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Research Article

TROCHANTERIC FRACTURE OF FEMUR BY DYNAMIC HIP SCREW AND CROSS SCREW FIXATION WITH MATHEMATICAL PROOF OF GREATER ABILITY

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ABSTRACT
In this paper we exercise with mathematical deduction to prove that Trochanteric Fracture management with DHS (Dynamic Hip Screw) should be accompanied with a cross-screw to resist translational as well as rotational forces experienced internally in human activities i.e. walking, running and other sportsmanship.

INTRODUCTION
Bone is a dynamic form of connective tissue which undergoes continuous remodelling for optional adaptation to its structure for functional demand and absorption of mechanical load. Bone matrix, a composite material of a polymer ceramic lamellar fibre, designed to demonstrate mechanical properties of bone tissue. Of course, mechanical properties depend on the bone composition (porosity, mineralisation etc.) as well as on its structural arrangement (trabecular or cortical).
Galileo (1638) first discussed about load bearing capacity of bones. After wards many others dealt with the same subject. Of them Ward (1838), Meyer (1867), Wolff (1870), Roux (1893) and Pauwels (1976) had done it with design and function of femur.
During our lifetime bone absorbs major part of forces, which act upon it. These forces creates small, elastic deformations towards the bone (for example; typically 0.1% to 0.2% temporary deformation of its length). If the amount of deformation exceeds a certain threshold then it stimulates the bone-growth.
The femur always experiences high, tensile and rotational forces in normal activities. In adult, force at hip-joint is nearly 4-times of the body-weight in walking and increases to 7-times in rapid-walking.

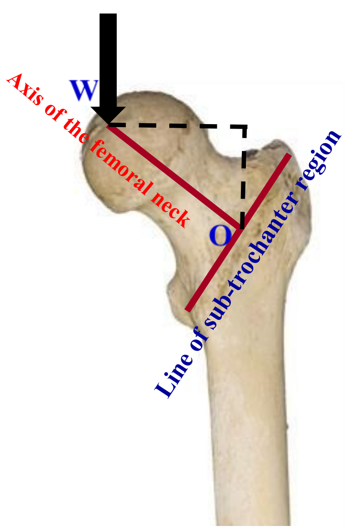

Figure-1

In [Figure-1] axis of the femoral neck is perpendicular to the line of sub-trochanter region. Muscular forces acting orthogonally at different places at the axis of femoral neck producing moment about O tending to create bending moment whereas semi-body-weight W also create moment about O.
Consequently, sub-trochanteric region absorbs high mechanical stresses to neutralise combination of body-weight and the multiple muscles exert which create tendency of deforming the proximal femur. Muscle force acts orthogonal to the axis of the femoral neck i.e. along the line of trochanteric region with a tendency of bending at the sub-trochanteric region.
Greater trochanter, possesses pillar-like structure, absorbs mechanical stress of the hip-joint. It resists the bending attitude of neck of the femur by contraction of *gluteus medius* and *gluteus minimus* muscles.
We may compare the internal bone structure of proximal femur with engineering structure of *Second Hoogly Bridge*.

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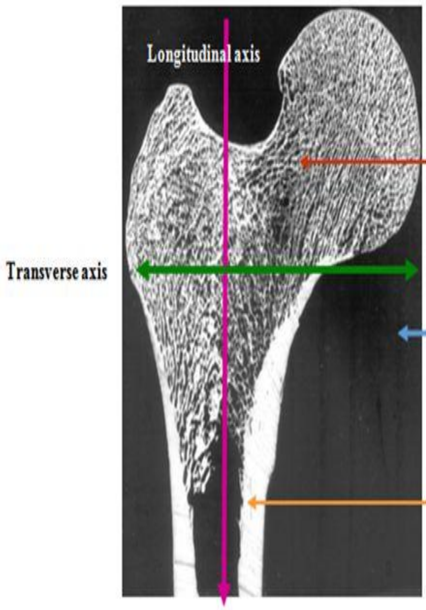

Figure 2A: Trabecular Bone & Cortical Bone Structure within Femur

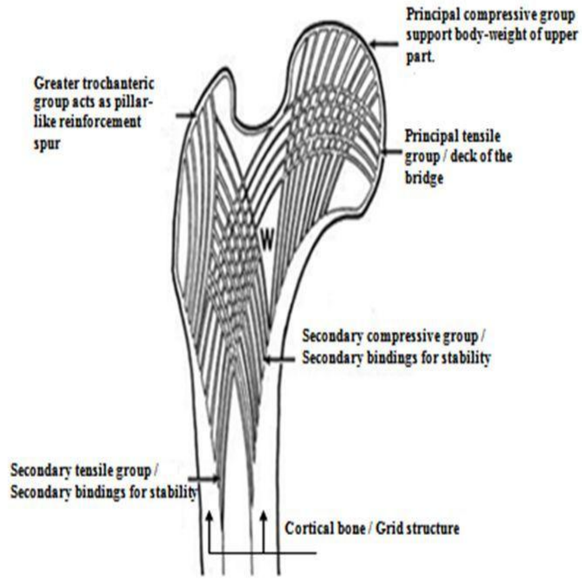

Figure 2B: Internal Structure of Human Femur

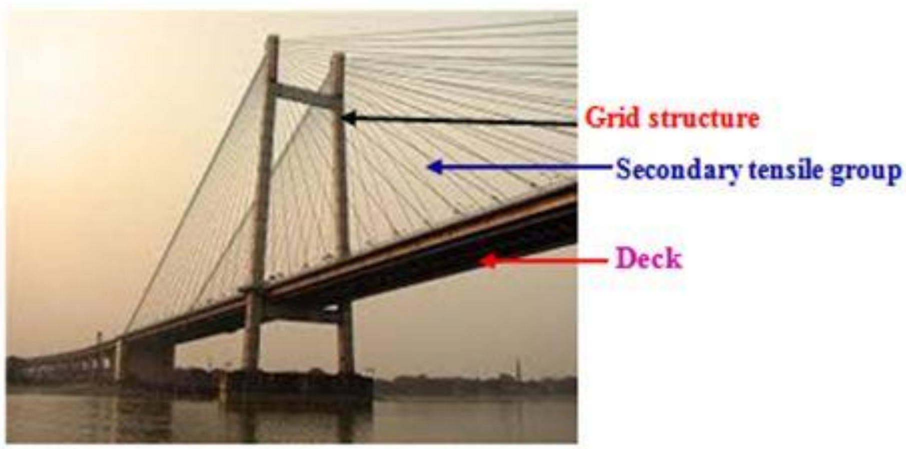

Figure 2C: Structure of Second Hoogly Bridge

As bone is an anisotropic structure, its mechanical properties must be in two orthogonal directions:
1) Longitudinal direction i.e. in the direction parallel to the osteon alignment which is usual direction of loading [Figure-2A].
2) Transverse direction i.e. in the direction at right-angle to the direction of long axis of bone [Figure-2A].
According to advancing of human-age, bones are tropically becoming less dense and thereby strength of bone decreases, meaning they are becoming more susceptible to fracture.
Osteoporosis is a disease involving a marked decrease in bone mass and it is most often found in post-menopausal women.
It is fact that trochanteric fracture occurs in the lateral trabeculae first and then extends to the medial trabeculae is further substantiated by the behaviour of this medial portion of the femur.
It had been shown by *stresscoat*[#] to be subjected to an initial tensile stress and yet it appears to fail because of compression type load. This can be explained by a stress-reversal reaction in which the arch of

the neck tends to become straightened and elongated under lateral load. Since both ends of the femur are restrained, trochanteric portion of the medial trabeculae can fracture only by compression.

[#] [Process of Stresscoat **-** Femora covered with an aluminum undercoating and allowed to dry for twenty-four hours before force were applied to bone for pattern analysis. *Stresscoat* is brittle lacquer that can be applied to the surface of an object and will crack when either static or dynamic loads are applied. The pattern of the cracks reveals the direction of the force applied to the bone where the force direction is always perpendicular to the crack.]

We know that there exists smooth, hard shell outside the femur called cortical bone and amazing crisscrossed, honeycomb like structure inside, called trabecular bone [Figure-2A]. The combination of cortical and trabecular bone make our skeletons strong, light, flexible and efficient. The structure of trabecular bone is the secret ingredient. Trabecular bracing structure is located precisely keeping correct angles to absorb force towards maximum of its capacity. So, when we jump over a puddle or run for a bus then our trabecular bracing directs the force towards the strongest part of our skeleton to prevent bone from breaking.

Most of us are not aware of our beautiful bone structure; but it has not gone unnoticed or unutilised.

The structure of trabecular bone was copied by the French bridge builder Gustave Eiffel, who wanted to build the tallest man-made structure in the world. When he built the Eiffel Tower in 1889, he calculated the positioning of the braces by the curves of the legs to absorb any force like high winds on the entire structure will be terminated to the strongest area at the four legs. This is why the Eiffel Tower continues to stand.

The Eiffel Tower is incredibly well optimised designed to stand tall and stand strong using minimum of material.

Rather than hide its inner workings with a façade, Eiffel exposed the skeleton of his masterpiece. In doing so, he revealed its hidden rules of harmony, many of the same rules are within our skeleton to keep its light-weight strength.

In early 1860s, engineers realised that human femur is made up of mathematically precise, crisscrossed pattern of fibres (called trabecular) that reduce the bone's weight giving maximum strength against multiple force.

This exquisite design of human femur inspired the architect who designed the Eiffel Tower [Figures 3A & 3B].

To consider lightness of Eiffel Tower let us imagine the smallest cylinder that completely wraps around Eiffel Tower.

The air in this tube outweighs all the iron used in the tower. The secret lies in understanding shapes of strength by studying our bones principles **—** Eiffel used in designing his tower.

Trochanter fracture is a term with which we are familiar as it the most common fracture along with intercapsular fracture of neck of femur in the elderly patients.

For a long time *Dynamic Hip Screw (DHS)* with *Plate* being used for treatment. However, DHS fixation is not enough for a good fixation as well as it is unable to provide *rotational stability* (Occur by enhancement of torsional force) in unstable fractures thus leading to failure. Use of *parallel screws along with DHS* has also been documented to check the rotational stability. Fortunately, by mathematical method it can be proved that *parallel screw along with DHS* also does not give rotational stability but is effective in proper union.

To overcome these difficulties and to prevent failure, use of additional cross screw along with DHS is being advocated in our institution.

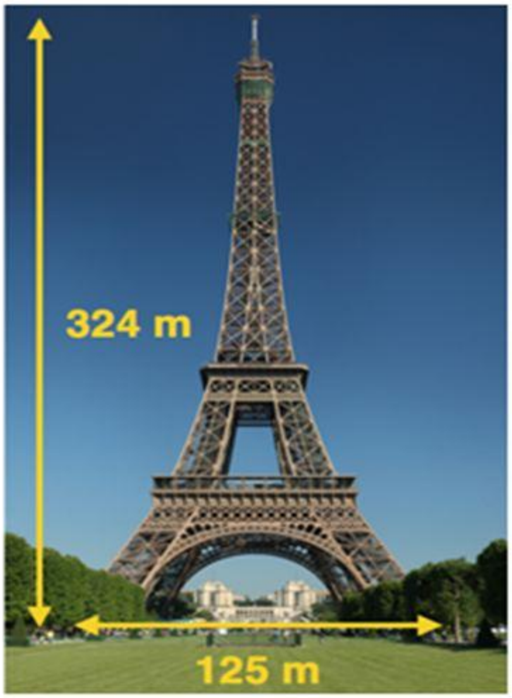

Figure 3A: Eiffel Tower

Figure 3B: Human Femur

Figure 3C: Volume of Air Consumed by Eiffel Tower

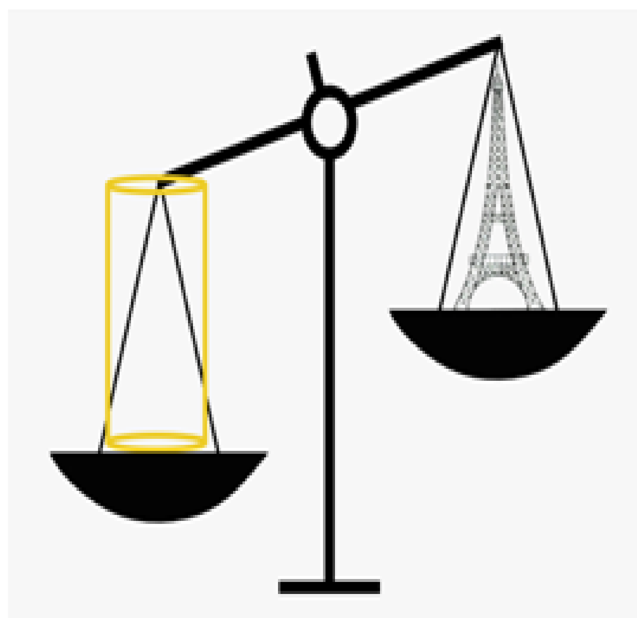

Figure 3D: Mass of Volume of Air Consumed by Eiffel Tower is Heavier than its Mass

Historical Back Ground

Knowledge of treatment of fractures in the prehistoric period can be explored from graveyards and tombs.

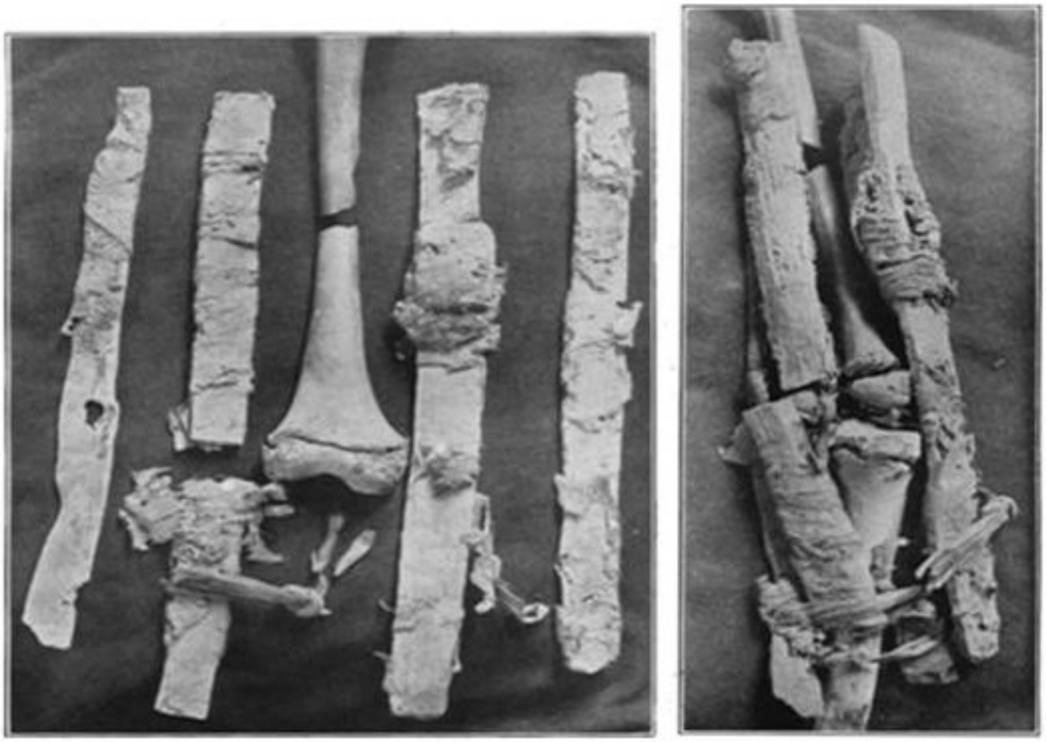

Figure 4: Prehistoric Use of Splint in Egypt

This was expressed by Sir Grafton Elliot Smith, an Egyptologist, as: *The most ancient records of the treatment of fractures are supplied by bodies found by the Hearst Expedition of the University of California excavating at Naga-el-der about 100 miles north of Luxor in Egypt.*

Bodies were found in rock tombs and were buried about fifth dynasty or 4500 to 5000 year ago. Fractures of bones in the two bodies were repaired by splints where oldest surgical or medical appliances of stone knives used in circumcision.

a) One body was of 14-years old girl having compound fracture at right-femur wrapped with four wooden splints by linen bandage.

b) Second one, having compound fracture at forearm. It was treated with splints and type of grass.

The earliest methods of holding a reduced fracture involved using splints:

a) These are rigid strips laid parallel to each other alongside the bone.

b) They also used stiff bandages for support; those were probably derived from embalming techniques.

But in the oldest literature of surgery (Smith, 1908) we find no treatment of fracture of lower part of body.

Ancient Hindus treated fractures with bamboo splints. In the treatment of *Vagna cikitsā* (भग्न-चिकित्सा) by Suśruta (600 BCE), known as *Father of Indian Surgery*; Ray *et al.*, (1993)

In श्लोक-१३ (Verse-13) [Chapter-III of *Cikitsā Sthāna* (चिकित्सा स्थान)]:

प्रथमे बय़सि त्वेवं भग्नं सुकरमादिशेत्।
अल्पदोषस्य जन्तोस्तु काले च शिशिरात्मके॥१३

Roman Transliteration

Prathame baẏasi tvevaṁ bhagnaṁ sukaramādiśet |

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Alpadoṣasya jantostu kale ca śiśirātmake ||13
If patients are young and healthy, fractures and dislocations heal quickly specially in winter.
In श्लोक- १४ (Verse-14):
प्रथमे बयसि त्वेवं मासात् सन्धिः स्थिरो भवेत्।
मध्यमेद्विगुणात् कालादुत्तरेत्रिगुणात् स्मृतः॥
अवनामितमुन्नह्येदुन्नतञ्चावपीड़येत्।
आञ्छेदतिक्षिप्तमधोगतञ्चोपरि वर्त्तयेत्॥१४
Roman Transliteration:
Prathame bayasi tvevaṁ māsāt sandhiḥ sthiro bhavet |
Madhyame dviguṇāt kālāduddare triguṇāt smṛtaḥ ||
Avanāmitamunnahyedunnatañcāvapīḍayet |
Āñchedatikṣiptamadhogatañcopari varttayet ||14
In younger age joints are stable, breaking are repaired within a month whereas break of joint of a middle aged takes twice the time to repair; old aged joint breaking takes three times to repair. In other cases healing period last longer, of course depending on the circumstances. Suśruta mentioned factures in the aged persons may create complications like fever, difficulty in urination, constipation and buzzing sensation in ear. We find following ślokas (verses) of *Jaṅghā-asthi, Ūru-asthi vagna-cikitsā* (जङ्घा-अस्थि, ऊरु-अस्थि भग्न-चिकित्सा) & i.e. treatment of broken tibia / fibula and femur.
Chapter-III of Treatment (तृतीय अध्याय चिकित्सितस्थानम् / Tṛtīya Adhyāya, Cikitsitasthānam)
श्लोक- २३ (Verse-23): Treatment of Fracture of Tibia, Fibula and Femur:
अभ्यज्यायामयेज्जङ्घामुरुञ्च सुसमाहित।
दत्त्वा बृक्षत्वचः शीता बस्त्रपट्टेन बेष्टयेत्॥२३
Roman Transliteration:
Abhyajyāyāmayejjaṅghāmuruñca susamāhita |
Dattvā vṛkṣatvacaḥ śītā bastrapaṭṭena beṣṭayet || 23
Explanation:
If Shanks (जङ्घा, Jaṅghā) *i.e. tibia & fibula or Thigh bone i.e. femur* (ऊरु-अस्थि, Ūru-asthi) *fracture takes place, fractured area should anointed with clarified butter* (घृत, Ghṛta) *or GHEE (embrocate the broken area to make soft i.e. to release tenderness) then pulled forward to place in normal position to put straight. Bind with hard skin of wood* (hard bark of woods) *and wrap* (बेष्टयेत्, Veṣṭayet) *by jute bandage* (बस्त्रपट्टेन, Bastrapaṭṭena).
श्लोक- २४ (Verse-24): Treatment of Separated Broken Femur:
मतिमांश्चक्रयोगेण आञ्छेदूर्व्वस्थि निर्गतम्।
स्फुटितं पिच्चितञ्चापि वध्नीयात् पूर्व्ववद्भिषक्॥ २४
Roman Transliteration
Matimāṁścakrayogeṇa āñchedūrvvasthi nirgatam |
Sphuṭitaṁ piccitañcāpi vadhnīyāt pūrvvavadbhiṣak || 24
Explanation:
When femur (Ūrvvasthi, ऊर्व्वस्थि, bone of the thigh) is *protruding out* (*Nirgata,* निर्गत, bone protruding from the skin) *after cracking or crushing type of fracture* (*Sphuṭitaṁ* स्फुटितं) *into several fragments* (*Piccitaṁ* पिच्चितं indicates partial splintering of bone) *and then it should be pulled forward using a wheel* (Pulling with force in curve path holding it tightly by a bundle of *Kuśa* कुश) *to place in normal state and the leg bandaged as earlier. Bandage was done by jute-bandage soaked with clarified butter after placing the splints.*
श्लोक- ५ (Verse-5): Splints or Kuśa (कुश):
मधुकोडुम्बराश्वत्थ पलाशककुभत्वचः ।

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बंशसर्ज्जवटानां वा कुशार्थमुपसंहरेत् ॥ ५
Roman Transliteration:
Madhukoḋumbarāśvattha palāśakakubhatvaca |
Baṁśasarjjavaṭānāṁ vā kuśārthamupasaṁharet ||
Explanation:
Suśruta used the barks of woods and also small pieces of woods (of matured trees) which were of *UḊUMBARA* (उडुमबर, Wild Fig-tree), *MADHUKA* (मधुक, Aśoka tree), *AŚVATTHA* (अश्वत्थ), *PALĀŚA* (पलाश), *KAKUBHAḤ* (कुकुभः, Arjuna tree), *BAMBOO* (बंश, Baṁśa), *VAṬA* (वट) and *ŚĀLA* (सर्ज्ज, *Sarjja*) were used as splits (*Kuśa*).
श्लोक- ६ (Verse-6): Plaster Paste:
आलेपनार्थं मञ्जिष्ठां मधुकं रक्तचन्दनम् ।
शतधौतघृतोन्मिश्रं शालिपिष्टञ्च संहरेत्॥ ६
Roman Transliteration:
Ālepanārthaṁ mañjiṣṭhāṁ madhukaṁ raktacandanam |
Satadhoutaghṛtonmiśraṁ śālipiṣṭañca saṁharet || 6
Explanation:
Suśruta prepared plaster with (1) Red-extract from the root of Indian Madder (मञ्जिष्ठा, *Mañjiṣṭhā,* a creeper having yellow-flower); (2) Extract from Aśoka wood (मधुक, *Madhuka*) of small pieces; (3) Extract from Red-Sandal wood (रक्त-चन्दन, *Raktacandana*) and (4) Powder from Yaṣṭimadhu (यष्टिमधु, *Sāli-rice,* Yaṣṭimadhu) i.e. *Sāli-rice* mixed with little amount of Clarified Butter. He named this paste as *Ālepa* (आलेप). Before band with plater effected area hundred-times washed with clarified butter mixed with water (after Śata-Dhauta, शतधौत, with clarified butter, घृत, in succession) to make it soft i.e. tender-free as well as decoction. All the above composition creates compression and hardness as Plaster of Paris. All extracts were made by mortar & pestle (खल-नुड़ि, Khala-nuḋi).
As this plaster paste cannot create so hard fixation, it should be re-plastered in some intervals depending the seasons. This has been expressed by following Śloka:
श्लोक-८ (Verse-8): Method of Plastering Bandage:
तत्रातिशिथिलं बद्धे सन्धिस्थैर्य्यं न जाय़ते ।
गाढ़ेनापि त्वगादीनां शोफो रुक् पाक एव च ।
तस्मात् साधारणं बन्धं भग्ने शंसन्ति तद्विदः ॥ ८
Roman Transliteration:
Tatrātiśithilaṁ baddhe sandhisthoiryyaṁ na jāyate |
Gāḋhenāpi tvagādīnāṁ śopho ruk pāka eva ca |
Tasmāt sādhāraṇaṁ bandhaṁ bhagne śaṁsanti tadvidaḥ || 8
Explanation:
Very loose bandage (तत्रातिशिथिलं, Tatrātiśithilaṁ) brings non-union of joint. Very tight bandage leads to edema of the skin, pain and make create ulcer (शोफो, रुक्, पाक; śopho, ruk, pāka). Hence, banding to be moderate binding (साधारणं बन्धं).
श्लोक- ७ (Verse-7): Replacement of Plastering Bandage:
सप्ताहादथ सप्ताहात् सौम्येष्वृतुषु बन्धनम् ।
साधारणेषु कर्त्तव्यं पञ्चमे पञ्चमेऽहनि ।
आग्नेय़ेषु त्र्यहात् कुर्य्याद्भग्नदोषवशेन वा ॥ ७
Roman Transliteration:
Saptāhādatha saptāhāt soumyeṣvṛtuṣu vandhanam |
Sādhāraṇeṣu karttavyaṁ Pañcame pañcame'hani |
Āgneyeṣu tryahāt kuryyādbhagnadoṣavaśena vā || 7

Explanation:

In pleasing season (सौम्यऋतु, Soumya-Ṛtu) bandaging should be done once in every seven days, in temperate season it should be done in every five days whereas in hot season it should be done in every three days. Of course these directions might be changed as symptoms (दोष, Doṣa).

श्लोक- ४० (Verse-40, First part): Fixation after Plastering:

अथ जङ्घोरुभग्नानां कपाटशय़नं हितम् ।
कीलका बन्धनार्थञ्च पञ्च कार्य्या विजानता ॥
यथा न चलनं तस्य भग्नस्य क्रिय़ते तथा ।
सन्धेरुभय़तो द्वौ द्वौ तले चैकश्च कीलकः ।

Roman Transliteration:

Atha jaṅghorubhagnānāṁ kapāṭaśay̱anaṁ hitam |
Kīlakā bandhanarthañca pañca kāryya vijānatā ||
Yathā na calanaṁ tasya bhagnasya kriy̱ate tathā |
Sandherubhay̱ato dvou dvou tale coikaśca kīlakaḥ | 40

Explanation:

In case of fracture of bones of the foreleg i.e. tibia / fibula and thigh bone i.e. femur it is beneficial to adopt lying in a specially made wooden plank^ having five pegs (किला, Kīlā) *to fasten the patient tightly without allowing movement of the affected part.*

(i) For fracture of tibia / fibula: one peg each on either side knee-joint to fix knee-joint and one peg each on either side ankle-joint to fix ankle whereas one peg below foot to fix foot;

(ii) For fracture of femur: one peg each on either side knee-joint to fix knee and one peg each on either side pelvic-joint to fix pelvic movements whereas one peg below foot to fix it.

[कपाट शय़ण, Kapāta Śay̱aṇa: (a) for fracture of tibia / fibula, the patient should be laid (शय़ण, Śay̱aṇa) on a wooden plank (कपाट, Kapāta) which is big enough to accommodate the patient comfortably. Five pegs / bolts (किला, Kīlā) are fitted: two pegs on the either side of the patient and one peg down below the heels.]

Writings of Hippocrates (Hesse and Gächter, 2004) discuss management of fractures in some detail, recommending wooden splints plus exercise to prevent muscle atrophy during the immobilisation.

His approach to very successful in treating relatively simple ailments such as broken bones which required traction to stretch the skeletal system and relieve pressure on the injured area. The Hippocratic – bench and other devices were used.

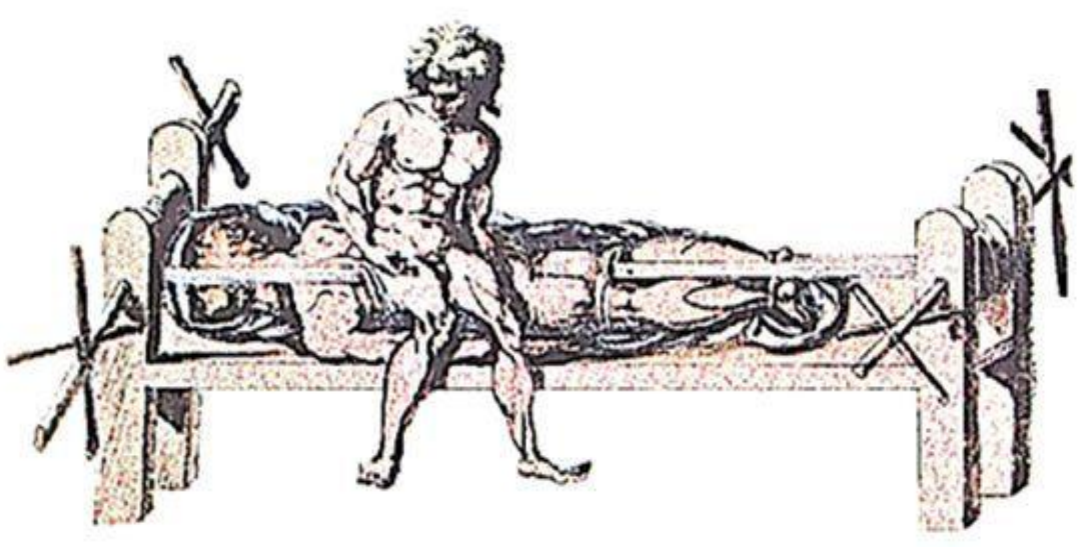


Figure 5: Hippocratic Bench for Traction

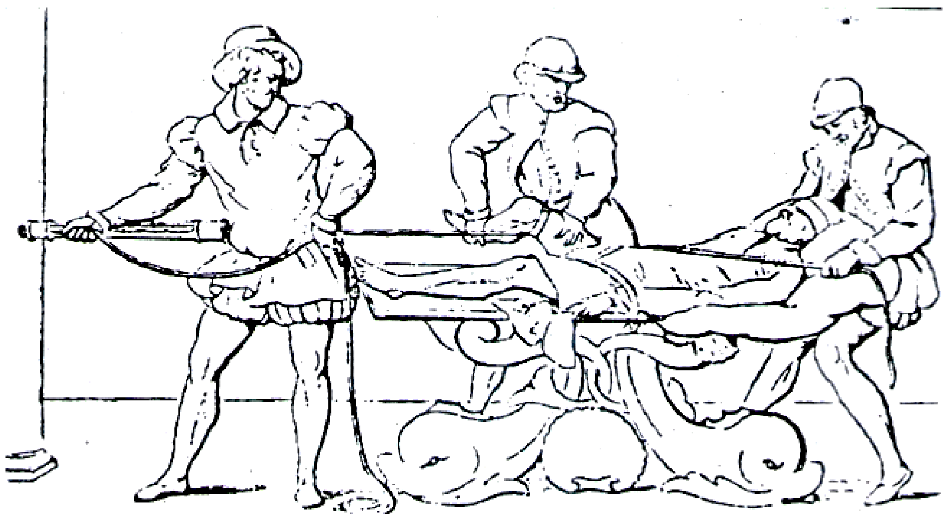


Figure-6: Paré's Method for reducing dislocation of the hip-joint

The ancient Greeks also used waxes and resins to create stiffened bandages and the Celsus (1st Century CE), writing in 30 CE, describes how to use splints and bandages stiffened with starch. Arabian doctors used lime derived from sea shells and albumen from egg whites to stiffen bandages. The Italian School of Salerno in the twelfth century recommended bandages hardened with a flour and egg mixture as did Medieval European bonesetters, who used casts made of egg white, flour, and animal fat. By the sixteenth century the famous French surgeon Pare (1840) championed more humane treatments in medicine and promoted the use of artificial limbs made casts of wax, cardboard, cloth, and parchment that hardened as they dried.

In ancient literature we find no treatment of trochanteric fractures in particular.

From the early 1800s on, the literature revealed that intertrochanteric hip fractures routinely healed but were mal-united in varus. Therefore, it leads to deformity and decreased function. Non-operative care of intertrochanteric fractures had significant because of concurrent medical problems and prolonged incumbency that prevented union from occurring.

So, progress in the care of intertrochanteric fractures has involved reducing the mortality concurrent medical problems and decreasing the degree of mal-union or nonunion of these fractures. These improvements have allowed patients to become more functional. Cooper (1832) also contributed to the knowledge of intertrochanteric fractures with his book of 1822 (*Dislocations and Fractures.*), in which he was the first to distinguish between fractures of the neck of the proximal femur (intracapsular) and those outside the joint capsule (extracapsular) through the trochanteric level. He recognized that extracapsular fractures united, whereas intracapsular fractures did not. His treatment consisted of bed rest, followed by the use of crutches and a cane, and then an elevated shoe, all in an attempt to save the patient's life if not the limb. An intertrochanteric fracture was described by Cooper in his treatise of 1851 as follows:

"...fracture of the femur through the trochanter major, passes obliquely upwards and outwards from the lower portion of the neck but instead of traversing the neck completely, it penetrates the base of the trochanter major; the line of fracture being such as to separate the femur into two fragments, one of which is composed of the head, neck and trochanter major, and the other of the shaft with the remaining portions of the femur". Treatment recommended by him was *"moderate extension and steady support of the limb in its natural position."*

Trochanteric fractures are then treated by using engineering metallic fixation devices (internal splint-age device) designed to maintain the non-displaced or reduced displaced fracture fragments in an anatomic, near-anatomic, or acceptable position. Fracture stability (the ability of the fracture pattern to resist deformation of weight-bearing) assists in the uncomplicated healing of the fracture.

The diagnosis and care of intertrochanteric fractures were then studied and written about by Dupuytren, Malgaigne (1847), Velpeau, and Whitman (1904; 1921), among others. In 1902, Royal Whitman first reported on the reduction of fractures with abduction, internal rotation, and traction under anesthesia with immobilisation in a spica cast from the nipple line to the toes.
Buck's Traction: One of the most common Orthopaedic mechanisms by which pull is exerted on the lower extremity with a system of ropes, weights and pulleys. Buck's traction, which may be unilateral or bilateral, is used to immobilise, position, and align the lower extremity in the treatment of contractures and diseases of hip and knee. The mechanism commonly consists of a metal-bar extending from a frame at the foot of the patient's bed, supporting traction weights connected by a rope passing through a pulley to a cast or a splint around the affected body structure. It is an Orthopaedic apparatus for applying longitudinal traction on the leg by contact between the skin and adhesive tape, for maintaining the proper alignment of a leg fracture. Friction between the tape and skin permits application of force through a cord over a pulley suspending a weight; elevation of the foot of the bed allows the body to act as a counter-weight; a type of traction in which a non-constricting boot with weights is worn by the patient to maintain proper alignment. This method of treatment always created Bed-Sores as patients could not be turned.

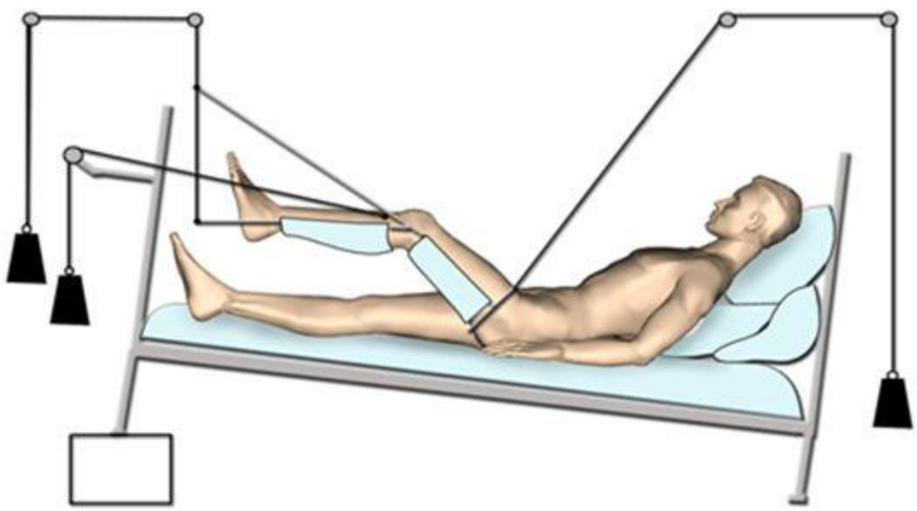


Figure 7: Buck's Traction

In 1822 Anthony White of London performed sub-trochanteric osteotomy of a 9-years boy for a deformity.
The beginning of major surgery of hip was by Barton (1827) of Philadelphia, America. He performed a femoral osteotomy between the greater and lesser trochanters to secure motion in an ankylosed hip.
Ledbetter (1933, 1944) - heel-and-palm test for adequate reduction, saying that *"after the leg has been brought down in the measured degree of abduction and internal rotation, the heel of the injured leg is allowed to rest on the outstretched palm. If the reduction is complete, the leg will not exert itself. Should there be no interlocking of the fragments, however, the leg will slowly rotate externally"*.
In 1850 Langenbeck, in Germany, attempted internal fixation of the reduced fracture in 1850 using an intramedullary nail and in 1854 introduced subcutaneous osteotomy of the femur.
In 1902, Royal Whitman first reported on the reduction of fractures with abduction, internal rotation and traction under anesthesia with immobilisation in a spica cast from the nipple line to the toes. Then, the era of Whitman Plaster starts. In this treatment plaster from umbilicus down to the toes of the affected side and half of the opposite in abduction, maintaining some traction, were the treatment of choice because by this contoured plaster development of bed-sores at sacrum was less. Even if there is any possibility of

sacral bed-sore, that area is cut out from the plaster to avoid bed sore and take care at the back of the person.
Dr. Bhattacharyya had the occasion to see Well-leg traction by some consultant in England. Where single hip down to the foot in the normal leg with a transverse wooden bar fined to the affected side with plaster in the leg + foot maintaining the traction, abduction + external rotation in the foot.
In Calcutta some of seniors used Boot-Plaster then, only in the foot with extension, ignoring the varus angulations at the fracture at the fracture side.

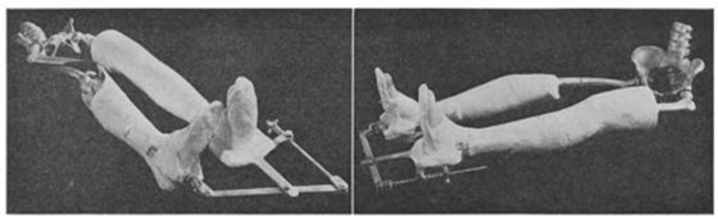


Figure 8: Well-Leg Traction by Roger Anderson

In Leadbetter (1944) described a cervical axial displacement osteotomy in which an osteotomy was done in the same axial line of the neck of the femur at the junction of the middle and inner thirds and the base of the greater trochanter; the lower neck and femoral shaft were displaced medially beneath the head of a point within the lower acetabular rim.
Modern treatment of intertrochanteric fractures involves surgical intervention in exchange of acceptable healing rates with nonsurgical methods.
Surgical methods have replaced previous nonsurgical methods of prolonged bed rest, prolonged traction in bed, or prolonged immobilization in a full-body (spica) cast. These methods give us acceptable healing rates of nonsurgical management, stops frequent non-Orthopaedic complications associated with prolonged immobilization or inactivity, as well as mal-union compromising patient function.

MATERIALS AND METHODS

A randomised retrospective study of 186 patients of age group 50 – 85 years were taken, with a mean age 67.5 years. Recording of their age, sex, premorbid mobility, any associated medical disease, fracture pattern, pre-operative, intra-operative and post-operative management was done. The fractures were classified according to Evans classification of Trochanteric Fractures into stable and unstable groups. The pure sub-trochanteric fractures were excluded from the study.
Our general protocol for all the elderly patients included routine investigations on complete blood profile, renal function tests, ECG and chest X-ray. If any medical problem was there then it was treated by our physician and only after having his not and his presence in the OT (Operation Theater) the surgery could be carried out.

RESULTS AND DISCUSSION

Operative Technique

a) Position of the Patient: Place the patient supine on the fracture table with a radiolucent paddle post placed in between the patients' leg. The uninjured leg is held in wide abduction using a foot-plate attached to one of the leg extension of the fracture table. The injured leg on the other foot-plate.
b) *Reduction*: Perform a closed reduction of the fracture. Generally, intertrochanteric fractures are reduced in neutral or slight internal rotation. Carefully, adjust the traction to obtain reduction. Check under image intensifier the reduction in both AP (antero-posterior) and Lateral views paying attention to medical cortical contact.
c) *Insertion of Guide Pin:* It depends on the angle of plate used. The level of entry of a 135^0 plate is at the level of lesser trochanter, which is approximately 2 cm below the *vastus lateralis* ridge, for every 5^0 increase in the angle of plate the distance shifts 5 mm downwards from the lesser trochanter.

d) *Procedure:* We use the lateral approach, making a 6 – 7 cm long incision extending from the greater trochanter downwards.

The *fascia* is cut the muscle is retracted and a 135^0 zig is placed on the bone at the desired site and under c-arm a guide pin is drilled to the femur head, the position is checked in both AP and Lat views. The pin is approximately 10 mm away from the head margin or is just in the subchondral bone. After measuring the secure fixation. Then, the femur is reamed over the wire with a predetermined length of reamer. Insert the dynamic hip screw and fix it with a plate. The plate is fixed to the femur by screws and then after that the compression screw is driven in and the desired compression is achieved which is checked under c-arm.

After this a 3.2 mm drill bit is loaded on the drill and about 15 – 25 mm below the tip of greater trochanter a hole is made through the femur to reach the head crossing the DHS just like a cross (×). Then an appropriate length cancellous screw is taken with a washer and inserted through the hole made. The soft tissue skin are then closed.

If the patient's general condition is well, then before discharge he/she is kept in the hospital under post-operative checkup for a period of 5 days. But if there be any complications or medical problems arise then the patient is kept under medical supervision and discharged only after attaining full fitness. The patient is re-called on the 12th post-operative day for removal stitches as well as post-operative checkup. From that day he is advised to walk with a pair of axillary crutches for tip toe walking. After about four weeks the patient is advised to walk with partial weight bearing and thereafter from six weeks depending on the fracture condition and the patient's healing condition the patient is advised for full weight bearing activities. In some patients early post-operative mobilisation was possible depending on the pain tolerance and their general condition. It's a fact that the patients' premorbid physical and mental profiles determine the ultimate rate of rehabilitation.

The patients were usually reviewed at 12th post-operative day and thereafter at 6-weeks, 3-months, 6-months, 1-year, 2-year, 3-year and so on and also early whenever the patient had any problem. On every visit, after the removal of the stitches, the patients were taken under radiographic verification to examine the progress of fracture union.

e) *Result:* Out of the 186 patients treated majority were female (56%) and rest were males.

1) 54% of patients treated were walking independently and rest were walking with assistance or were bed-ridden.

2) Most of the cases admitted were from home after a fall.

3) According to Evans Classification of Trochanteric Fractures 63.5% were of unstable type and rest were of stable type.

4) 21.5% of the admitted patients had associated with morbidity factors like *pulmonary disease, cardio vascular disease, hypertension, diabetes* etc.

Most of the fractures were reduced on the fracture table by closed reduction and then fixed internally but some (0.01%) of the fractures required open reduction due to severe communition of the fracture fragments. There were a few post-operative complications in the patients like a) infection nearly 0.03%; b) delayed union nearly 0.02%; c) varus deformity of more than 10^0 nearly 0.03% and d) shortening nearly 0.03% were seen in the patients treated. The post-operative radiographic assessment of all the patients was also done to visualise a) fracture pattern; b) state of fracture union and c) any visible complications on X-ray. It revealed the above mentioned results.

f) Discussion:

Human trabecular bone is generally much weaker in absorbing shear than compression reflecting different failure mechanisms at the tissue level.

Femurs are subjected to external and internal rotation applied at a constant angulation rate of 0.1 degree per second to a maximum torque of 12 Nm (Newton-metre).

As we know that transmission of force within femur is so rapid that it is only possible when the path of transmission is shortest and consequently that is *geodesic*.

Of the 186 cases of Trochanteric fractures treated by DHS with additional cross screw fixation gave good result in terms of early union and movement. Almost all the fractures showed union in twelve weeks-time. The positive points in favour of using a cross screw are:-

1) It prevents hardware failure as previous encountered in using DHS.
2) It provides good rotational stability in unstable fractures.
3) As this fixation decrease the period of bed confinement, it is very helpful in preventing the complications of prolonged recombendency in old age like chest infection, deep vein thrombosis, bedsores etc.
4) It provides good reduction and union of comminuted intertrochanteric fractures.

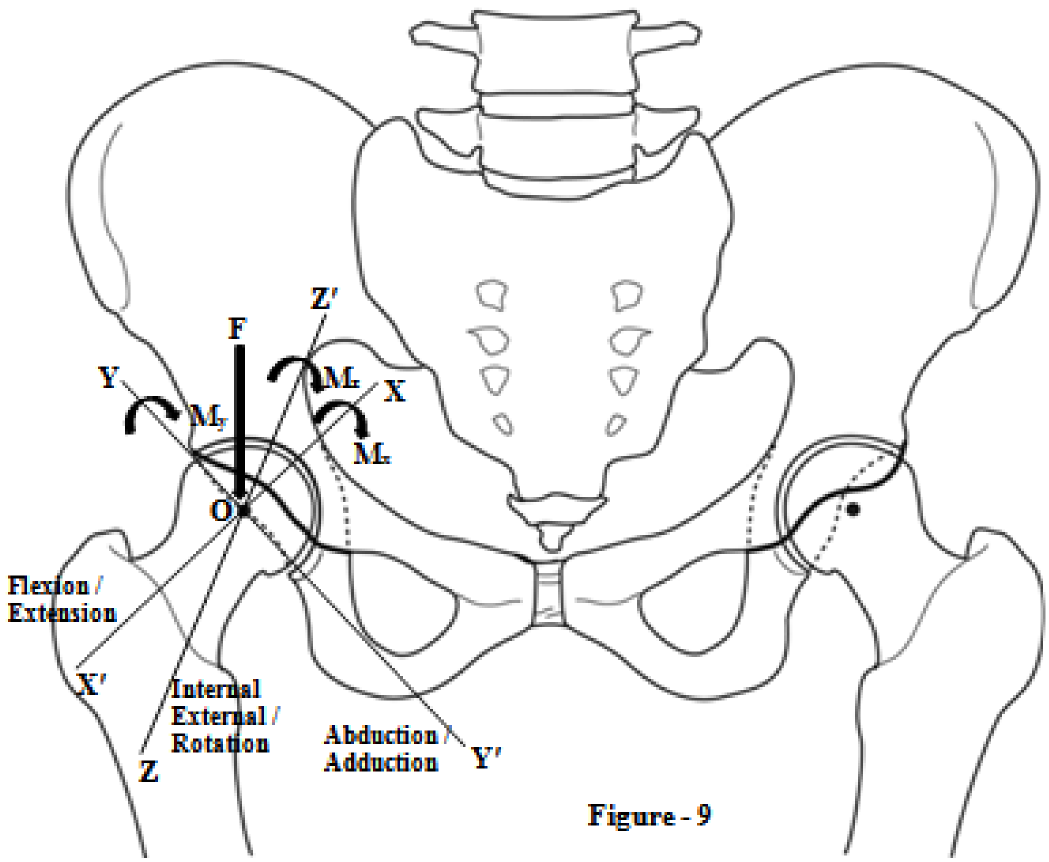


Figure - 9

If we look at the forces at the fracture site inter-trochanteric fracture:-
Before going for Trochanteric Fracture management by DHS we must mathematical examination Hip-joint in respect of force acting and it can be analyzed by three-dimensional co-ordinate system.
Here (in figure-9) three orthogonal components of force i.e. weight F of the are measured simultaneously along x-axis i.e. XX′ (along the longitudinal axis of the neck of the femur), y-axis i.e. YY′ and z-axis ZZ′ with origin (O) at the centre of the femoral head where forces acting along these axes are taken as F_x, F_y and F_z respectively. Here, F_x (along XX′) will cause compressive strains in the neck while F_y(YY′) and F_z(along ZZ′) will cause bending of neck. The bending moments created by P_y and P_z occur about z-axis and y-axis and are designated as M_z and M_y respectively. We are eager to mention that occurrence of (a) flexion / extension about XX′; (b) abduction / adduction about YY′ and (c) internal / external rotation about ZZ′ take place.

Average Femoral Torsion	$12.3^0 \pm 6.9^0$	-4.2^0 to 32.9^0
Average Ultrasound Femoral Torsion	$17.7^0 \pm 7.2^0$	-1.0^0 to 36.6^0

Research Article

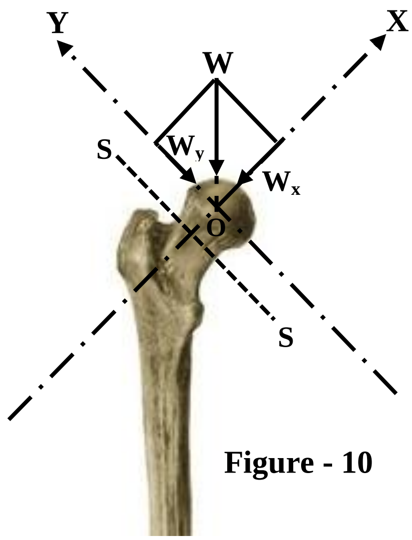


Figure - 10

Forces acting at hip-joint are not fixed but changing dynamically as femur changes its position to cause head to move within the acetabulum. Force acting on the head of the femur produces stress as well as strain on the neck of the femur. Therefore, these effect is a cause of breaking the neck of the femur by minimum external blow, due to fall, in addition to internal forces to increase the intensity of stress as well as strain beyond its (neck of the femur) strain absorbing capacity.

[Figure – 10] Half of the body weight (W) can be sub-divided into two coplanar orthogonal components of forces along X-axis (along longitudinal axis of the neck of the femur) and Y-axis (perpendicular to neck of the femur) having origin O (at the centre of head of the femur). By using parallelogram of forces W_x represents stress and W_y represents strain. Theoretically, it is possible to determine stress on the basis of using strain-gauges applied to the neck of the femur with the help of the recorded values but practically it is not feasible. Moreover, physical properties of bone not only varies from person to person but also intra-individually. So, calculation will not be in general. Bone is made up of a heterogeneous material, therefore Hook's Law[57] for solid metallic substances will not be applicable properly to estimate strain with respect to stress. But deduced formula of Hooke's Law for anisotropic materials will be applicable for bone.

For anisotropic material we can use generalised Hooke's laws $\sigma_{ij} = c_{ijkl} \times \epsilon_{kl}$ implies that $c_{ijkl} = c_{jikl}$ by using symmetry of the Cauchy stress tensor $(\sigma_{ij} = \sigma_{ji})$ where symmetry of the infinitesimal strain tensor implies that $c_{ijkl} = c_{jikl}$ and these symmetries are called the minor symmetries of the stiffness tensor (c). Since, the displacement gradient and the Cauchy stress are work conjugate, the stress–strain relation can be derived from a strain energy density functional (U), then

$$\sigma_{ij} = \frac{\partial U}{\partial \epsilon_{ij}} \Longrightarrow c_{ijkl} = \frac{\partial^2 U}{\partial \epsilon_{ij} \epsilon_{kl}}$$

The arbitrariness of the order of differentiation implies that $c_{ijkl} = c_{jikl}$. These are called the major symmetries of the stiffness tensor. The major and minor symmetries indicate that the stiffness tensor has only 21 independent components.

The parcel of bone, no matter how small, can be compressed, stretched, and sheared at the same time, along different directions. Likewise, the stresses in that parcel can be at once pushing, pulling, and shearing because the structure is three-dimensional.

Figures (11A, 11B) reveal that anisotropic materials are directionally dependent (compressional and tensile lines of forces are inter-related). Let us consider directional properties at a point represent directional properties of the whole system. Here, stress and strain are of second rank tensor thereby resultant strain is such that all the components of strains are linearly related all the components of

stresses. There are stress terms as σ_{xx}, σ_{yy}, σ_{zz}, σ_{xy}, σ_{yx}, σ_{xz}, σ_{zx}, σ_{yz}, σ_{zy} referring to x, y, z directions in terms of integers 1, 2, 3. Then, generalised Hook's Law for anisotropic material is:
$\epsilon_{ij} = c_{ijkl} \times \sigma_{kl}$ when *i*, *j*, *k*, *l* = 1, 2, 3
Where, c_{ijkl} is a fourth rank tensor and are termed as *material compliance* and ϵ_{ij} is mathematical strain tensor.
Similarly, stress-strain tensor can be expressed as:
$\sigma_{ij} = c_{ijkl} \times \epsilon_{kl}$ when *i*, *j*, *k*, *l* = 1, 2, 3
Where, c_{ijkl} represents material stiffness or modulus tensor. Here, $c_{ijkl} = c_{jikl}$ and $c_{ijkl} = c_{ijlk}$.
{Stiffness is the rigidity of an object its complementary is flexibility. The stiffness, *k*, of a body is a measure of the resistance offered by an elastic body to deformation where, $k = \frac{F}{\delta}$ for *F* = force applied and δ = deformation.}
g) The Young's Modulus of aligned composite fibers (longitudinal spur & transverse spur) may be calculated by *Rule of Mixture* &*Inverse Rule of Mixture* for loading parallel and perpendicular fibers:
A. Rule of Mixture: $Y_{ax} = V_f . Y_f + (1 - V_f) . Y_m$ … … … …(1)
B. Inverse Rule of Mixture: $Y_{tans} = \left\{ \frac{V_f}{Y_f} + \frac{(1-V_f)}{Y_m} \right\}$ … … … (2)
Where, Y_f = Young's Modulus of bone fibers; Y_m = Young's Modulus of bone matrix; Y_{ax} = Young's Modulus of bone-composite along the axis (i.e. longitudinal); Y_{trans} = Young's Modulus of bone-composite along transverse axis; V_f = Volume of fraction of bone-fibres.

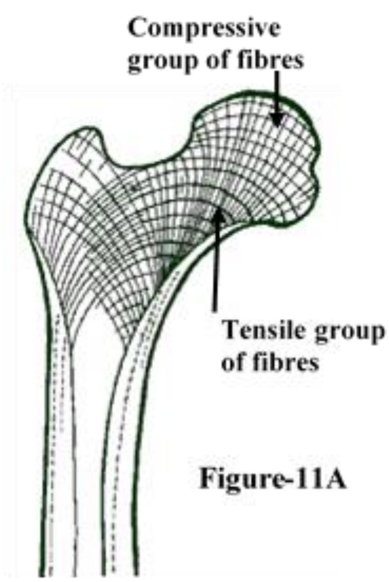


Figure-11A

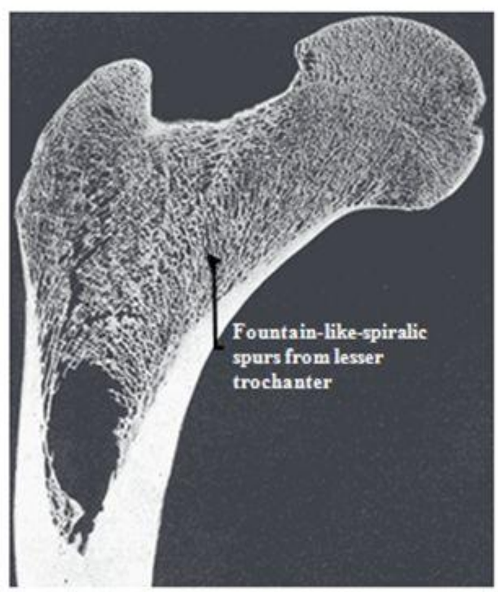


Figure -11B

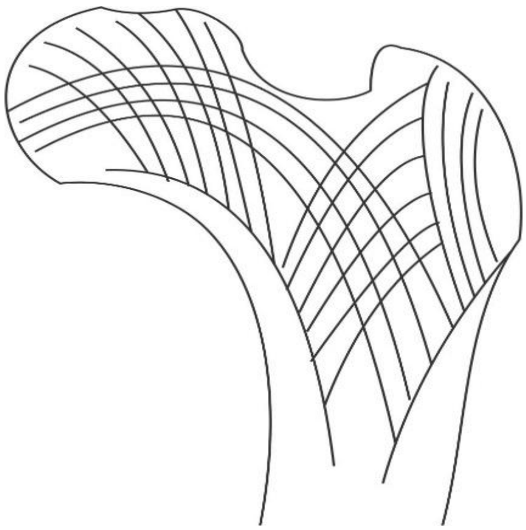


Figure 12A: Longitudinal

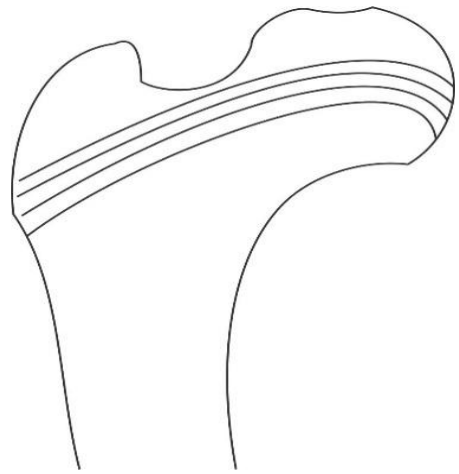
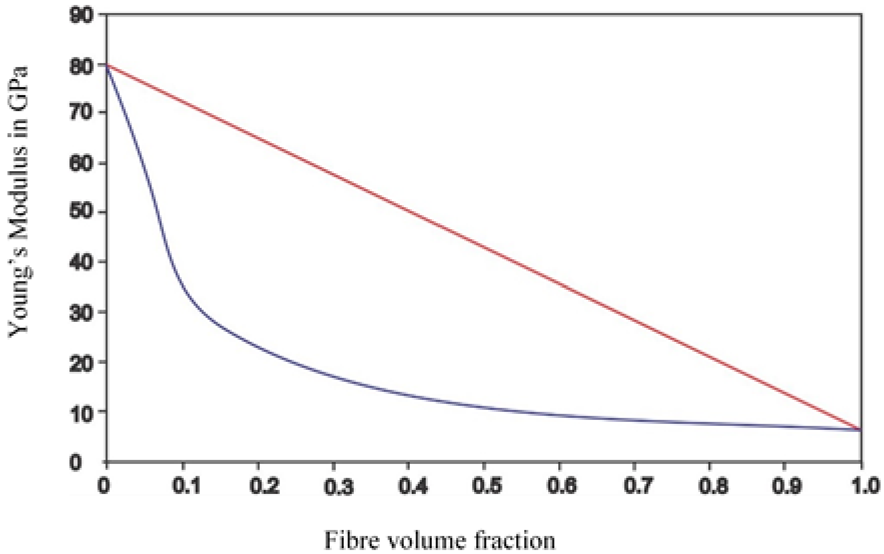


Figure 12B: Transverse Spur

The below given graph indicates values of Young's Modulus in longitudinal (Red) and transverse (Blue) directions against range of fibre fractions as well as actual values. Moreover, formulae (1) & (2) determine $Y_{ax} > Y_{trans}$ that the composite will be stiffer in the axial direction than in transverse direction. So, cortical bone will be stiffer in the parallel osteons.
Therefore management of retention of transverse structure is essential where DHS and parallel screw to DHS are introduced in trochanteric fracture management and to strengthen mostly transverse spur of proximal femur.



h) The spur-trusses *'deck-girder'* [Figure-12C] forms a pillar-like support for the deck i.e. neck & head of the femur, which acts like cantilever.
Insertion of parallel screw to DHS [Figure-13A] was considered on the concept of anti-torsional implantation. But both the screws are on the same plane. So, these are not capable of absorbing rotational

force as every rotational or anti-rotational force is three-dimensional. On that argument, we are able to accept it as *anti-bending device* i.e. to support and increase the efficiency of deck-spur.
It was first introduced by Bartle and Hofer (1996).

Figure 13A: Additional Parallel Screw with DHS

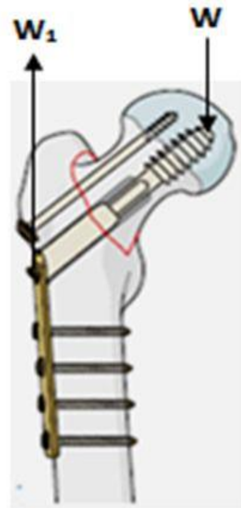


Figure 13B: Effective Forces on DHS due to Body-Weight

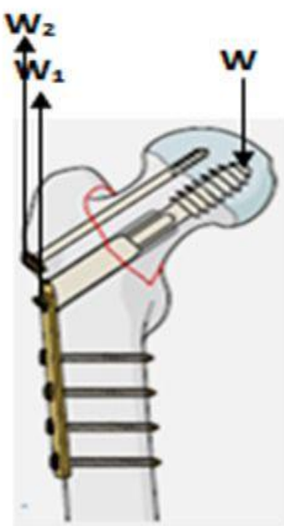


Figure 13C: Effective Forces on DHS due to Body-Weight

Figure 13D: Trochanteric Stabilizing Plate along with DHS & Parallel Screw

[Figure-13B & 13C] Body-weight is generally coming down through the head of femur. But here as the femur is implanted with DHS along with parallel screw (in some cases *trochanteric stabilising plate is used)* due experiencing trochanteric fracture (red marked) the one-sided body-weight W will be transmitted on the DHS and pass through it towards the plate of DHS whereas a part of the body-weight is being absorbed by the bone itself due to its compactness and heliacal trabecular structure within.
In general, $W_1<W$ as a part of W is absorbed by the bone itself due to its flexibility and weight-bearing capacity. But with additional parallel screw may yield $W_1 + W_2 \approx W$. Therefore, it becomes stable against bending down of neck of femur.

DHS (Dynamic Hip Screw) is fitted along Coronal plane, therefore, it is a coplanar two-dimensional device. So, it is not capable of absorbing three-dimensional torque properly

i) Most of the human movements are translation followed by rotation [Figure-9]. Structure of curvilinear lines of forces within the trochanteric regions reveals that *lesser trochanter* control and absorb the rotational stress with its fountain-like-spiralic spurs [Figure-11B].

In inter-trochanteric fracture we need management by introducing devices of absorbing rotational or torsional force whereas translation takes care of itself.

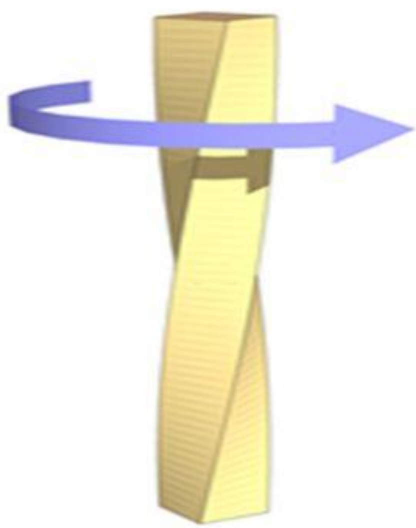


Figure 14: Twisting Attitude of Proximal Femur

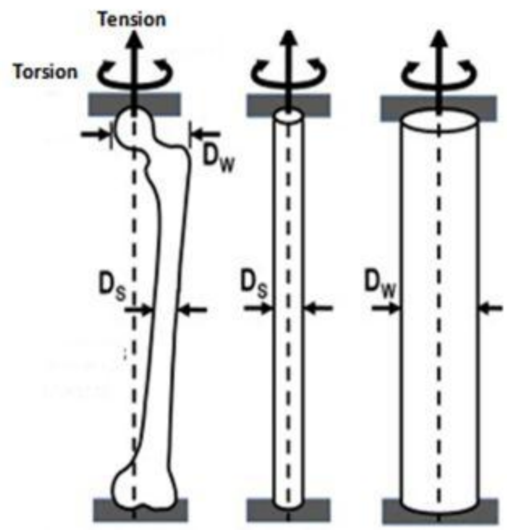


Figure 15: Tension (Translation) and Torsion of Femur due to Movements

The proximal end of femur is experiencing free rotation [Figure-14] where distal end experience no rotation [Figure-15]. There exists couple linear relation between torsion on human femur in daily activities. Here, D_W = Distance between head of femur and greater trochanter which experiences torsion most; D_S = Average diameter of shaft of the femur [Figure-15]. The shear stress or twisting force in a solid circular shaft in a given position can be expressed as:

$$\tau = \frac{T_m . r}{P_m}$$

Where, τ = shear stress; T_m = twisting moment; r = distance of stress surface from centre of the circular shaft; P_m = polar moment of inertia of surface area of perpendicular to point of action of stress= $\frac{\pi . D^4}{32}$; D = outer diameter of the shaft.

Within the extreme upper part of the femur spiralic fountain spurs are in the shape of an inverted conical helix (Helix has constant curvature as well constant torsion; so it is the shortest path of transporting forces). It is geodesic (A geodesic line or briefly geodesic on a surface may be defined as a curve whose osculating plane at each point contains the normal to the surface at that point. Osculating plane: A plane containing two consecutive tangents is called *osculating plane.*) of a right-circular-cone. As we know that transmission of force within femur is so rapid and that is possible only when the path of transformation is shortest and consequently that is geodesic. Path of force transport on conical helix shows translation as well as torsion.

Figure 16A: Insertion of Cross Screw along with DHS

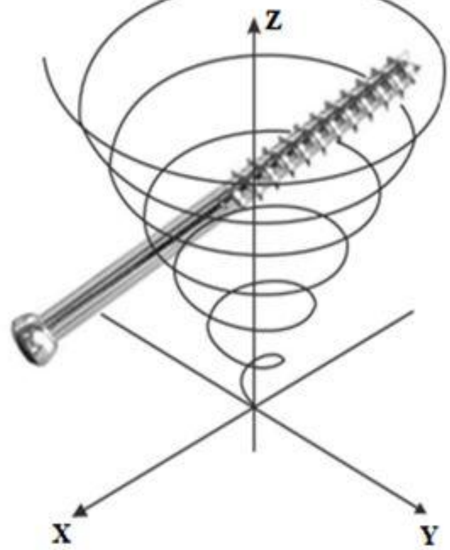


Figure 16B: Cross-Screw Cutting Spiral

The cross-screw cut numbers of spiralic spurs as well as transvers spurs to retain the fixation of sub-trochanteric region with neck of the femur for normalcy. It facilitate third axis other than direction of DHS with parallel screw i.e. it binds movements along coronal as well as sagittal planes, to absorb rotational and torsional forces along with translational forces. It also leave no space to distort the facture union and rapid healing occurs.

Therefore, essentiality of cross-screw insertion is 3-D management of force-absorbing facilities in trochanteric fracture occurs as because it is capable of resisting / absorbing rotational (Torque = something that produces or tends to produce torsion) *as well as translational* (Forces along linear direction) *forces produced by gait.*

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