15
Tying shoe with foot across opposite thigh	Sagittal	110
	Frontal	23
	Transverse	33
Sitting down on chair rising from sitting	Sagittal	104
	Frontal	20
	Transverse	17
Stooping to obtain object from floor	Sagittal	117
	Frontal	21
	Transverse	18
Squatting	Sagittal	122
	Frontal	28
	Transverse	26
Ascending stairs	Sagittal	67
	Frontal	16
	Transverse	18
Descending stairs	Sagittal	36

The surprising differences between the moments are the relatively similar values between the STS and stair ascent/descent tasks. It would be expected that due to the impact nature of stair descent hip moments would be high.⁸⁵

Normal kinematic and kinetic peaks for the hip during normal walking, fast walking, ascending and descending stairs,⁹ and sit-to-stand¹⁰

	Normal walking	Fast walking	Stair ascent	Stair descent	Sit-to-stand
Hip flexion angle (°)	25.41	36.54	59.59	29.12	91.60
Hip extension angle (°)	-16.21	-17.26	-0.12	3.64	1.60
Hip adduction angle (°)	3.48	3.07	5.65	2.54	3.50
Hip abduction angle (°)	-11.05	-13.64	-10.84	-6.99	-4.10
Hip flexion moment [N*m/kg]	0.22	0.51	0.23	0.01	
Hip extension moment [N*m/kg]	-0.96	-1.26	-0.48	-0.54	-0.67
Hip adduction moment [N*m/kg]	0.64	0.50	0.46	0.80	0.12
Hip abduction moment [N*m/kg]	-0.06	-0.11	-0.09	-0.04	

PATHOMECHANICS OF INJURY⁹²⁻⁹⁶

Intertrochanteric fractures occur as a result of fall, involving both direct and indirect Forces.

Kocher has suggested two mechanisms of injury:^{92, 93}

1. First is that of a fall producing a direct blow over the trochanter
2. Lateral rotation, of the limb with osteoporotic and weakened bone may also be a factor for early and frequent fractures. The severity of the fracture directly related to the degree of osteoporosis, which results in a weakened bone stock.
3. A third recently suggested mechanism is cyclical loading. This which produces micro and macro fractures, which is commonly seen in osteoporotic and diseased bones.

Most hip fractures are the immediate consequence of falling. A simple fall from a standing height has several times the potential energy required to fracture even a normal hip. Falling from a lower initial height, such as falling out of a low bed, will have less potential energy. In order to transmit this energy to the proximal femur, the primary impact of the fall must occur near the hip. Protective responses, like grabbing an object, and local shock absorbers, like fat and muscles around the hip, might absorb part of the energy of a fall. If the

residual energy of the fall that is transmitted to the proximal femur exceeds a critical threshold, then the proximal femur will fracture. This threshold depends on the strength of the bone in the proximal femur for the particular direction and rate of the force that is applied.⁹⁴

FACTORS CONTRIBUTING TO INCREASE RISK OF HIP FRACTURES⁷⁹

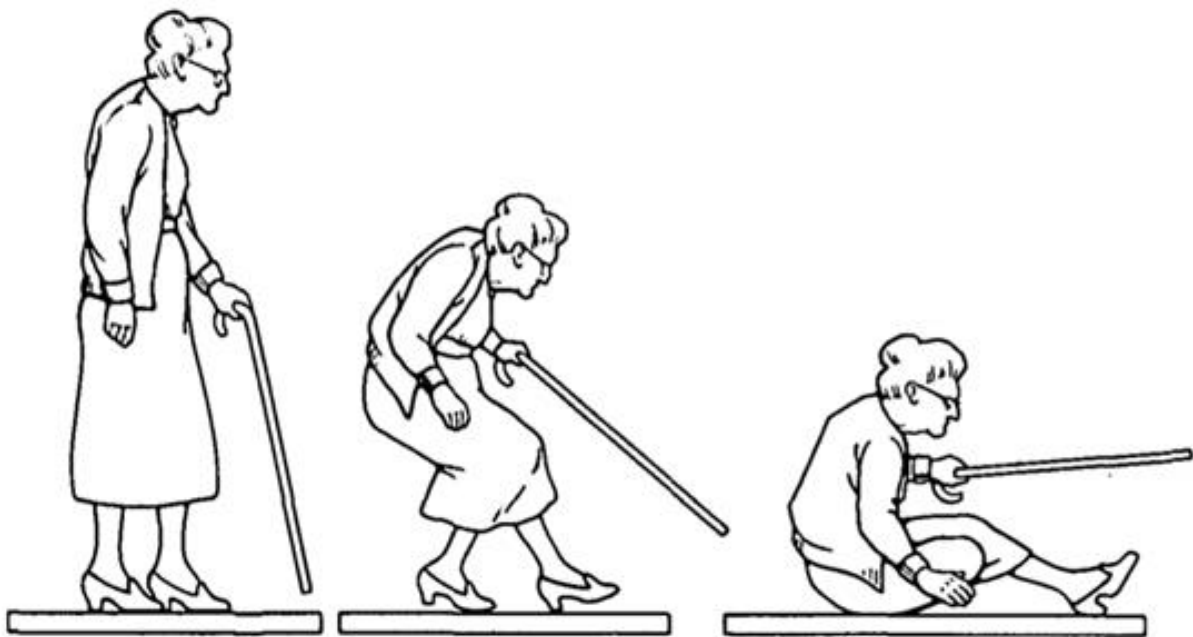
Step	Potential Contributing Factors
1. Orientation of fall	• Slow gait speed • Fall during bed and chair transfers • Fall during descent of stairs or curbs
2. Protective responses	• Slow reaction time in upper and lower extremities (response and movement times) • Muscular weakness • Sedation (alcohol, sedative drugs) • Syncope or impaired consciousness during fall • Disorientation, dementia • Sudden onset of fall (slippery surfaces) • Delayed recognition of falling (peripheral neuropathy, impaired vestibular function)
3. Local shock absorbers	• Weakness or atrophy of muscles surrounding the hip • Reduced fat around hip and buttocks • Hard impact surface
4. Bone strength	• Osteoporosis (reduced mineral density) • Osteomalacia • Qualitative microscopic abnormalities (microdamage, crystal size) • Architectural weakness (loss of major trabeculae, thinned cortices, thin bone diameter)

It has been hypothesized that in order for the fall from a standing height to cause a hip fracture, a sequence of four conditions must all be satisfied⁹²⁻⁹⁶

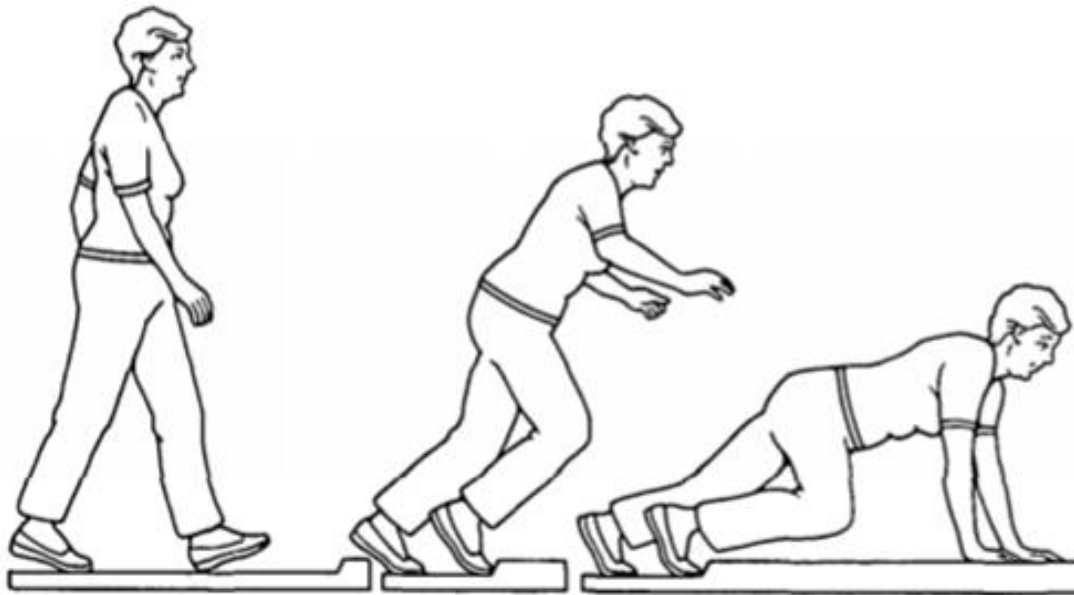
1. The fall must be oriented so as to land on or near the hip
2. Protective responses must be inadequate to reduce the energy of the fall below the critical threshold
3. Local shock absorbers, such as fat and muscles around the hip, must be inadequate to absorb enough of the energy of the fall to prevent the fracture
4. Bone strength in the proximal femur must be insufficient to resist the residual energy of the fall that is transmitted to the hip.

ORIENTATION OF THE FALL⁹⁴

In order for most of the energy of a fall to be transmitted to the proximal femur, the faller must land on or near the hip. If the principal impact occurs elsewhere, little or no energy will be transmitted to the proximal femur. Falls that carry the pelvis straight down, to the side, or backwards are the type most likely to cause a direct impact on or near the hip. These types of falls are more likely when the faller has little or no forward momentum, as when the faller is standing still, or walking slowly.



In contrast, falls that occur at a more rapid gait speed will tend to carry her forward on to hands or knees and are more likely to fracture the distal forearm than the hip



Gait speed slows about 25% from age 65 to 85. There may be a threshold for gait speed below which falls are very likely to land on the hip. If so, then, with advancing age, an increasing proportion of elderly walk at speeds that increase their risk of landing on the hip and suffering a hip fracture. Falls that occur in certain circumstances might also be more likely to carry the faller onto her hip. Falls that occur during transfers between bed and chair have little or no forward momentum and are more likely to impact near the hip. The incidence of such falls also increases with age

PROTECTIVE RESPONSES⁹²⁻⁹⁴

The onset of a fall initiates several types of reflexes and postural responses that can prevent a fall, change the orientation of the faller, or reduce the energy of a fall if it occurs. Once a fall is inevitable, grabbing nearby objects could substantially slow the rate of falling. By quickly extending the arms, the faller can absorb the energy of the fall with the arms and hands and minimize the force of impact on the hip or other parts of the body. Quick stumbling movements of the feet might also decrease the downward velocity of the fall and thus decrease its potential energy. Because falls occur rapidly, the effectiveness of these responses depends on their speed of execution. During falls, there is a critical threshold time for protective reactions; responses delayed beyond that threshold will be too late to reduce the energy or change the direction of a fall. Reaction times slow with aging; thus, protective responses may be too late to protect the very elderly faller against hip fractures. Sedatives and alcohol also slow reaction times, and this might partly explain the increased risk of hip fractures associated with use of long acting sedatives and regular intake of alcohol. The effectiveness of protective responses also depends on strength. If muscles are too weak to hold the arm in extension, an outstretched arm may absorb little or no energy of a fall. Thus, the decline in arm strength that occurs with aging might increase the risk of hip fractures after a fall while

decreasing the risk of Colles' fractures. Protective responses are lost during syncopal falls. We have found that the risk of suffering a fracture of any type is four times greater during a syncopal than during a nonsyncopal fall. The incidence of syncopal falls and "drop attacks" also increases substantially with age and might account for a small part of the increased risk of fractures with aging.

LOCAL SHOCK ABSORBERS

Skin, fat, and muscles surrounding the hip are capable of absorbing substantial amounts of energy of an impact. Therefore, falls may be more likely to cause hip fractures in those who have less soft tissue around the hip. Abductors of the hip are the largest group of muscles attached to the proximal femur. It has been observed that, among women, the isometric strength of hip abductors declines about 27% from age 65 to age 80. This age-related decline in strength may indicate a similar decline in the capacity of muscles around the hip to absorb the energy of impact and may, in turn, account for some of the increased incidence of hip fractures with aging. There have been no studies of changes in skin and fat around the hip with advancing age.

BONE STRENGTH

If the residual energy of the fall applied to the proximal femur exceeds the strength of the bone, the proximal femur will fracture. Hence, bone strength is the last defense against hip fractures. In the very small proportion of hip fractures that occur "spontaneously" during weight bearing, osteoporosis, fatigue damage, or other localized disease may be the sole causal factor.

According to Horn and Wang, it is the result weakened bone stock which fails to withstand a sudden bending or twisting strain thrown on it while the patient is weight bearing.

The supportive evidence lies in the radiological characteristic finding of medial side comminution with varus deformity and gaping of the fracture on the lateral side. During ambulation, both static and dynamic forces are applied to the proximal femur: Due to these a distending force is generated on the lateral aspect of the neck-shaft angle and by inference a compression force is generated on the medial aspect. In daily ambulation dangerously large stresses must be thrown on the peculiarly susceptible neck shaft angle and there exists an, inbuilt mechanism to mitigate these stresses.

Those muscles, which, by their active contraction while the limb is weight bearing, tend to straighten out the neck-shaft angle could be regarded as constituting a stress resistor system.

These muscles include the short external rotators, the piriformis, the uppermost fibers of the adductor magnus, the adductor brevis and the pectineus, all those muscles pursuing a more or less horizontal course between the trunk and the femur. The stress resisting effect of these muscles has been compared to that of a tensioned steel cable in a beam of pre-stressed concrete, except that the tension in the muscles can vary reflexly in response to the varying stresses thrown on the bone.

Horn and Wang suggested that failure of this stress resistor mechanism to operate either because of muscle weakness or delayed reaction time, especially in a osteoporotic and weak bone may be an etiological factor in the causation of intertrochanteric fractures.

EXTRA-SKELETAL RISK FACTORS FOR HIP FRACTURES⁷⁹

Intrinsic Factors	Balance, gait or mobility problems Medications (e.g. sedatives, anti-hypertensive drugs) Visual impairment Impaired cognition Postural hypotension Alcohol
Environmental factors	Poor lighting Steep stairs Carpets or rugs Slippery floors Badly fitting footwear Inaccessible cupboards or windows

A study on risk factors for hip fractures in Indian population revealed that 50% of Indian women and 36% of Indian men over the age of 50 suffer from osteoporosis and are at risk for hip fracture. The importance of increasing activity level, calcium and vitamin D intake, decreasing caffeine intake, and maintaining a healthy BMI was emphasised and may decrease the prevalence of hip fractures in the Indian population. In addition to emphasizing these dietary and lifestyle improvements, public awareness programs can encourage early screening and treatment strategies. These would help to further reduce the prevalence and thus morbidity and mortality of hip fractures.⁹⁶

FRACTURE CLASSIFICATION

Classifications for intertrochanteric fractures have been made by numerous authors over the past decades. Despite the many attempts a universally accepted and reliable classification is still yet to be made and is in continuous evolution.

Sir Astley Cooper was the first to adequately differentiate between intra and extra capsular hip fractures without the aid of roentgenograms and his classification aided in proper prognosis and treatment of hip fractures.

After the discovery of Rontgen rays, the initial classification systems were based on anatomical pattern of fractures. With the advancements in surgical techniques, imaging modalities and better fixation implants, the classification of intertrochanteric fractures were made to address the reduction potential and aid in fracture management decision.

BOYD AND GRIFFIN (1949)²⁶

- Classification based on instability in coronal and sagittal planes
- Included all fractures from extracapsular part of the neck to a point 5 cm distal to the lesser trochanter
- Useful in planning treatment and estimating prognosis



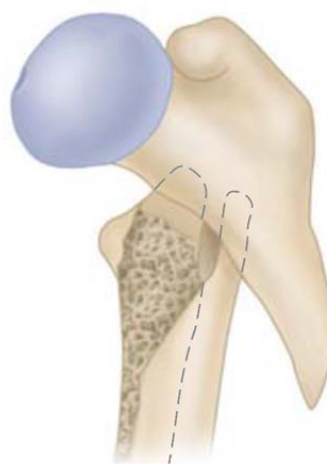
Type 1



Type 2



Type 3



Type 4

TYPE I: Fractures that extend along the intertrochanteric line i.e. from greater to lesser trochanter

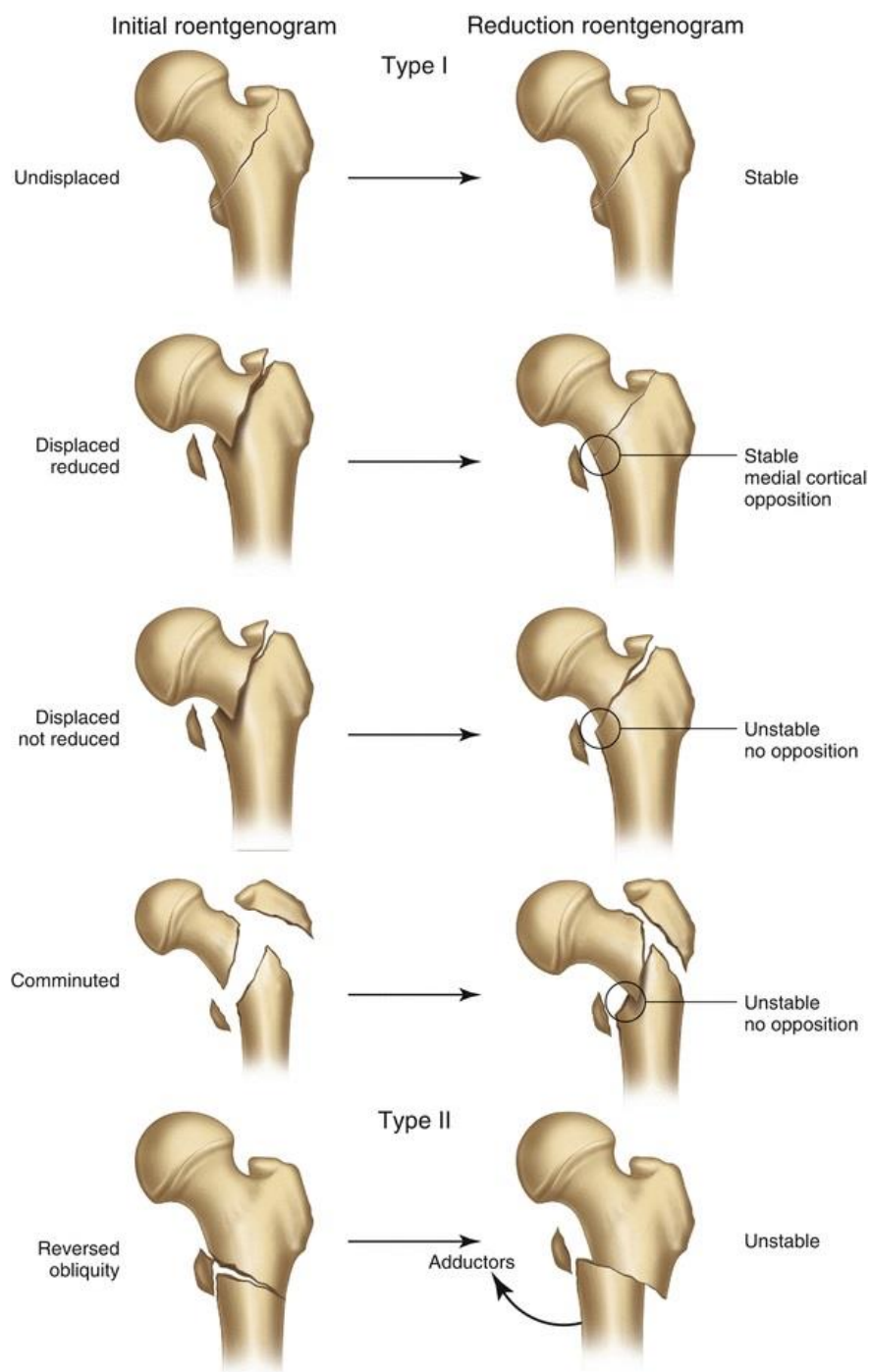
TYPE II: Comminuted fractures with the main fracture line along the intertrochanteric line but with multiple secondary fracture lines (may include coronal fracture line seen on lateral view)

TYPE III: Fractures that extend to or are distal to the lesser trochanter

TYPE IV: Fractures of the trochanteric region and proximal shaft with fractures in at least two planes

EVAN'S CLASSIFICATION²⁷

In 1951, Mervyn Evan presented a simpler classification based on dividing fractures into stable and unstable groups giving emphasis for deciding the line of treatment based on stability of fracture and improving outcome. He further



divided the unstable into those in which stability could be restored by anatomic or near anatomic reduction and in those in which anatomic reduction would not create stability.

The importance of posteromedial cortex continuation contributing to stability was emphasised.

TYPE - 1:

Stable:

- Undisplaced fractures
- Displaced but after reduction overlap of the medial cortical buttress make the fracture stable

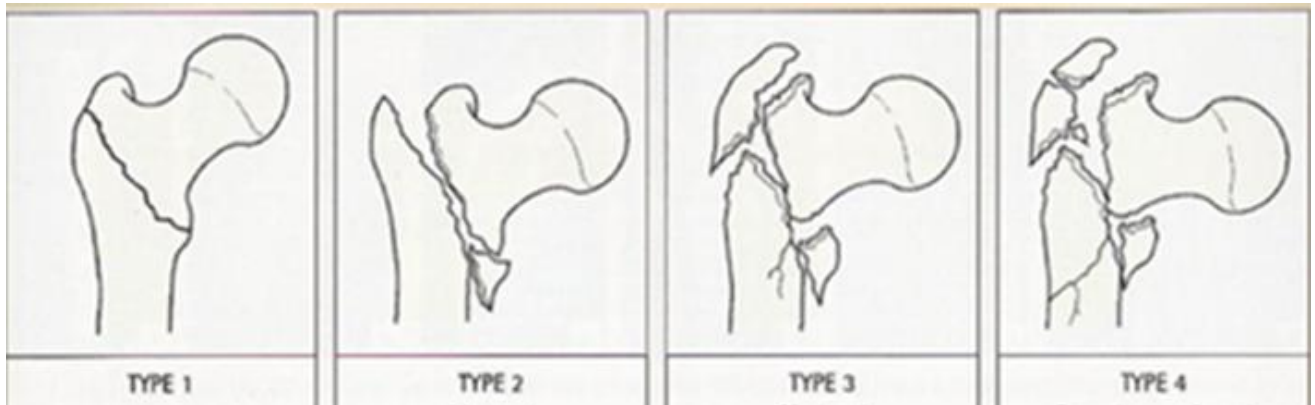
Unstable:

- Displaced and the medial cortical buttress is not restored by reduction of fracture
- Displaced and comminuted fractures in which the medial cortical buttress is not restored by reduction of the fracture and coxa-vara deformity expected

TYPE - 2: Reverse obliquity fractures

The obliquity of major fracture line is reversed, that is it extends outward and downward from the lesser trochanter. There is tendency for inward displacement of the distal femur due to adductor pull making these fractures highly unstable.

KYLE'S CLASSIFICATION³⁰



TYPE- 1 (STABLE): Two part undisplaced fracture

TYPE-2 (STABLE): Fractures that are displaced into varus with a smaller lesser trochanteric fragment with intact posteromedial cortex

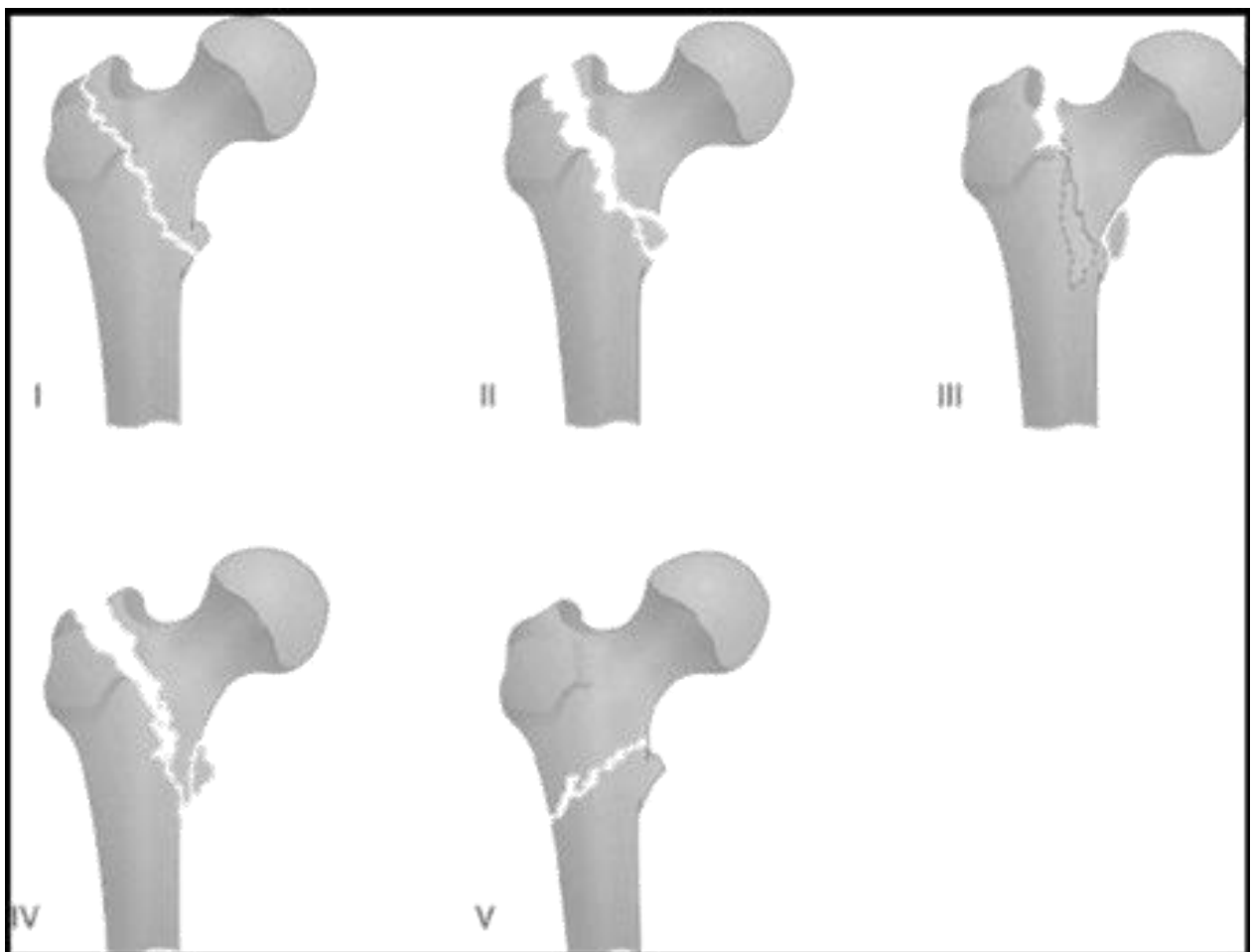
TYPE-3 (UNSTABLE): Four part fractures that are displaced into varus with posteromedial cortical comminution and a greater trochanteric fragment

TYPE-4 (UNSTABLE): Type 3 fracture with subtrochanteric extension

TRONZO CLASSIFICATION²⁹

Tronzo proposed a classification based on the reduction potential.

According to him trochanteric fractures are divided into 5 types and each type requires a specific mode of reduction and fixation with a nail plate assembly



TYPE - 1 : Incomplete trochanteric fractures.

TYPE - 2 : Non - comminuted trochanteric fractures with or without displacement in which both trochanters are fractured

TYPE - 3 : Comminuted fractures in which the lesser trochanteric fragment is large. The posterior wall is exploded with the back of the inferior neck already displaced in the medullary cavity of the shaft fragment. These are unstable fractures. A variant of type 3 fracture also has the greater trochanter fractured off and separated.

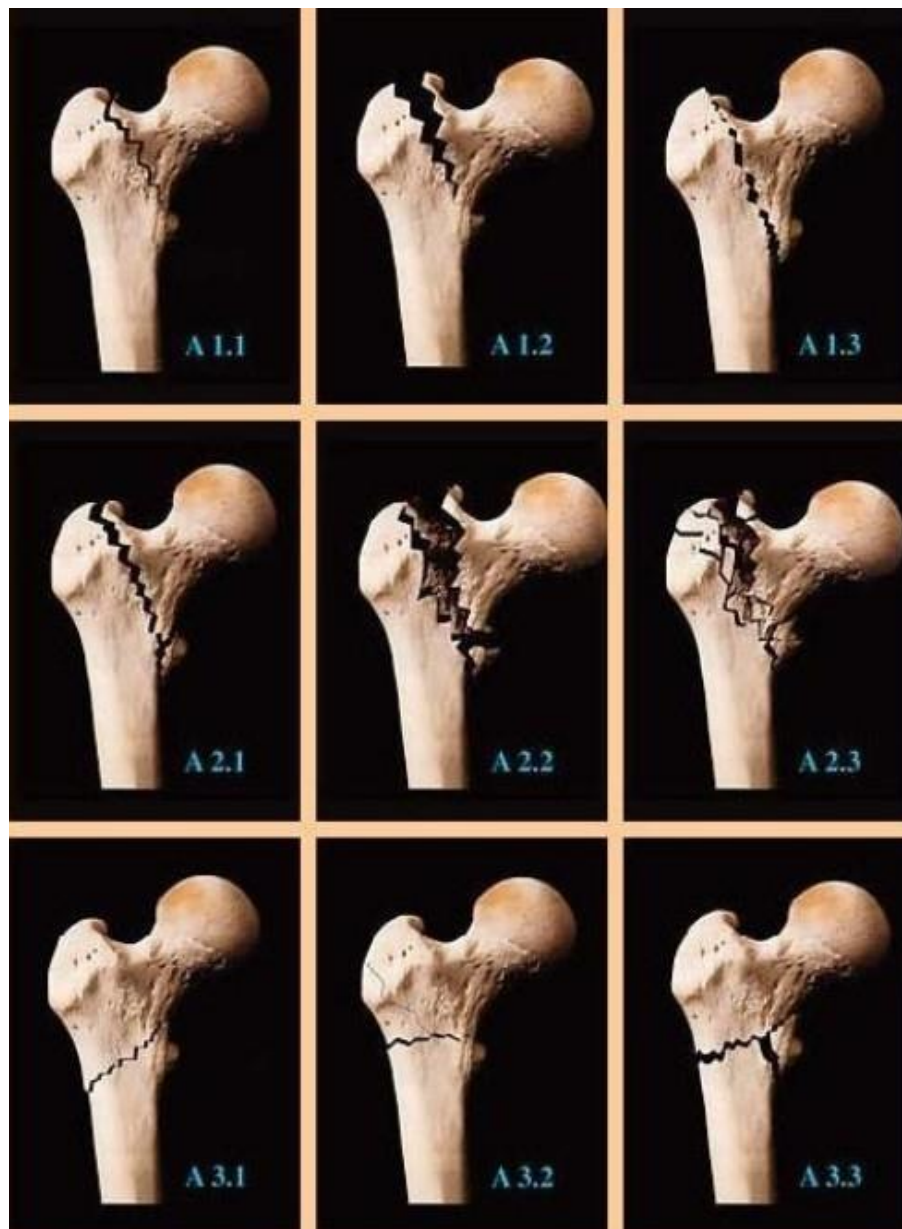
TYPE - 4 : Comminuted trochanteric fracture with disengagement of the two main fragments, unstable with the posterior wall exploded and spike of the neck fragment displaced outside of or medial to the shaft.

TYPE - 5 : Trochanteric fractures with reverse oblique fracture line.

AO /OTA CLASSIFICATION²⁸

AO group has classified the trochanteric fractures into stable and unstable types. The stable trochanteric fractures have an intact medial buttress comprising 70% of the cases.

The unstable problematic types have large posterior fragment in addition to the medial fragment. They emphasize that for stability, the medial and



posterior cortex should be intact. In treatment of unstable trochanteric fractures medial buttress should be reconstructed before fixation with an implant.

TYPE A1: Pertrochanteric simple (oblique fracture line extending from the greater trochanter to the medial cortex; the lateral cortex of the greater trochanter remains intact - two fragments)

A1.1 : along the intertrochanteric line

A1.2 : through the greater trochanter

A1.3 : below the lesser trochanter

TYPE A2 : Pertrochanteric multifragmentary (oblique fracture line extending from the greater trochanter to the medial cortex; the lateral cortex of the greater trochanter remains intact - separate posteromedial fragment).

A2.1 : with one intermediate fragment.

A2.2 : with several intermediate fragments.

A2.3 : extending more than 1 cm below the lesser trochanter

TYPE A3: Intertrochanteric fracture line extends across both the medial and lateral cortices.

A3.1 : Simple oblique (reverse obliquity pattern)

A3.2 : Simple transverse

A3.3 : Multifragmentary

STABLE INTERTROCHANTERIC FRACTURES^{99,100}

a) The fracture runs from the greater trochanter obliquely downwards and medially to exit just above the lesser trochanter. A good portion of the calcar is attached to the proximal fragment anteromedially. Quite commonly there is an avulsion fracture of the lesser trochanter. As a rule the distal fragment is in external rotation. Rarely, the inferomedial spike of the proximal fragment is impacted into the metaphysis of proximal fragment

b) An avulsion does not result in instability because it does not weaken the medial buttress.

UNSTABLE INTERTROCHANTERIC FRACTURES^{99,100}

a) The medial fragment varies in size and reaches distally to a varying degree. As a rule it contains the lesser trochanter. If the lateral wall remains intact then the distal fragment migrates proximally because of muscle pull. Commonly there is in addition quite a large posterior fragment. Occasionally, the proximal fragment contains a long medial spike made up of calcar and lesser trochanter. This makes it into a long oblique or spiral fracture.

b) If the greater trochanter is fractured then the distal fragment is not pulled upwards.

c) A badly comminuted intertrochanteric fracture has in addition to the fractures of the lesser and greater trochanters further comminution posteriorly and medially.

d) The intertrochanteric fracture is almost horizontal. Often one finds this fracture associated laterally with a further anterior or posterior fragment and occasionally both.

e) Occasionally the fracture has a reverse course beginning laterally and distally and running upwards and medially. Medially it exits above the lesser trochanter. Commonly it is associated with a fracture of the greater trochanter.

A fracture classification system is only of value if it leads to better care of fracture or permits more accurate prognosis. There are so many classifications but there is not a single classification based on which choice of implant and surgery can be decided. Most classifications are based on stability of fractures, but the concept of stability is evolving with inclusion of 3D CT and emphasis on lateral wall comminution increasing.

MANAGEMENT OF TROCHANTERIC FRACTURES :

The main aim of IT fracture management is to more than union of the fractured bones, as they usually unite is to prevent residual deformity and functionally patient should be as normal as possible.

Trochanteric fractures can be managed in two ways,

1. Conservative or non-operative method.
2. Operative method

MANAGEMENT OF INTERTROCHANTERIC FRACTURES:

A) CONSERVATIVE MANAGEMENT:

Hip fractures including intertrochanteric fractures were initially treated conservatively using splint and traction. However owing to the high rate of morbidity and mortality following hip fractures and the operative treatment showing good results, the conservative approach was abandoned. However a few exception exist for non-operative treatment for intertrochanteric fractures such as:

- Elderly patient with high medical risk for anaesthesia and surgery
- Non ambulatory patient with minimal discomfort following fractures

B) SURGICAL MANAGEMENT:

Surgical treatment of intertrochanteric fractures with early mobilisation of the patients is considered the ideal treatment.

The goals of operative treatment are:

- Early mobilization of the patient
- Restoration of the patient to preoperative status at the earliest
- Rigid and stable fixation of the fracture fragments or replacement with endoprosthesis

MODULAR BIPOLAR HEMIPROSTHESIS

The first successful bipolar prosthesis was developed by Dr James Ennis Bateman and Averill. They used a HWPE for the inner bearing surface thus solving the issue of metallosis and early wear failure in the previously available metal on metal design.^{8, 18, 50}

It was also protective for the acetabulum and reduced incidence of protrusion acetabuli and cartilage wear.



Figure 55: BIPOLAR FEMORAL PROSTHESIS

The success in hip joint replacement is based on the effective application of Wolff's law.

A self-aligning system for long term use obviates the problem of obtaining the functional alignment of the acetabular component at the time of operation and conforms to Wolff's law.

TOTAL PROSTHESIS PRINCIPLE:

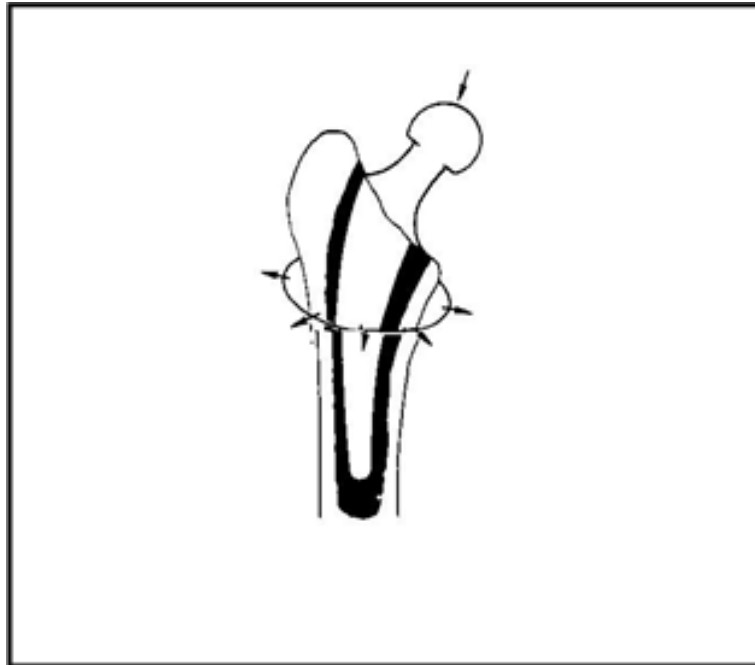
The prosthesis locks the implant together without acetabular fixation

1. Head stability
2. Insulation of metal-bearing elements
3. Motion range
4. Bearing seat strength
5. Stem contour and length.

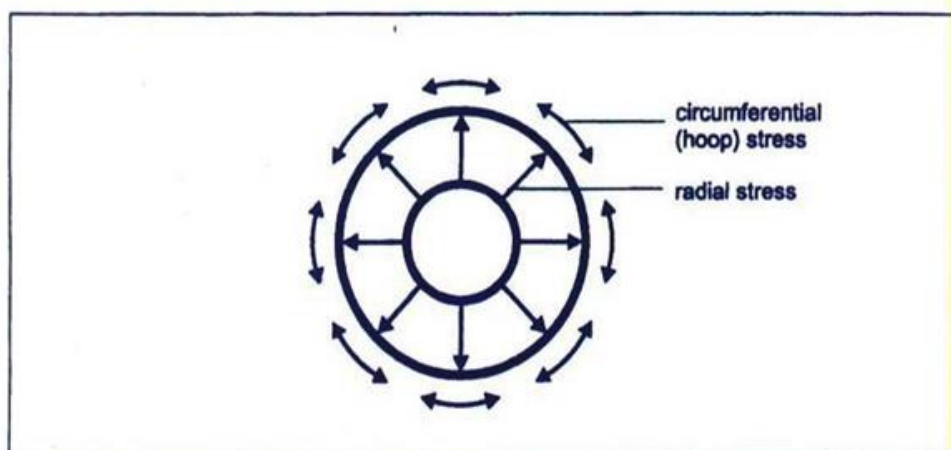
Rotational stability of the stem can be increased both proximally and distally. Increasing the width of the proximal portion of the stem to better fill the metaphysis increases the torsional stability of the femoral component.

Modifications of the distal portion of the stem may add to rotational stability as well. Longitudinal cutting flutes and extensive porous coatings that

“scratch” the diaphyseal endosteum improve rotational stability in the absence of cement.



HOOP STRESSES



**DIRECTION OF RADIAL AND TENSILE HOOP STRESSES
IN A HOLLOW CIRCULAR STRUCTURE**

BONE CEMENT: Polymethyl Methacrylate (PMMA)^{72,81}

This is used to fix the implants to bone. It is not an adhesive, but rather a filler and depends on mechanical interlock for stability at the cement bone interface. It is cold curing because the application of heat and pressure to polymerize and harden it is unnecessary. It is self-curing, because there is a catalyst in the powder and an accelerator in the liquid.

The cement is supplied in packets of powder containing pre polymerized PMMA, Barium sulfate and a catalyst or initiator. The accompanying vials of liquid contain methylmethacrylate monomer, cross-linking agents and accelerators.

Mixing should be done according to the manufacturer's instructions. Manual mixing produces cement mantles with a high degree of porosity, which encourage crack propagation and hence failure. Vacuum mixing and centrifugation may accomplish porosity reduction.

Heat stable Antibiotics can be added in concentration of 0.5gm to 2 gm of powdered form to a 40 gm package of cement to decrease infection. This may decrease fatigue strength significantly and therefore is not routinely recommended.

On introducing the PMMA into the femoral canal, there may be transient hypotension as a result of peripheral vasodilatation and direct myocardial depression by the monomer entering the circulation. The lungs quickly clear this. A secure mechanical bond is extremely important because it prevents motion at the bone-cement interface. Motion causes component loosening as a result of bone resorption and fracture of the cement.

Bone cement can withstand considerable compression, but fails under tension or shear force. If the cement is not tightly packed between the bone and the implant component, and if gaps and spaces are left between the surfaces, the cement will break because it is subjected to shear and tension, rather than compression forces.

THE EFFECT OF FEMORAL SHAPE ON LOAD TRANSFER

All stems are tapered to prevent subsidence and many, especially the cement less ones, have a proximal wedge so that the stem can rest on the bone, allowing transmission of compressive forces as well as shear forces.

The shape of the stem is very important in cement less femoral implants because the stem needs to contact a large proportion of the femur. If its outer dimensions at any point along its length are smaller than the corresponding inner dimensions of the medullary canal, there will be gap. Careful stem selection overcomes most potential shape problems, but the range of shapes and sizes offered in a commercial hip system may not always be adequate to cover a wide range of femurs.

JOINT WEAR

Wear can be defined as the loss of material from the surfaces of the prosthesis as a result of motion between those surfaces. Material is lost in the form of particulate debris.

There are three main types of wear that occur between bearing surfaces.

- Adhesive wear
- Abrasive wear
- Fatigue wear

The factors that determine wear are (1) the coefficient of friction of the materials and their surface finish (2) the hardness of the materials (3) the applied load (4) the sliding distance for each cycle and (5) the number of cycles that occur over time.

Adhesive wear

Adhesive wear occurs because the two bearing surfaces stick to each other when they are pressed together and one, usually the softer one, is torn off by the harder one. Bearing surfaces should, therefore, be made up of materials that have a low level of adhesion. Lubricants provide a layer between the two materials which reduces wear.

Abrasive wear

Abrasive wear occurs because surfaces are not perfectly smooth. Bearing surface, that need to endure heavy loads under many cycles of loading, such as hip joint replacements, must have highly polished surfaces, with a typical surface roughness of 0.3 microns so as to minimize abrasive wear. Good circulation of lubricant is important so that wear particles can be removed and not rub against the bearing surfaces causing even more wear.

Fatigue wear

Repetitive loading produces subsurface cracks and particles, or sheets of material subsequently delaminate and are lost from the surface.

In total hip arthroplasties, abrasive and adhesive mechanisms are the most important. With the highly conforming surfaces in total hips, fatigue wear appears far less important than in total knee arthroplasties.

IMPLANT DESIGN⁷²

The ultimate goal of a biomechanically stable hip joint is by restoration of the normal centre of rotation of the femoral head which is influenced by:

1. Vertical height (vertical offset)
2. Medial offset (horizontal offset)
3. Version of the femoral neck (anterior offset)

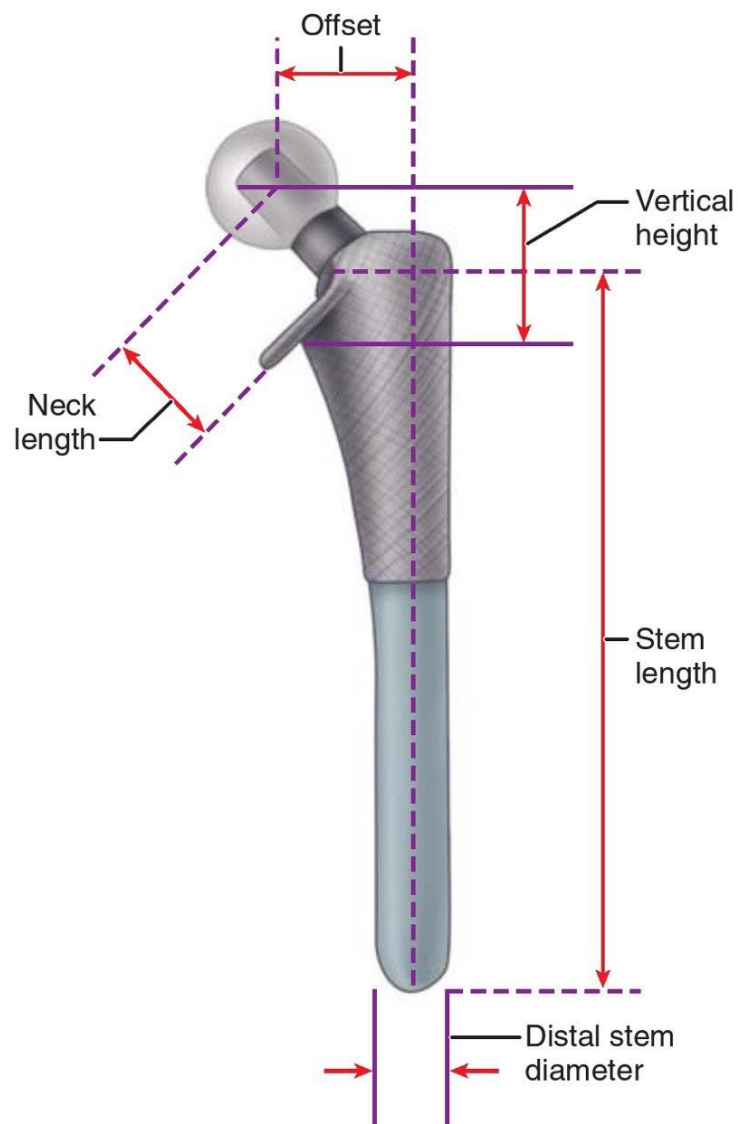


Figure 57: FEMORAL COMPONENT FEATURES

VERTICAL OFFSET

Vertical height and offset increase as the neck is lengthened. Modern implants use modular heads with variable internal recesses that fit onto a Morse taper on the neck of the stem with neck length typically ranging from 25 to 50 mm and adjustment of 8 to 12 mm for stem size available.

Vertical height (vertical offset) is determined by base length of the prosthetic neck plus the length gained by the modular head along with depth of implant insertion into the femoral canal

HORIZONTAL OFFSET

Horizontal offset is the distance from the centre of the femoral head to a line through the axis of the distal part of the stem and is primarily a function of stem design.

Higher offset stems create a larger abductor moment arm, decreasing hip joint reaction force with a corresponding reduction in the abductor force and decreased risk of impingement. The disadvantage being increased soft tissue tension and potential trochanteric pain. Intentional increase of femoral offset can be used to augment hip stability with the disadvantage being potential

trochanteric bursitis and gluteal pain. Decreasing the horizontal femoral offset may lead to increased hip joint reaction forces, instability, abductor weakness and gluteus medius lurch, bone impingement and dislocation.

Reduction of the neck-stem angle increases offset but reduces vertical height. When the neck is attached more medially, offset is increased without changing height where leg length is unaffected.

VERSION

Version refers to the orientation of the neck in reference to the coronal plane and is denoted as anteversion or retroversion. Restoration of femoral neck version is important in achieving stability of the prosthetic joint. The normal femur has 10 to 15 degrees of anteversion of the femoral neck in relation to the coronal plane when the foot faces straight forward. Proper neck version usually is accomplished by rotating the component within the femoral canal.

FRICTION PROPERTIES OF THE BIPOLAR

The Bipolar system functions with wear at two levels not one. This is accomplished by having a 22 mm diameter low torque bearing within a polyethylene head so that the shear stresses on acetabular cartilage are reduced.

Geometric relationship of this 2 layer system between a 22 mm internal bearing and the larger prosthetic outer head acting within the acetabulum allows the coefficient of friction of metal on polythene and metal on articular cartilage to function in tandem. It follows then that the friction of the prosthetic head within the acetabulum is greater than that required to move the 22 mm artificial bearing which is machined precisely to fit in a polythene socket.

In addition, the design of the inner bearing limits motion to a range which accommodates that required for normal activities such as: walking, climbing stairs and moving from a sitting to a standing position. Such restriction of range of motion of the inner bearing avoids the possibility of prosthetic head moving into an unfavourable varus position with the femur in neutral position.

The system is locked by a thin outer metal shell snapping on the polythene head securely locking the whole mechanism. The absence of a fixed bearing eliminates acetabular complications inherent in a fixed cup.

The implant has functioned well without mechanical flaws. It is felt that near physiological shear stress levels at the cartilage prosthetic head interface is largely achieved. The system has resulted in minimal wear at both the inner and outer bearings. The single assembly implant has provided safety and security as major factors for its increasing usefulness.

MECHANISM OF THE IMPLANT

The implant was designed to permit major motion at the inner bearing, which is geometrically perfect, so that complementary motion follows at the outer bearing triggered by even minimal irregularities of the articular cartilage. Articular cartilage then acts as a brake on outer bearing action while inner bearing motion continues uninterrupted.

It was essential to assess the implant function in a weight bearing or walking stance. The radiographic studies showed that the implant functioned as designed in all examples, but the range of respective motion between inner and outer bearing varied to a degree according to the pathological state.

In common applications then, the results were:

Fractures: 82% inner bearing & 18% outer bearing dominance.

Osteoarthritis: 95% inner bearing & 5% outer bearing dominance.

Osteonecrosis < 50 yrs: Action was almost a balanced one with 50% at inner bearing & 50% at outer bearing.

Osteonecrosis > 50 yrs: Motion was 70% at inner bearing & 30% at outer bearing.

The inner bearing motion increased significantly with weight bearing.¹⁰²

EROSION OF ACETABULUM BY MIGRATION

An early prediction was that the Bipolar implant would simply act as a single unit, similar to the fixed stem Moore prostheses, and so be subject to a likelihood of acetabular penetration.

There is minimal acetabular erosion while using bipolar prosthesis when compared to unipolar system. The common denominator in protecting the acetabulum is the preservation of the subchondral layer of bone.

It is possible to contour the acetabular floor to provide an accurate seat simply by using a hand held 1 inch burr rather than the heavy total acetabular reamer. In this fashion, there are always islands of articular cartilage which survive and these have to be supported by subchondral bone, so that a scaffolding of safe control is provided.

The acetabular floor retains a regenerative property which will regenerate bone and even hypertrophic subchondral layers from the stimulation of weight bearing with an accurately fitted bipolar cup.

DISLOCATION AND INSTABILITY

It was predicted initially that the bipolar implant would have considerable instability and probably sufficient to favour frequent dislocation. The

infrequency of dislocation with the bipolar implant has made it not to be considered a potential complication. Confidence in the security of the bipolar implant has recently been highlighted by their use in salvage of failed total hips as replacement for the femoral portion, so that, in essence, there is a tripolar property or motion at 3 levels.

WEAR PROTECTION WITH THE USE OF BIPOLAR IMPLANTS:

There are many factors favouring this hypothesis:-

1. The floating or mobile outer head has far less tendency to stick to the acetabulum to form a surface adhesion compared to the fixed acetabulum of a 2-piece arthroplasty.
2. Socket loosening cannot happen with the bipolar system, because of the controlled bearing units.
3. There is no "rock-like" facing of metal backing to favour pressure grinding-like action on the polyethylene insert. Metal backing of the acetabular cup provides a rigid wall favouring a grinding element from pressure.
4. A 2-piece as opposed to a 1-piece system always has greater polyethylene content which can be eroded.

5. Perfect congruity in 2-piece pressures is never obtained, because of the difficulty in estimating angle variation from the stem to the socket.
6. A 1-piece unit is perfectly machined, giving perfect congruity.
7. The controlled head can never be out of alignment, because its socket moves with the stem.
8. Propensity for adjustment is totally lost with 2-piece implants, once any loosening starts.
9. The Bipolar adjusts within the acetabulum to a position of stability, but even minute head motion alters stress on the acetabular floor so that trabecular fatigue does not occur.
10. In metal backed cups, there is a crushing element thrust, because the natural resiliency of the living acetabular floor is lost.
11. The acetabulum is a living layer with vitality in the subchondral bone which too frequently is excised for acetabular cup fixation. No such hazard exists with the bipolar head.
12. The single assembly is a safer system with the implant encasing a multiple bearing insert locked in place.

MATERIALS AND METHODS

A prospective study on about 30 patients meeting the inclusion and the exclusion criteria during the study period from November 2016 to October 2018, admitted to R. L. Jalappa hospital attached to Sri Devaraj Urs Medical College, with minimum 6 months follow up period, will be taken up for the study after obtaining the informed consent

INCLUSION CRITERIA

Unstable intertrochanteric fracture (Boyd and Griffin Type II, III and IV)

Patient more than 60 years of age

EXCLUSION CRITERIA

Pathological fractures

Associated ipsilateral fractures of shaft of femur and tibia

Polytrauma patients

Previously non-ambulatory patients

Patients unfit for surgery

PREOPERATIVE EVALUATION:

After patient's admission detailed history regarding mode of injury, associated co-morbid condition was taken. Clinical assessment of the patients was done in detail. Oral or parenteral NSAIDs were given to relieve the pain.

The following investigations were done routinely on all these patients preoperatively.

Blood investigations includes Haemoglobin %, blood grouping and Cross matching, fasting and Post prandial blood sugar, serum electrolytes, blood urea and Serum creatinine.

Consent was obtained for the participation in the study and for the procedure after explaining the options available, details and complications of the procedure.

PREOPERATIVE PREPARATION:

Injection Xylocaine 0.5cc intradermal and injection TT 0.5cc was intramuscular given the day prior to surgery. Intravenous antibiotic were given an hour before the surgery.

The back, lateral aspect of the hip from the iliac crest to the distal thigh, groin was prepared.

SURGICAL TECHNIQUE^{103,104}

Position of patient : Lateral decubitus position. Padding of bony prominences. Operative limb was allowed to be mobile to allow for checking stability during procedure.

Surgical Approach: Posterolateral Gibson approach

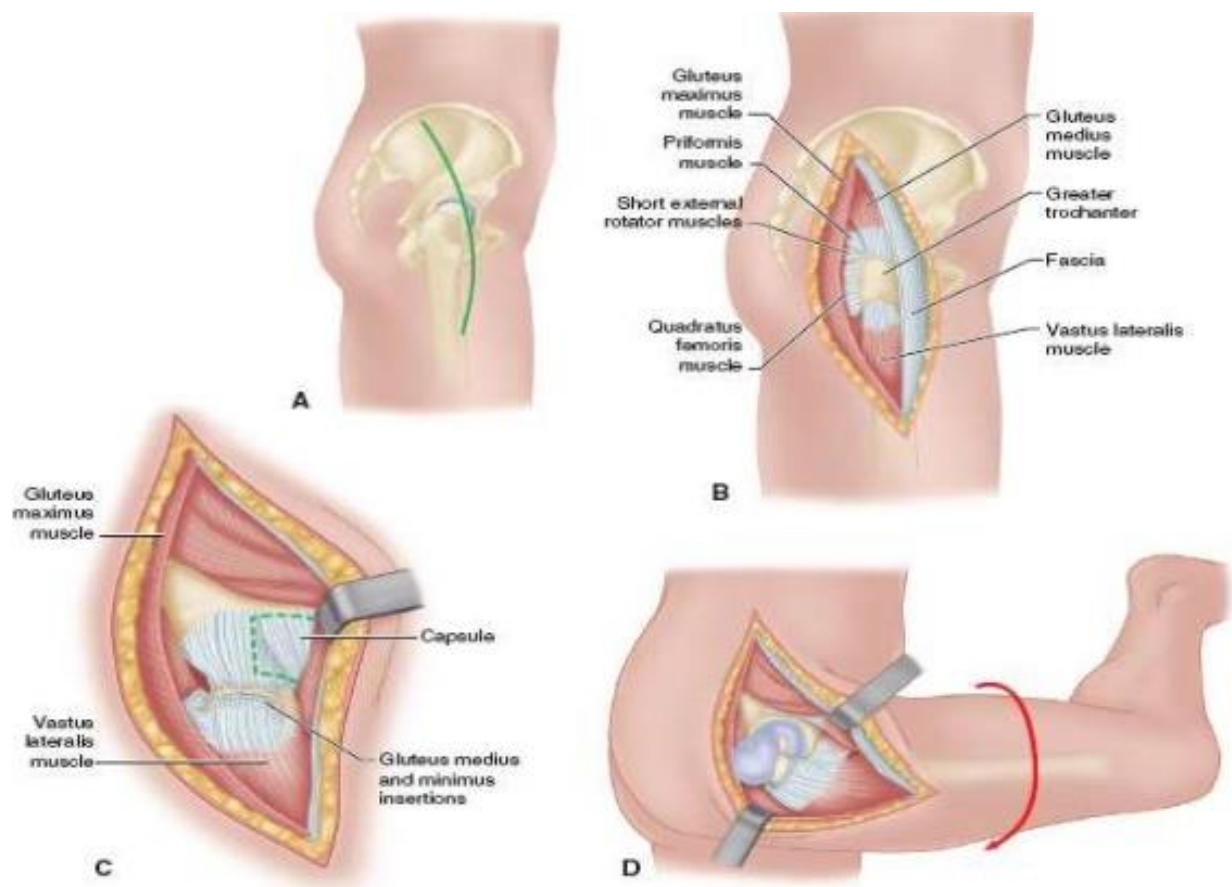


Figure 58: POSTEROLATERAL GIBSONS APPROACH

PROCEDURE

All surgeries were performed through Gibson's postero-lateral approach. The proximal limb of incision starts from a point 6-8 cm anterior to the PSIS just distal to the iliac crest extending distally along the anterior edge of greater trochanter up to 10-12 cm along the line of femur shaft. ITB was incised along its fibres from distal to proximal up till GT.

Proximally fibres of gluteus maximus were dissected along skin incision to expose fracture site. In cases with lateral wall comminution care was taken to maintain the integrity of gluteus medius and vastus lateralis. In cases where greater trochanter was fractured femoral head was approached through fracture

After careful dissection of fracture site and retraction of fracture fragments of greater trochanter, base of femur neck was approached. We extracted femur head and the attached neck through this trans-trochanteric window.

With the removal of the head, the fracture now had three main fragments namely the greater trochanter, the lesser trochanter and the shaft with defective neck and posteromedial cortex. Isolated displaced fragments of the lesser trochanter were reduced and fixed with stainless steel wire which was placed through a drill hole in the lesser trochanter. The fragments of the greater trochanter were provisionally reduced over the distal femur fragment with

tension band wiring. In cases where posteromedial cortex was severely defective, bone graft obtained from femoral head and neck was used to reconstruct the calcar. Trial prosthesis was inserted after broaching with special attention to anteversion and vertical offset. With trial prosthesis reduction was achieved and checked for following as present below.

Few essential steps in performing hemiarthroplasty in unstable inter trochanteric fractures that we followed are:

1. Maintaining the version (anteversion-retroversion) of the prosthesis: In cases where anatomical reference point of lesser trochanter, due to comminution could not be taken, version in all such cases was determined using the imaginary transcondylar axis of the lower end of the femur as a guide.

2. Maintaining the vertical offset: In severely comminuted fractures, it was difficult to determine the prosthesis length properly because of loss of anatomical landmarks like trochanters. Femoral medullary canal was broached to appropriate stem size. Trial reduction was performed to determine the exact length that will bring the knee of the operating limb at level with the opposite limb, provide adequate soft tissue tension, that keeps the prosthesis in congruence. The definitive femoral stem was inserted into the femoral canal containing cement to the exact length and version as determined by trial prosthesis.

3. Cementing: Second generation cementing technique was done in all cases. Hand mixing of cement was done. Use of cement restrictor, cement gun, delivering cement in a retrograde fashion when in doughy state with drain inside canal was performed in all cases. Care was taken to prevent cement in between fracture fragments. Any protrusion of cement between fragments was cleaned out using curette.

4. Reconstruction of greater and lesser trochanter: In cases where the greater trochanter was the fracture en mass, it was reattached to the main shaft using steel wires. In cases where the greater trochanter was coronally split a tension band was applied beneath the gluteus medius tendon and a bony tunnel was drilled in the distal greater trochanter. The gluteus medius, greater trochanter, and the vastus lateralis apparatus were maintained in continuity as a stable lateral sleeve. This was then fixed loosely to the shaft fragment with steel wires. In cases where both greater and lesser trochanters were comminuted, they were both segregated together with the ethibond sutures to form separate masses and were reattached to the shaft after the insertion of a cemented femoral stem. Thus at the end of reconstruction, the greater trochanter, the lesser trochanter, and the shaft were wired together using steel wires.

POST OPERATIVE PROTOCOL

A compression bandage was applied to the lower limb and heparin was given subcutaneously to prevent DVT for 3 days. Blood haemoglobin was assessed postoperatively and blood transfusions were given whenever required. Intravenous Augmentin was given for one week. Diclofenac 75mg or tramadol was given intravenous for analgesia.

After 48 hours wound was inspected for check dressing and vacuum drain was removed. Suture removal was done on the postoperative day 14. Patients were followed up at an interval of 4 weeks, 6 weeks, 3 months and 6 months.

PHYSIOTHERAPY PROTOCOL¹⁰⁵

Patients were mobilised on bed in the first or second day itself and then from bed to chair mobilisation was done on second or third day onwards. This was followed by mobilisation using walker and gait training under supervision.

PRECAUTIONS for first 6 WEEKS -

- Pillow under ankle while sleeping
- Wedge pillow between legs while sleeping
- Weight-bearing as tolerated unless otherwise stated with walker

- No Flexion > 90 degrees, No Adduction past midline. (no leg crossing) , No Internal Rotation

Plain X-ray of Pelvis involving both hip was taken post operatively and evaluated.

FOLLOW UP

- Patients were analysed clinically and radiologically at each follow up visit.
- Radiologically the patient was assessed for position of stem, stem loosening or subsidence, periprosthetic fracture.
- Clinical and functional assessment was done using modified Harris hip score at each visit.
- Any other complication during the post-operative period was noted down and managed.
- Harris hip score is a validated 15 item questionnaire in which scores range from 0 to 100.

< 70	Poor
70-79	Fair
80-89	Good
90-100	Excellent

RESULTS

The following observations were made in our study conducted between November 2016 and October 2018

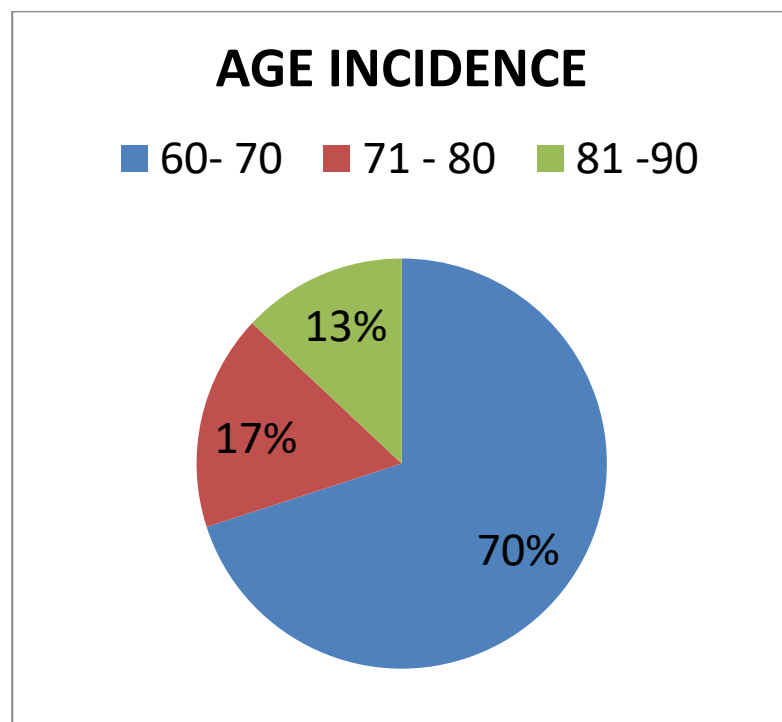
Total number of patients included in the study were 30 unstable intertrochanteric elderly patients treated with primary cemented modular bipolar hemiarthroplasty.

1. AGE DISTRIBUTION

Average age in our study was 70 years and maximum patients belonged to age group 60-70 years

Age	Number of patients	Percentage
60-70	21	70
71-80	5	17
81-90	4	13

CHART 1:

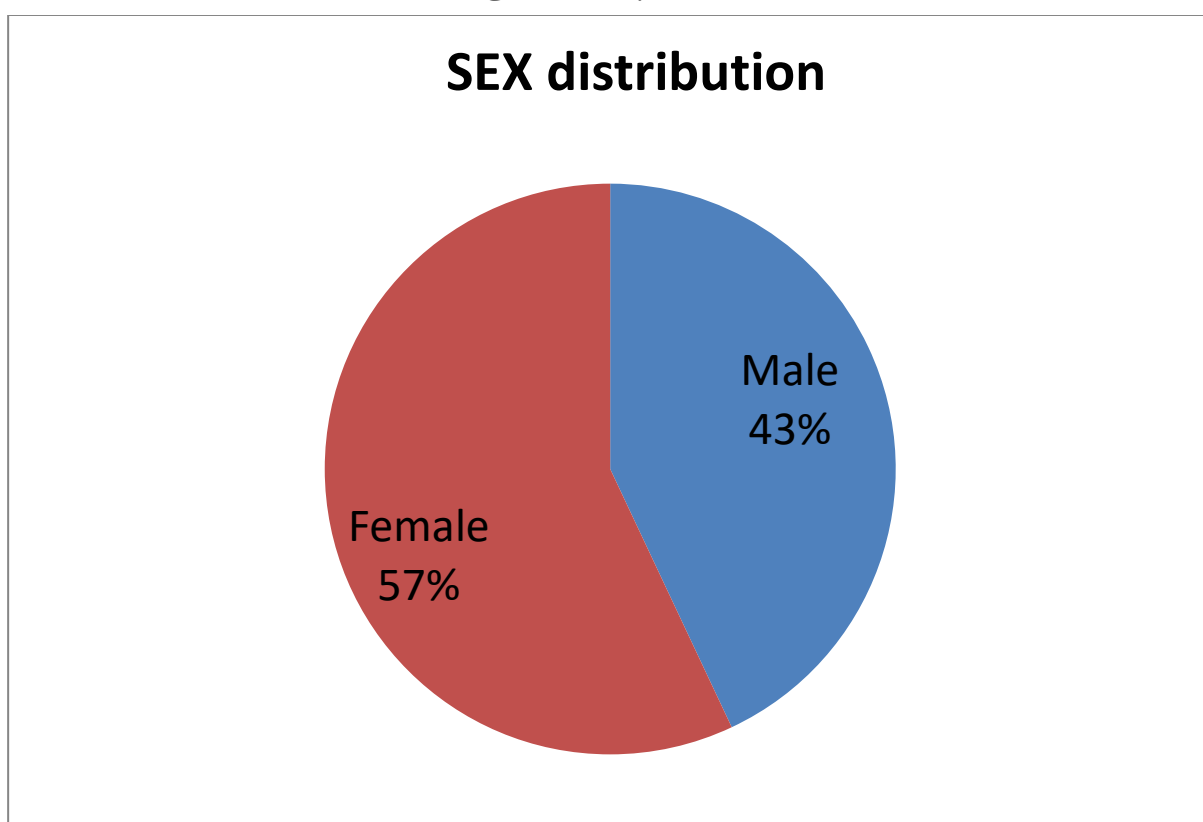


2. GENDER DISTRIBUTION

There were 17 females (57%) and 13 males (43%) in our study

Gender	No.	Percentage
Male	13	43
Female	17	57

CHART 2:

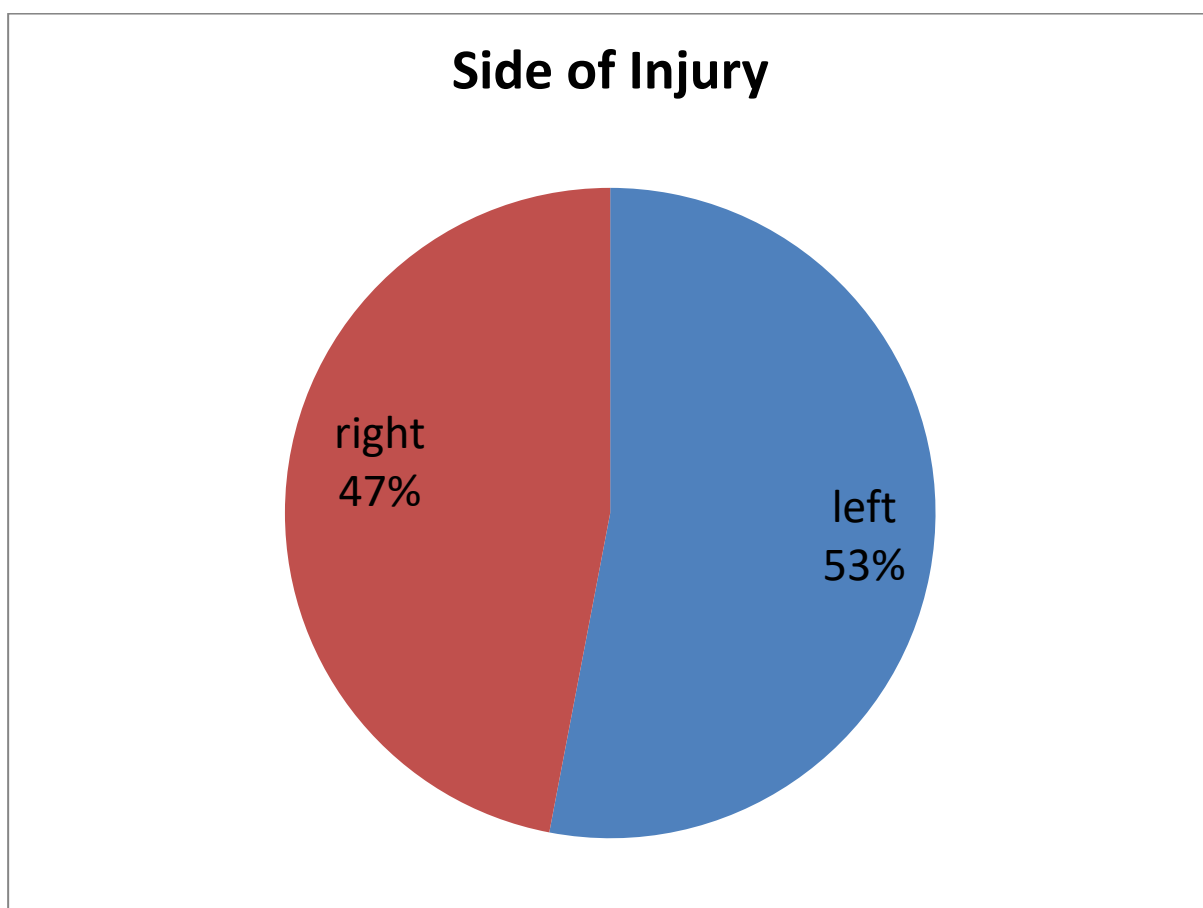


3. SIDE INVOLVEMENT

16 patients (53%) had left sided injury and 14 patients (47%) had right sided injury

Side	No.	Percentage
Right	14	47
Left	16	53

CHART 3:

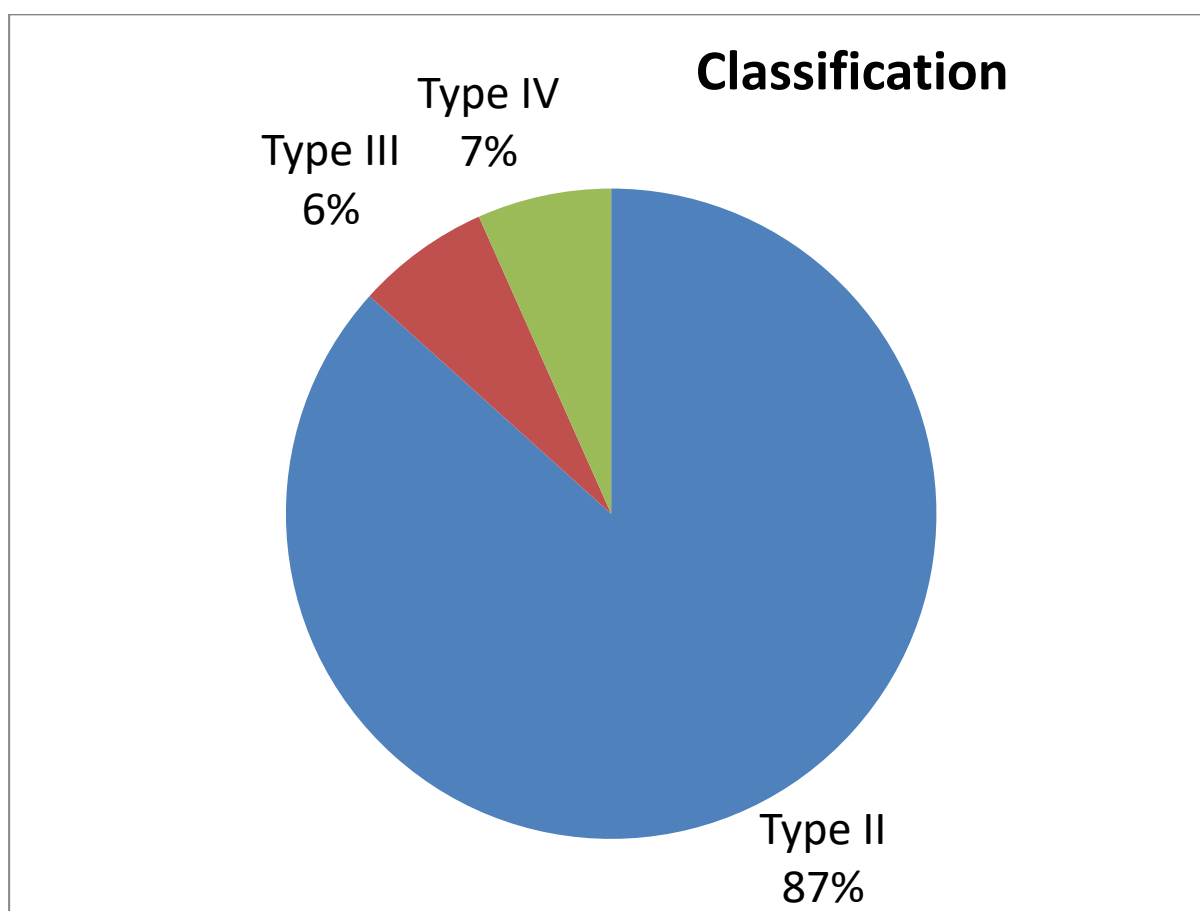


4. FRACTURE CLASSIFICATION

In our study 26 patients had Boyd Griffin type II, 3 patients had type III and 1 patient had type IV

CLASSIFICATION	No.	Percentage
Type II	26	86%
Type III	2	6%
Type IV	2	6%

CHART 4:



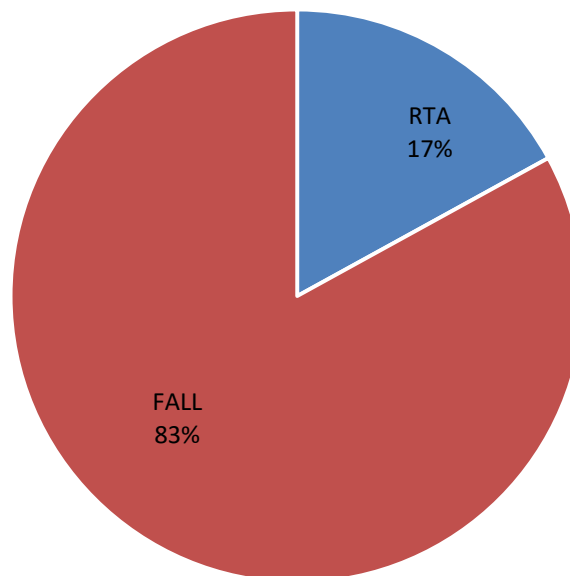
5. MODE OF INJURY

25 patients (83%) had history of fall as the cause of injury whereas for 5 patients (17%) road traffic accident (RTA) was the mode of injury.

MOI	No.	Percentage
Fall	25	83
RTA	5	17

CHART 5:

MODE OF INJURY

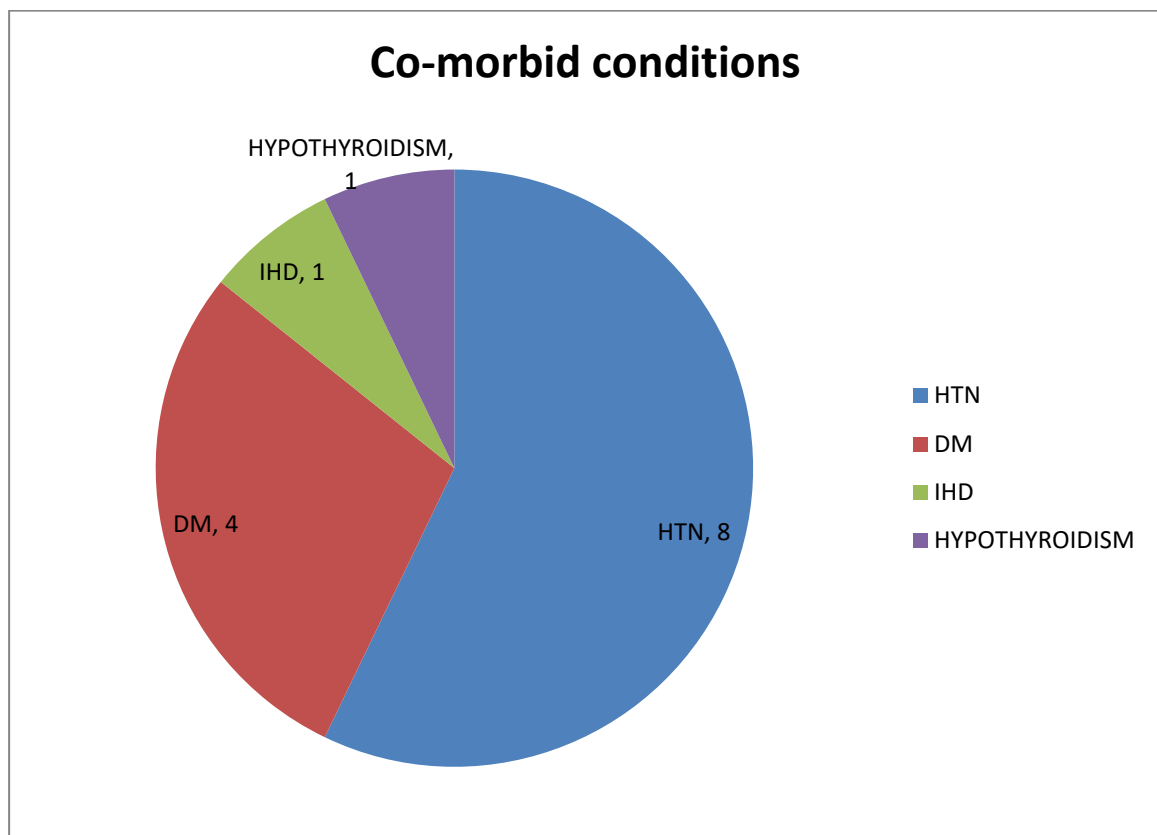


6. ASSOCIATED CO-MORBID CONDITIONS

14 Patients had associated co-morbid conditions. Out of which 8 patients were hypertensive, 4 had type 2 diabetes mellitus, 1 ischemic heart disease (IHD) and 1 hypothyroidism

Condition	No.	Percentage
Hypertension	8	27
Diabetes mellitus	4	13
IHD	1	3
Hypothyroidism	1	3

CHART 6:



7. Time to surgery

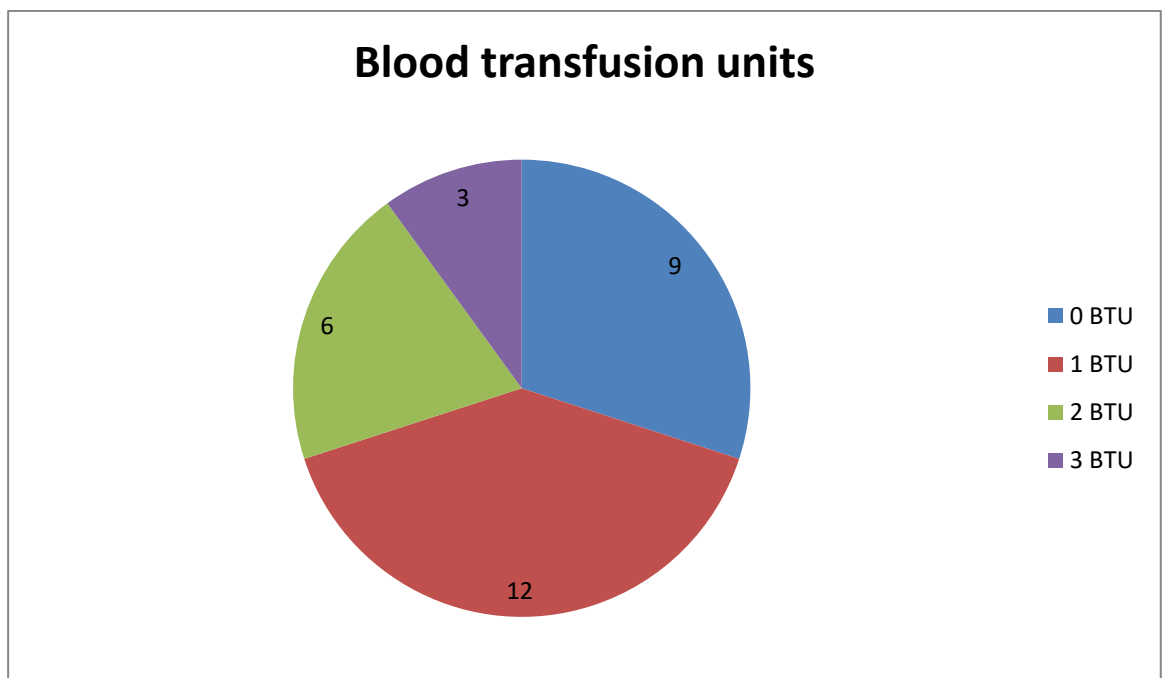
Mean time from injury to surgery was 6.06 days

8. Mean time taken for surgery was 90 minutes

9. A total of 21 cases required blood transfusion all of which were uneventful

BTU	No. of cases
0	9
1	12
2	6
3	3

CHART 7:



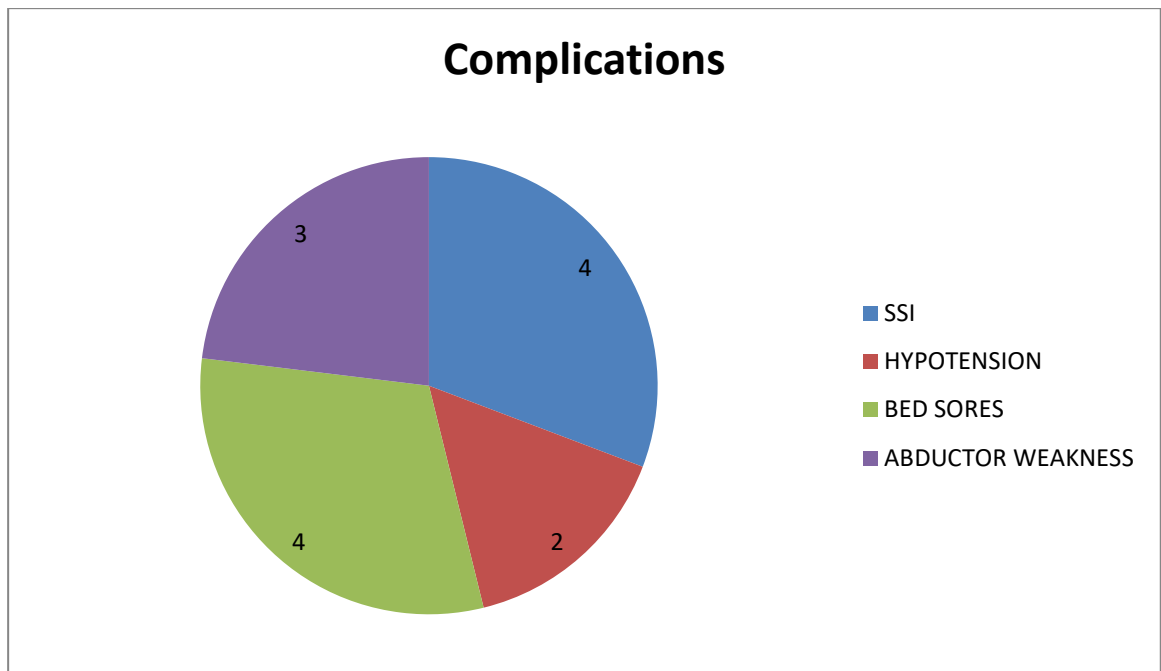
10. Mean hospital stay was 14.5 days.

11.COMPLICATIONS

A total of 13 cases (33%) had post-operative complications. 4 patients had surgical site infections and 4 patients had bed sores and 3 had abductor weakness.

Post-op complication	No.(cases)
Surgical site infection	4
Hypotension	2
Bed sores	4
Abductor weakness	3

CHART 8:

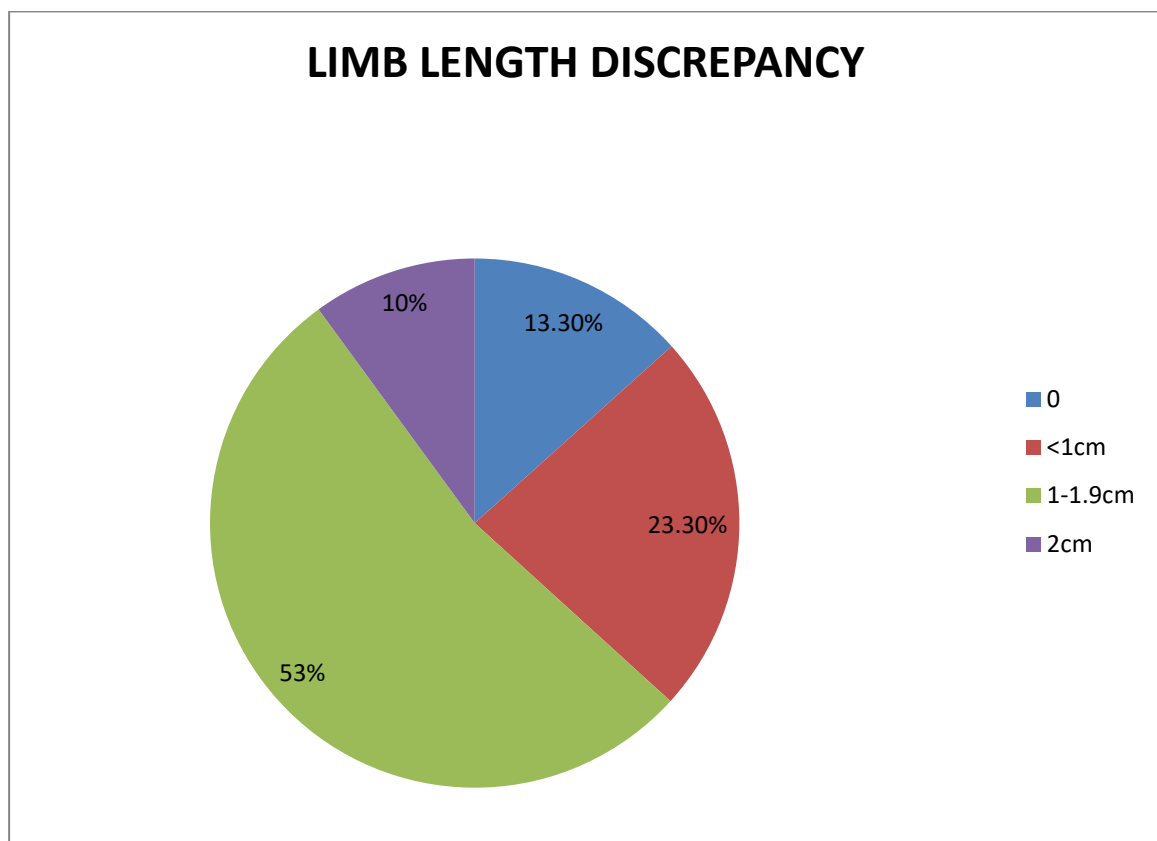


12. LIMB LENGTH DISCREPANCY

3 patients had limb length discrepancy of 2 cm and none had >2cm shortening

LLD	No. of cases	Percentage
<1CM	7	23.3
1-1.9CM	16	53
2CM	3	10
Nil	4	13.3

CHART 9:

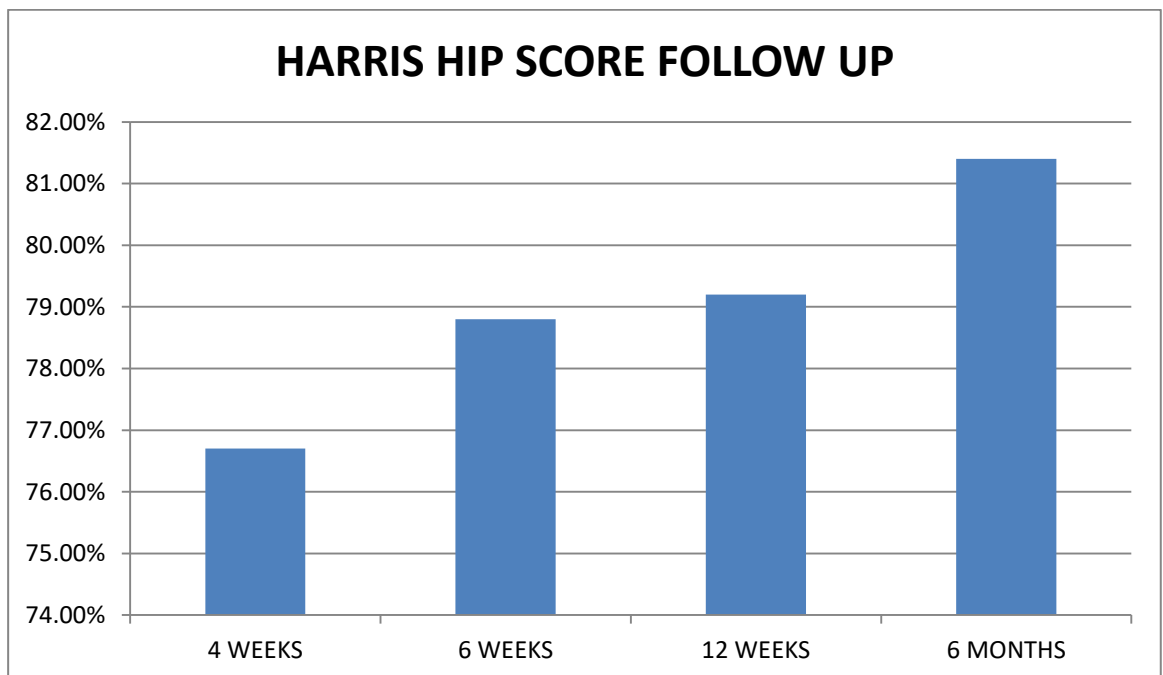


13. HARRIS HIP SCORE- FUNCTIONAL OUTCOME ANALYSIS

Patients were clinically assessed using Harris Hip score during each follow up visit.

Follow up period	Harris Hip Score
At 4 weeks	76.7
At 6 weeks	78.8
At 12 weeks	79.2
At 6 months	81.4

CHART 10:



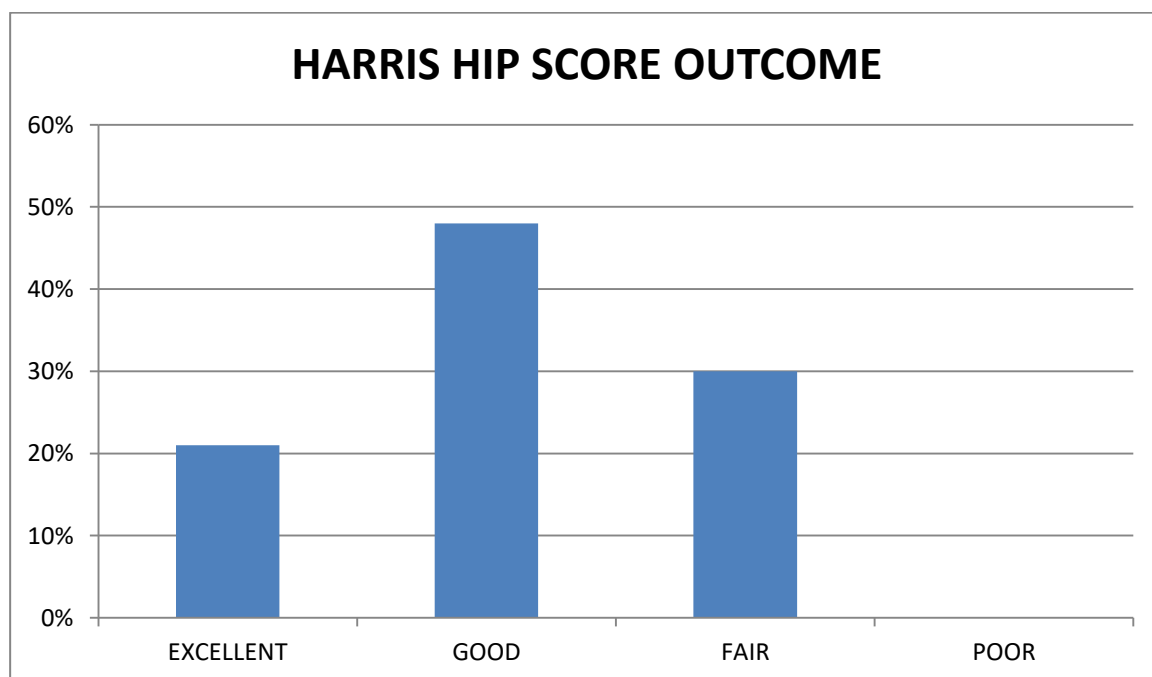
HARRIS HIP SCORE AT 6 MONTHS

One patient died after 4 weeks due to myocardial infection.

Out of 29 patients, 69% of patients had excellent and good results

HHS	No.	Percentage
Excellent	6	21
Good	14	48
Fair	9	31
Poor	0	0

CHART 11:



14. Mean bed to chair time was 1.16 days and involved static and dynamic quadriceps exercises

15. Mean chair to walker time was 3.1 days with gait training done in the hospital under supervision.

CASE ILLUSTRATION

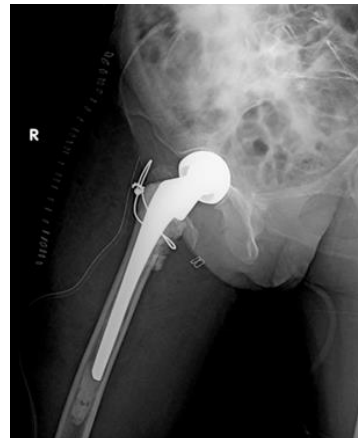
CASE 1

TYPE II BOYD & GRIFFIN INTERTROCHANTERIC FRACTURE

PREOPERATIVE RADIOGRAPH:



IMMEDIATE POST OPERATIVE RADIOGRAPH:



FINAL FOLLOW UP RADIOGRAPHS:



CLINICAL PICTURE :

FINAL FOLLOWUP

HIP MOVEMENTS : RIGHT HIP



ACTIVE ABDUCTION



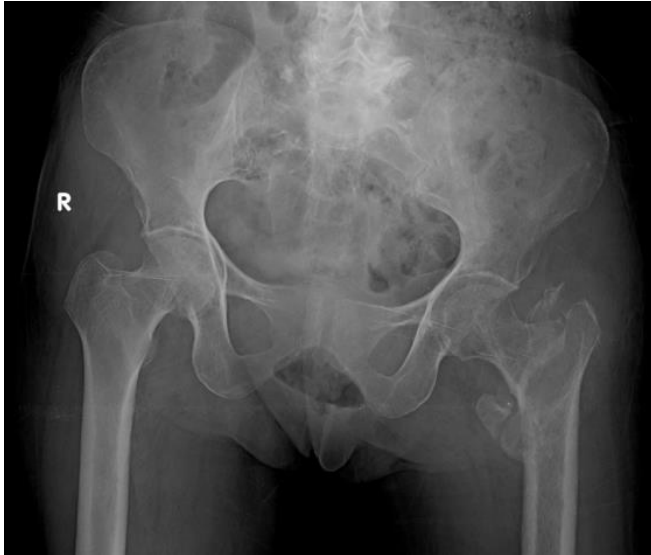
ACTIVE FLEXION



CASE 2

BOYD & GRIFFIN TYPE II IT FRACTURE

PREOPERATIVE RADIOGRAPH:



POST OPERATIVE RADIOGRAPH:



IMMEDIATE POST OP

6 MONTH FOLLOW UP

CLINICAL PICTURE :

FINAL FOLLOW-UP

ACTIVE ABDUCTION



ACTIVE FLEXION



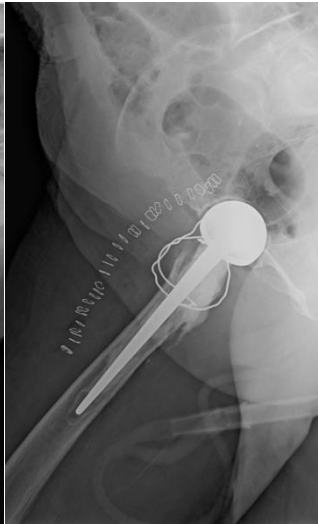
CASE 3

TYPE II BOYD & GRIFFIN IT FRACTURE - RIGHT FEMUR

PREOPERATIVE RADIOGRAPH:



POST OPERATIVE RADIOGRAPH:



IMMEDIATE POST OP

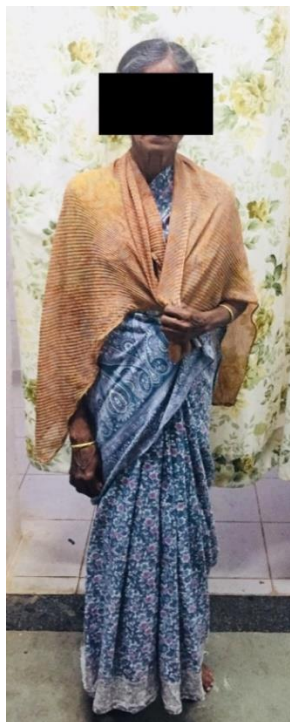
6 MONTH FOLLOWUP

CLINICAL PICTURE

CLINICAL PICTURE

FINAL FOLLOW UP:

ACTIVE ABDUCTION



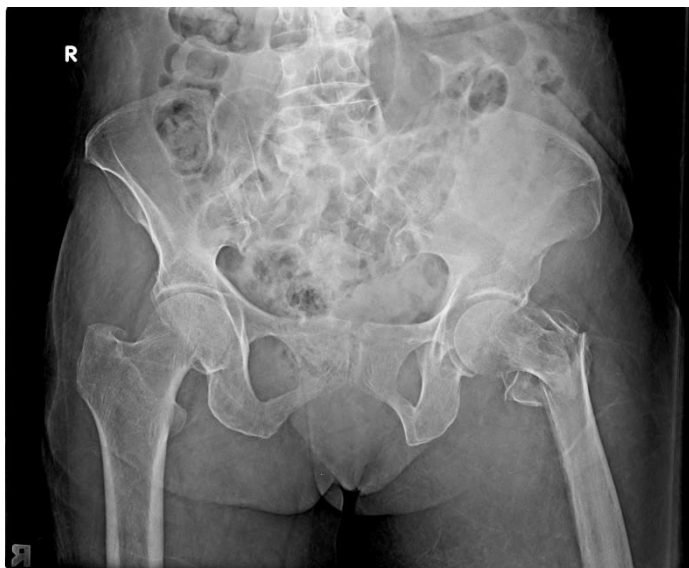
ACTIVE FLEXION



CASE 4

TYPE II BOYD & GRIFFIN INTERTROCHANTERIC FRACTURE LEFT FEMUR

PREOPRADIOGRAPH



IMMEDIATE POST OP RADIOGRAPH FOLLOWUP



FINAL



COMPLICATION

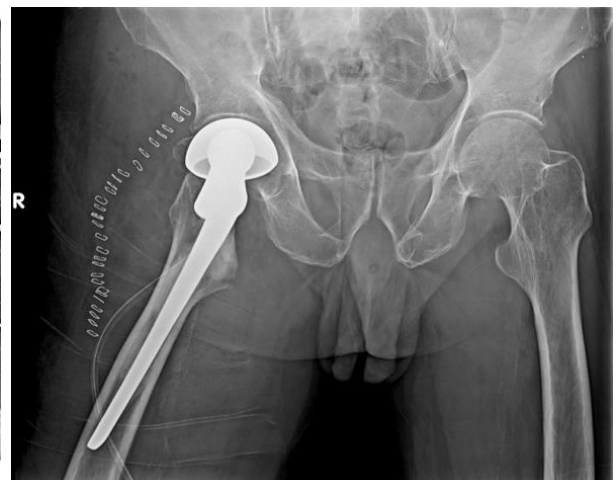
CASE 5: TYPE II BOYD & GRIFFIN INTERTROCHANTERIC FRACTURE LEFT FEMUR

RADIOGRAPH

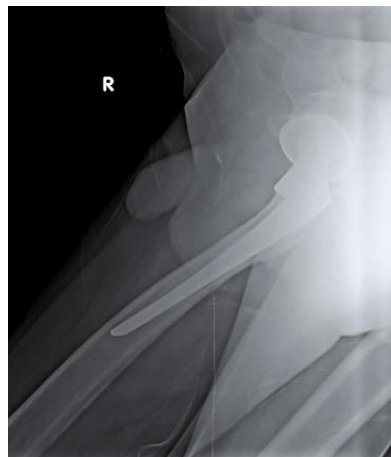
PREOPERATIVE



IMMEDIATE POST OPERATIVE



FINAL FOLLOW UP RADIOGRAPH:



CLINICAL EXAMINATION:

WALKER ASSISTED AMBULATION

TRENDELENBURG GAIT



DISCUSSION

The management of intertrochanteric fractures has evolved over time with the present treatment dominated by internal fixation methods. Although giving optimal results in most stable fracture patterns their usage in unstable IT fractures has been afflicted with complications and remains a matter of debate among the surgical community. Internal fixation with dynamic hip screw, proximal femoral nail and hemiarthroplasty are the most common treatment options available.

High failure rate ranging from 50-56% was noted with internal fixation of unstable fractures was noted in studies by Sinno et al., Kyle et al., and Haidukewych et al.^{5,30,58}

Early weight bearing in physiologically elderly and osteoporotic patients leads to fixation failure and poor results. Hence they are bedridden for prolonged duration in the post-operative period which has damaging effects on their overall health and wellbeing. The fracture itself might not produce severe moribund effects but the recumbency that it entails adversely increases the chances of mortality and morbidity in these elderly patients.

Hemiarthroplasty is a frequently employed alternative as it gives stability and allows early full weight bearing. Most of the complications associated with internal fixation are avoided with the use of prosthetic replacement. Although

the direct benefits of hemiarthroplasty might not be obvious in the outset, the patients returning to a better level of activity, close to pre-injury levels which not afforded by internal fixation, has good proven favour for the advent of hemiarthroplasty.

Initially hemiarthroplasty was used only in the treatment of failed fixation of intertrochanteric fractures. However its benefits soon saw in its primary application with Tronzo in 1974 being the first surgeon to use long- stem Matchett Brown endoprosthesis for the primary treatment of intertrochanteric fractures.²⁹ This encouraged further research in the use endoprosthesis for IT fractures and soon other surgeons started reporting good results with the use of various prosthesis. Even though several decades have passed since, the use of endoprosthesis for unstable IT fractures still remains a controversy among the surgical community.

Our study aims to further the research in this aspect and was conducted on 30 patients in a rural population with intertrochanteric fractures reporting to our tertiary care centre over a period of 2 years with 6 months follow up period.

This study in a rural population posed significant challenges with respect to lack of awareness of disabilities post injury and significant financial constraints. The patients and their family were counselled and aided when feasible to receive appropriate treatment. Although the socioeconomic scores

were not a parameter of this study, the aim is to show that hemiarthroplasty surgery can be justified even in constrained populace as its benefits far outweigh their usual advocated deficiencies. Rural population is also more active in their lifestyle compared to urban areas and hence the benefit of early rehabilitation also has compounding benefit in this population.

The average age for intertrochanteric fractures in our study was 70.06 years whereas the mean age in studies conducted by Gashi et al was 76 years , by Xiang ping Lou et al was 81 years, by Suresh Babu et al was 77 years, by Skender Ukaj et al was 78 years and 80 years in a study conducted by Thakur et al. 75.6 years in a study conducted by Rodop et al. 80.4 years by Stern et al. 82.2 years by Stuart Green et al. Inter trochanteric fractures occur more commonly in elderly due to generalized osteoporosis, reduced soft tissue over bone and decreased reflexes. The lower mean age in our study can be attributed to the fact that most elderly patients, in their later decades were unwilling for surgery and received conservative management.^{106-110,57,51,52}

In our study, 53% females and 47% males were included . A study by Gashi et el had 62% females and 38% males. Xiang Ping et at studied 31% men and 69% women whereas 73% were females and 27% were males in a study conducted by Suresh Babu et al and 57% females and 43% males by Skender Ukaj. Rodop et al included 63% women and 37% men in his study. 78% females and 22% males in a study conducted by Stern et al and 75% men , 25 %

women were studied by Stuart Green et al. Based on most other studies including study, it can be observed that females are more affected than males. This can be attributed to poor bone quality due to more pronounced osteoporosis commonly seen in post-menopausal women.^{106-110,57,51,52}

Mode of injury in our study was fall in 83% of patients and road traffic accidents in 17% of patients almost similar to a study conducted by Gashi et al where 96% of patients sustained intertrochanteric fracture after a fall. As seen in other studies our study too had a higher incidence of a trivial fall causing an IT fracture. This is an indication of the poor bone quality which can be a significant factor towards the choice of implant, with hemiarthroplasty circumventing many of the challenges associated with osteosynthesis.⁵⁷

Associated co-morbid conditions were present in 46% of patients in our study .In a study conducted by Xiang Ping et al , 64% of patients had co-morbid conditions. In both the studies, Hypertension was the predominant co-morbid condition. Elderly patients are prone to develop co-morbidities which need to be appropriately managed¹⁰⁶

Time taken from injury to surgery was 6.06 days in our study. Whereas it was 5.61 days in a study conducted by Suresh Babu et al, 5.61 days in a study by Sancheti et al, 3.5 days by Atul Patil et al and it was 7.1 days in a study conducted by Rodop et al. The delay in time taken from injury to surgery was

because of patients presenting late, associated co-morbid conditions which required stabilization before surgery.^{108,10,65,57}

Average time taken for surgery was 90 minutes which was similar to study conducted by Xiang Ping et al (90 minutes). 96 minutes by Suresh Babu et al, 62.6 minutes by Skender Ukaj et al, 120 minutes by Meghanath et al, 96 minutes by Thakur et al, 71 minutes in a study conducted by Medagam Reddy et al and 40 minutes by Rodop et al. All procedures were done by senior surgeons in our study to achieve a less than average operating time. The increasing experience with hemiarthroplasty procedure and better implant designs has brought down the surgical time associated with this procedure.^{107-9,110-2,57}

STUDY	SURGICAL TIME(Minutes)
Xiang Ping et al	90
Suresh Babu et al	96
Skender Ukaj et al	62.6
Meghanath et al	120
Thakur et al	96
Medagam Reddy et al	71
Rodop et al	40
Our study	90

The mean hospital stay after surgery in our study was 14.5 days . In other similar studies it was 19.5 days (Xiang Ping et al), 10.96 days (Suresh Babu et

al), 9.6 days (Skender Ukaj), 17.5 days (Thakur et al). The patients received physiotherapy for the entire duration of hospital stay and received gait training before being discharged.¹⁰⁷⁻⁹

COMPLICATIONS¹⁰⁶⁻¹¹²

In our study, 4 patients had surgical site infections all of which were superficial and 4 patients had bed sores and 3 had abductor weakness.

In a similar study by Megadam et al, 4.7% patients developed bed sores, 9.5% had wound dehiscence. Xiang Ping et al conducted a study in which 8% patients developed surgical site infection, 16% had abductor weakness , 2.7% developed bed sores and 1 patient developed pneumonia. Skender Ukaj et al , in a study involving 56 patients, observed 1 case of surgical site infection. Thakur et al observed 1 case of SSI and 1 case of Bed sore in a study conducted on 42 cases.

Gashi et al observed 5% infection, 3.3% deep vein thrombosis, 8.3% bed sores and 16.7% mortality on 2 years follow-up. In a study conducted by Rodop et al on 54 patients, one patient had deep infection for which prosthesis had to be removed, 4 cases of non-union of greater trochanter and 4 patients died out of which 2 were due to pulmonary embolism and the other two were unrelated to surgery. Stern et al observed 7.6% rate of complications in his study conducted on 105 patients. 3 cases had deep infections. One superficial

infection. One case had removal of prosthesis. One patient had pulmonary embolism.

Stuart Green et al studied 20 patients who underwent bipolar hemiarthroplasty for intertrochanteric fractures and observed that there were no infections or dislocations but 4 patients died out of which one died due to respiratory failure.

The patients in our study the patient with SSI received intravenous antibiotics as per the report on culture and sensitivity and all infections were resolved after the course was complete. Patients with bed sores developed due to non-compliance with physiotherapy received regular wound management and were healed before discharge with no progression in grade seen in any of the patient. Some patients developed abductor weakness and required assistance of a cane to walk in two cases and one case walked with a limp and lurch without any aid. There were no cases of deep infection, need for prosthesis removal, deep vein thrombosis, implants subsidence or loosening, dislocation or periprosthetic fractures or pneumonia in our study. There was one death in our study after 4 weeks of surgery which was due to unrelated cause (myocardial infarction).

Shortening of limb was observed in 86.7% cases in our study but none >2cm. 63 % had shortening of 1-2 cm. Skender Ukaj et al observed

shortening<2cm in 4 patients. Suresh Babu et al observed shortening of limb in all cases, average being 1.1cm. Four patients were treated by heel raise while the rest of the patients did not have any functional restriction and did not require any aid or intervention.

Functional outcome in our study was assessed using Harris Hip score. We compared our outcome to similar other studies. Harris hip score at 3 months follow up in our study was 79.2 which is a good result. Gashi et al conducted similar study and HHS at 12 weeks was 77.8 and 76 in a study conducted by Meghanath et al.

Whereas HHS at 6 months follow up in our study was 81.4 with 69% of patients having excellent to good score. In similar studies by Megadam et al HHS was 79.8 and Sancheti et al reported 71% of good to excellent results in their study. It was 65.8% by Xiang Ping et al., 39.7% by Suresh Babu et al., 45.2% by Thakur et al. and 74.5% patients had excellent to good results in a study conducted by Rodop et al.

STUDY	HHS(EXCELLENT TO GOOD)%
Sancheti et al	71%
Rodop et al	82%
Xiang Ping et al	65.8%
Suresh Babu et al	39.7%
Thakur et al	45.2%
Rodop et al	74.5%
Our study	69%

The patients in our study returned to their daily activities of living and showed considerable improvement in their psycho-social well-being after the surgery and did not have any major complications during the follow-up duration. Hemiarthroplasty apart from directly influencing the management of intertrochanteric fracture also helped patients to rehabilitate early and thus improving their general condition by avoiding prolonged recumbence which can be cause of numerous serious complications with elderly patients. Patient selection is highly important and assessment should be made for the risk-benefit ratio for the procedure and surgery done accordingly. Although most patients benefit from early rehabilitation, the complications associated with hemiarthroplasty procedure might put considerable strain on some patients who should be assessed and excluded for surgery and avail other modalities. Overall the functional benefits of hemiarthroplasty seem to far outweigh its liabilities and should be considered as a primary modality of treatment in elderly unstable intertrochanteric fracture patients.

CONCLUSION

In this study, primary modular bipolar hemiarthroplasty was performed for unstable intertrochanteric fractures in 30 elderly patients of more than 60 years in our institute, Sri Devaraj Urs medical college and research centre.

The procedure offered, faster mobilization, rapid return to pre injury level, improved the quality of life and gave a long term solution in elderly patients with intertrochanteric fractures of the femur. The bipolar hemiarthroplasty has reduced the complications of prolonged immobilisation, prolonged rehabilitation, marked residual deformities and need for revision surgeries. The potential of bipolar hemiprosthesis in myriad of indication points to its versatility.

The present study showed early return to functional level with good short to mid-term survival in our patients. There were no prosthesis related complications in our study and most patients returned to an active lifestyle with good improvement in overall general condition.

According to the results observed in our study, we are of the opinion that treatment with hemiarthroplasty may be considered as the first choice of treatment in elderly patients with unstable inter trochanteric fractures which allows early mobilization and hence avoiding serious complications of prolonged immobilization.

SUMMARY

Thirty patients with unstable intertrochanteric fractures in elderly patients were treated with cemented modular bipolar hemiarthroplasty from November 2016 to October 2018.

Patients above the age of 60 years were included in the study and the average age group in our study was found to be 70 years. The majority of the patients were female (57%) and the cause was mainly due to trivial fall. Majority of the patients (86%) presented with Boyd and Griffin type 2 fracture. Our study had almost equal number of right and left sided involvement.

For all patients surgery was done under spinal anaesthesia using a cemented modular bipolar hemiprosthesis using the posterolateral Gibsons approach. Almost all cases were operated within a week of the sustenance of injury (average 6 days).

Patients were encouraged and mobilised at the earliest. They were made to sit and attempt to stand with support after 2 days post surgery and underwent physiotherapy with protected range of motion exercises and gait training as tolerated. Most of the patients were able to walk with an aid 3 days after surgery and were able to return to good level of function before being discharged from the hospital.

The functional assessment according to the Harris hip score (HHS) showed good to excellent results in most of our patients (69%) while the rest had fair results (31%) at the final follow-up. The average HHS after 1 month and three months after surgery were 76.7 and 79.2, which are good results, while the score at final followup at 6 months was 81.4 which is an excellent result.

In 4 patients (13.3%) surgical site infections were noted, all of which were superficial and 4 patients (13.3%) had bed sores and 3 (10%) had abductor weakness and received walker assisted gait training. There were no complications of deep infection, need for prosthesis removal, deep vein thrombosis, implants subsidence or loosening, dislocation or periprosthetic fractures or pneumonia in our study.

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CONSENT FOR PARTICIPATION IN THE STUDY

STUDY TITLE: FUNCTIONAL OUTCOME OF MODULAR CEMENTED BIPOLAR PROSTHESIS IN UNSTABLE INTERTROCHANTERIC FRACTURES IN ELDERLY PATIENTS IN A RURAL POPULATION

CHIEF RESEARCHER/ PG GUIDE'S NAME: Dr. ARUN H. S.

PRINCIPAL INVESTIGATOR: Dr. SARATH CHANDRA POODI

NAME OF THE SUBJECT :

AGE :

GENDER :

- a. I have been informed in my own language that this study involves pre and post operative X-ray, blood & urine investigations, surgical treatment with a modular cemented bipolar prosthesis for hemiarthroplasty, pre & post operative hospital stay and regular follow up. I have been explained thoroughly and understand its complication and possible side effects.
- b. 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.
- c. 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.
- d. 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).
- e. I confirm that _____ (chief researcher/ name of PG guide) has explained to me the purpose of research and the study procedure that I will

undergo and the possible risks and discomforts that I may experience, in my own language. I hereby agree to give valid consent to participate as a subject in this research project.

Participant's signature/thumb impression

Signature of the witness:

Date:

1)

2)

I have explained to _____ (subject) the purpose of the research, the possible risk and benefits to the best of my ability.

Chief Researcher/ Guide signature

Date:

CONSENT FORM FOR ANAESTHESIA & SURGERY

I _____ aged _____

unreservedly and in my full senses here by give my complete consent to take part in above mentioned study which includes undergoing a procedure (surgery) Modular bipolar hemiarthroplasty and screening of x-ray of hip and femur, pre operatively and post operatively and also during the following visits.

The nature and risks involved in the procedure have been explained to me in my own language , to my satisfaction. For academic and scientific purpose, the operation/ procedure may be television or photographed, or used for statistical measurements.

Date :

**Signature/Thumb Impression/
Of the Patient**

Name:

Full Address:

PROFORMA

Name : Case no. :

Age : IP/OP no. :

Sex : DOA :

Address : DOS :

Occupation : DOD :

Diagnosis :

Chief complaints :

History of presenting illness :

- Mode of the injury- Road traffic accident / Self fall / Assault
- Head injury Yes / No
- Associated injures Yes / No (specify)

Past history : K/C/O DM-T2 / HTN / ASTHMA / TB / THYROID DISORDERS / Others

Previous surgeries: No / Yes (specify)

Family history:

Personal history: Habits – None / smoking / alcohol consumption / others (specify)

General physical examination:

Vital signs

BP / mmHg

RR cpm

PR /min

Temperature - Afebrile / Febrile °F

Systemic examination

CVS

RS

CNS

PA

Local examination: Right / Left Lower limb

- Inspection- Attitude- Limb in external rotation – Yes / No
 - Swelling – present / absent
 - Deformity – present / absent
 - Wounds – present / absent
 - Other -

- Palpation - Local rise of temperature – present / absent
 Tenderness – present / absent,
 Abnormal mobility – present / absent
 Crepitus – present / absent
- Measurements - Length of the lower limb Right Left
- Movements – HIP – Flexion, extension, adduction,
 abduction, Internal and external rotations :
 KNEE –
 ANKLE – Dorsi flexion: Plantar flexion:
- Distal neuro vascular status –
 Femoral artery Palpable / Not palpable / Feeble
 Popliteal artery Palpable / Not palpable / Feeble
 Dorsalis artery Palpable / Not palpable / Feeble
 Sensory disturbances Present /absent (specify)
 Motor disturbances Present /absent (specify)
- Associated injuries

Investigations:

Blood :	Haemoglobin	TC
	ESR	DC
	RBS	Blood urea
		S. Creatinine
	HIV	HbsAg

S. Sodium

S. Potassium

Urine: Albumin

Sugar

ECG :

Radiography: X-ray of Hip and Femur – Antero-posterior and Lateral views

Right / Left intertrochanteric fracture Boyd and Griffin Type II / III / IV

Treatment :

Pre-operative

Antibiotics

- | | | |
|---|----|----|
| ☐ Inj. Taxim 1gm | IV | BD |
| ☐ Inj. Amikacin 500mg | IV | BD |
| ☐ Inj. Augmentin 625mg | IV | BD |

Analgesics

- | | | |
|---|---------|----------|
| ☐ Inj. NAC 75mg | IV / IM | BD / SOS |
| ☐ Inj. Tramadol 50mg | IV / IM | BD / SOS |

Post-operative

Antibiotics

- | | |
|---|-------|
| ☐ Inj. Taxim 1gm | IV BD |
| ☐ Inj. Amikacin 500mg | IV BD |
| ☐ Inj. Augmentin 625mg | IV BD |

Analgesics

- | | | |
|---|---------|----------|
| ☐ Inj. NAC 75mg | IV / IM | BD / SOS |
| ☐ Inj. Tramadol 50mg | IV / IM | BD / SOS |

Others

Type of Anaesthesia :

General / Spinal

Duration of surgery -

Mins

Intra operative complications – Hypotension / Femur fracture / Nerve injury /
Others (specify)

FOLLOW UP

HARRIS HIP SCORE:

6 WEEKS -

3 MONTHS -

6 MONTHS -

Complications: None / Yes (specify)

Key to master chart

HHS	Harris Hip Score
S.No	Serial Number
MOI	Mode of Injury
POD	Post op day
MI	Millilitre
MIN	Minutes
CM	Centimetre
WK	Weeks
RTA	Road Traffic Accident
TTS	Time To Surgery
BTU	Blood Transfusion Units
IOC	Intra Op Complications
POC	Post Op Complications
BL	Blood Loss
ST	Surgery Time
LLD	Limb Length Discrepancy
BTOC	Bed To Chair
CTOW	Chair To Walking
LTF	Loss To Follow Up
IMP LOS	Implant Loosening
MAN	Mantle
POST OP	Post Operative

MASTERCHART

S.NO	AGE	SEX	OP. NO.	MOI	COMORBIDITIES	SIDE	TTS	HS	PO4	PO6	PO12
1	68	M	657797	FALL	Hypertensive	RIGHT	7	13	74	76	80
2	70	F	645097	FALL	Diabetes Mellitus	LEFT	12	25	70	70	74
3	69	F	632790	FALL		LEFT	9	14	70	70	0
4	74	M	629442	FALL		RIGHT	6	10	80	84	86
5	72	M	627568	FALL	Hypertensive	RIGHT	8	9	78	86	88
6	88	M	611573	FALL		LEFT	4	8	76	80	84
7	80	F	610613	FALL	Hypertension	RIGHT	5	14	74	74	88
8	65	F	596798	FALL		LEFT	3	17	76	78	86
9	70	M	593868	FALL	Hypertension	LEFT	4	24	72	76	76
10	65	F	589725	FALL	Diabetes Mellitus	RIGHT	7	16	76	76	78
11	75	F	582967	FALL		LEFT	2	15	80	82	84
12	60	F	582529	FALL		RIGHT	3	10	82	84	86
13	65	M	577344	RTA		RIGHT	5	9	78	80	82
14	64	F	563562	FALL	Hypertension	RIGHT	8	12	70	72	72
15	64	F	554575	FALL	---	RIGHT	6	11	80	84	86
16	70	F	535483	FALL	---	LEFT	7	10	76	76	78
17	88	F	534409	FALL		LEFT	9	20	76	78	78
18	90	M	525991	RTA	Hypertension	LEFT	9	23	78	80	86
19	61	M	479781	FALL	---	LEFT	10	15	74	76	78
20	85	F	479305	FALL	---	LEFT	8	14	78	80	82
21	60	M	436216	FALL	Diabetes Mellitus	LEFT	5	15	77	79	81
22	60	M	422685	RTA	---	LEFT	5	7	80	82	84
23	70	M	419709	FALL	IHD	LEFT	7	15	82	84	86
24	80	F	391881	FALL	Hypertension	RIGHT	4	21	76	78	80
25	68	M	371723	FALL		RIGHT	7	14	82	84	88
26	64	M	357833	FALL	---	RIGHT	6	9	76	78	80
27	60	F	358611	RTA	---	RIGHT	2	8	78	80	82
28	70	F	337515	FALL	Diabetes Mellitus	LEFT	5	13	76	78	80
29	62	F	323833	FALL	---	LEFT	4	24	74	76	78
30	65	F	322194	RTA	Hypothyroidism	RIGHT	5	20	82	84	86

PO24	IOC	POC	BTU	BL (ML)	ST (MIN)	LLD (CM)	BTOC (POD)	CTOW (POD)	LTF	IMP LOS
86	Hypotension	HYPOTENSION	3	500	98	0	1	2	NO	ABSENT
76	Nil	SSI BED SORE	1	250	92	2	3	7	NO	ABSENT
0	Nil	Nil	1	350	92	1	1	3	YES	ABSENT
90	Nil	SSI	0	400	90	0.5	1	3	NO	ABSENT
88	Nil	Nil	2	400	85	1	2	3	NO	ABSENT
88	Nil	Nil	1	250	92	2	1	2	NO	ABSENT
94	Nil	HYPOTENSION	1	250	88	1	2	6	NO	ABSENT
88	Nil	Nil	0	350	80	0	1	4	NO	ABSENT
78	Hypotension	BED SORES	0	250	90	1	1	2	NO	ABSENT
78	Nil	BED SORES	0	400	86	0	1	3	NO	ABSENT
86	Nil	Nil	0	250	92	1	1	3	NO	ABSENT
88	Nil	Nil	0	350	92	0.5	2	3	NO	ABSENT
86	Nil	Nil	0	200	90	0.5	1	2	NO	ABSENT
74	Nil	Nil	2	300	100	1.5	1	2	NO	ABSENT
96	Nil	Nil	3	500	98	0	1	2	NO	ABSENT
78	Nil	Nil	1	300	72	1.5	1	4	NO	ABSENT
78	Nil	Nil	1	250	92	0.5	1	3	NO	ABSENT
94	Nil	Nil	1	350	92	1	1	3	NO	ABSENT
78	Nil	SSI	0	200	90	0.5	1	2	NO	ABSENT
86	Nil	Nil	2	400	85	1	2	3	NO	ABSENT
72	Nil	Nil	1	350	92	2	1	7	NO	ABSENT
86	Nil	SSI	2	500	102	0.5	1	4	NO	ABSENT
92	Nil	Nil	0	250	90	1	1	3	NO	ABSENT
82	Hypotension	BED SORES	3	500	86	1	1	3	NO	ABSENT
92	Nil	Nil	2	250	102	0.5	2	2	NO	ABSENT
82	Nil	Nil	1	300	78	1	1	2	NO	ABSENT
88	Nil	Nil	1	200	80	1.5	1	3	NO	ABSENT
80	Nil	Nil	1	200	90	1	1	5	NO	ABSENT
78	Nil	Nil	1	300	98	1.5	1	2	NO	ABSENT
82	Hypotension	Nil	2	300	80	1	1	4	NO	ABSENT



INTRODUCTION





OBJECTIVES





REVIEW OF LITERATURE





MATERIALS

&

METHODOLOGY





RESULTS





DISCUSSION





CONCLUSION





BIBLIOGRAPHY





SUMMARY

