"FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY"

BY

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LIST OF ABBREVIATIONS

AA	-	Alpha Angle
ACL	-	Anterior Cruciate Ligament
ICN	-	Intercondylar Notch
PCL	-	Posterior Cruciate Ligament
MCL	-	Medial Collateral Ligament
IC	-	Intercondylar
AL	-	Anteromedial
PM	-	Posteromedial
MFL	-	Meniscofemoral Ligament
MM	-	Medial Meniscus
LM	-	Lateral Meniscus
BL	-	Blumensaat Line
BA	-	Blumensaat Angle
T1W1	-	T 1 Weighted Image
T2WI	-	T 2 Weighted Imaging
ICNW	-	Intercondylar Notch Width
NWI	-	Notch Width Index
NA	-	Notch Angle
NW	-	Notch Width
ICNA	-	Intercondylar Notch Angle
ND	-	Notch Depth
DWI	-	Diffusion Weighted Imaging
FSE	-	Fast Spin Echo
GRE	-	Gradient Echo Sequence
MHz	-	Mega Hertz

MRI	-	Magnetic Resonance Imaging
NMR	-	Nuclear Magnetic Resonance
SWI	-	Susceptibility Weighted Image
PD	-	Proton Density
PET	-	Positron Emission Tomography
RF	-	Radiofrequency
STIR	-	Short Tau Inversion Recovery
T	-	Tesla
TSE	-	Turbo Spin Echo
FS	-	Fat Suppression
Ω	-	Omega
DOA	-	Date of Admission
DOS	-	Date of Surgery
DOD	-	Date of Discharge
IP No	-	Inpatient Number

ABSTRACT

TITLE: "FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY"

Background:

Knee (Genu) joint is the most vulnerable joint of the human body. The incidence of injury to the ligaments of the knee is relatively high, at 15%. The Anterior Cruciate Ligament (ACL) has a unique anatomical structure and orientation which makes it extremely vulnerable to injuries, accounting for approximately 56% of all knee joint ligament injuries. The intercondylar notch is an important anatomical landmark in the distal part of the femur. An ACL injury is closely associated with the size of the femoral intercondylar notch. Hence, it is important to investigate the femoral intercondylar notch. Due to its high soft-tissue resolution, MRI has become the primary modality in investigating complex anatomical regions such as knee joint. The subtle alteration in the signal intensity of soft tissue of the knee joint allows for the recognition of abnormalities with high precision. ACL is an extra-synovial and intracapsular ligament. It is a dense fibrous band composed of collagen fibrils. ACL is not as strong as Posterior Cruciate Ligament (PCL). The ACL is divided into two bundles namely the anteromedial and the posterolateral bundles. The bundles are named for their locations relative to each other at their tibial insertion. The anteromedial bundle tightens with flexion of the knee and resists anterior translation of the tibia in flexion, while the bulkier and less isometric posterolateral bundle tightens with knee extension and resists hyperextension. ACL derives its blood supply

from branches of the middle geniculate artery. The central core of the ACL is relatively avascular; hence ACL tears heal ineffectively. The noncontact mechanisms for ACL tears account for approximately (70-80%) of all ACL tears. The most common mechanism responsible for ACL tears is the pivot-shift mechanism: hyperextension, such as that occurring in gymnast or sports personnel.

AIMS and OBJECTIVES:

- To analyze the femoral ICN measurements in patients with non-contact ACL tears and to study their correlation.
- Parameters to be evaluated are Alpha angle (ACL- Blumensaat Line intersection, Femoral Intercondylar Notch Width (ICNW), Notch Angle (NA), Notch Width Index (NWI), Notch shape and depth.

Methodology:

A Cross-sectional, one year hospital-based study conducted in our quaternary care centre among 50 patients with a mean age of 31 years; after clearance from College Ethical Committee. All patients referred to the Department of Orthopaedics for suspected ACL injuries and other pathologies of the knee were included in the study after informed consent. Patients older than 18 years of age and who fulfilled the inclusion criteria were subjected to MRI of the knee in 3T MRI scanner and Intercondylar notch morphometry parameters were calculated.

Results:

The data obtained was statistically analyzed using SPSS software. There was a significant correlation between the Age and Triangular shaped intercondylar notch

using the student's unpaired "T" test (p value 0.0125) which is (p value < 0.05) and is statistically significant. The finding of the triangular-shaped notch was more common in young adults with a mean age of around 25 years. There was no significant difference in notch depth, notch width, intercondylar notch width index, notch angle, and alpha angle among the samples.

<u>Conclusion:</u>

Based on our study we conclude that a Triangular shaped intercondylar notch especially in adolescents and young adults predisposes to increased risk of an ACL tear.

<u>Keywords:</u> Anterior Cruciate Ligament, femoral intercondylar notch morphometry, pivot shift, triangular shaped.

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REVIEW OF LITERATURE

The knee joint is a pivotal hinge and the largest compound Synovial joint in the human body. It is vulnerable for injuries due to the lack of bony support. Stability for the joint is mainly provided by a complex arrangement of ligaments, tendons and muscles [(1), (2).]

ACL is an important intracapsular ligament which contributes for roughly 90% of the stability of the knee. ACL is most commonly injured (56%) and majority (70%) of the ACL injuries occur in individuals involved in aggressive sporting activities [(3).]

The ACL originates from the dorsomedial facet of the lateral femoral condyloid (condyle) and inserts on ventromedial tibial plateau, just ventral to the intercondylar eminence [(4)] and it helps prevents translation of tibia anteriorly [(5).] Isolated ACL injuries are rare; approximately 50% of them are seen in association with other ligamentous injuries of the knee [(6).]

Since ACL injuries are associated with higher rates of complications contributing to profound health impairment and high treatment costs, it becomes necessary to thoroughly understand the risk factors in order to predict the ACL injuries which may help in their effective prevention [(7), (8).] The intrinsic risks for ACL injuries are anatomic and neuromuscular [(9).]

Morphologic orientation of the intercondylar notch is one of the most important anatomic risk factors [(10).]

Femoral Intercondylar Notch (ICN) is an area which separates the mediate and lateral femoral condyloid in the posterior aspect [1]. The ICN is an anatomical area of interest as it houses the Cruciate ligaments among others [11], ICN is relatively narrower in gentlewomen when collated to gentlemen and the risk of ACL injuries being higher in gentlewomen [12], [13], [14], [15]. The femoral intercondylar notch morphometry and ACL injuries are closely associated.

The association between ACL tears and narrow ICN was studied in 1938 by Palmer [16]. Numerous studies have been conducted since then but have conflicting reports suggesting that there is poor understanding of the relationship between the ICN morphometry and risk of ACL injuries [17], [18], [19], [20], [21], [22].

Therefore, it is important to find out more facts on size and morphology of the femoral intercondylar notch [23].

MRI is a non-invasive investigating modality which has high soft tissue resolution and is accepted as the best imaging tool for evaluation of the knee joint [24], [25], [5]. The images can be obtained in various planes and in 3-dimension (3D) which is helpful to analyze the areas where the anatomy is complex, like the ICN [26].

1.1.1 GROSS ANATOMY OF THE KNEE (GENU) JOINT

The Genu joint being a sizeable and intricate synovial type of joint in the humans; comprises of 3 compartments which include 2 condylar joints formed between 2 femoral condyles separated by ICN and the proximal broad and flattened tibial surface separated by the eminence; and third compartment is the patella-femoral articulation.

The Tibio-femoral juncture acts as a hinge and the patello-femoral joint as a plane gliding type of joint. The joint is covered by a capsule in the lateral and posterior aspect which attaches to the boundary of the articulating bony surfaces. Capsule is enhanced by the inserting adjacent tendons; Vastus externus and medialis on the sides and by the semimembranosus tendon on posterior side. The capsule is absent along the anterior margin.

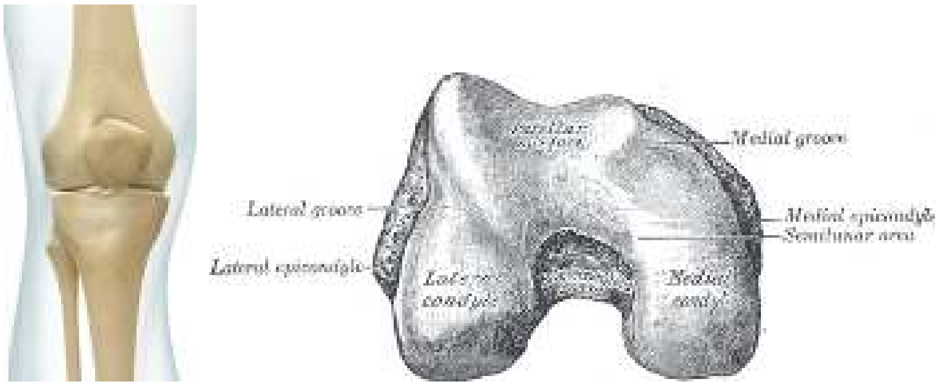


Fig.1.1: Images showing bony make up of knee joint and articular surface of distal end of femur

Intercondylar region:

Intercondylar notch (ICN) is a cone shaped structure situated in the dorsal aspect of the distal femur betwixt the femoral condyles. It is an important structure as it contains many intrinsic ligaments of the knee. The contents of ICN are ACL and PCL, Meniscofemoral ligaments and peri-cruciate fat. The region is intracapsular, extra synovial and so are its contents.

The roof of ICN along which the Blumensaat line (BL) passes includes the synovial clefts, precruciate and posterior cruciate recesses. The walls are formed by the inner cortical margins of the 2 femoral condyles. On the dorsal most aspect ICN is limited by the joint capsule and distally by tibial eminences.

The shape of the ICN shows age dependent variations due to changing configuration of the femoral condyles. The various configuration of the ICN are "A / Triangular" shaped described in children, inverted "U" shaped in adolescents and "Ω" Omega shaped in and over 4th decade.

These variations are seen in both sexes, there is a compelling difference in size of ICN in both sexes [(27), (28)].

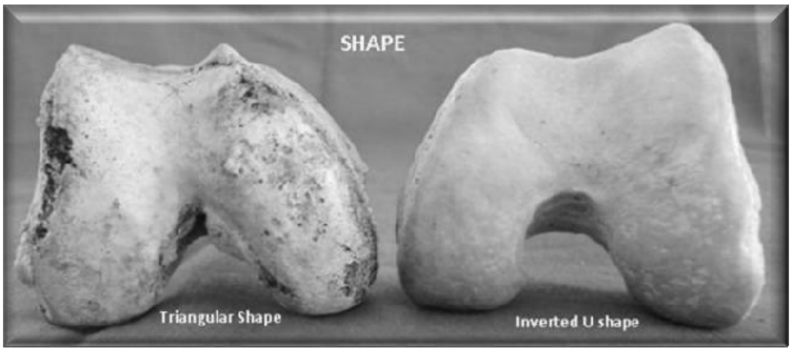


Fig.1.2: Picture of dry femora representing shapes of femoral Intercondylar notch.

Ligaments and Menisci

The ligaments are the most important stabilizers of the knee as they are present both within and outside the joint capsule.

Intra capsular ligaments are mainly the cruciate ligaments; and the extra capsular ligaments being the Patellar tendon and the Fibular and the Tibial collateral ligaments respectively.

Cruciform (Cruciate) ligaments:

ACL and PCL are the 2 cruciform ligaments present in the knee and are named so based on their attachment on the tibial surface. They are the strongest ligaments of the knee. And as the name indicates the cruciates cross one another inside the joint.

Anterior Cruciate Ligament (ACL):

ACL is intracapsular and extra synovial in location which is anchored to the tibia at the frontal aspect of intercondylar zone and course upwards, backwards and laterally. The ligament fans out at its attachment to the dorsal part of the mediate surface of lateral femoral condyloid. In a standard adult human ACL length estimate to 38mm and 11mm in breadth, but is modestly smaller in women.

It has three functional bundles and according to their tibial attachment they are named as Anteromedial (AM), Intermediate and Posterolateral (PL). The anteromedial bundle is stressed during flexion, when majority of the ACL is relaxed. The huge, posterolateral part is under tension on extension.

ACL prevents dorsal translation of the femur on the tibia and also restricts the tibia from being pulled anteriorly when the knee joint is in flexion.

Fig.1.3: Superolateral aspect of knee showing cruciate ligaments

Posterior Cruciate Ligament (PCL):

PCL also lies extra synovially, it courses from the depression in the dorsal Intercondylar (IC) quarter of tibia and progresses upwards, onwards and mediately to attach onto the foremost part of lateral facet of the mediate femoral condyloid. It is thicker than ACL and measures 13mm in width and 38mm in length. The principal role of PCL is preventing dorsal translation of tibia therefore balancing the function of ACL. PCL also has two components, an AL and a PM bundle, termed according to the anatomic location of the femoral position to the tibial insertion.

Others

Minor intra capsular ligaments include:

- Anterior transverse inter-meniscal ligaments,
- Posterior transverse inter-meniscal ligament,
- Meniscofemoral Ligament (MFL),
- Oblique meniscomeniscal ligament and the
- Plica synovialis infrapatellaris (Patellar Plica).

Extracapsular Ligaments

Ligamentum patellae is the continuation of Quadriceps femoris tendon and it is attached above to the inferior most edge of the genus patella and below to the tibial eminence.

Fibular collateral ligament is cordlike which is attached proximally to the lateral condyloid of the femur and distally to the apex capitis fibulae (Fibular head).

Tibial collateral ligament is a smooth levelled band and is attached proximally to the mediate condyloid of the femur and distally to the mediate facet of the corpus tibiae.

Oblique popliteal ligament (Bourgery ligament) is a broad, flat tendon like extension of the semimembranosus muscle. It augments the dorsal most aspect of the capsule.

Menisci

These are two semi lunar or crescentic intra capsular fibrocartilages which are attached to mediate and lateral tibial condyles by anterior and posterior horns.

These ligaments help to widen and deepen the articular surface and acts as a cushion betwixt the articular facets of femur and tibia.

The outermost boundary is thickened and anchored to the capsule, and the thin medial boundary being free and concave. The menisci are immobile as they are attached to collateral ligaments.

Transverse or (Anterior) meniscomeniscal ligament of the genu affixes the ventral convex margin of the lateral meniscus (LM) to the ventral most end of medial meniscus (MM).

These two menisco-femoral ligaments securely link the posterior end of the LM to the inner facet of the mediate femoral condyloid [35].

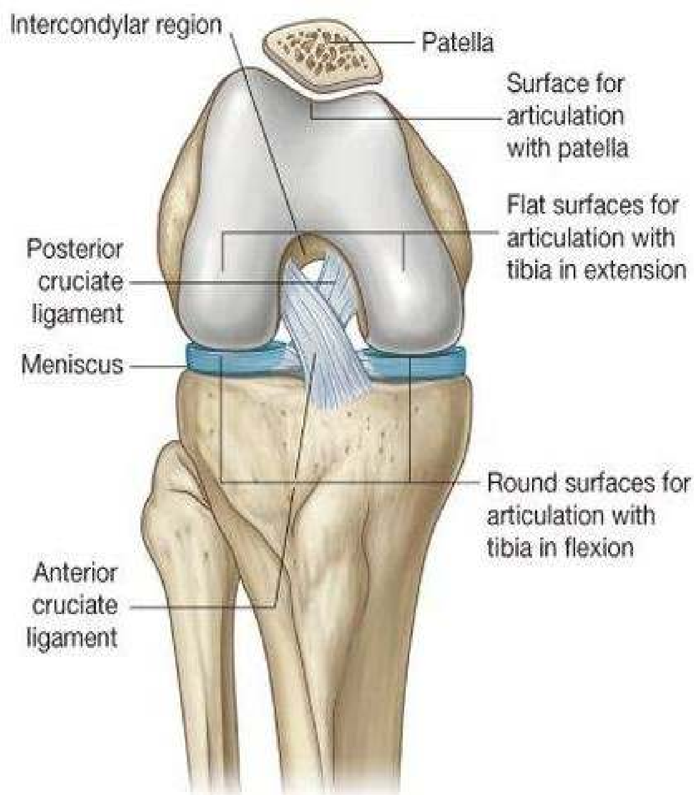


Fig.1.4: Representative Image depicting medial and lateral meniscus.

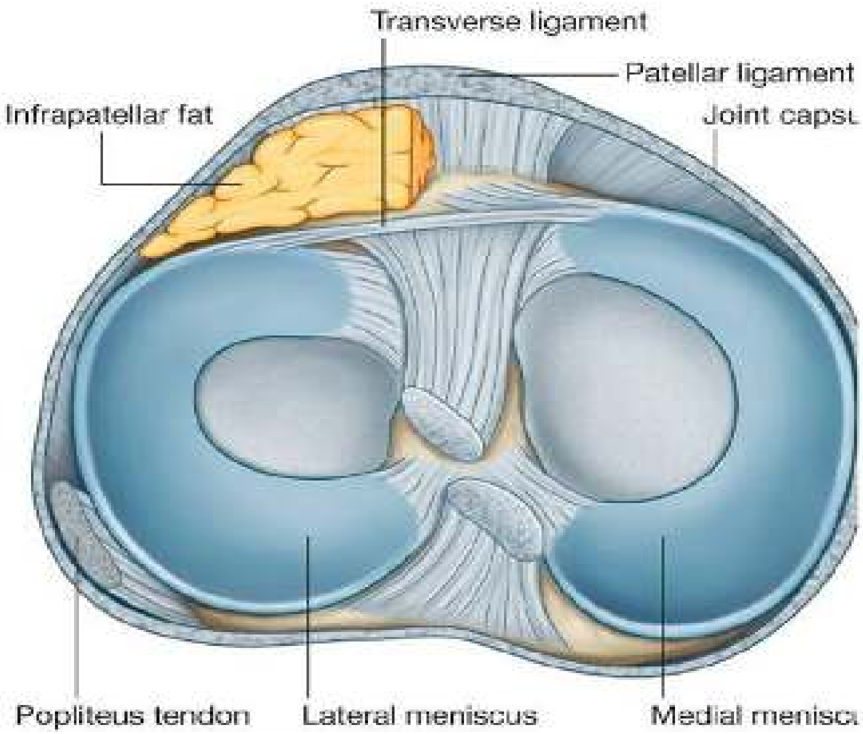


Fig. 1.5- Illustration diagram depicting the menisci

RADIOGRAPHIC AND MRI IMAGING OF KNEE

RADIOGRAPHY

Historic perspective: Wilhelm Conrad Roentgen, a professor from Würzburg, Germany, accidently discovered X–rays while working on the properties of Crookes cathode tube in the year 1895. He received the 1st Nobel prize for his discovery in Physics in 1901.These newly found rays were put to medical use the following year and since then there has been tremendous advancement in the field of radiography and imaging technology [29].

General Principle: When fast moving electrons accelerated by high voltage in a Roentgenogram tube are stopped by the spinning negative electrode (Anode) X-rays are produced.

These X-rays are made to pass through the object to be imaged and finally strike the film- screen detectors placed behind the object where the latent image is formed due to differential attenuation of X–rays by the tissues [(30), (31), (32).]

Radiographic technique and relevant anatomy:

Two basic orthogonal projections are taken: Antero- posterior and lateral views. The projections are acquired on an 8x10 inch sized cassette; and grid is used. The film focal distance is maintained at 40 inches and KVp used is about 60 to 65.

Antero-posterior view: This can be performed in supine or sitting position. The radiographic cassette is placed in close acquaintance with the popliteal fossa of the genu. After centralizing the patella, the central ray is positioned at 90 degrees to the long axis of the joint and an inch below the apex of patella.

Lateral view: With the knee flexed at 45 or 90 degrees the patient is made to lie on the site to be examined against the cassette. The central ray is positioned at 90 degrees to the long axis of tibia over the condyles [(33).]

Radiographic Anatomy:

The bony outline and joint contour are well demonstrated on plain radiographs. The typical junctural aperture betwixt the genu and patello-femoral joint is 3mm.

Due to presence of periarticular fat patellar tendon is visualized in the lateral projections. The displacements of these physiological fat planes help to assess the presence of effusion.

Though the plain radiography has limited value in assessing the acute ligamentous injuries of the knee there are indirect signs that help in suspecting these injuries [(34).]

Signs of ACL tear are:

Anterior tibial translation > 7mm on a lateral radiograph. Osteochondral impacted breach of the patellar condyloid sulcus of the lateral femoral condyloid is addressed as "Lateral femoral notch sign". Avulsion fracture of tibial spine or at the origin of ACL, and avulsion of cortex of lateral tibial condyle (Segond fracture) [(35).]

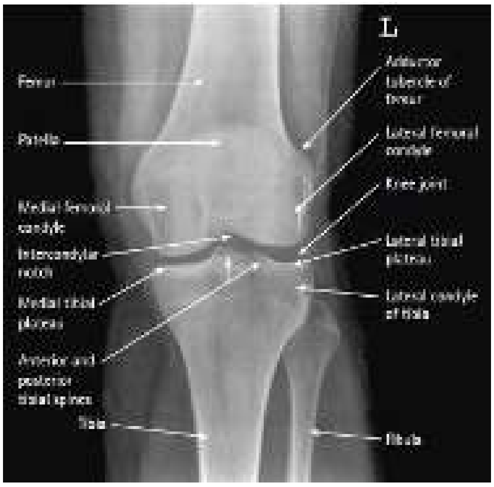


Fig.1.6: Radiograph of knee in AP View

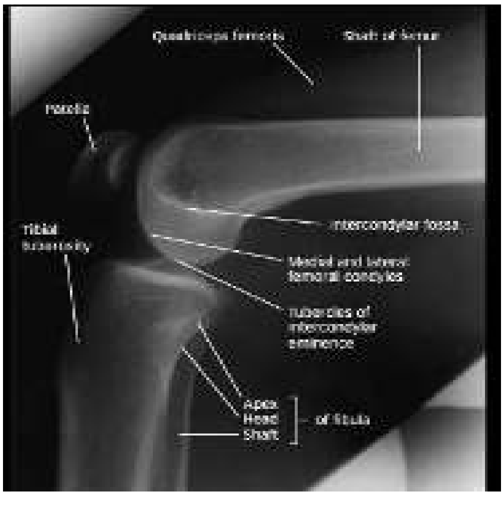


Fig.1.7: Radiograph of knee in lateral view

MAGNETIC RESONANCE IMAGING

Historic perspective:

Felix Bloch and Edward Purcell independently detected the nuclear magnetic resonance (NMR) phenomenon, for which both shared the Nobel Prize for Physics in 1952. Their work was particularly accredited to a property of atomic nuclei having an odd number of nucleons that process at Larmour frequency in a magnetic field, the frequency depending on the magnetic strength.

In the year 1973 MRI was first demonstrated on two small tubes of water by Paul Lauterbur which he named Zeugmatography. He introduced the use of gradients in the magnetic field by analysis of the characteristics of the emitted radio waves which determine their origin. This made it possible to build up two-dimensional pictures of structures.

The contributions of Sir Peter Mansfield are numerous and essential which include, NMR diffraction in solids, slice selection, active magnetic shielding of gradient coils, echo volume & echo planar imaging and active acoustic shielding methods that lower noise levels produced by gradient coils.

Sir Lauterbur shared the noble prize with Sir Peter Mansfield for the discoveries concerning MRI in the year 2003.

The word "nuclear" was replaced with "imaging" due to public relation concerns [(36), (37), (38)].

Brief principle of MRI:

When a particular nuclei with an odd proton or neutron number, or odd number of both are kept in a strong magnetic field, they position themselves with this field of magnet and they start to turn in circles round a central point at a very precise rate called the "Larmor frequency".

When this precise frequency is used to make a radio transmission, the nuclei will take in and hold this radio frequency (RF) energy and get "excited." After the end of this radio transmission, the nuclei will relax by emitting radio waves. This emission of energy by the relaxed nuclei is the source of the NMR signal. This signal is received by a coil which sends the echoes to a computer which uses Fourier transformation and other sophisticated algorithms to construct images.

The Larmor frequency is decided by each independent nucleus and the power of electromagnetic field is denoted by aforementioned equation below and is measured in Tesla(T).

$$\omega = \gamma B0$$

"ω" - Larmor frequency, B0 - constant magnetic field strength, γ - ratio of magnetic moment of nuclei to its angular momentum.

The type of the frequency signal generated by the NMR experiment depends on the number of nuclei present (spin density) and the time taken by the nuclei to relax (T1 and T2). T1 ("spin-lattice relaxation time") measures the rate of return of the nuclei to position with the constant magnetic field (B0) and portrays the chemical property of the proton. T2 ("spin-spin relaxation time") calculates the dephasing of the nuclei in the transverse plane and shows the relationship of the proton to the surrounding nuclei. The pulse sequence determines the degree of dependency of NMR signal on spin density and T1 or T2 [(31), (39)].

PATIENT PREPERATION AND TECHNICAL CONSIDERATION

Patient Positioning:

Patient lies on his/her back with his/her knees positioned in a closely coupled extremity coil.

- External rotation (15 –20 degrees) to aid in visualizing the ACL longitudinally.
- Flexed slightly (5 - 10 degrees) to increase the accuracy of assessing the patello- femoral compartment and patellar alignment.
- Localizer beam centered at lower border of patella.

Technical concerns and Imaging Protocols:

A three-plane localizer should be taken in the beginning to localize and plan which is usually done in less than 25 seconds withT1 W low resolution scans.

Routine sequences:

Axial T1 or PD FSE.(TE:22;TR:2870)   Axial FS (TR:3400;TE:22)

Sagittal FS PD FSE(TR:2870;TE:22) -fluid-sensitive sequence Sagittal T2 GRE(TR: 4200;TE:92)

Coronal T1 or PD FSE: ACL sprain or scarring (TR: 2500;TE:22) Coronal FS PD FSE(TR:2500;TE:22):

Slice thickness:

Axial and coronal plane: 4mm sections

Sagittal plane: 3mm – 4mm thick sections

RELEVANT MRI ANATOMY OF KNEE

Meniscal anatomy:

Menisci are C-shaped fibrocartilaginous cushions anchored to the condylar surface of tibia. They provide mechanical stability for gliding of femorotibial joint, joint lubrication and reinforces the joint stability.

Intact menisci on spin – lattice relaxation times 1 and 2 demonstrate an unvarying low Susceptibility weighted image (SWI). They appear triagonal on cross section with outermost surface being curved convexly and tip pointing towards the ICN.

Menisci are divided capriciously into anterior and posterior horns with the midsubstance body lying betwixt the 2 horns; giving a bow tie appearance peripherally.

MM has a more unbarred “C-shaped” layout whereas LM is more circular.

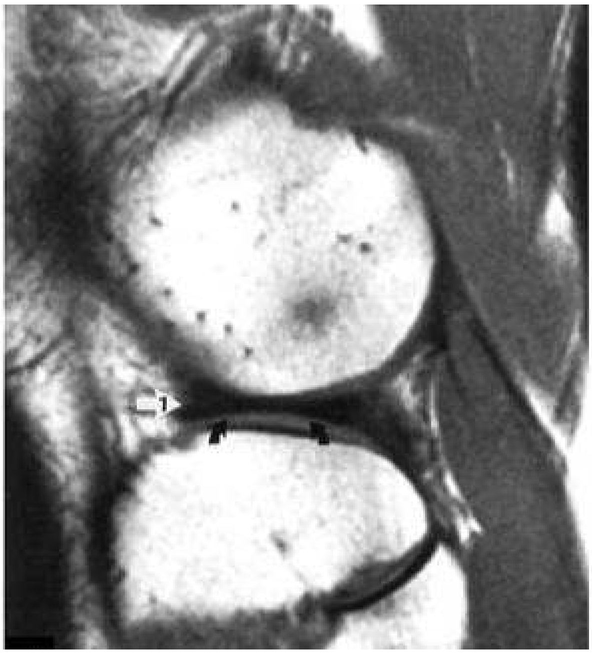


Fig.1.8: Sagittal image of knee demonstrating unvarying low signal intensity of body of LM shown by curved black arrows.

Fig.1.9: Sagittal images of knee demonstrating unvarying low signal intensity of anterior and posterior horns of lateral meniscus.

Intercondylar notch:

Intercondylar notch is best imaged in axial sections, on superior images from femoral condyles. Posteriorly the notch is seen as a wide concave, “U” shaped groove betwixt the posterior mediate and lateral femoral condyles.

Anterolateral aspect of this posterior intercondylar notch is of utmost importance in imaging for ACL, as the origin of the ACL fibres are seen as obliquely arranged thin and uniformly hypointense band of fibres arising at this point.

The medial half of the “U” formed by posterior inter condylar notch shows the origin of broad fibres of PCL.

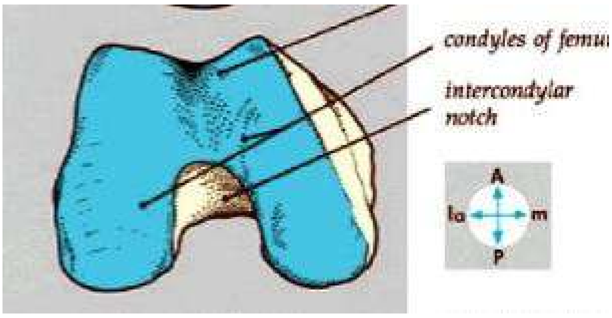


Fig.1.10: Pictorial depiction of intercondylar notch

Figures showing the “U” shaped posterior intercondylar notch depicting ACL origin (Fig.1.11) and PCL origin (Fig.1.12) as indicated by the white arrow.

Blumensaat line (BL) and Blumensaat angle (BA):

BL courses parallel to the roof of the posterior ICN and BA is an angle formed betwixt this line and a line coursing along the margin of the ACL throughout its entire length. The apex of this angle is seen superiorly directed in normal knee.

Significance: In case of ACL tear the ACL fascicles fail to parallel the BL and shows a positive BA, i.e., the apex of the angle is seen directed inferiorly [40], [41] (Fig.1.19).

Intercondylar notch morphometry:

Investigations have demonstrated that femoral ICN morphometry is one of the apprehended anatomic parameters which has a close association with non-contact ACL injuries. Various studies have standardized different methods of measuring the same. A most accepted measurement was given by Stein et al in his study on Osteoarthritis of knee. The measurement of intercondylar notch width index and alpha angle (Angle formed betwixt the BL and the central line of femur) is made as narrated by researchers Gormeli and Tomas Fernandez-Jaen respectively in their studies. The various morphometries were procured in frontal and vertical planes. A section showing popliteal groove is taken to do all the measurements.

(Fig 2.1 and Fig 2.2) A straight line was drawn through the ventral articular facet of mediate and lateral condyles.

Intercondylar notch depth was determined by drawing a perpendicular line from proximal aspect of the notch to a line drawn at the ventral articular surface.

ICN Width (ICNW) measured by drawing a line at foremost 1/3rd of the depth in vertical or coronal planes.

Intercondylar Notch Angle (ICNA) is measured as a line originating from the proximal most part of the notch to a point lying far distant from the notch at the level of both the condyloid.

Intercondylar Notch Width Index (ICNWI) is measured as a proportion of notch breadth to the breadth of distal femoral condyles at a fair mark at the Sulcus popliteus. (Fig.1.13)

Alpha angle is determined in sagittal plane as the intersection between the BL and mechanical axis of femur [(42), (43), (44).]

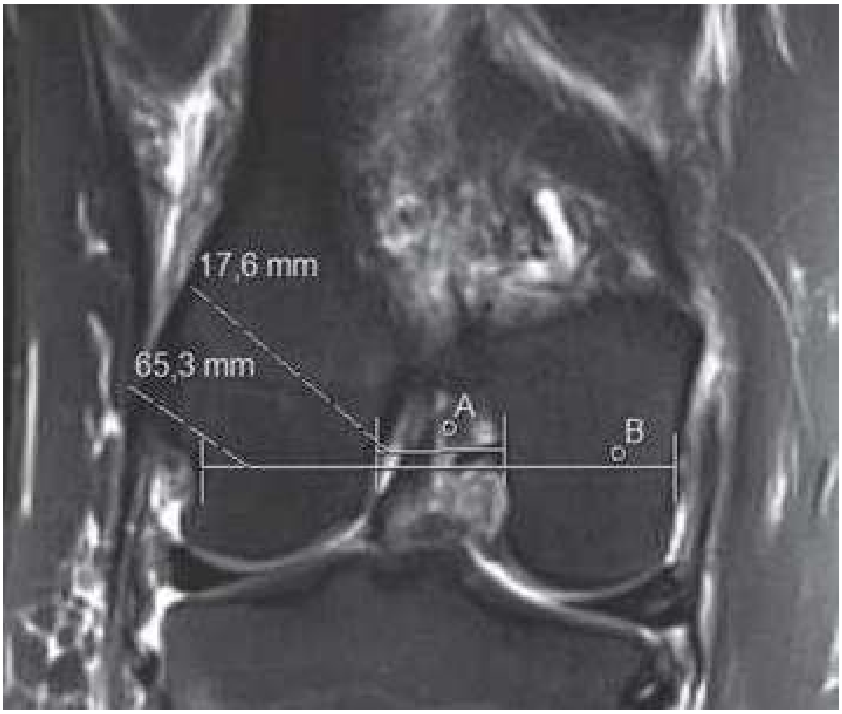


Fig.1.13: Image demonstrating measurement of ICNWI

Cruciate Ligaments:

Posterior Cruciate Ligament (PCL) :

Along with being a chief restraint for dorsal translation of knee, PCL also provides a secondary support for valgus, varus and external rotation of knee. PCL is composed of anterolateral and posteromedial bundles.

Same sequences used for ACL are used for PCL. On MR imaging, Normal PCL is seen as homogenous low-signal intensity with a circular morphology. PCL appears arcuate shaped in sagittal imaging.

It runs in an opposite course to that of ACL and attaches to the posterior inter condylar area and posterior surface of tibia. Any increase in signal intensity in PCL indicates a partial or full thickness tear.

Anterior Cruciate Ligament (ACL) :

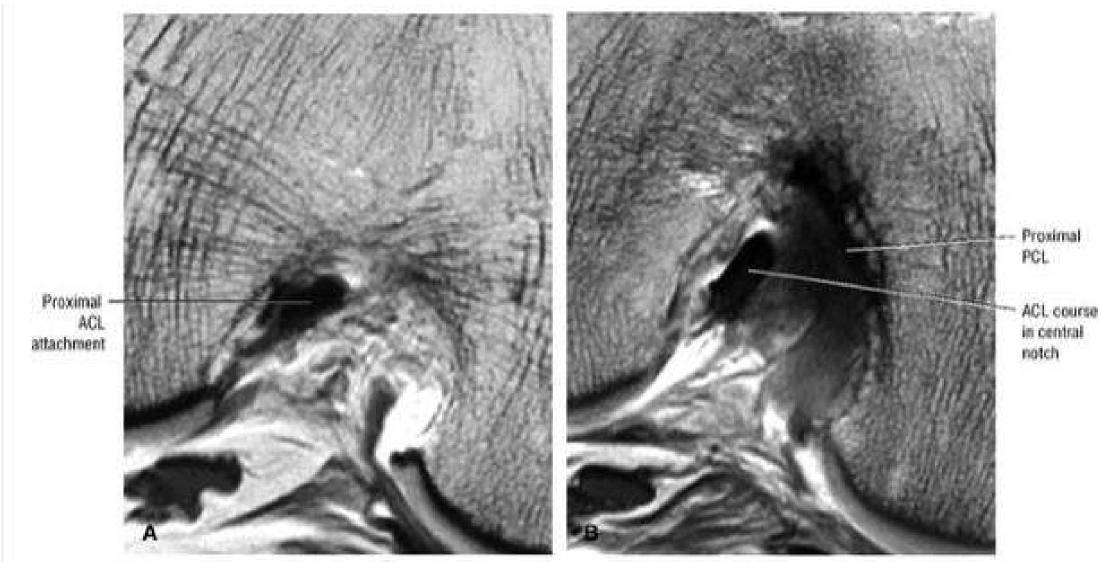
Axial, Coronal and Sagittal images are used routinely for dedicated ACL imaging.

For assessing acute or subacute ACL injuries, T1 and T2 weighted SE, PD and T2 weighted spin-echo images are frequently used. To study morphology and signal intensity changes, T2 W GRE images or FS PD Weighted FSE are ideal. FS PD weighted FSE sequence are the best sequence for demonstrating ACL contour in cases of ligament disruption.

A standard ACL is depicted as a streak of low Susceptibility weighted image (SWI) in all the standard positions with striations of fibres seen separately near its attachments.

ACL appears as 3-4mm thick single hypointense band with a straight anterior margin, best assessed with the knee fully extended. With minimal flection of knee the signal intensity is minimally decreased.

The fat and synovium that separates the ACL fibres are seen as intermediate to bright signal intensity linear stripes on T-1 weighted image (T1 WI) in betwixt the low wave intensity fibres. Postero-lateral bundle of ACL forms the bulk of the ligament and displays more intermediate signal intensity on T1 W images. On all conventional sequences ACL demonstrates a greater signal intensity than that of PCL.



Figures depicting the axial intercondylar anatomy of ACL (Fig.1.14) and PCL(Fig.1.15).

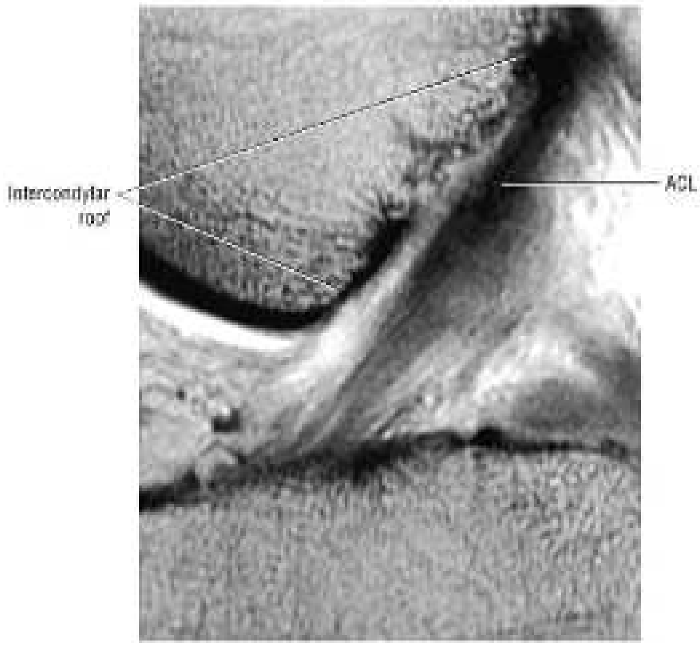


Fig.1.16: Sagittal image through intercondylar notch showing the ACL fibres paralleling the intercondylar roof

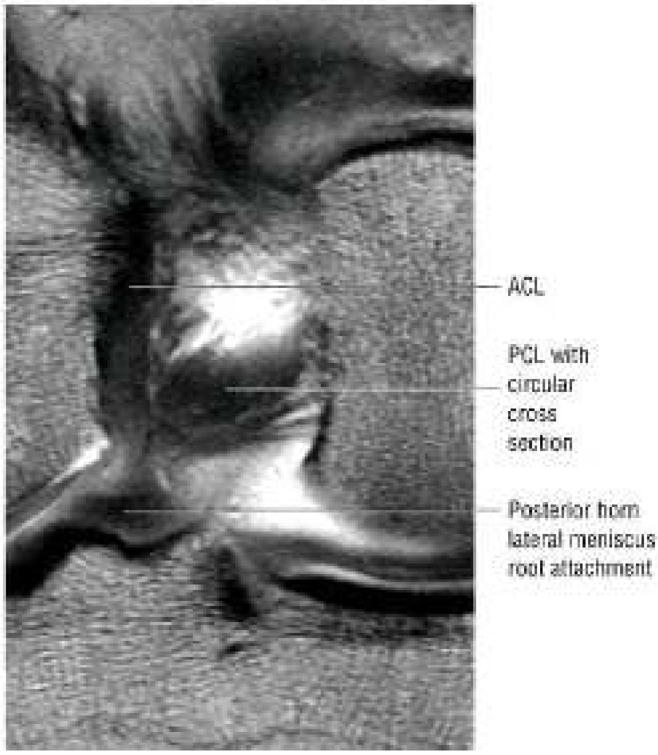


Fig.1.17: Coronal images showing a band like morphology of ACL.

ACL TEARS -

ACL is habitually the traditional ligament to be damaged in human race, almost always necessitates a surgical repair.

The heterogenicity of collagen fibers in ACL and the fibroblast function within the synovial cavity in combination hinders the intrinsic healing capacity of ACL and thus leading to a chronic disability, articular cartilage destruction and meniscal tearing.

Mechanism of injury:

ACL tears can occur in sports and non-sports related events in males and females. Various mechanisms in and around the knee have been described for ACL tears. These injuries can be as a result of contact, non-contact and due to chronic over use. 70-80% of ACL injuries are attributed to non-contact mechanism. Injuries most often occur with rapid deceleration resulting in forced valgus and external rotation, but ACL tears can also follow external rotation with hyperextension, internal rotation with full extension, and with forward displacement of the tibia.

Pivot shift mechanism is a most common mode in non-contact injuries. Here there is a valgus load along with flection and lateral twirling of the shinbone or mediate twirling of the femur.

Hyperextension due to a faulty landing during a jumping event and rapid contraction of quadriceps subjecting a fixed tibia to internal rotation are other noncontact mechanisms responsible for ACL injuries.

ACL injuries are usually associated with meniscal tears and other intraarticular pathologies like medial and lateral compartment articular cartilage erosions and chondral fractures.

O'Donoghue's triad: Injury to ACL, MCL and Medial Meniscus (MM) associated with valgus stress in external rotation (clip injury). Its most common cause is non- contact twist injury. (Fig.1.18)

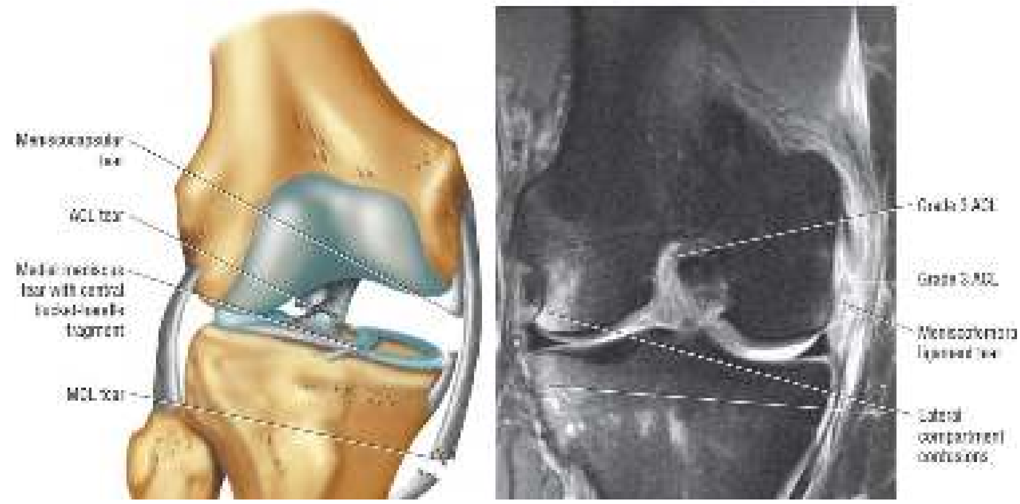


Fig.1.18: Schematic and Coronal FS PD FSE image demonstrating O'Donoghue's triad.

Clinical Assessment of ACL injuries:

Acute tears: Clinically acute ACL tears will be associated with evident hemarthrosis within several hours of injury in most of the patients and an audible tap.

Tests to demonstrate acute tear:

- Anterior tibial translocation test/ Anterior Drawer Test
- Lachman's (Noulis) test
- Pivot-shift test

Isolated ACL tears are best assessed using Lachman's test.

Subacute tears: There is decreased laxity in these tears due to adhesions to the PCL.

ACL tears can be classified into three categories for clinical assessment:

- Category A: portrays intrasubstance tear without alteration in ligament length.
- Category B: portrays intrasubstance tear with an increase in ligament length.
- Category C: portrays complete ligamentous severance.

MR Signs portraying ACL injury/tear:

Prime Signs:

- A deviation from the normal course of ACL (abnormal BA) (Fig .1.19)
- Abnormal signal intensity in the ligament.
- Discontinuity of the ligament fibers.

Minor signs:

- Osseous contusions of the posterolateral tibial plateau. (Fig.1.19)
- Contusion or fracture of posteromedial tibial plateau.
- Anterior displacement of tibia.
- Uncovering of undersurface of posterior horn of lateral meniscus.
- PCL buckling

Positive posterior cruciate line and angle.

Axial, frontal and median images are required for accurate assessment of ACL tears. An acute ACL tear shows a loss of continuity of fibres with a wavy contour and more horizontal orientation of ACL fibres along with increased signal intensity in the ligament itself that is appreciated well in T2, FS PD FSE and T2 sequences.

Interstitial tear of ACL shows widening of the entire ligament with variable increase in signal intensity. (Fig.1.23) Fluid if present between the fibres is best assessed on axial images. (Fig.1.22) Coronal images are useful to differentiate grades of ACL injuries and to differentiate partial from complete tears.

Hemarthrosis which is commonly seen in acute tears can be demonstrated as uneven free rim of Infrapatellar (Hoffa's) fat pad. (Fig.1.25).

Sub-acute tears will show all the features of acute tear with better visualization of the abnormalities due to resolution of acute edema and hematoma. (Fig.1.24)

In case of Chronic tears, there will be resolution of synovitis and edema and absence of irregularity of margins of Hoff's fat pad along with non-visualization of ACL fibres in sagittal and coronal planes. (Fig.3.10). A Positive "Empty notch sign", i.e. absence of ACL fibres in lateral intercondylar notch can be demonstrated in coronal images. (Fig.1.26) [40].

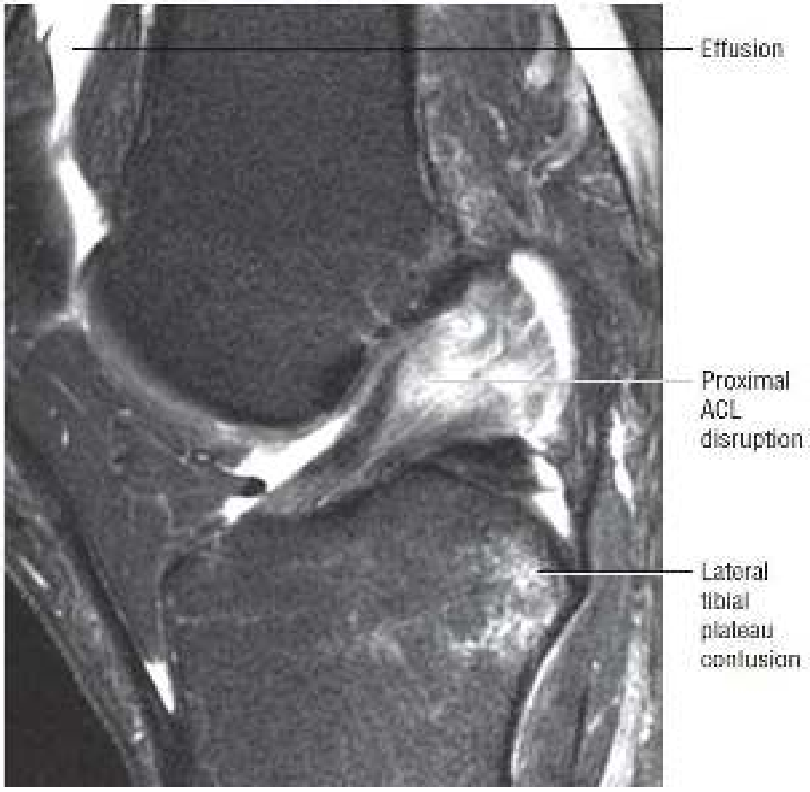


Fig.1.19: Sagittal image showing acute rupture of proximal ACL fibres. The slope of ACL decreased relative to BL.

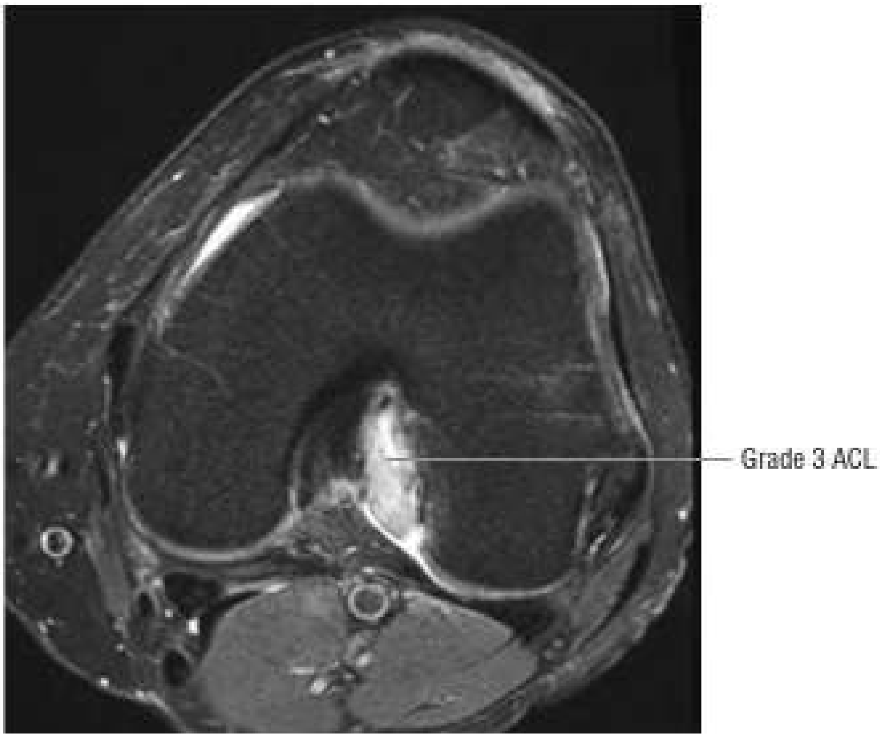


Fig.1.20: Axial FS PD FSE image showing Grade 3 ACL tear.

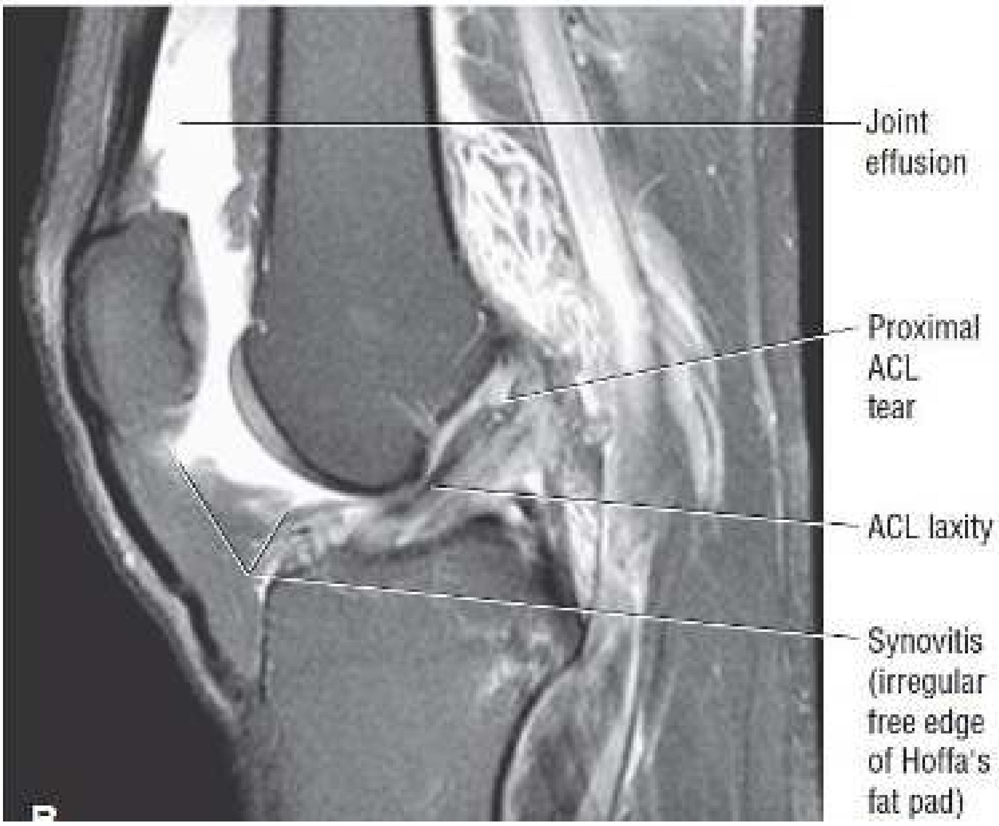


Fig.1.21: Sagittal FSE image showing acute signs of ACL tear

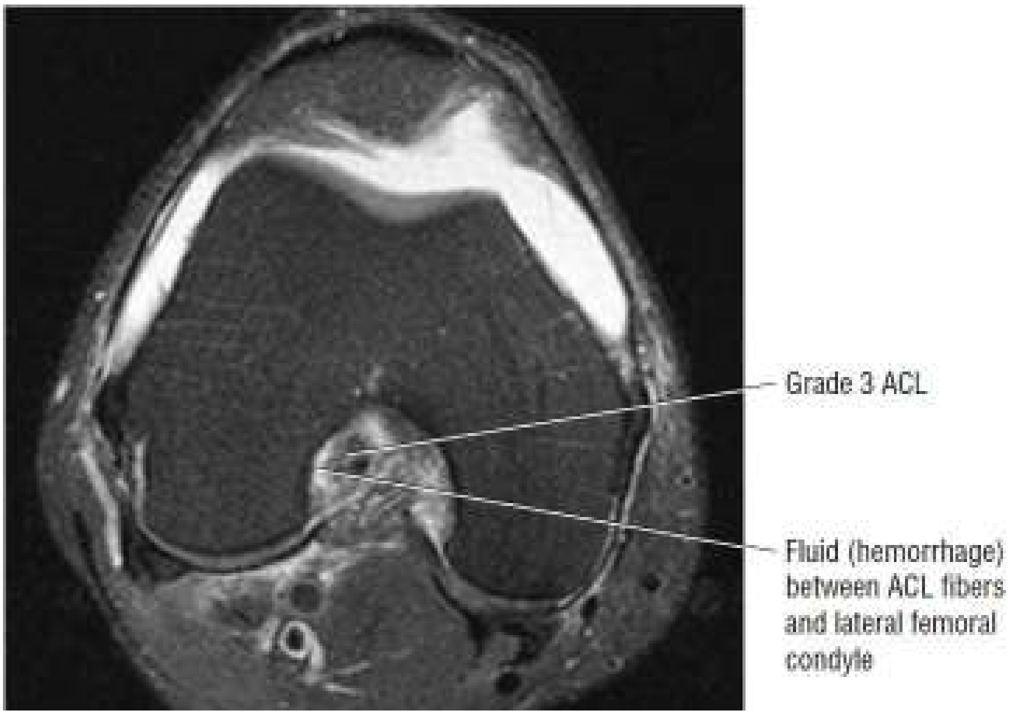


Fig.1.22: Axial FS PD FSE image demonstrating Fluid in acute tear

Fig.1.23: T2 Sagittal image showing interstitial ACL tear.

Fig.1.24: Sagittal PD image demonstrating Subacute tear of proximal fibres.

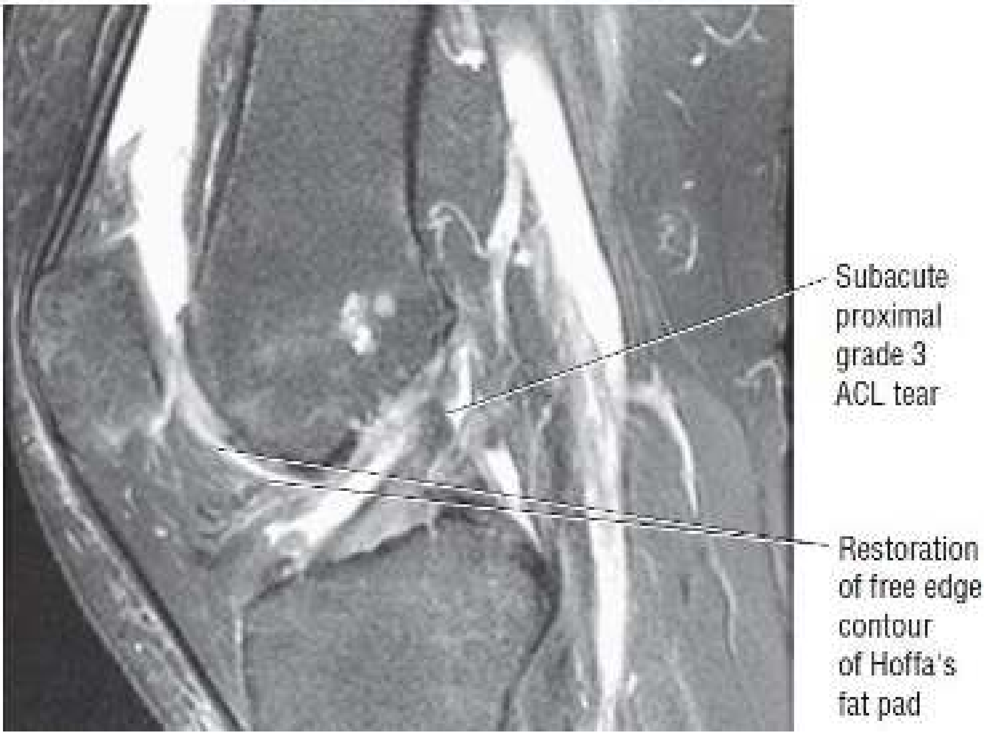


Fig.1.25: Reduction in signal intensity from acute ACL injury

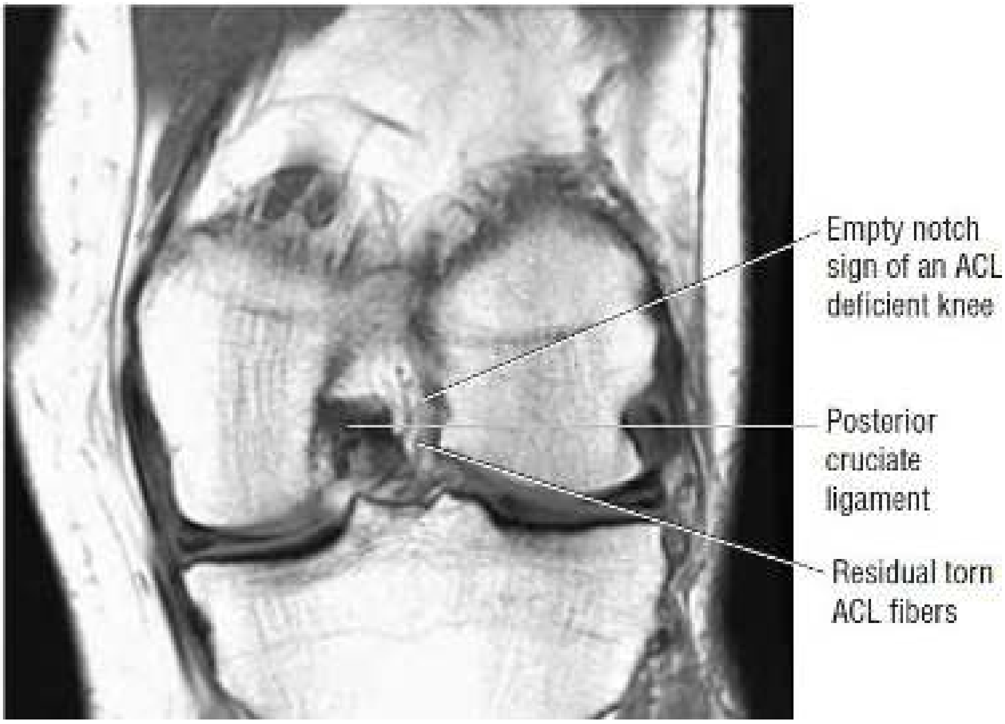


Fig.1.26: Demonstrates Empty notch sign in T1 weighted coronal images.

1. Tomas Fernandez et al did a case-referent study on 530 patients to study the relationship of intercondylar notch width and alpha angle (angle formed by BL with long axis of femur) with ACL tear. This study concluded that torn ACL are associated with a stenotic ICN shape and also that the tears are more common in men than women [(42).] This study also proved that ACL tears or injuries are more common in the males as compared to the females.

2. Shelbourne k d et al did a prospective study on 713 patients by measuring ICNW intra-operatively in patients undergoing ACL reconstruction. Their study concluded that notch width between height groups for gentlewomen or gentlemen was not statistically significant. They also showed that, females had statistically significant stenotic notches as compared to males pre-operatively. However Post-op there was no significant change between both the genders. Most importantly the study showed that patients with a stenotic notch has a soaring incidence of ripping up their opposite ACL [(20).] This study also proved that stenotic "Triangular" shaped notch is more vulnerable for ACL tears.

3. Eduard Alentorn-Geli et al did a study to evaluate association of torn ACLs with the ICN Angle and ICNW in male participants. They also evaluated the consortium of these injuries with other unorthodox knee morphometries. The study concluded that the ICN angle is a superior parameter in evaluating stenotic notches and its relation with torn ACL compared with the ICNW and also that enlarged dorsal tibial inclination may be correlated with ACL ligament injuries in gentlemen [(12).]

4. A comparative study done by Park et al on 226 subjects, (147 men and 79 women), showed that there is significant dissimilarity in bone osteology between men and women, and also in bone osteology between the ACL torn and the non-ACL torn participants. Additionally, they concluded that the female outpatients with small Notch Width (NW) and NWI in MRI, were more prone to have higher probability of torn ACL [(45).]

5. Ravichandran D et all conducted a study, Group A (dry bones) and Group B (cadaveric knees) and measured dimensions including notch width, condylar width, notch depth, condylar depth and the shape of the notch using standard guidelines in both groups. This study showed a normal range of ICNWI and notch depth index in Indian population and also inferred that stenotic notch may be a cause for dysfunctional ACL and in extreme cases may lead to tear of the same [(28).] This study also proved that stenotic "Triangular" shaped notch is more vulnerable for ACL tears.

6. Nawal M Al Moosawi et all did a retrospective case-referent study on 350 participants to study the importance of femoral NWI in foreseeing the ACL tears and concluded that the difference in the mean NWI in participants having a torn ACL and without a torn ACL is not statistically significant and also that there does not exist statistical difference in the persistence of tears in participants with and without severe notch stenosis [(46).]

7. Shweta Jha and Renu Chauhan conducted a study on 100 dry femora to know the contribution of morphometry of the condyloid and ICN of femur in ACL injury in citizens of India as there are sparse literature on that. They found that there was no statistically noteworthy dissimilarity betwixt the ACL injured

and knees having a normal ACL morphology. However, this study gave a normal mean condylar width and height, ICNW, depth and configuration in Indian population to abet Orthopaedicians in repairing torn ACL and regulate an appropriate surgical attention in knee injuries [47].

8. Lutul D. Farrow, MD did a study to distinguish the osteology of the femoral ICN mainly to aid during ACL reconstruction surgery because the accepted method of femoral tunnel placement is of utmost importance [48].

9. Andrade R, et al. did a dissertation on Notch morphology being a risk factor for ACL tears and sprains. They concluded that individuals with compact ICNW, reduced NWI and enlarged dorsal, mediate and lateral tibial inclination had more risk of ACL injuries [49].

10. Lena Hirtler et al did a study to test whether the variation in morphology (i.e., size & shape) with age exist in intercondylar notch and also to provide landmarks and measurements best adaptable for the intercondylar notch on MRI. They concluded that distal femur is prone to remodel depending on the age with an increase in width and contour changes and that the intercondylar notch should be quantified to estimate the risk of ACL tear, osteoarthritis, and, osteochondritis dissecans in children [50].

11. Gormeli et al supervised a study on the influence of ICNWI on ACL injuries and saw that NWI is significantly stenosed in participants with bilateral and unilateral ACL tears compared with the healthy controls which suggests that a stenotic NWI escalates the risk of ACL injuries [43]. This study also proved that stenotic "Triangular" shaped notch is more vulnerable for ACL tears.

12. V. Stein et all did a study on the association of narrow femoral notch to ACL tears in patients with degenerative arthritis of knee. They showed that a smaller NWI has association with ACL injuries in participants with degenerative arthritis of knee [(44).]

13. Ameet KJ and Murlimanju BV did a morphometric Analysis of Femoral Intercondylar Notch and Its Clinical application on 97 dry femora and found that majority of the notch had inverted "U" shape morphology and few had inverted "V" shape. The mean intercondylar notch width, intercondylar notch depth, condylar width and condylar depth was calculated and the data were compared on the right and left sides and they saw that the difference observed between the right and left sides were not statistically significant [(51).]

METHODOLOGY

Source of data:

The pilot investigation was conducted in the Division of Orthopaedics, KLE Society's Dr. Prabhakar Kore Hospital and Quaternary Medical Research Centre as well as KLE's Charitable Hospital Belagavi, on subjects of age ≥ 18years obtained as a sample among the In-patients, Outpatients and the Emergency services of Orthopedics Department of KLE Society's Dr. Prabhakar Kore Hospital and Quaternary MRC as well as KLE's Charitable Hospital Belagavi who are referred for MRI in Division of Radiology and Diagnostic imaging, KLE Society's Dr. Prabhakar Kore Hospital and Quaternary Medical Research Centre, Belagavi. The study population consisted of individuals with non-contact ACL injuries.

Sample size:

Time bound study with a minimum of 30 patients, but to get confirmative and statistically significant results the sample size was increased to 50 patients. All the out- patients /in-patients who came for MRI knee to the Department of Radiodiagnosis.

Sampling technique:

Purposive sampling technique.

Type of study:

One Hospital-based cross-sectional study

Method of study:

After taking informed and written consent, with a brief clinical history, patient is subjected for a knee MRI evaluation and the intercondylar measurements were made in the standard planes as described.

MRI sequence and parameters

A 3 Tesla MRI scanner (Siemens Magnetom Spectra Germany) with a multichannel phased array dedicated knee joint coil was used for image acquisition; and position of the patient was supine with slight flexion at knee of 5-10 degrees. Various measurements were planned to be done on,

Axial T2 Weighted: TR:4,200ms TE;73

PD-FS:TR:3,400ms TE:22

Sagittal T2 Weighted: TR:4,200ms TE ;93

T1:TR: 629ms TE;13

PD-FS:TR :2870ms TE:22

Coronal T2 Weighted:TR 3,500ms TE:93

PD-FS :TR 2,500ms TE:22 PD:TR 2,600ms TE:24

A field of view of 16x16cms, 256x256 matrix size, slice thickness of 3mm and flip angle 25 to 40 degrees, bandwidth of 180-200 Hz/pixel was employed.

Methods:

Femoral morphologic parameters were measured in axial and coronal plane as described by Stein et al at sections showing the popliteal groove [44].

The dorsal condylar reference line was delineated tangentially to the distal most tip of mediate and lateral condyloid.

Femoral intercondylar notch measurements:

- Intercondylar Notch Depth: Measured as a perpendicular line drawn from the proximal most tip of the notch to a line connecting the dorsal most tips on the ventral articular surfaces of both the femoral condyles.
- Intercondylar Notch Width: Denoted by a line parallel to the dorsal condyloid line at anterior 2/3rds of the notch depth.
- Intercondylar Notch Angle: Intersection between the proximal most tip of the ICN to distal most part of the notch at mediate and lateral condyloid.
- Intercondylar Notch Width Index (ICNWI): The ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove.
- Alpha angle: The "α" angle was measured in a sagittal section where the whole Blumensaat Line is appreciated as the intersection between the BL and the mechanical axis of the femur (α).
- Notch shape: "Triangular", "U" and "Ω" shaped intercondylar notch.


Fig.2.1 & Fig.2.2-Axial and sagittal images showing intercondylar notch measurements.

Inclusion criteria:

1. Patients with history of trauma and clinical evidence of knee joint instability
2. Patients > 18 years who accept radiographic and MRI examination of the affected knee before surgery.

Exclusion criteria

1. Patients < 18 years
2. Patients with significant joint degeneration and other arthritic disorders
3. Patients with any congenital deformity of the knee joint

Statistical methods to be applied

The facts and figures composed was scrutinized using both descriptive and inferential statistical methods. Descriptive methods such as Mean and Standard deviation were calculated for quantitative data, whereas frequency and percentage were obtained for categorical data.

Inferential methods such as Chi-square and Student's unpaired "T" test were used to calculate the "P" value. "P" value < 0.05 was taken as statistically significant.

Level of significance in the present study was 5% and statistical analysis were performed using SPSS 20.0 version. (*Machines IB. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp Armonk, New-York; 2013.)

Suitable diagrams like bar diagram, pie diagram and box plots are used to represent the data.

RESULTS

Our study was conducted in a Quaternary care center and since it was a time bound study, we were able to recruit 30 cases of non-contact ACL injury and to come to a conclusion; samples were increased from 30 to 50 which were all confirmed by clinical examination and imaging modalities. In our study the minimum and maximum age of cases was 17 and 48 years respectively with an average age of 31 ± 9.04 years. (Table 1.0 and Fig.3.1)

Table 1.0: Descriptive analysis of age

AGE	NUMBER	%
15-24	18	36.00
25-34	11	22.00
35-44	18	36.00
45-54	3	6.00

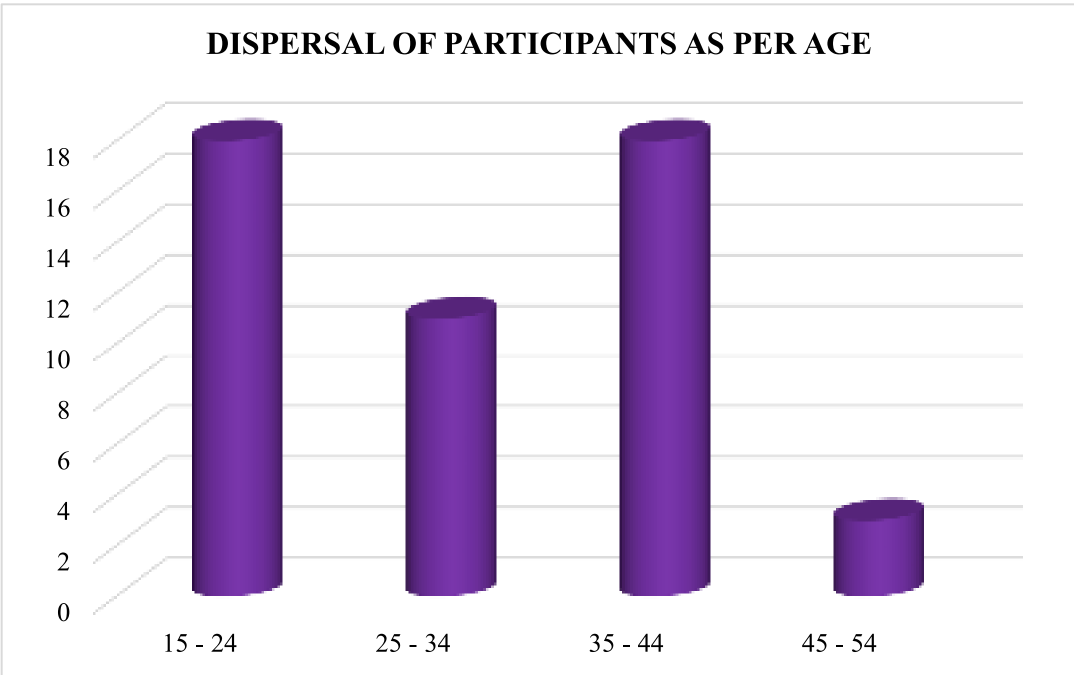


Fig 3.1: Simple bar chart depicting Age distribution of the sample.

In terms of sex distribution, our sample had male predominance, where in there were 36 males and 14 females (Table 1.1 and Fig.3.2)

Table 1.1: Sex distribution of the sample

GENDER	NUMBER OF PARTICIPANTS	%
GENTLEWOMEN	14	28.00
GENTLEMEN	36	72.00
IN TOTO	50	100.00

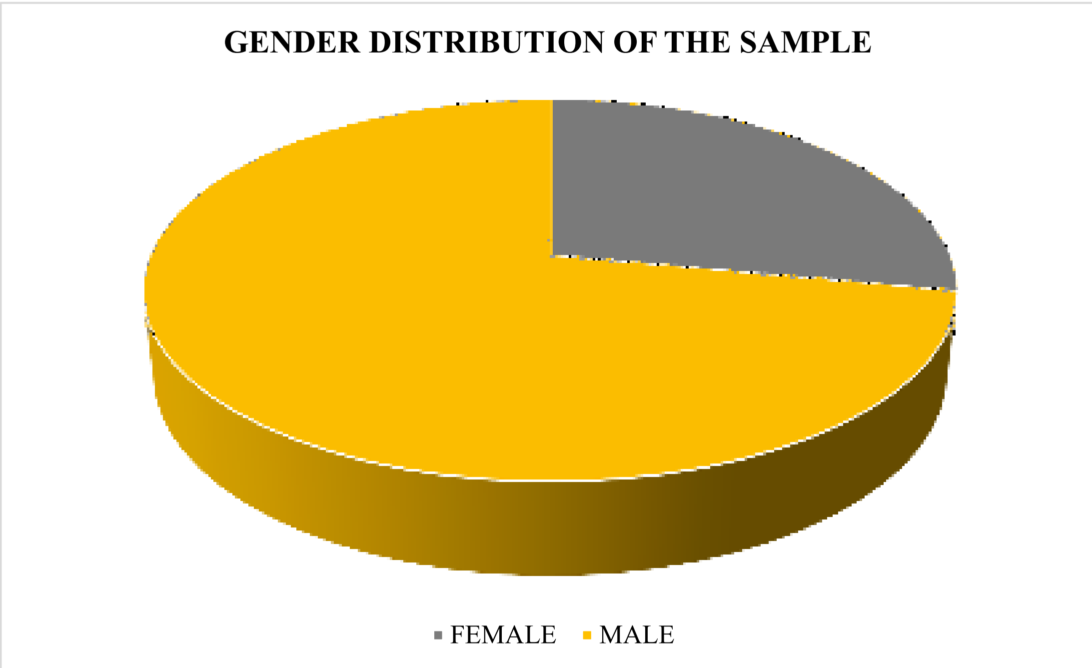


Fig 3.2: Pie chart depicting the sex distribution in the sample.

On MRI of the knee, the Femoral Intercondylar Notch morphometry revealed that out of the total 50 samples; 12 had a Triangular shaped ICN, 17 had an Omega shaped ICN and 21 had a U-shaped ICN. The finding of Triangular notch shapes was more common in the young adults with a mean of around 25 years (Table 1.2 and Fig 3.3)

Table 1.2: Intercondylar Notch Shapes among the participants.

NOTCH SHAPE	NUMBER	%
TRIANGULAR	12	24.00
OMEGA	17	34.00
U	21	42.00
TOTAL	50	100.00

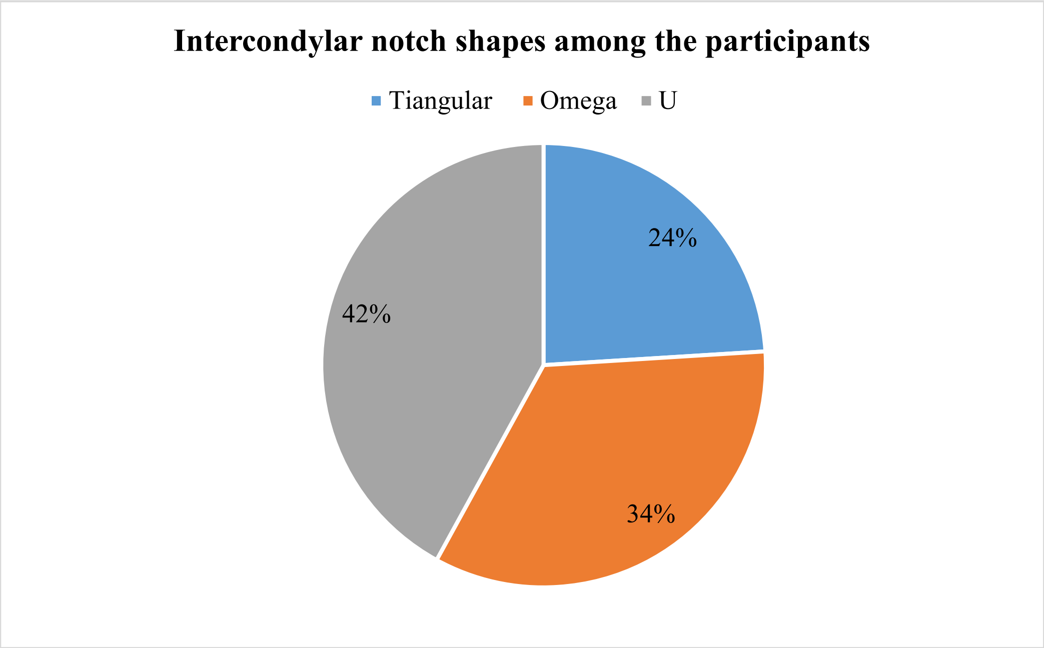


Fig 3.3: Pie chart depicting the Intercondylar notch shapes in the sample.

On the MRI scan of the knee, the femoral intercondylar notch morphometry revealed that the mean Notch depth was 3.42 ± 0.35 with a minimum notch depth of 2.6 and a maximum depth of 4.12. No statistical significance was found with this parameter.

The mean Notch width was 2.30 ± 0.33 with a minimum width of 1.48 and a maximum of 3.2. No statistical significance was found with this parameter.

The mean ICNWI was 0.32 ± 0.04 with a minimum ICNWI of 0.2349 and a maximum ICNWI of 0.4360. No statistical significance was found with this parameter.

The mean Notch angle (in degrees) was 48.53 ± 7.57 with a minimum angle of 35.4 and a maximum angle of 65.6. No statistical significance was found with this parameter.

The mean Alpha angle (in degrees) was 47.92 ± 3.79 with a minimum Alpha angle of 35.3 and a maximum Alpha angle of 54.6. No statistical significance was found with this parameter.

Table 1.3: Depicting association between the gender and notch shapes.

	TRIANGULAR SHAPE		OTHER SHAPES	
GENDER	**NUMBER**	**%**	**NUMBER**	**%**
FEMALE	4	33.33	10	26.32
MALE	8	66.67	28	73.68
TOTAL	12	100.00	38	100.00

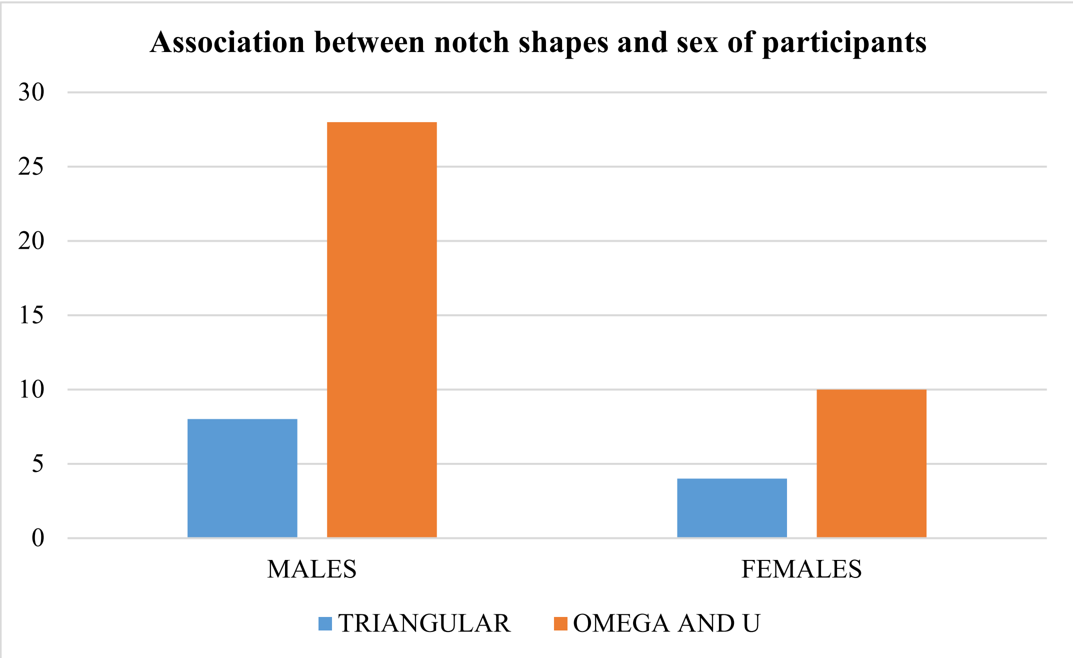


Fig 3.4: Bar chart depicting notch shapes in sex of the participants.

The p value using the Chi – square test is 0.6369 which is not significant, therefore there is no association between the gender and the intercondylar notch shapes.

Table 1.4: Comparison between triangular notch and other shapes (U & Omega)

	TRIANGULAR SHAPE				OTHER SHAPES					
	Mean	**S.D.**	**Min**	**Max**	**Mean**	**S.D.**	**Min**	**Max**	**p Value**	**Inference**
AGE	25.42	8.44	17	43	32.76	8.58	17	48	0.0125	S
N.D (in cm)	3.45	0.37	3.01	4.22	3.55	0.38	2.6	4.23	0.4468	NS
NW (in cm)	2.39	0.30	1.9	2.98	2.37	0.32	1.48	3.2	0.8134	NS
NWI	0.33	0.04	0.2639	0.3835	0.32	0.04	0.2349	0.4360	0.3099	NS
NA (in degrees)	52.57	7.08	37.8	58	48.43	6.83	35.4	65.6	0.0757	NS
α ANGLE (in degrees)	47.53	3.93	43.7	54.6	48.05	3.79	35.3	53.1	0.6864	NS

(S – Significant, NS – Not Significant)

In the following table the p value is calculated using the students unpaired "T" Test.

The significant difference for the parameter "AGE" indicates that the triangular shaped intercondylar notch is more likely to be seen in young adults around the mean age of 25 years.

For the other parameters significant difference is not found.

DISCUSSION

The ACL is the most common ligament to be injured in both contact and non-contact sports injuries. The mechanism of an ACL tear in non-contact injury is when loading a fully extended knee there is axial rotation and excessive valgus force with its center of gravity shifted away [(52), (53)].

ICN is an area of interest as it houses this important ligament which is a crucial stabilizer of the knee joint. There have been numerous studies and Meta-analyses conducted to assess the alliance betwixt ICN morphometry and ACL tears, but results have been a source of debate and inconclusive.

A study done by Palmer et al in 1938; the first to describe the association betwixt stenotic ICN and increase in likelihood of ACL tears and sprains [(16)]. Anderson and colleagues have also shown that femoral notch stenosis is associated with an escalation in the prevalence of ACL tears. And similar were the results of the study conducted by Ireland et al and they also showed that results were not affected by gender [(17), (19)].

Shelbourne et al, Lund-Hanssen et al and Souryal et al also concluded that ACL tears were common with people having narrow intercondylar notches [(20), (21), (22)].

Al-Saeed et al. studied the relationship between femoral notch morphology, femoral notch width index (NWI) and ACL tears using MRI of the knee and found a stenotic notch appeared to be a risk factor for ACL injury, whereas a reduced notch index had no significant correlation to ACL injury [(54)].

Herzog et al demonstrated using measurements from both radiographs and MRI that there is no significant difference between the notch measurements of athletes with chronic ACL tears [55].

Stijak et al concluded that maximal index of Notch Width and maximal index of notch shape were not significantly different in injured ACL and control groups [10].

The results of the present study have shown that there is an association between young male individuals having a Triangular shaped notch with an ACL injury.

Other measurements employed in our study were ICNW, ICNA, AA, and ICNWI. There was no significance between these.

A study was done by Lombardo et al in professional male basketball players also didn't find any alliance betwixt ICNWI and the prevalence of ACL injury [9]. The final outcome of this study is clarified as the project has few restraints.

CONCLUSION

Although there are many studies that suggest that there are various anatomic risks that are susceptible to ACL tears or sprains. There is no clear consensus on which particular parameter is the most common or specific one that is responsible for ACL injuries.

On the basis of our study, which has its own limitations as mentioned in the above discussion we conclude that a Triangular shaped intercondylar notch in young adults and adolescents predisposes to a higher prevalence of ACL tears; and also, that the males are at a higher risk as compared to the females.

However, considering this study as a Pilot project there is a huge scope in the near future for a detailed in-depth study considering age and sex matching with a multicentered setup which will overcome the drawbacks of this study.

LIMITATIONS

First, the participants involved are minimal due to the time-bound nature of the study. Second, no gender-based comparison could be done as this was a single center-based short time course study, we had to include all subjects with a non-contact ACL tears and sprains; the main purpose being to answer the primary objectives of this study and hence the filter of age and sex matching could not be adapted in our study. Third, since no set values have been accepted, the outcomes of this study could only be differentiated betwixt participants with ACL tears and those with intact ACL; in the absence of any set reference values.

Lastly to the best of our knowledge, we have very limited literature in the Indian population on this subject, as we know that there is a huge difference in the Asian Indian population and the Western population in terms of genetic make-up and skeletal morphology, the difference in results is bound to occur. However further studies in the dedicated Indian populations need to be done in order to further validate the results obtained by our study.

SUMMARY

- The study was done to measure the **"FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY"**

- Objective of the study:

  - To analyse the Femoral ICN measurements in patients with non-contact ACL tears and to study their correlation.
  - Parameters to be evaluated are Alpha angle (ACL-BL intersection, Femoral Intercondylar Notch Width (ICNW), Notch Angle (NA), Notch Width Index (NWI), Notch shape and depth.

- Through a proper questionnaire patient demographic detail, personal data and the mode of injury were taken into study who met the inclusion and exclusion criteria.

- The participants who underwent 3 T MRI of the injured knee were noted.

- The results were evaluated by statistical analysis using SPSS software and tabulated.

- MRI study to evaluate Intercondylar Notch morphometry in non-contact ACL injuries, a cross sectional time bound study done between 01st January 2020 to 31st December 2020. This study was conducted in 50 patients who fulfilled the selection criteria and underwent 3 Tesla MRI for the pathology in the knee.

- In this study we observed that there was statistically significant difference in one out of the Six parameters assessed among the samples enrolled in the study. There was a noteworthy consortium between the age and Triangular shaped intercondylar notch.

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ANNEXURE I – CONSENT FORM

"FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY"

PRINCIPAL INVESTIGATOR: ________________

INTRODUCTION AND PURPOSE: The present pilot study is conducted among participants who present to the Orthopaedics OPD/IPD of KLE's Dr Prabhakar Kore Hospital and Quaternary MRC and KLE's Charitable Hospital Belagavi aged above 18 years to measure the **FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES.** You are requested to participate in the study and your participation is completely voluntary.

PROCEDURE: If you agree to participate in this study, the relevant data will be collected as per the proforma and the final diagnosis will be confirmed radiographically. After getting enrolled in the study, you will be evaluated, complete detailed history will be taken and thereafter MRI scans will be done on OPD/IPD basis. The test is painless and can be performed within 30 minutes. The scanning will be carried out only once.

BENEFITS:

1. You will not be eligible for any kind of monetary benefits or free services by virtue of participation in the study.
2. As a tool in confirming the clinical diagnosis of ACL injury or tear.

RISKS:

No risks associated with the investigation.

WITHDRAWING / REMOVAL FROM STUDY:

You can withdraw from the study anytime you want to.

PRIVACY AND CONFIDENTIALITY:

All information about the participant during the course of the study will be kept confidential to the extent permitted by law.

COSTS:

MRI of the KNEE JOINT: Rs 4500.

AUTHORISATION TO PUBLISH THE RESULTS:

The researcher may use the information gathered from this study for presentation in scientific meetings and conferences. However, your identity will not be revealed.

QUERIES:

If you have any questions about the rights of a research participant, you can contact **Dr. Roopa Bellad**, Professor, Dept of Paediatrics and Chairman Ethical Committee on Human subjects, J.N Medical College Belagavi.

CONSENT SUMMARY

I have understood the information given by the doctor/s and in the information sheet above.

The nature, aims and objectives, outcome and the expected effects of the study have been thoroughly explained to me in my vernacular language …………………………………. that I can apprehend and understand. I have been informed what I have to do as a part of the study. I have had the time and opportunity to enquire about the study and the investigations that I will be undergoing and I have been fully satisfied with the explanations given.

I am ready to participate voluntarily in this study.

I agree to co – operate with the principal investigator and voluntarily undergo the procedures and investigations required in the study.

I understand that I have the full liberty to withdraw from the study at any given point of time without any justification.

I know that the results and the reports from this study may be used in scientific research, paper presentations, poster presentations, academic purposes and may be used for publications on web or print media.

By signing the consent form, I have not given up any legal rights which I am otherwise entitled to as a subject in the study.

I am aware that I will get a copy of this consent form which will be duly signed and dated.

Date: Witness:

Signature of the subject: Date:

I confirm that I have explained about the nature, purpose, objectives and the expected outcomes of the study to the subject whose name is printed above.

Signature and name of the person providing the required information:

ANNEXURE-II

PROFORMA

"FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL – BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON-CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY "

PATIENT NO: IP NO:

NAME:

AGE: SEX:

ADDRESS:

OCCUPATION:

DOA: DOS: DOD:

1] CHIEF COMPLAINTS:

2] PRESENTING COMPLAINTS:

Pain

Swelling

Instability

Giving away sensation

Stair climbing difficulty

Wound

Deformity

3] HISTORY OF PRESENT ILLNESS:

4] NATURE OF INJURY:

Road Traffic Accident

Sports injuries

Others

5] MODE OF INJURY:

Direct

Indirect

6] DURATION SINCE INJURY:

…………. days

7] History of Diabetes Mellitus, Hypertension, Asthma, Rheumatoid Arthritis, Tuberculosis and other chronic illness –

Yes -

No -

8] Previous history of ACL injury OR any other ligamentous injury of the knee

Yes -

No –

9] Previous history of any medication received:

10] Previous history of any surgeries:

11] PERSONAL HISTORY:

Diet : Veg/ Mixed/ Nonveg

Appetite : Increased or Decreased

Habits : Smoking/ Alcohol /Tobacco chewer / others

Bowel & Bladder Habits : Normal or Abnormal

12] FAMILY HISTORY:

13] GENERAL PHYSICAL EXAMINATION:

Built: Well /Moderate/ Poor

Temperature: Pulse:

Blood Pressure: Respiratory Rate:

Pallor

Cyanosis

Icterus

Clubbing

Pedal oedema

Lymphadenopathy

14] SYSTEMIC EXAMINATION:

Cardiovascular System Examination:

Respiratory System Examination:

Per Abdomen Examination:

Central Nervous System Examination:

15] LOCAL EXAMINATION:

INSPECTION:

Lower Limb Involved	RIGHT	LEFT
Pain		
Attitude		
Skin: Blebs / Ecchymosis / Avulsed / Bruise		
Swelling		
Effusion		
Deformity		

PALPATION:

Tenderness

Abnormal mobility

Loss of transmitted movements and continuity of bone

Peripheral Pulses: Dorsalis pedis / Posterior Tibial

Neurovascular Deficits: (Tingling numbness, Power) – Yes / No

Presence of any associated injury:

Yes

No

If yes specify -

RANGE OF MOVEMENTS:

Knee joint movements Flexion: Extension:

<u>Clinical special tests interpretation:</u>

A] Anterior drawer test:

B] Lachman's test:

C] Posterior drawer test:

D] Lever sign test / Lelli's test:

E] Others:

16] RELEVANT INVESTIGATIONS:

1. MRI SCAN
2. X RAY OF KNEE JOINT
3. ROUTINE INVESTIGATIONS:

Hb%, TLC, DLC, ESR, Platelet Count, Blood Grouping, CRP, RBS, Coagulation profile

4. HIV, HbsAg, HCV
5. URINE: albumin, sugar, microscopy.

17] DIAGNOSIS:

1. MRI SCAN –
2. X RAY OF KNEE JOINT -

18] TREATMENT:

FIRST AID: YES: NO:

Fluid Replacement

Immobilization of the Injured Limb

Analgesics

Physiotherapy:

Knee joint

Ankle and active toe movements

Static quadriceps exercises

Mobilization of knee

Non weight bearing with walker / knee immobiliser

Time of full weight bearing

To be evaluated: Intercondylar Notch Width Indices and Blumensaat Line Angle (Alpha angle) on MRI scan:

1] NOTCH DEPTH:

2] NOTCH WIDTH:

3] NOTCH WIDTH INDEX:

4] NOTCH ANGLE:

5] NOTCH SHAPE:

6] ALPHA ANGLE:

ANNEXURE-III- ETHICAL CLEARANCE LETTER

K.L.E. ACADEMY OF HIGHER EDUCATION AND RESEARCH
(Deemed - to - be University)
Accredited 'A' Grade by NAAC (2nd Cycle) Placed in Category 'A' by MHRD (GoI)
JAWAHARLAL NEHRU MEDICAL COLLEGE,
NEHRU NAGAR, BELAGAVI-590010 (KARNATAKA-INDIA)
Website: http://www.jnmc.edu
E-Mail : dome@jnmc.edu
Phone: (+91-(0)831 Office : 2472550
Principal: 2471701
Fax No. +91 (0)831 – 2470759

Ref: MDC/DOME/ 243 **Date: 24/12/2019**

To,
REG NO. BL0119003
PG student in Orthopaedics,
J.N.Medical College,
BELAGAVI.

Sub: Institutional Ethical Clearance for the study.

With reference to the above, we wish to inform you that your proposed research project titled **"FEMORAL INTERCONDYLAR NOTCH MEASUREMENTS INCLUDING ACL-BLUMENSAAT LINE ANGLE (ALPHA ANGLE) IN ADULTS WITH NON CONTACT ACL INJURIES – A ONE YEAR CROSS SECTIONAL STUDY "**, is ethical and justifiable. The proposed research project has been cleared by the JNMC Institutional Ethics Committee on Human Subjects Research.

(Dr. Anita Dalal)
Member Secretary
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

(Dr. Roopa M Bellad)
Chairman,
JNMC Institutional Ethics Committee
on Human Subjects Research,
J.N.Medical College, Belagavi.

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ANNEXURE IV - PHOTOGRAPHS

REPRESENTATIVE IMAGES

Fig.3.5: Sagittal image showing complete tear of ACL

Fig.3.6: Sagittal image showing chronic complete ACL tear

Fig.3.7: Coronal T2 STIR image showing Interstitial edema of ACL

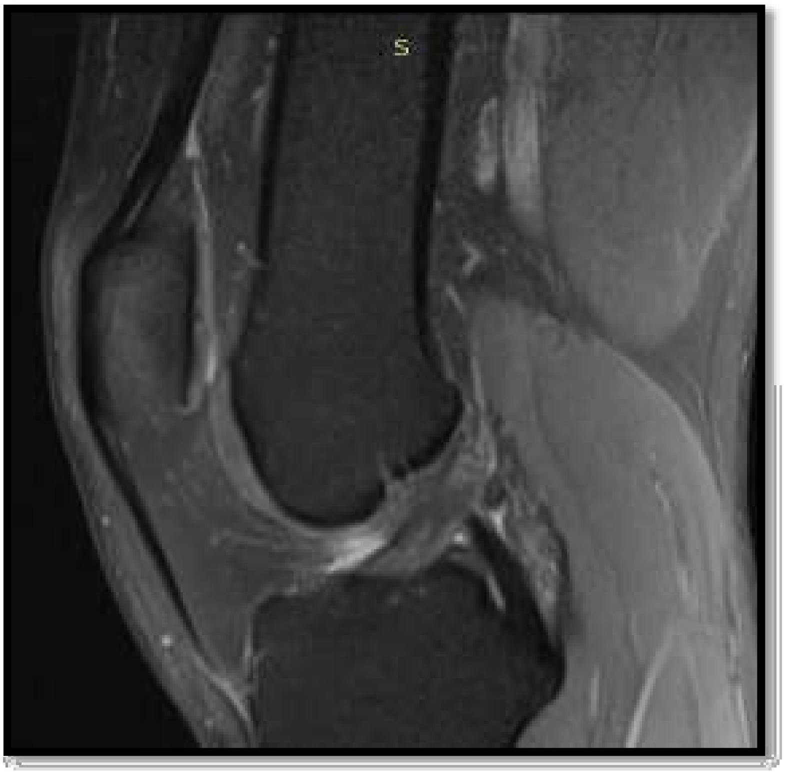


Fig.3.8: Sagittal image showing mucoid degeneration of ACL

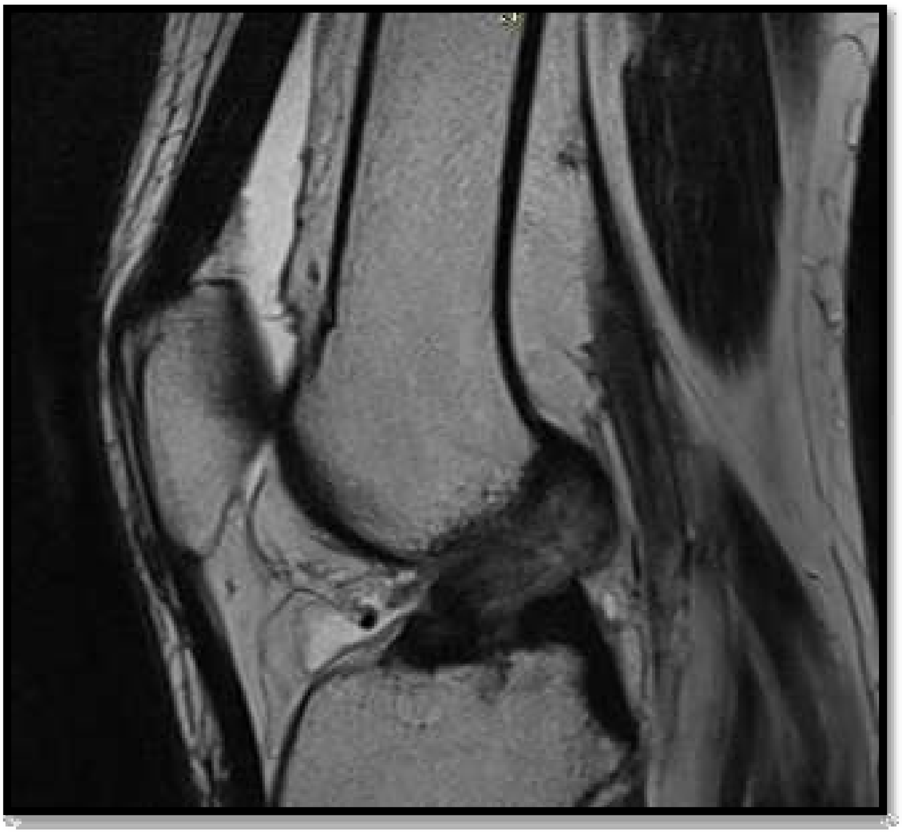


Fig.3.9: Sagittal image of knee showing partial thickness tear of ACL.

CASE 1

- Notch depth → 3.65
- Notch width → 1.76 cm
- NWI → 0.269525268
- Notch angle → 42 degrees
- Notch Shape → U shaped
- Alpha angle → 46.7 degrees

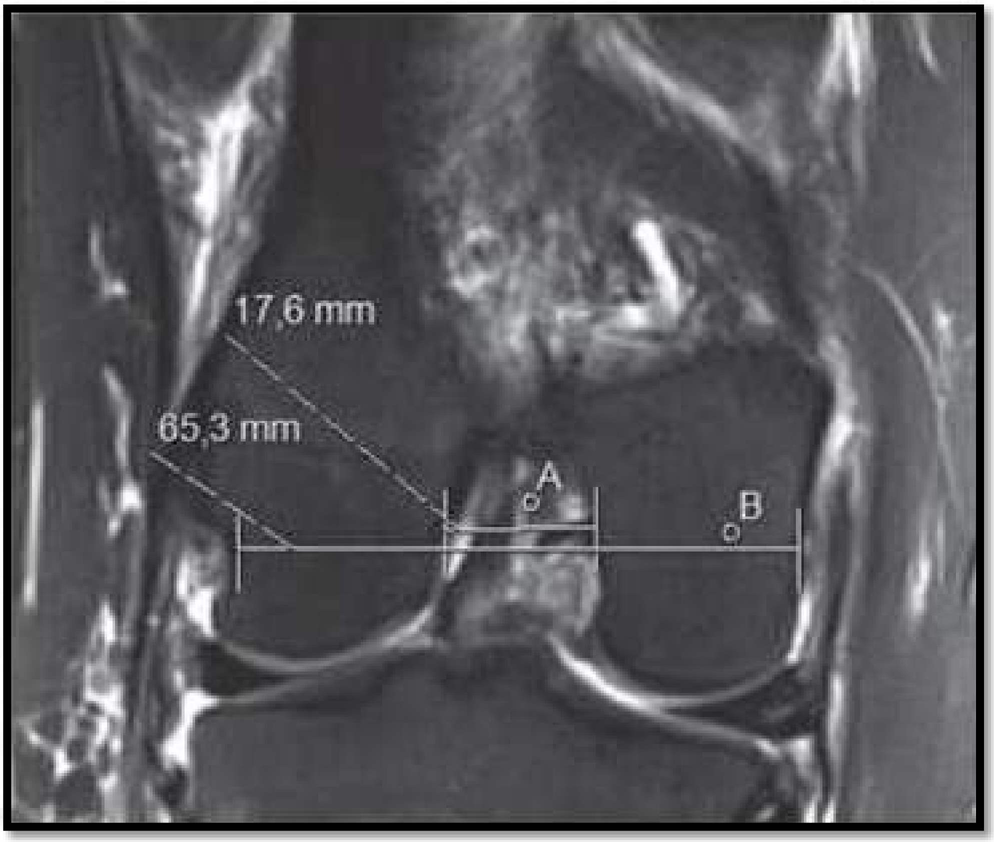


Fig.3.10: Depicting the Intercondylar measurements (Case 1)

ICNW and ICNWI.

Fig.3.11: Depicting "U" shaped intercondylar notch (Case 1)

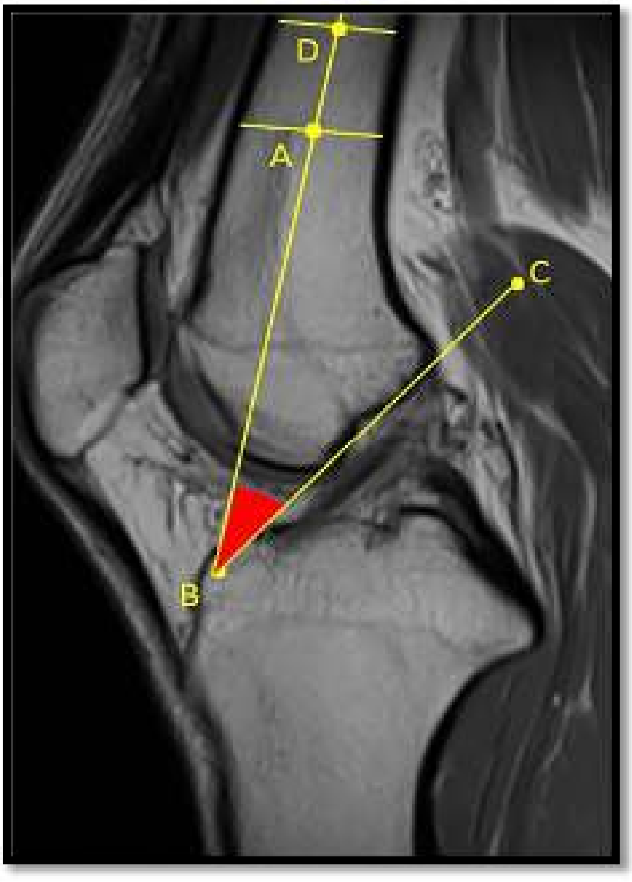


Fig.3.12: Depicting the Intercondylar measurements (Case 1)

ALPHA Angle.

Case 2

- Notch depth → 3.2 cm
- Notch width → 2.6 cm
- NWI → 0.333333333
- Notch angle → 57.2 degrees
- Notch Shape → U shaped
- Alpha angle → 52.5 degrees

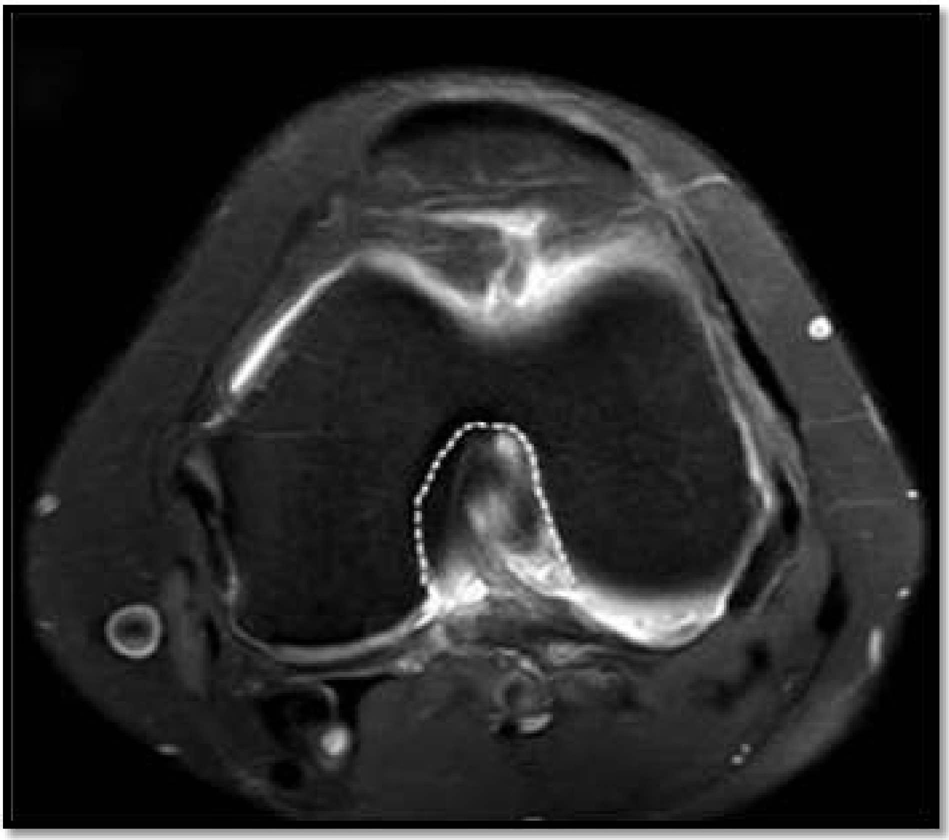


Fig.3.13: Depicting "U" shaped intercondylar notch (Case 2)

CASE 3

- Notch depth → 2.75
- Notch width → 1.86 cm
- NWI → 0.2242967992
- Notch angle → 54.7 degrees
- Notch Shape → U shaped
- Alpha angle → 51.3 degrees

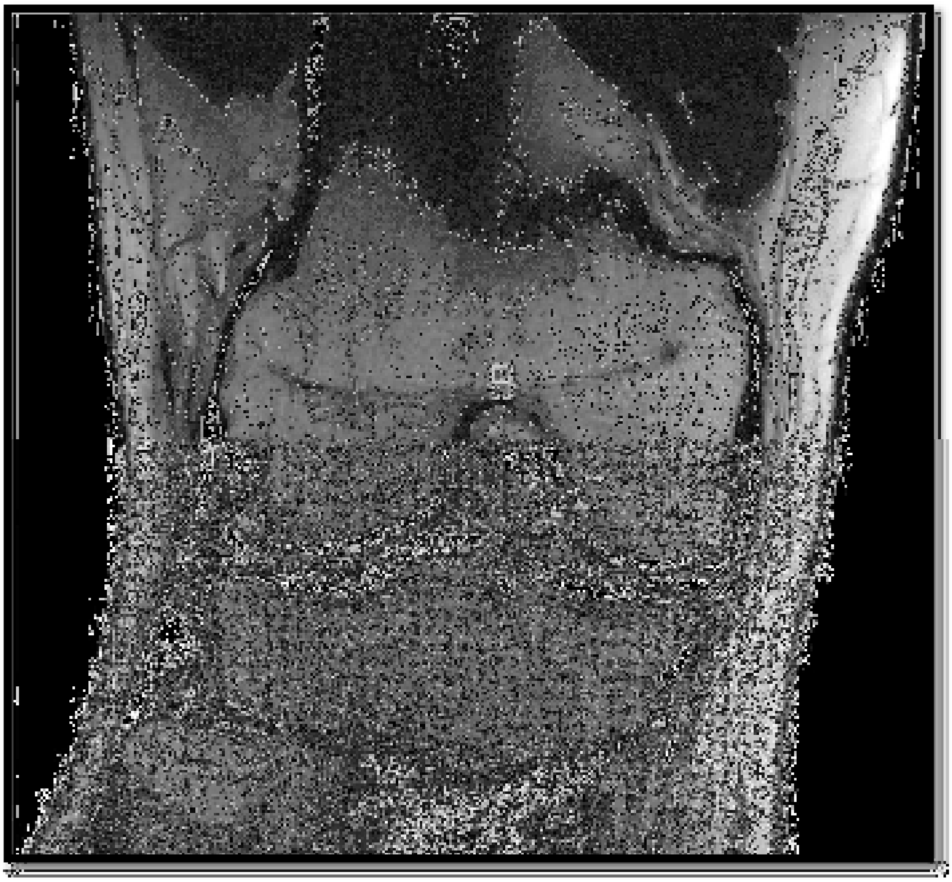


Fig.3.14: Depicting the Intercondylar measurements (Case 3)

ICNW and ICNWI.

Fig.3.15: Depicting the Intercondylar measurements (Case 3) ALPHA Angle.

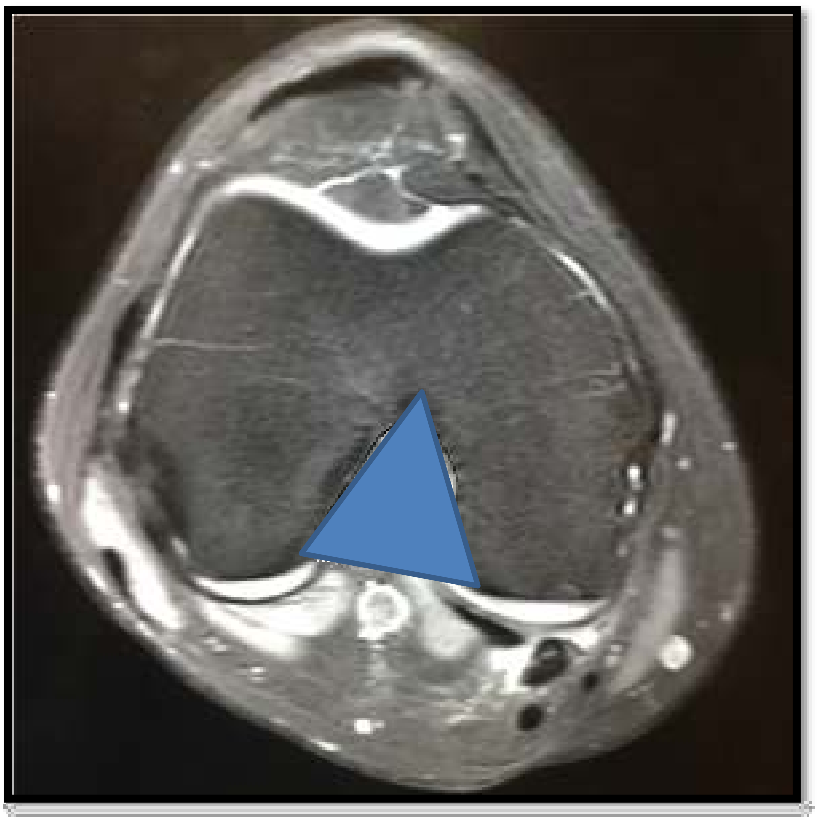


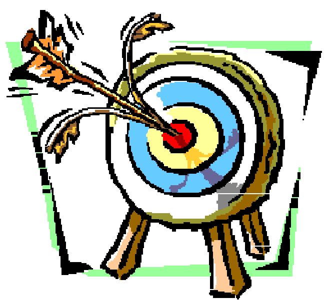
Fig.3.16: Depicting the Intercondylar measurements, Triangular shaped Intercondylar notch (Case 4)

ANNEXURE V - MASTER CHART

CASE NO	PATIENT IP/OP No	AGE	SEX	MRI DATE	MRI No	NOTCH DEPTH (in cm)	NOTCH WIDTH (in cm)	NOTCH WIDTH INDEX	NOTCH ANGLE (in degrees)	NOTCH SHAPE	ALPHA ANGLE (in degrees)
1	997895	17	MALE	26-01-2020	M9640	3.5	2.1	0.293296089	46.7	U	35.3
2	992357	48	FEMALE	04-09-2020	M9094	3.7	2.6	0.361111111	50	OMEGA	46.1
3	999781	25	FEMALE	27-12-2020	M11951	3.2	2.5	0.333333333	57.2	OMEGA	52.5
4	998094	24	MALE	13-01-2020	M12379	3.21	2.2	0.323529412	50.2	U	48.2
5	997541	43	MALE	28-01-2020	M12724	3.01	2.4	0.336605891	56.7	TRIANGULAR	43.7
6	996531	21	MALE	14-03-2020	M13813	3.25	2.2	0.293333333	50.9	U	49.6
7	995400	26	MALE	11-05-2020	B11520	2.75	2.07	0.3234375	54.7	U	41.7
8	991670	31	MALE	11-06-2020	M14808	4.02	2.65	0.348684211	41.5	OMEGA	47.3
9	987631	20	MALE	07-03-2020	B07320	3.39	1.48	0.234920635	35.4	U	51.3
10	990034	29	MALE	02-07-2020	M15185	3.95	2.03	0.270666667	43.5	U	47.4
11	1070065	26	MALE	25-07-2020	M15518	3.47	2.9	0.353658537	58.4	U	50.7
12	998980	22	MALE	18-03-2020	M13889	3.22	2.2	0.289473684	48.1	U	40.2
13	1012266	34	MALE	25-05-2020	M13987	3.32	2.12	0.278947468	44.8	OMEGA	46.4
14	1001068	39	MALE	12-02-2020	M13117	2.6	2.07	0.272368421	65.6	OMEGA	49.9
15	999749	38	MALE	05-02-2020	M13102	3.26	2.24	0.355555556	48.4	OMEGA	49.8
16	993496	24	MALE	03-01-2020	M12147	3.12	1.9	0.271428571	45.2	OMEGA	51.2
17	991243	39	MALE	04-08-2020	M15786	3.35	2.5	0.328947368	37.2	U	42.3
18	1014589	37	MALE	25-05-2020	B281220	3.67	2.1	0.269230769	42	U	47.8
19	997761	19	FEMALE	03-01-2020	M12143	3.6	1.9	0.263888889	37.8	TRIANGULAR	44
20	993923	37	MALE	09-09-2020	M12216	3.53	2.6	0.305882353	55	OMEGA	51.8
21	1000769	19	FEMALE	03-01-2020	M12142	3.37	2.5	0.342465753	58	TRIANGULAR	45.7
22	1019876	22	MALE	09-06-2020	M14757	3.58	2.1	0.265822785	46.6	U	47.2
23	1099875	36	FEMALE	03-12-2020	B031220	3.42	2.12	0.282666667	50.2	OMEGA	52.2
24	1109876	35	MALE	05-01-2021	A050121	3.74	2.3	0.2875	54.6	U	43.4
25	1112578	24	FEMALE	11-01-2021	A110121	4.12	2.4	0.340425532	38.1	U	45.4
26	1108976	40	MALE	17-12-2020	M17383	4.12	2.29	0.31369863	37.6	OMEGA	45.4
27	1010987	31	FEMALE	02-12-2020	M17057	3.44	2.14	0.271918679	42	U	50.5

CASE NO	PATIENT IP/OP No	AGE	SEX	MRI DATE	MRI No	NOTCH DEPTH (in cm)	NOTCH WIDTH (in cm)	NOTCH WIDTH INDEX	NOTCH ANGLE (in degrees)	NOTCH SHAPE	ALPHA ANGLE (in degrees)
28	1017635	40	MALE	21-11-2020	M16846	3.27	2.53	0.338688086	52.2	OMEGA	48.6
29	999902	41	MALE	05-11-2020	M16578	3.35	3.2	0.435967302	51.4	U	50.1
30	1109690	17	MALE	31-01-2021	M18365	3.12	2.59	0.375907112	55.9	TRIANGULAR	50.9
31	998980	34	MALE	05-11-2020	B064567	3.54	2.98	0.340678654	54.6	TRIANGULAR	49.4
32	1011752	24	FEMALE	11-01-2021	B231236	3.62	2.1	0.368745132	47	U	50.3
33	1000034	31	MALE	05-11-2020	M16578	4.22	2.6	0.314523678	54.8	TRIANGULAR	52.1
34	1000783	17	MALE	31-01-2021	M18365	3.78	2.28	0.383452619	53.8	TRIANGULAR	51
35	1010235	41	FEMALE	30-01-2021	M18345	3.66	2.67	0.345221786	51	OMEGA	48.8
36	1013890	36	MALE	09-03-2021	M19329	3.44	2.8	0.357189034	48	U	47.2
37	1123909	38	MALE	12-04-2021	M200073	3.65	2.5	0.312456903	49	OMEGA	48.9
38	1158731	34	MALE	19-07-2021	TSS1881	3.54	2.24	0.353245431	52	TRIANGULAR	54.6
39	1165009	22	FEMALE	13-10-2021	M23826	3.63	2.5	0.34580761	56	TRIANGULAR	47.6
40	1123126	43	MALE	25-09-2021	MR748	3.53	2.6	0.305782346	55	OMEGA	51.7
41	1190911	28	MALE	01-10-2021	M23564	3.01	2.4	0.336605891	56.7	TRIANGULAR	43.7
42	999934	40	FEMALE	28-09-2021	M5125	3.28	2.65	0.334678234	51.2	U	46
43	1081150	45	FEMALE	20-09-2021	M23236	4.12	2.4	0.340425532	38.1	U	45.4
44	1078431	24	MALE	20-09-2021	M23247	4.1	2.6	0.340982316	53.8	OMEGA	53.1
45	1155089	22	MALE	17-08-2021	MR490	3.01	2.4	0.336605891	56.7	TRIANGULAR	43.7
46	1123409	22	FEMALE	21-08-2021	M22448	4.23	2.6	0.35678412	53.1	OMEGA	52
47	1178600	19	FEMALE	06-08-2021	M22117	3.6	1.9	0.263888889	37.8	TRIANGULAR	44
48	1100992	37	MALE	20-07-2021	M21672	4.15	2.4	0.340425532	38.1	U	48.4
49	1010786	43	MALE	10-07-2021	M21418	3.82	2.61	0.356423145	54.8	OMEGA	49.6
50	1011565	46	MALE	12-07-2021	M21495	3.67	2.45	0.340980213	53.6	U	52.1

Introduction



Aims & Objectives

Review of Literature

Methodology

Results

Discussion

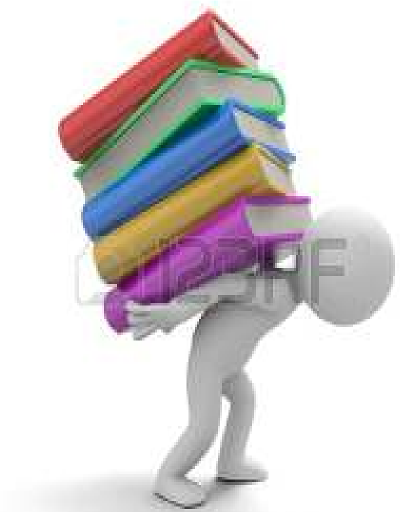
Conclusion

Limitations

Summary

Bibliography

Annexure-I



Annexure-II

Annexure-III

Annexure-IV

Annexure-V