FUNCTIONAL OUTCOMES OF PRIMARY ANTERIOR CRUCIATE LIGMENT RECONSTRUCTION TREATED WITH QUADRICEPS TENDON VERUS HAMSTRING TENDON AUTOGRAPT USING SUSPENNSORY FIXTION AT FEMORAL AND INTERFERANCE SCREW OR TIBIAL BASE PLATE FIXATION AT TIBIAL SIT: ARANDMIZED CONTROLLED STUDY

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in

ORTHOPAEDICS

LIST OF ABBREVIATIONS

mm - Millimeters

cm – Centimeters

ACL – Anterior Cruciate Ligament

AP – anterio-posterior

IV – Intravenous

BP – Blood pressure

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INTRODUCTION

One of the ligaments in the knee joint that ruptures most frequently is the anterior cruciate ligament. Reconstruction has long been a recognised method of treating instability and associated complications. [1–3].

Conservative or expectant treatment is an option more suited for people who don't have a high level of activity or associated lesions[4]. Conservatively treated Anterior Cruciate Ligament tears may have residual instability and pain. Pain can be due to instability of knee itself or instability related lesions i.e, Ramp lesion, bucket handle tears & posterior horn longitudinal tears of medial and lateral meniscus, chondral defects, stenosis and osteophytes at intercondylar notch[5]. Post traumatic osteoarthritis of knee is common finding in chronic Anterior Cruciate Ligament tears. Arthroscopic Anterior Cruciate Ligament reconstruction using autograft is a standard practice because allografts carry risk of slower graft incorporation and concern about higher rupture rates in some young highly active groups, concern about disease transmission and increased cost[6].

Bone Patellar tendon Bone graft has been considered the gold standard for anterior cruciate ligament reconstruction because of high strength, stiffness, ease to harvest, consistency of the graft size, and potential for bone integration.[7] However, patellar tendon rupture, patellar/tibial fracture are possible complications intra operatively. Post operatively common complaints of quadriceps weakness, loss of full extension, anterior knee pain, difficulty in kneeling has brought the attention towards other graft options.[7–10]

Hamstrings tendon autograft is common choice amongst surgeons due to a greater cross-sectional area and the maintenance of the extensor mechanism's integrity. The disadvantages of Hamstrings tendon graft may include a longer healing time and graft integration time within the bone tunnel, flexor weakness with compromise in internal rotation and loss of proprioception of the knee.[11] Above all Hamstrings tendon autograft has elastic modulus similar to that of native Anterior Cruciate Ligament, making post operative Lachman test springy firm end point similar to native Anterior Cruciate Ligament [5].

In recent years, the Quadriceps tendon as graft choice is being used increasingly for anterior cruciate ligament reconstruction because of its reliable graft size as the quadriceps tendon has the same width as the patellar tendon but a larger cross sectional area, resistance to rupture, harvesting with minimally invasive technique. It can be adjusted in width and length as per the patient's needs.[12] Compared to the hamstrings graft, laxity on pivot shift is less and hence it has failure rates that are lower than hamstrings

graft.[10] Disadvantages of Quadriceps tendon all soft tissue autograft include an extra incision required for graft harvest and Quadriceps atrophy post operatively which is inevitable[5].

In summary, Hamstrings tendon autograft is being used commonly in day to day practice for primary Anterior Cruciate Ligament reconstructions and Quadriceps tendon or Bone Patellar tendon Bone graft grafts are used as second option in multiple ligament injuries or revision surgeries. Studies claim that the quadriceps tendon as a graft tends to perform better than or equal to the hamstrings tendon. There is less substantial evidence to confirm the same, and hence to gather more proof, we plan to conduct this randomized controlled trial to assess the graft with better outcomes and fewer complications.[13–15]

AIM

To study and compare between the functional outcomes of primary single bundle arthroscopic Anterior Cruciate Ligament Reconstruction with Hamstrings versus Quadriceps tendon autografts using suspensory fixation for Femoral end and Interference screw/ Tibial base plate for Tibial end.

REVIEW OF LITERATURE

Galen[16] was the first to describe the fundamental characteristics of the anterior cruciate ligament, that it acts as a joint stabiliser and it limits excessive motion at knee joint (Circa 170 AD)

James Stark[17], According to an Edinburgh-based general practitioner couple of cases of cruciate ligament tears in 19th century, the knee would give way with a snap and the patient would lose control of the leg while lifting it. The first clinician to describe cases of anterior cruciate ligament insufficiency in English literature is frequently credited as "Stark".

A study titled "Clinical and experimental inquiry into bloody effusions of the knee joint in sprains" was published by Paul F. Segond[18] in 1879. Through his studies, he learned that anterior cruciate ligament tears were commonly seen along-side tibial plateau lateral margin avulsion fractures. He inspired the term of the fracture, 'Segond fracture' which is now recognised as the pathognomonic sign of an Anterior Cruciate Ligament tear.

The 1st repair of ACL by catgut ligatures stitched to the synovial membrane and tissues on the inner side of the external condyle in 1895 was reported bu A W Mayo Robson[19].

The first Anterior Cruciate Ligament Reconstruction was done using an iliotibial band by retaining upper attachment in thigh and was passed through canals bored into femur and tibia by Ernest W. Whey Groves[20] in 1917.

William C Campbell [21] published the first description of the use of medial-third patellar-tendon transplant in ACL-Reconstruction in 1935.

In 1939, Harry B. Macey[21] was the first to describe the semitendinosus auto-graft in ACL-Reconstruction.

The first application of the bone block of patellar tendon(central third) for anterior cruciate ligament reconstruction was made in 1963 by Kenneth G. Jones[22].

Extra-articular reconstruction using Tensor fascia-lata (Lateral Extra-articular Tenodesis) was done first by D L McIntosh[23] in 1972 and Lateral Pivot shift was first described in his article.

Rubin, Marshall and Wary[24] in 1975 used the first Dacron prosthetic in ACL-Reconstruction.

Joseph S. Torg, a trainee of John Lachman, first described the Lachman test[25] in 1976, which aids ACL tear diagnosis, specifically those for anteromedial bundle.

The use of Quadriceps tendon autograft for Anterior Cruciate Ligament Reconstruction was first described by Marshall et al.[26] in 1979.

In 1982, Lipscomb[27] performed the first ACL-Reconstruction by harvesting Hamstrings tendons.

The patellar-tendon based graft was used for anterior cruciate ligament reconstruction by Clancy initially and turned out to be the strongest, having 160% of the normal anterior cruciate ligament's strength, according to Nayes et al.[28] in 1984. In comparison, the semitendinosus and gracilis had 70% and 49% of the normal anterior cruciate ligament's strength, respectively.

In 1988 the arthroscopic Anterior Cruciate Ligament Reconstruction using quadrupled semitendinosus and gracilis autograft was first done by M.J.Fredman[29].

In their article, Anterior cruciate ligament reconstruction with autografts[30] in 1991, Tom Rosenberg first described use of Endobutton for graft fixation and L Paulos explained use of Polyethylene Anchor.

In 1997, Simonian P et al.[31] carried out a study on 9 patients followed up for 3 years. The effect on knee function, flexion & extension strength, individual posterior thigh muscle size, and the degree of hamstrings tendon retraction were specifically assessed. The HSS, Lysholm, and Tegner functional evaluation scores on average were 47.9, 88, and 0.27 respectively. Average quadriceps and hamstring strength was 93.7% and 95.3%, respectively, for the operated limbs compared to the unoperated limbs; neither drop was significant. In conclusion, despite a more proximal insertion of the retracted tendons, tendon harvest of the hamstrings muscles did not significantly impair function and strength. The majority of cases also showed partial but never full regrowth or scarring.

Christos DP et al.[32] published a study in 2001 with four cases of patellar fractures in 478 Anterior cruciate ligament reconstructions between 1992 and 1999, using the medial third of the patellar tendon graft. All of them were transverse fractures of the patella but only one was displaced. All patients suffered local injury to the donor knee between 2 and 4 months postoperatively. No

significant differences in the final outcome were noticed between the cases complicated with patellar fracture and those with uncomplicated Anterior Cruciate Ligament Reconstruction.

In 2005, Burks R et al.[33] incorporated At 3 and 12 months, the MRI cross-sectional area of 9 patients having ACL-Reconstruction with doubled hamstrings tendons was measured. The semitendinosus muscle was often retracted. The hamstrings occasionally merged proximally with the gastrocnemius or sartorial fascia. In one instance, the hamstrings reached a location close to the place of first attachment. At six months, hamstring strength testing on the operating side showed a 26% deficit at 60 degrees/second and a 16% deficit at 180 degrees/second. At one year, the mean deficit at 60 degrees per second was 21%, and the mean deficit at 180 degrees per second was 13%. Hence At one year, there was regular retraction of the semitendinosus muscle belly and considerable and chronic atrophy on the surgical side in the semitendinosus and gracilis muscles. One year after using the tendons for ACL reconstruction, there were still hamstring strength deficiencies.

J O Anders et al.[34] in their study in 2007, 45 patients between the ages of 19 and 52 who underwent anterior cruciate ligament reconstruction with a bone-tendon-bone graft were examined 36 months following the procedure to determine their proprioceptive abilities and functional success. The International Knee Documentation Committee (IKDC) score was applied to evaluate functional performance. In 95% of cases, very favourable and positive results were observed. Defects in the active angle reproduction test were very low after ACL- reconstruction, but defects were still present.

Snow B et al.[35] conducted a study in 2012 in which MRI were made of both limbs of ten patients nine to eleven years after they had ACL reconstruction with ipsilateral hamstring autograft. The volume of the individual thigh muscles bilaterally was calculated. The mean volume on the operatively treated side was 54.2% of that on the non-involved side for the gracilis muscle and 58.5% for the semitendinosus muscle. A 7% decrease in quadriceps volume and an 8% increase in the volume of the long head of the biceps on the operatively treated extremity were noted. Hence the gracilis and semitendinosus muscles showed persistent atrophy on the operatively treated side with evidence of fatty infiltration and variability in tendon regeneration. There was also persistent atrophy of the quadriceps muscles and compensatory hypertrophy of the long head of the biceps.

Using hamstring tendon autografts, Choi J et al.[36] in 2012 comprised 45 patients whose flexor strength, functional capability, and preoperative and postoperative MRI outcomes were assessed at least 2 years after surgery. These patients underwent primary anterior cruciate ligament

reconstruction. According to the hamstring tendon regeneration seen on MRI, the patients were split into 3 groups: those who had both semitendinosus and gracilis tendons renew, those who had just one tendon regenerated, and those who had no tendon regenerated. Between the groups, there were significant variations in the flexor deficit measured by the isokinetic tests performed in the standing and prone positions. There was a strong association (r = -0.472) between the outcome of the carioca test and the quantity of regenerated hamstring tendons. In the prone position isokinetic test, the proximal shift substantially linked with the flexor deficiency.

In a study published in 2014 by Leiter J et al.[37], 68 participants (43 men and 25 women) were included for analysis. At a mean follow-up of 14.6 years, 9% of patients had ruptured their anterior cruciate ligament again, whereas 5% had torn the anterior cruciate ligament on the opposite side. Osteoarthritis was more common and severe in knee reconstructions (P = 0.01). Surgery on the medial meniscus was a reliable indicator of osteoarthritis. On the IKDC, 75% received a normal or nearly normal knee score. Since the time of surgery, the Tegner Activity Level Scale scores have reduced (P 0.001) and the mean Lysholm score has increased to 75.8%. The contralateral knee had stronger knee extension.

In a study published in 2016 by Mohtadi N et al.[38], 330 patients with isolated anterior cruciate ligament insufficiency were taken into account. In total, 25 unique operations were necessary for 24 patients (7.3%), comprising 25 separate operations for patellar tendon, quadrupled hamstring, and doubled hamstring. Meniscal tears (3.6%), intra-articular scarring (2.7%), chondral pathology (0.6%), and wound dehiscence (0.3%) all required repeat surgery. Overall, the quadrupled/doubled hamstring groups experienced more complications (patellar tendon: 24, quadrupled hamstring: 31, doubled hamstring: 45), but at two years, more patellar tendon patients reported moderate to severe knee pain (patellar tendon: 17, quadrupled hamstring: 9, doubled hamstring: 4).

In a 2016 study by Konrath J et al.[39], 20 subjects who had had bilateral MRI after receiving a hamstring tendon graft as part of an ACL surgery performed strength testing. Only 35% of the patients displayed gracilis and semitendinosus tendon regrowth. Comparing the regenerated tendons to the contralateral side, they were longer and had more volume. For muscles whose tendons did not regenerate, semitendinosus and gracilis muscle size deficits were larger. Additionally, the total medial knee and hamstring muscles on the operative side had volume reductions of 10% and 12%, respectively. The biceps femoris muscle was shown to have a 7% higher volume in the postoperative limb, which was correlated with a weaker internal/external tibial rotation strength ratio. Because of

this, the semitendinosus and gracilis have significantly changed muscle-tendon characteristics after being harvested, and these changes may be to blame for the surgical limb's weak knee flexors.

In 2017, Sudevan PV et al.[40] reviewed the outcomes of 21 knees that had undergone endoscopic ACL-Reconstruction utilising BTB autograft from March 2014 to August 2015. An average follow up duration was 18-months. Out of 21; 9.5% patients fair, 66.7% good to fair & 23.8% received good to excellent outcomes. Out of 21; 9.5% patients fair, 66.7% good to fair & 23.8% received good to excellent outcomes. The two most frequent side effects were reported to be anterior knee discomfort and decrease of range of motion. One of their patients required removal of the interference screw as a result of interference screw protrusion on the tibial side.

A 2017 study by Shakked R et al.[41] compared hamstring autograft to bone-patellar tendon-bone autograft for anterior cruciate ligament repair in young female patients in order to assess patient-reported results, objective knee stability, complication rates, and the incidence of failure. There were 28 patients in the hamstring group and 37 patients in the bone-patellar tendon-bone group. There were no appreciable variations in the visual analogue score, Lysholm score, Kujala score, or Tegner level for patients who did not receive revision. The rate of return to an activity level at or above the level prior to injury was not different. Compared to the hamstring group, a significant number of patients in the bone patellar tendon bone group had graded 1a-Lachman & negative pivot-shift ($p<0.001$). Mean side to side manual maximal arthrometric testing showed significant difference ($p=0.001$). In the bone-patellar tendon-bone group, there were noticeably fewer repeat surgeries and a reduced percentage of graft failures. In the subjective functional results following anterior cruciate ligament reconstruction, they found no difference.

A study with 43 patients who underwent bone-tendon-bone graft reconstruction of the anterior cruciate ligament was done in 2018 by R Seijas et al.[42] The paratenon of the patellar tendon was closed during the same procedure for all patients. A radiological examination was done both before and two years after the procedure. All patients' axial views, patellar tilts, and Insall-Salvati indices were examined. The control group consisted of the healthy contralateral knees. No appreciable variations from preoperative measures or the 2-year follow-up were found. Hence During the two-year radiological follow-up period, there was no evidence that the patellar tendon used in anterior cruciate ligament reconstruction with paratenon closure altered patellar height.

In their study published in 2018, Sung jae kim et al.[43] included 237 patients operated with ACL-reconstruction between 2001 & 2008. Patients were separated into two groups depending on whether

they had generalised joint laxity or not. These groups were further divided into two subgroups depending on whether BPTB or hamstrings-graft were employed. Results from a 2 year follow up period showed the patients having hamstring grafts had worse outcomes than those who did not have generalised joint laxity. Results from a 5 year follow up period revealed regard-less of graft, patients with generalised joint laxity had worse outcomes than those without generalised joint laxity.

In a 2019 study, Rousseau R et al.[44] included 958 individuals who had isolated anterior cruciate ligament injuries and underwent surgery with just one knee surgeon. The percentage of patients experiencing anterior knee-pain was more in BPTB group during first two years following surgery (23.3% versus 12.6%, P 0.001); however, this difference was not significant after 2 years (3.1% versus 2.5%, P =.63). In the patellar tendon group, there were substantially fewer patients who experienced graft rerupture than in the hamstring group (25 of 811 [3.1%] versus 57 of 811 [7%], P = 0.023). Similar findings were observed in terms of the discomfort caused by the hardware (7 of 811 [0.8%] in the patellar tendon group vs. 113 of 811 [13.9%] in the hamstring group, P = 0.001) The patellar tendon group had a greater percentage of anterior cruciate ligament tears compared to the control group (17 of 811 [2%] vs. 41 of 811 [5%], P = 0.016).

In 2020, SJ Kabir et al,[45] in a study including 25 patients with Chronic ACL-deficient knee presenting from January 2018 to December 2019 were included in the study. The patients were followed till 6 months with specified program of rehabilitation. Results were evaluated by an independent examiner using radiography, subjective and objective evaluation. Assessment using Mean lysholm score was 50 preoperatively and 90.8 at the latest follow up ($p<0.005$). No patient complained of instability at latest follow up. The quadriceps muscle showed atrophy at final follow-up. Five Patients complained of anterior knee pain.

In 2021, Defroda S et al.[46] in their study with Ninety patients, reconstructed with Bone Tendon Bone or Hamstring graft, were randomized using two initial graft tension protocols; 1. normal anteroposterior laxity (low-tension) and 2. AP laxity over-constrained by 2 mm (high-tension). 72 patients had data available at 7 years, with 9 excluded for graft failure. Outcomes included the Knee osteoarthritis Outcome Score and Tegner activity scale. There were significantly improved outcomes in the high-tension compared to the low-tension Hamstring group for SF-36 subset scores for bodily pain (p=0.012), social functioning (p=0.004) and mental health (p=0.014) 84-months post-surgery. No significant differences in any outcome were found within the Bone Tendon Bone group.

In order to examine the pain levels and analgesic use following a single bundle anterior cruciate ligament restoration with free quadriceps tendon versus hamstring tendon autograft, Cristian Tudor et al.[47] included 48 patients for a randomised controlled study in 2016. In comparison to participants with hamstring grafts (13%), a much higher percentage of subjects with quadriceps grafts (50%) were pain-free after surgery. Comparing the Hamstrings group to the Quadriceps group, the proportion of patients who needed an additional analgesic medication was 38% greater in the Hamstrings group.

In a study published in 2017, Etienne Cavaignac et al.[48] examined 95 patients who had isolated anterior cruciate ligament reconstruction, 50 of them underwent the procedure using the quadriceps tendon and 45 using the hamstrings. There were 3 reoperations on the hamstrings and 4 on the quadriceps tendon group (including 2 revisions). The Lysholm, KOOS Symptoms, and KOOS Sport scores in the quadriceps tendon group were considerably higher than in the hamstrings group. In comparison to the HT group, the Quadriceps Tendon group had a larger percentage of the negative Lachman component (90% vs. 46%, P=0.005). Compared to the hamstrings group, there was a tendency for the negative pivot-shift component to be larger in the quadriceps tendon group (90% vs 64%; P=0.052). In both groups, “the Shelbourne-Trumper score” was identical. In terms of isokinetic strength, there was no distinction between groups. The study found that using a quadriceps tendon graft in anterior cruciate ligament reconstruction produces functional results that are on par with or better than those obtained with a hamstring graft, without increasing morbidity.

Data from 80 patients with a 2-year follow-up were prospectively gathered by Armin Runer et al.[15] in 2017. 24 months after surgery, the mean Tegner activity score of the HT group was considerably ($p = 0.04$) lower than the pre-injury state for the quadriceps tendon and hamstring tendon autografts. 27 patients (67.5%) in the quadriceps tendon group and 32 patients (80.0%) in the hamstrings tendon group had reached their pre-injury activity levels at the time of the last follow up. Thirty-three patients (82.5%) with quadriceps tendon autograft and twenty-eight (82.4%) with hamstrings tendon autograft reported "no pain" or "slight pain" during vigorous exercise. According to the Lysholm score, a total of 37 patients (92.5%) from the quadriceps tendon cohort and 35 patients (87.5%) from the hamstrings tendon cohort reported "good" or "excellent" results. Both the grafts from the quadriceps tendon and the hamstrings tendon exhibit acceptable and comparable PRO scores, making the quadriceps tendon a reliable graft substitute for the hamstrings tendon in the primary reconstruction of the ACL.

When compared to an ACL-reconstruction with the hamstrings tendon in soccer-players, Jose Luis Martin Alguacil et al.[49] 's randomised controlled trial on 56 patients showed same functional outcomes & better iso-kinetic Hamstring tendon vs Quadriceps tendon ratio at 12 months of follow-up. The results of the ratio analysis of the participants over time revealed significant differences at 60, 180, and 300° at 3, 6 and 12 months of follow-up. Furthermore, after 3 and 6 months follow up, they found significant differences in the participants' peak torque at extensor strength, with greater values in the hamstrings tendon group, and not after 12 months of follow-up. At 24 months follow up, there were no appreciable changes in functional outcomes or arthro-meter evaluations. This graft's benefit over hamstring tendons for ACL-reconstruction may be due to the larger hamstring/quadriceps tendon ratio that was seen with quadriceps tendon.

In a study conducted in 2019 by John Nyland et al.[13], the quadriceps tendon group included 17 patients, whereas the hamstrings tendon group had 61 patients. Overall, pivot shift laxity was higher in Group 2. Greater pivot shift laxity was seen in Group 2 suspensory femoral fixation compared to Group 1 compression femoral fixation. Additionally, based on the initial and end subject numbers, Group 2 compression femoral fixation showed higher failure rates and more anterior knee laxity than Group 1 compression femoral fixation. Based on the initial and final subject numbers, hamstrings tendon compression femoral fixation had a higher failure rate than suspensory femoral fixation.

A retrospective cohort analysis with a 12-month follow-up was carried out in 2019 by Ralph Akoto et al.[14] The study included data on 92 patients. At the follow-up, there were no discernible differences in the Tegner score ($p = 0.9$), subjective or objective IKDC score ($p = 0.9$; $p = 0.6$), knee stability (Lachman Test, $p = 0.6$; Pivot-Shift Test, $p = 0.4$; Side-to-Side Difference, $p = 0.4$), functioning testing (One-Leg Hop Test, $p = 0.6$; Thigh Circumference, $p = 0.4$ 85% of the quadriceps tendon group and 83% of the hamstrings tendon group failed the Lachman test. 80% of the quadriceps tendon group and 85% of the hamstrings tendon group failed the pivot shift test. In conclusion, the press-fit approach used to fixate the Quadriceps tendon transplant produced positive results that were on par with those of a conventional interference screw-fixed hamstring tendon graft. As a result, it is a trustworthy substitute for main ACL surgery.

In a retrospective study conducted in 2019, Adrian Todor et al.[50] identified 82 patients who had undergone anterior cruciate ligament reconstruction utilising either a free quadriceps tendon autograft or hamstring tendon. Of these, 72 (87.8%) patients returned to the hospital for follow-up. Regarding KT-1000 readings, no statistically significant difference between groups was found. The mean postoperative Lysholm, modified Cincinnati, and overall SF-36 scores did not significantly

change across groups. The quadriceps graft group showed a smaller change in thigh diameter from side to side.

90 patients who underwent anterior cruciate ligament reconstruction using quadriceps tendon, hamstring tendon, or bone patellar tendon bone were examined one year after surgery in a research by Mauarbes D et al.[51] published in 2020. The mean POSAS (patient and observer scar assessment scale) is significantly lower in quadriceps tendon patients (p 0.0001), the mean incision is shorter (2.8+/-0.4 cm vs 6.4+/-1.3 cm), the extent of hypo-aesthesia is less severe (8.7+/-5.1 cm^2 vs 88.2+/-57 cm^2; p=0.0001), and Lysholm-score is higher (90.1 10.1 In KOOS, there was no discernible change (90.7 7.2 vs. 88.4 7.0). There was no discernible difference between the quadriceps tendon group and the hamstrings tendon group in terms of the mean POSAS-score (24.8+/-6.3 vs 31.8+/-6.2), the mean incision-length (2.8+/-0.4 cm vs 2.5+/-0.6 cm), the KOOS (90.7+/-7.2 vs 89.8+/-8.2), or the mean Lysholm-score (90.1+/-10.1) The Hamstrings tendon group had a considerably larger mean measured region of hypoesthesia (70.3+/-77.1 cm^2 vs. 8.7+/-5.1 cm^2; p=0.0001).

100 patients who had all-soft tissue quadriceps tendon autografts after revision anterior cruciate ligament restoration were enrolled in the study by Hunnicutt J et al.[52] in 2021. With an average follow-up of 42.2+/-21.2 months, the mean IKDC scores considerably improved (54.3 13.0 vs. 82.8 13.8). Knee laxity side-to-side disparities at 6 weeks (1.2 1.5 mm), 3 months (1.2 1.8 mm), and 6 months (1.4 1.6 mm) did not alter significantly with time. Patients with prior hamstring versus patella tendon autografts did not differ significantly in terms of quadriceps or hamstrings Limb Symmetric Index (P > 0.050). Using all-soft tissue QT autografts for revision anterior cruciate ligament reconstruction, reasonable complication rates (11/80 patients with follow-up) were observed. Strength following prior patellar tendon versus hamstring autograft does not suffer from secondary injury to the extensor mechanism by quadriceps tendon autograft harvest.

52 patients who undergone an anterior cruciate ligament reconstruction were included in a study by Pomenta Bastidas et al.[53] in 2022. A mean follow-up of 27.4 months was used to analyse 44 individuals (20 quadriceps tendon, 24 hamstrings tendon). In the quadriceps tendon group, two patients underwent revision surgery (including one), while one patient in the hamstrings tendon group required revision surgery. The postoperative Lysholm (96.05 vs. 96.05), IKDC (86.2 vs. 91.2), and Tegner (6 vs. 5) scale scores did not significantly differ between the two groups. In all groups, there were almost the same numbers of negative Lachman and pivot shift tests (45% vs. 50% and 40% vs. 45.8%, respectively). Both the percentage of participants who returned to their previous

level of activity (62.5 vs. 45%, p = 0.17), and the degree of satisfaction (95.2 vs. 80%, p = 0.16), did not significantly differ between the groups.

Brinkman J et al,[54] in his retrospective study in 2022, "Mid-Term Outcomes of the All-Soft Quadriceps Tendon Autograft are Non-Inferior to Hamstring Autograft in Primary Anterior Cruciate Ligament Reconstruction: Comparison with Minimum 5-year Follow up" included patients in 37 Quadriceps and 46 Hamstrings autograft groups. The average graft-size in the Quadriceps group was higher (9.64mm vs 7.90mm, p=0.001). At two years post-operatively, IKDC and Lysholm-scores were comparable between two groups. The Quadriceps group showed substantially higher IKDC (p=0.018) and Lysholm (p=0.007) scores five years after surgery. At both two and five years post-operatively, the groups showed comparable rates of reaching "minimal clinically important difference" (MCID) criteria. Similar rates of return to sports & post-operative complications were also seen across the two groups.

EMBRYOLOGY

The first signs of knee joint development appear around 4th weeks and formation of recognisable knee is formed by 6th weeks of intrauterine life[57].

Wojciech Ratajczak[58] studied 43 embryos at developmental stages 18 to 23 (44–56 postovulatory days). At stage 18, embryos show the homogenous interzone of the eventual knee joint.

The cruciate ligaments are created in the medial region of this interzone during stage 19, which also sees the differentiation of this interzone into dense, intensely stained, peripheral parts that are the meniscal primordia. Stage 20 is when all of the internal knee joint structures are more completely defined, and the final embryonic week is when they are fully formed (stages 21–23).

The ACL is initially a ventral ligament that invades as the intercondylar gap develops. It develops prior to joint cavitation and is always extra synovial. The idea that both tissues work together is supported by the fact that meniscus and the cruciate ligament both come from the same blastema[57].

ANATOMY

The ACL is an extra-synovial intra-articular structure as it is surrounded entirely by synovium made up of many fascicles of thick connective tissue and links the femur and tibia. It starts on the medial surface of the lateral femoral condyle's posterior part, runs in an oblique fashion within the knee joint and inserts into a large space in the middle of the tibial plateau. The ligament's fibres slightly rotate externally during its course[59].

It is 44 mm^3 thick near mid-substance (average width of 11mm[59]) which increases about three times the area near its origin and insertion[60,61]. It is approximately 31 to 38 mm long[62].

As anatomical location of the graft in an isometric position during ACL restoration is so crucial, understanding the structure of the ACL attachment sites is vital.

Femoral-Attachment: Lateral femoral-condyle posteriorly at medial surface of intercondylar-notch is where ACL begins.(Fig. 1) ovoid area of about 18 mm long and width of about 11mm[46]. The attachment anteriorly is nearly straight, and posteriorly convex[59].

Tibial attachment: The medial and lateral tibial spines, which are located anterolateral to tibial-tubercle in inter-condylar fossa, are where the ACL inserts. Axial area of the ACL insertion is 11 mm in coronal & 17 mm sagittal plane[60,63].

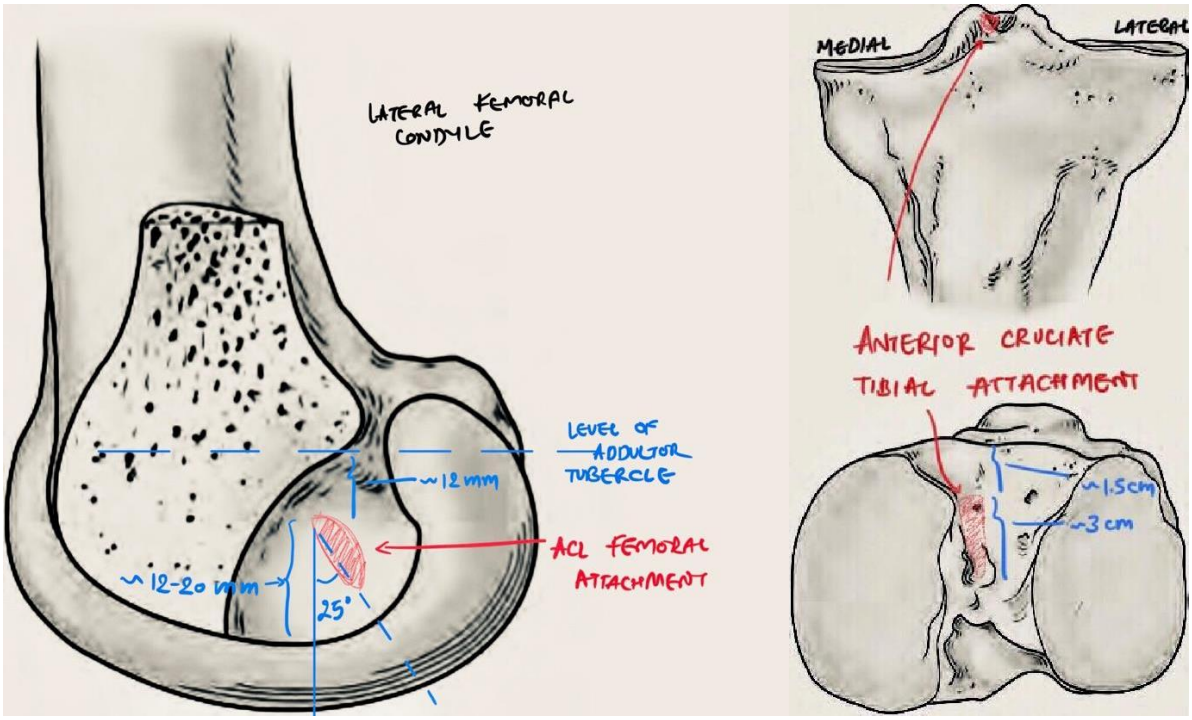


Fig. 1: Femoral and Tibial attachments of Anterior cruciate ligament

Single, Double and even triple bundle theories have been proposed. Two functional bundles are now a widely accepted idea; the anteromedial (AM) bundle and the posterolateral (PL) bundle are the two bundles that are distinguished by their separate tibial insertions. The PL bundle, in contrast, starts distally in the femoral origin and inserts in the PL aspect of the tibial insertion[60]. The AM bundle, on the other hand, begins in the proximal section of the femoral origin. During ACL reconstruction surgery, these anatomical aspects have received more attention.

In their investigation, Gabriel et al.[64] discovered that the anteromedial bundle is relaxed in flexion and tightest in extension, while the posterolateral bundle is relaxed in flexion and tightest at 60 degrees of knee flexion.

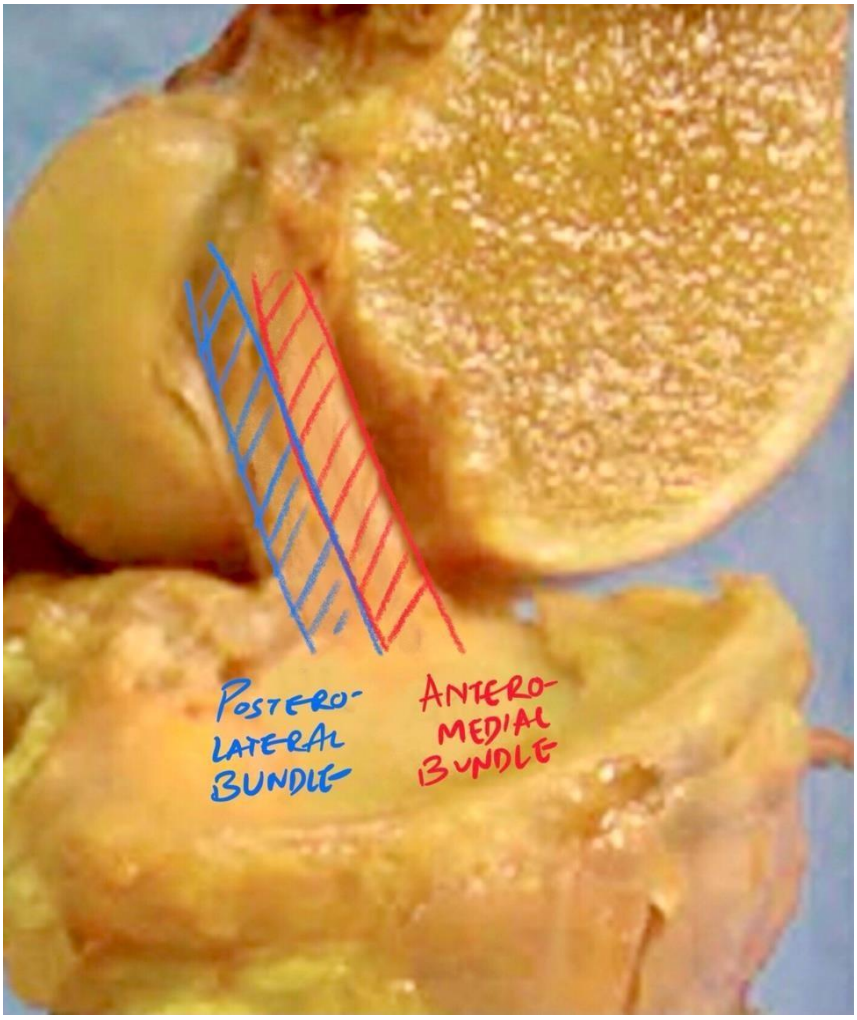


Fig. 2: Left knee in extension, medial femoral condyle removed: The Antero-Medial and Postero-Lateral bundles are parallel

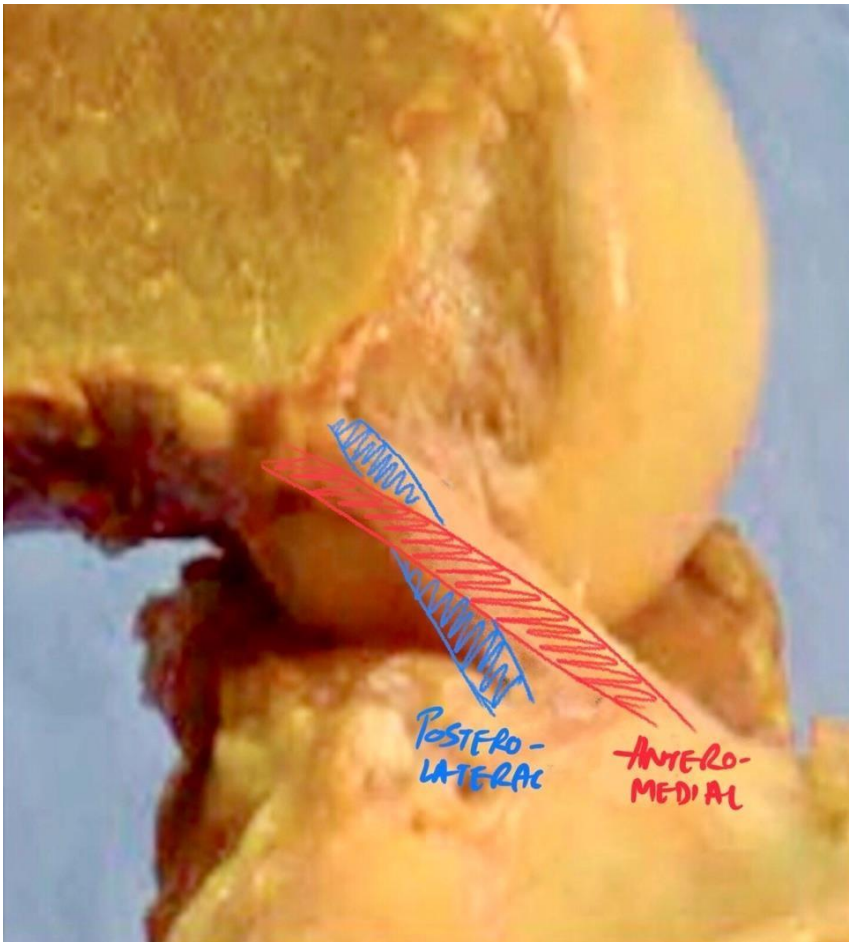


Fig. 3: Left knee in flexion, medial femoral condyle removed The Antero-Medial and Postero-Lateral bundles are crossed

As the knee moves from extension to flexion, the anteromedial and posterolateral bundles' alignment shifts. The anteromedial and posterolateral bundles' femoral attachment sites are vertically oriented and parallel when the thigh is fully extended (Fig. 2). However, this orientation shifts to a horizontal position when knee is bent 90 degrees (Fig. 3). Anteromedial and posterolateral bundles twist as a result of this shift, causing the two bundles to cross one another.

Functionally, the PL bundle becomes tighter as full extension is approached, while the PL bundle becomes looser as the knee flexes (Fig. 3). Therefore, failure of the PL bundle will tend to have a bigger impact on the Lachman while isolated rupture of AM bundle will tend to have a greater impact on the anterior drawer test. Also, PL-bundle is crucial in preventing both internal and exterior rotation[65,66].

Blood supply[67]**:** The middle-genicular branch of popliteal-artery, provides majority of blood flow for ACL. This branch directly pierces the posterior capsule. At the junction of the joint capsule distal to the infrapatellar fat pad, branches penetrate the synovial membrane. This synovial plexus might also receive some blood vessels from a few of the lateral inferior geniculate artery's smaller, terminal branches. The entire ligament is covered by the synovial plexus. The ligament is penetrated by thinner branches. These anastomose with a system of longitudinally oriented endo-ligamentous vessels that run parallel to the collagen bundles in the ligaments.

Despite the many blood supply routes mentioned above, diffusion from the surrounding synovial fluid is the main source of sustenance for the ACL. There is no blood supply from tibial attachment and just a small amount from femoral attachment.

Nerve supply[68]**:** The ACL is found to be innervated by posterior-articular branch of posterior-tibial nerve. Near ACL origin & sub-synovial layers are where majority of the neural structures are found. The receptors present in ACL that function as nociceptors include the stretch-receptor-like ruffini receptors and free nerve terminals. The ACL's substance has been found to include small nerve fibres with proprioceptive and pain-related functions.

Histology[69]: Collagen fibrils with a diameter of 150–250 nm, which interlace to form a complex network, make up the ACL. The ACL fibrils have a special organisational structure. They could be non-linear, parallel/twisted, helical and planar networks. The fascicles in the centre of the ACL can be straight or distorted, in contrast to the fascicles on the periphery of the ACL, which are grouped in a helical pattern. The "crimp" and "recruitment," respectively, have been described as the wave's mainstay and the ACL fibril's non-linear pattern[70].

Collagen fibre clusters unite to produce subfascicles (Fig. 4), encircled by endotendineum. Epitendineum surrounds each fascicle. Both the synovial sheath and the paratenon encircle the entire ligament.

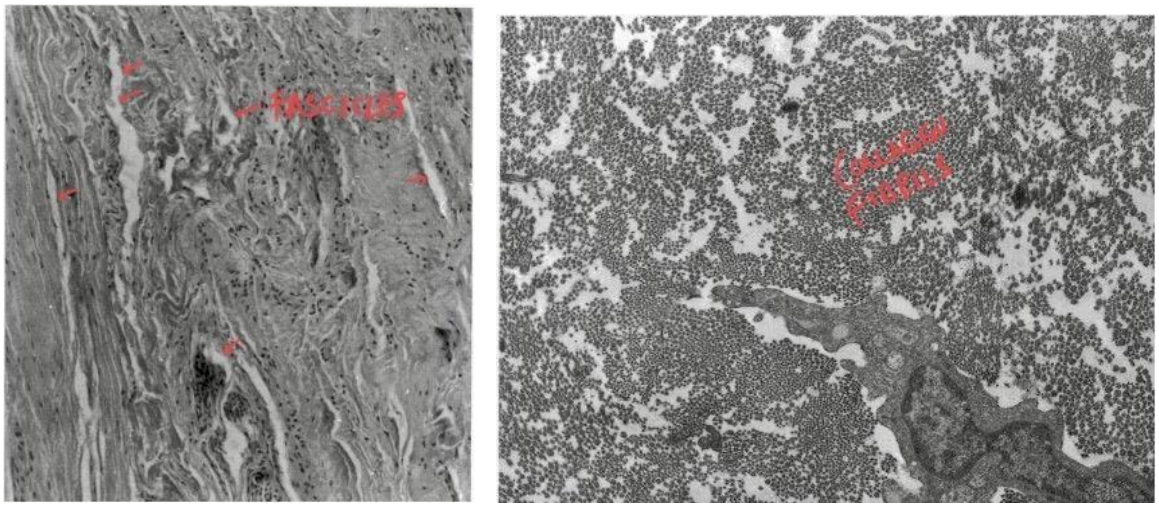
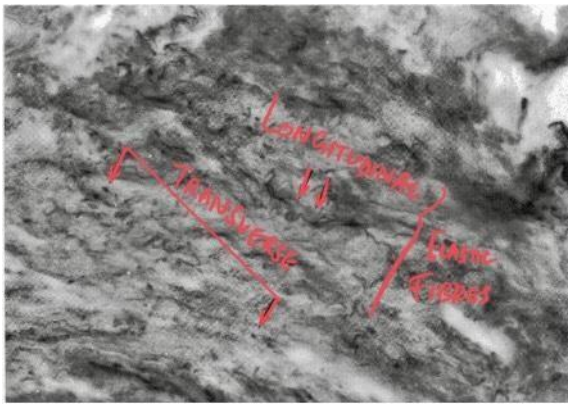


Fig. 4[69](left): Longitudinal paraffin section of ACL fibre bundle subdivided into small undulating fascicles.

Fig. 5[69](right): Transverse section of ACL- fascicles composed of an inhomogeneous population of collagen fibrils. An elongated fibroblast is observed between the collagen fascicles.

The matrix's regular sinusoidal pattern is represented by the crimp. The matrix's accordion-like design serves as a buffer, allowing for minimum extension without causing harm to the fibres. As a result, it serves as a "shock absorber" along the tissue's length[71]. To put it another way, when a tensile stretch occurs, the "crimp" in the fibrils is initially straightened by small stresses, and subsequently larger stresses are required for the stretching of these fibrils. A non-linear load elongation curve develops as a result of larger loads being applied because more fibrils are recruited to carry the load and the tissue stiffness gradually increases.

Microscopically ACL is made up of 3 zones; The proximal section is quite cellular and contains fibroblasts, glyco-proteins, and type II collagen. Fusiform and spindle-shaped fibroblasts, dense collagen fibres in the middle, elastic fibres that can endure repeated maximum stress, and oxytalan fibres (Fig. 6) that can withstand multidimensional loads are all present. Chondroblasts and ovoid fibroblasts are prevalent in the distal section.



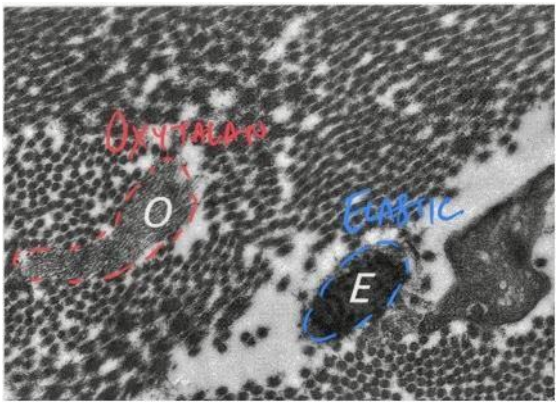


Fig.6 [69](left) : paraffin section showing abundant elastic fibres both in transverse(single arrows)and longitudinal(double arrows)sections

Fig. 7[69](right): elastic fibres (E) situated between 2 fascicles of collagen fibrils. An oxytalan fibre(O) is also present

The transitional area between flexible, ligamentous tissue and hard bone is a crucial part of the ACL structure. This connection of the ligament is mediated by a transitional zone of fibrocartilage and mineralized fibrocartilage. The ligament itself, the subchondral bone plate to which the ligament is linked, the nonmineralized cartilage zone, and the mineralized cartilage zone make up the usual architecture. In addition to allowing a progressive change in intrinsic elasticity, this change in microstructure also successfully reduces stress concentration at the site of attachment.

Functions of Anterior Cruciate Ligament[72]:

Along with its proprioceptive and mechanical capabilities, the ACL contributes to the static & dynamic balance of joint. Since nerve endings can be seen in the ACL through histological investigations, proprioception is ascertained.

The ACL's maximum tensile strength is roughly 1725 +/- 270 N, which is less than the peak force experienced during strenuous sports endeavours. Dynamic stabilisers, like the muscles that provide stress across the knee joint, improve stability. Proprioceptive signals about joint position are effective for muscles to assist in protective stability of the knee[59].

Both at extension (PM Bundle) and at 90 degrees flexion (AM Bundle) ACL resists anterior translations is its mechanical function. PM bundle resists hyperextension as well. By serving as a restraint on internal rotation, the ACL controls the knee's rotation. As joint approaches terminal extension, tension in the ACL stabilises it. Also, ACL acts as additional barrier against adduction & abduction stresses at all ranges of knee-flexion.

Injury Mechanism:

The medial & lateral structures provide coronal plane stabilisation to joint, whilst the cruciates, in conjunction with capsuloligamentous structures, provide sagittal-plane and rotatory stability. Depending upon how the joint is positioned, the major and secondary stabilisers alter. When the knee is in flexion, femur is rotated on tibia and the knee capsule and other ligamentous structures are relaxed, which causes ligament injury.
Ligament damage happens when there is enough force applied by any technique to result in persistent distortion. The most frequent cause of ACL tears is rotational trauma, including flexion-valgus-external rotation, flexion-varus-external rotation, forceful external rotation, or hyper extension trauma. Rotational trauma frequently results from an abrupt change in direction or from deceleration; it can occur as a noncontact injury(70%) after a sudden change in direction while playing football or soccer, or it can occur as a contact injury(30%) in a car collision with bent knees.

The MCL must be intact before valgus forces can result in a serious knee injury, however the ACL is damaged when the MCL is damaged due to persistent abduction thrust. When rotation component also occurs, the medial meniscus becomes entrapped in-between the joint surfaces of femoral & tibial condyles, resulting in the classic "Unhappy triad of O' Donoghue".

Women are more susceptible to ACL injury due to Smaller intercondylar notch, Greater Q angle and Smaller size of ACL and lesser strength. Although Demographically Men sustain more ACL injuries.

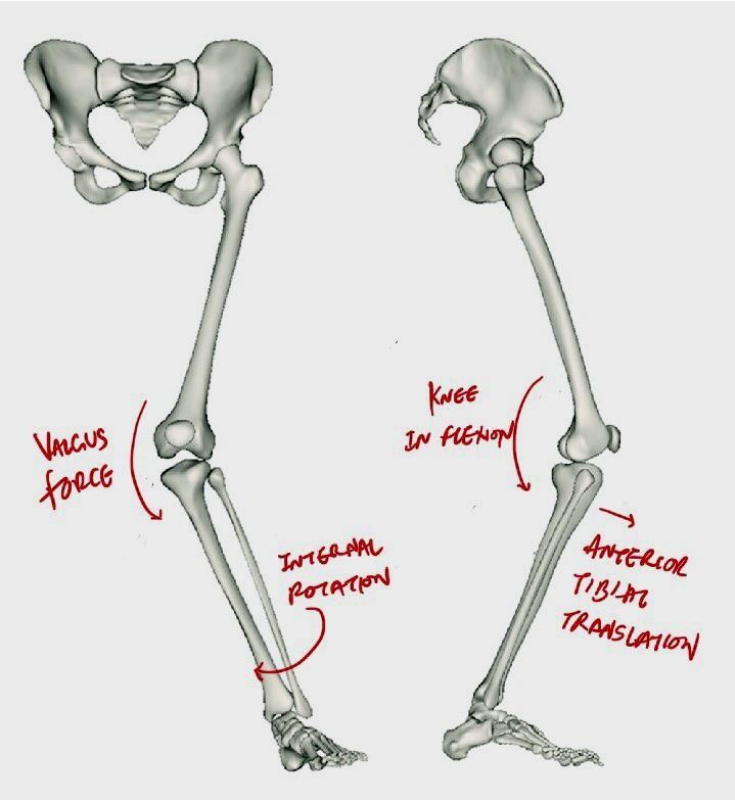


Fig. 8: Mechanism of ACL injury

Classification[73]:

A sprain is a ligament-only injury, according to the American Medical Association manual. Three levels of severity are used to categorise sprains;

A 1st-degree ligament sprain is defined as a small-scale tear of the ligament's fibres accompanied by localised tenderness without instability. They are simply symptomatically treated; a patient can typically resume their normal activities in a few days after suffering a first-degree sprain.

Second-degree sprains: More ligamentous fibres are disrupted, more functions are lost, more joint reactions and there is mild/moderate instability. These sprains can be treated conservatively if there is only minor local injury and joint reaction, but the ligament must be protected. It is necessary to wait until the inflammatory reaction has gone and rehabilitation is finished before engaging in vigorous activity again. Protection may be offered by a functional brace that prevents motion across particular arcs.

A third-degree sprain: is characterised by total ligament damage and pronounced instability. Unless there is a specific contraindication, surgical repair may be necessary for third-degree sprains with total ligament destruction.

For first-, second-, and third-degree sprains, these are frequently categorised as mild, moderate, and severe, respectively. The degree of instability shown after stress testing can be used to further grade third degree sprains, or those exhibiting considerable laxity.

With instability level 1, the joint edges separate by 5 mm or less, by 5 to 10 mm for level 2, and by >10 mm with level 3. Although it is unavoidably wrong, it nonetheless provides a helpful index for therapeutic applications. Consistent categorisation is essential for appropriate communication.

Natural history:

In the first year following repair and resumed sports activity, the risk of second ACL tear is fifteen times higher than in patients who had not previously sustained an ACL injury.

Around 50 to 70 percent of acute ACL injuries also involve meniscal injuries, and acute injuries most frequently impact the lateral meniscus. Due to anomalous loading and shear pressures, there is a high prevalence of late meniscal damage in ACL-injured knees. Medial meniscus is more usually injured in chronic ACL injuries because of its close relationship to the capsule. Studies have shown that meniscal tears and chondral injuries, which eventually lead to arthritis, will develop in an ACL injury sufferer who returns to athletics and repeatedly encounters episodes of instability.

After first ACL damage, osteochondral alteration happens in 21 to 31% of individuals. For individuals with both acute and chronic ACL injuries, MRI is a sensitive method for detecting the bone injuries. These osteochondral defects could be osteoarthritis' precursors.

Clinical Evaluation:

A thorough clinical history is the first step in the clinical examination of a patient with an ACL injury. The typical history is decelerating type injury (non-contact) or a motion while patient jumps. Patient generally hears/feels pop in joint when injury occurs. The patient typically is unable to stand up right soon after the injury. The patient cannot resume his activity immediately, and walking is often challenging. Haem-arthrosis starts to appear after a few hours. Physical examination is simpler if done before to the onset of haem-arthrosis.

Discomfort and knee giving way are frequent symptoms at the time of presentation. ACL tears typically result from non-contact injuries, whereas multiple ligaments might be injured during contact.

Meniscal injuries are diagnosed by locking episodes, click, or clunk sensations. Knowing about a patient's condition and specific needs aids in customizing treatment for each particular patient.

Physical Examination:

It involves inspection followed by palpation, measurement and movement. Then, to help with the diagnosing and ensuing treatment plan, tests are done for the menisci, collateral ligaments, and cruciate ligaments.

Tests performed in ACL injuries:

"Anterior Drawer test"[73]**:** Patient in lying down position, with knee flexed 90^0 and hip in 45^0 flexion. Examiner sitting on patient's foot (dorsal aspect) to stabilise it. A gentle anterior and posterior pull and push are applied to the proximal part of the tibia. It is noted how much the tibia moves relative to the femur. The same is carried out in both 30° external and 30° internal rotation.

A displacement compared to opposite side of around 5 to 7 mm is sign of an ACL injury. To prevent receiving a false positive result from the anterior drawer test, one should first look for posterior tibial sagging.

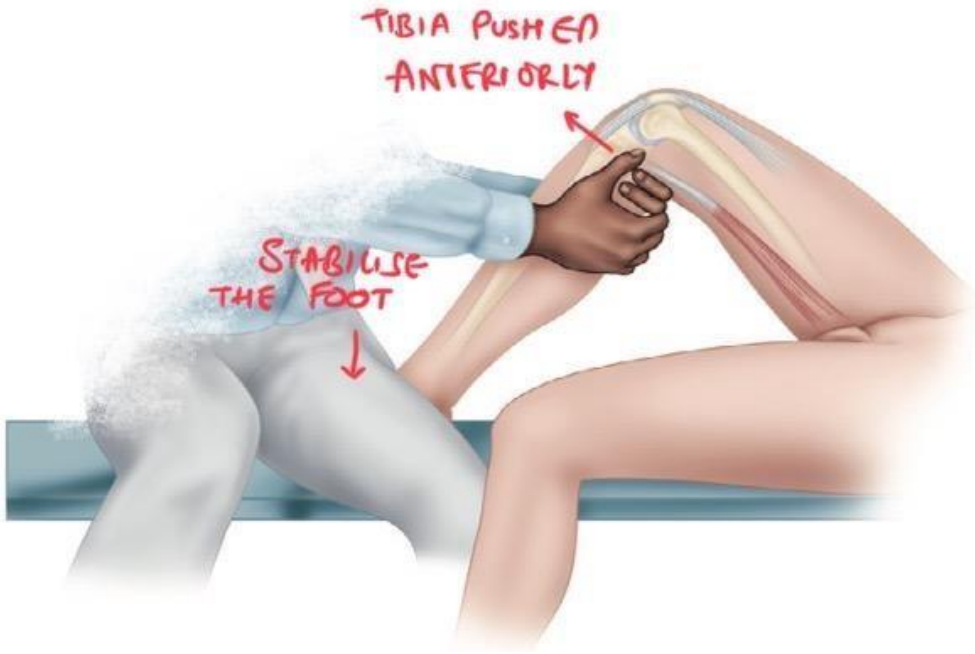


Fig 9: Anterior Drawer Test

Lachman test[73]**:** An acutely sore knee prevents doing the anterior drawer test since 90o flexion is not possible. Lachman test might be used in this circumstance. The patient is lying on his or her back with joint in a position of slight external-rotation and between 0-20 degree flexed. Stabilizing femur with one hand while raising the proximal end of the tibia forward to translate it anteriorly with the other.

The anteromedial joint edge supporting the proximal tibia should be supported by the thumb. Feeling of Tibia translating on femur softly in the end confirms ACL injury.

Anteromedial bundle is relaxed in flexion and tightest in extension, thus Lachman test is more specific for AM bundle; while the posterolateral bundle is relaxed in flexion and tightest at 60 degrees of knee flexion making Anterior drawer test more specific for PL bundle[64].

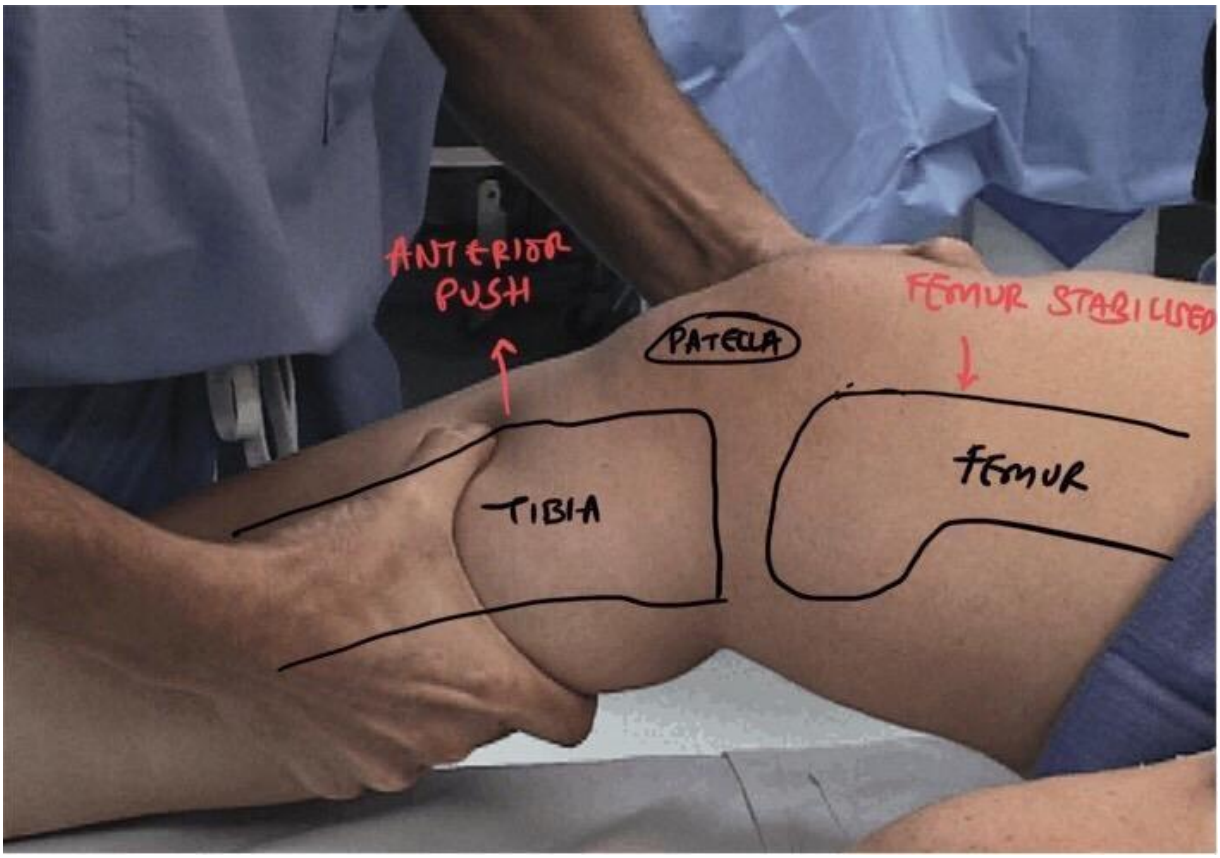


Fig 10: “Lachman Test”

"Slocum's Anterior Rotatory Drawer test"[73]**:** Here, anterior-drawer is performed in three different rotations: 15^0 internal, neutral, and 30^0 external.

If anterior-drawer is elicitable in 0 degree, increases in external-rotation by 30 degrees, and reduces in internal rotation by 15 degrees, it implies anteromedial rotatory instability.

Pivot shift test[73]**:** The subluxation that takes place when the ACL is injured is elicited by using this indirect test for ACL damage.

The typical pivot-shift has been demonstrated by "Callway & McIntosh". Patient is positioned in lying down position as examiner raises the affected limb from the table, holds the ankle, and rotates iternally . The knee will be fully extended on a totally relaxed limb.

The test could not be precise if the knee does not fully extend (because of discomfort or swelling).

Gravity forces the femur to drop posteriorly when the ACL is ruptured, which leads the tibia to sublux anteriorly over the femur. The examiner grasps the proximal third leg at lateral aspect and provides a valgus force while flexing the knee by another hand. On flexing the knee 15 to 30^0, anteriorly subluxed tibia will reduce into its normal place with sudden clunk.

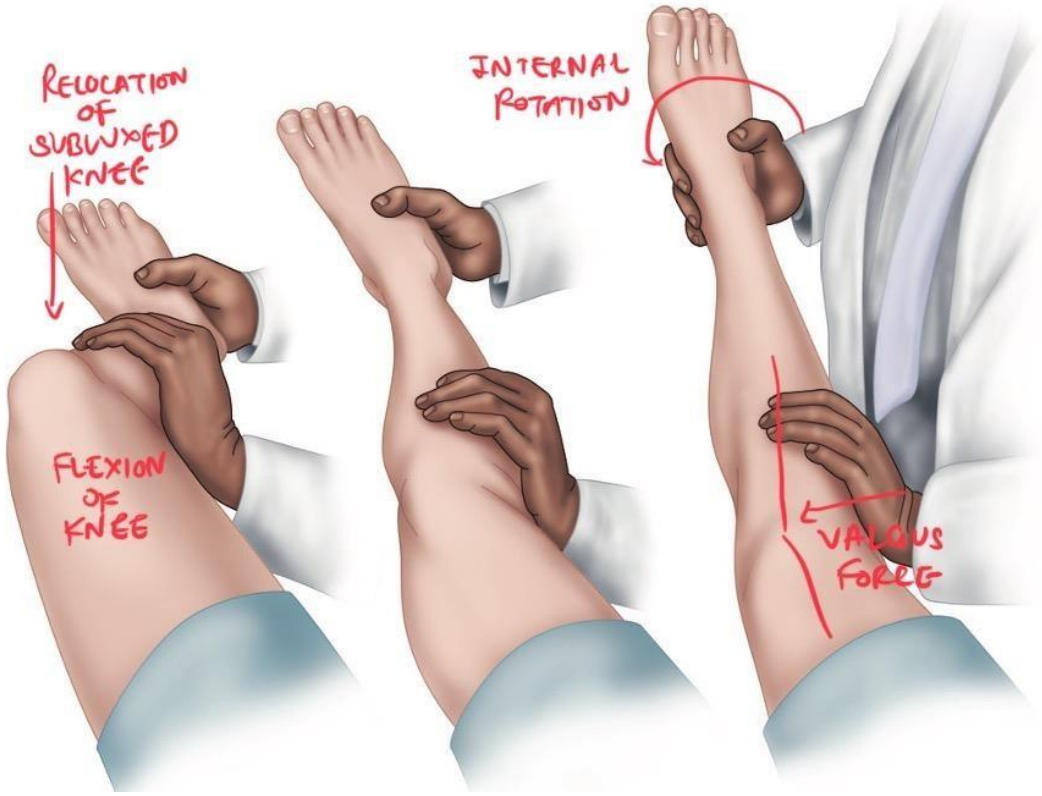


Fig.11: Pivot-Shift Test

"Slocum's method"[73]**:** Patient is kept in lateral position, on his or her side, knee extended and foot firmly planted, 30 degrees pelvis tilt posteriorly. The knee is then gradually extended. When a reduction occurs in knee flexion between 25 and 45 degrees, the test is deemed successful. Slocum's method has the advantages of being less uncomfortable and allowing for the detection of lower levels of instability.

Fig 12: Slocum's Method Pivot shift test

Flexion rotation drawer test[73]**:** The femur is allowed to fall back and rotate externally by gravitational force as the leg is elevated upward with patient lying down and knee in 20-30^0. When the knee is ACL deficient, applying posterior push to tibia and flexion increase to 40^o will yield reduction with typical 'thud'.

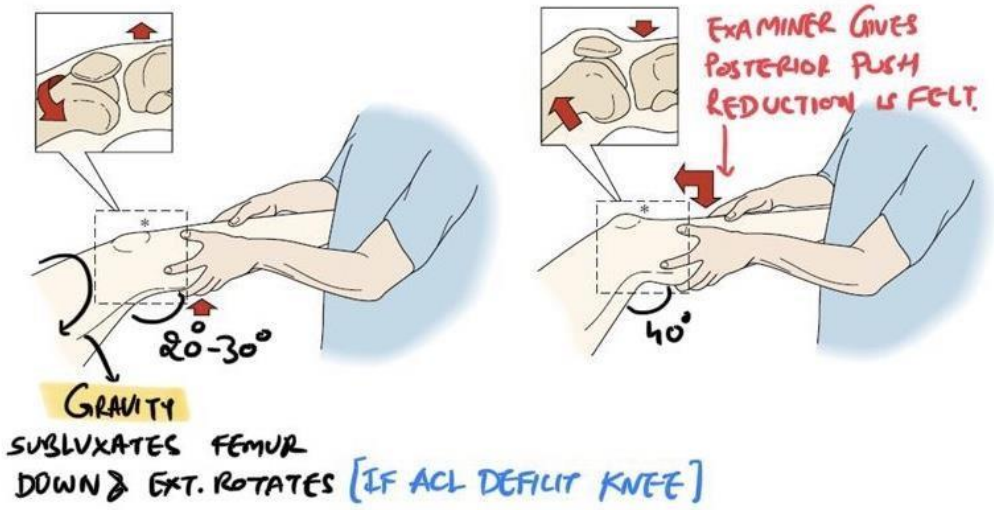


Fig 13: "Flexion-Rotation Drawer test"

Radiographic Evaluation:

To check for degenerative changes, fractures, alignment and other associated injuries, AP and lateral X-rays must be taken. The radiographs could show Segond's fracture, avulsion fracture at lateral rim of tibia. Radiographs can also reveal tibial spine avulsion fractures. These are more frequent in patients with immature skeletons.

While performing the anterior drawer test, stress radiographs (lateral) used to demonstrate ACL injury on X-ray. An abnormal anterior translocation is one that is greater than 5mm. When compared to the contralateral knee, a discrepancy of greater than 3 cm is likewise regarded as noteworthy. X-rays can occasionally show prominent lateral condyle-patellar groove known as “deep lateral femoral notch sign”, which results from a pivot-shift injury.

Magnetic-Resonance Imaging:

Non-invasive method to see ACL & other soft-tissue components of knee made possible by MRI, it aids in patient's preoperative evaluation. T2-weighted sequences in 2 to 3 orthrogonal planes are the bare minimum protocol needed for imaging of the ACL.

The typical ACL appears as solid/striated band and a small divergence(distally) on a sagittal picture. The ACL is frequently straight, while normal ACLs can exhibit minor inferior convex drooping.

When compared to PCL, the ACL has a slightly higher signal intensity. The ACL can be clearly seen in a coronal section, however compared to the sagittal plane, the band is typically attenuated and less thick.

In a research by Adriaensen et al[74]. 94% of patients were able to see the anteromedial and posterolateral bundles of the ACL when they underwent three tesla field strength MRI.

The central portion of the ligament is where ACL tears occur most frequently. Injuries occur more frequently distally at the point of the tibial connection than they do proximally near the origin (7–20%).

Primary signs of ACL injury:

1. ACL non-visualisation at its normal location (Fig. 12)
2. Focal-interruption in continuty
3. Angulation or non-linearity (Fig. 13)
4. Ab-normal axis of ACL i.e, Proximally poor visualisation with distal ligament axis flattened (Fig. 14)

Axis of ACL is normally parallel to “Blumensaat line” (intercondylar-roof line) on sagittal plane. If the axis is seen horizontal compared to blumensaat’s line; it is considered abnormal.

Fig. 14 : ACL non-visualisation at its normal location

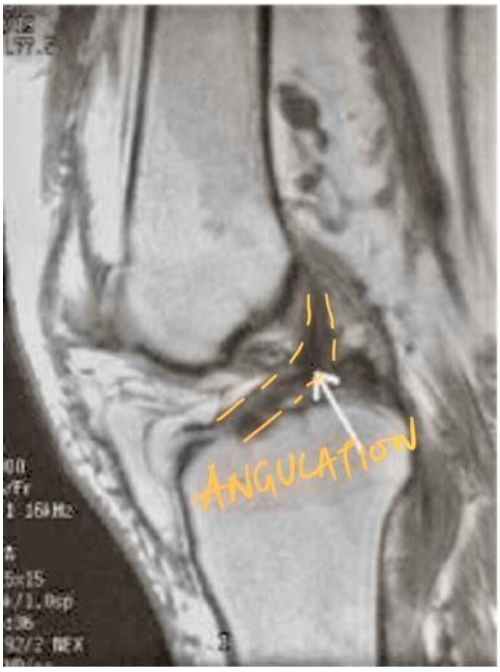


Fig. 15**:** Angulation or non-linearity

Secondary Signs :

Secondary indicators are those that indicate an ACL damage in addition to the actual abnormalities of the ACL.

1. Bone bruising & osteochondral fracture from pivot shift in the condyles
2. Counter-coup medial tibial bone bruising
3. The tibia's anterior translation (sagittal MRI)
4. LCL that is vertical
5. Segond's fracture (Fig. 15)
6. fractured tibial spine
7. Redundant or oddly curved PCL (Fig. 16)
8. Arcuate fibular head fracture

Fig. 16: Segond fracture

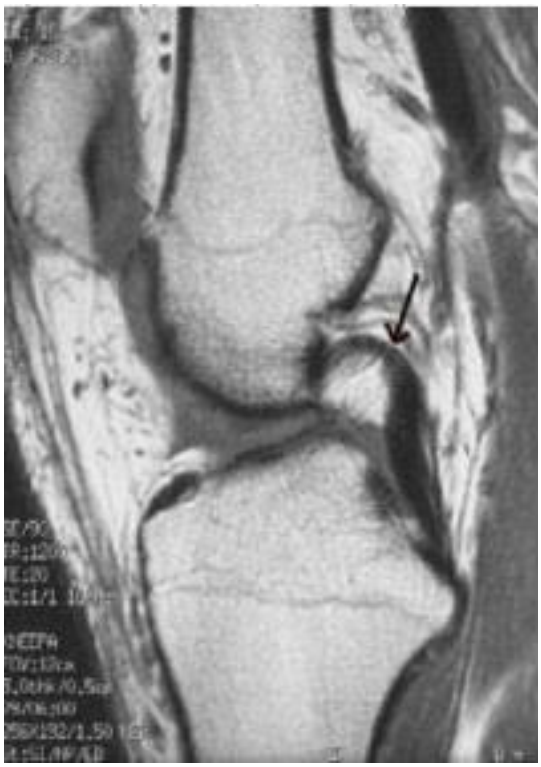


Fig. 17: PCL is redundant

Chronic ACL-tears:

The signs of chronicity are bone-bruising and edema at the knee. Otherwise all signs of acute ACL tears are also seen.

When ACL is absent and the lateral intercondylar notch on the MRI merely reveals fat, this condition is known as the "empty notch sign."

The sensitivity and specificity of MRI for identifying ACL injuries with direct symptoms range from 92 to 94% and 95 to 100%, respectively[76].

INSTRUMENTATION

Arthroscopic ACL reconstruction requires some specialized equipments for arthroscopy of knee and for the procedure itself.

1. Camera
2. Television monitor
3. Light source & fibre-optic cable
4. Endoscope (4mm 30^0)
5. Shaver system and hand piece
6. Pneumatic Tourniquet

Instruments needed for surgery include:

- 2.4 mm drill tip guide pins
- Beathed Pin (Extra-long 2.4 mm long with sutured eye)
- Trocar (5 mm)
- Cannula
- Probe
- Meniscus punch
- Burrs and shaver system (motorized instruments)
- Tibial aimer
- Cannulated reamers (4.5 to 10 mm)
- Femoral aiming guide (6-7mm off-set)
- Depth-gauge
- Graft preparation board

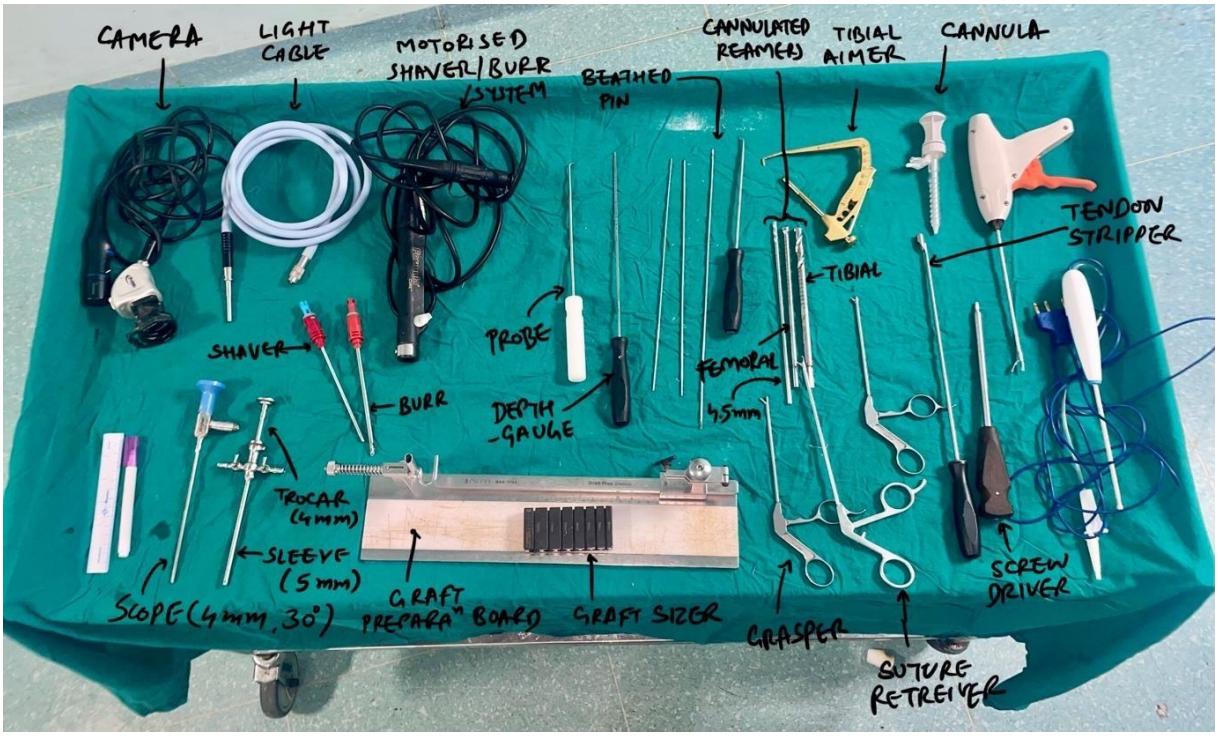


Fig 18: Specialized equipments and instruments required for ACL Reconstruction

Fig 19: Trolley with video, light and motorized device system

AVAILABLE GRAFT OPTIONS

Autografts:

Most commonly used due to easy availability, zero cost and no immune reactions, only disadvantage includes donor-site morbidity.

1. Patellar Tendon with attached bone plugs (BPTB)
2. Semitendinosus/ Semitendinosus + Gracilis tendons (HT)
3. Quadriceps tendon (QT)
4. Peroneous longus tendon (PL)

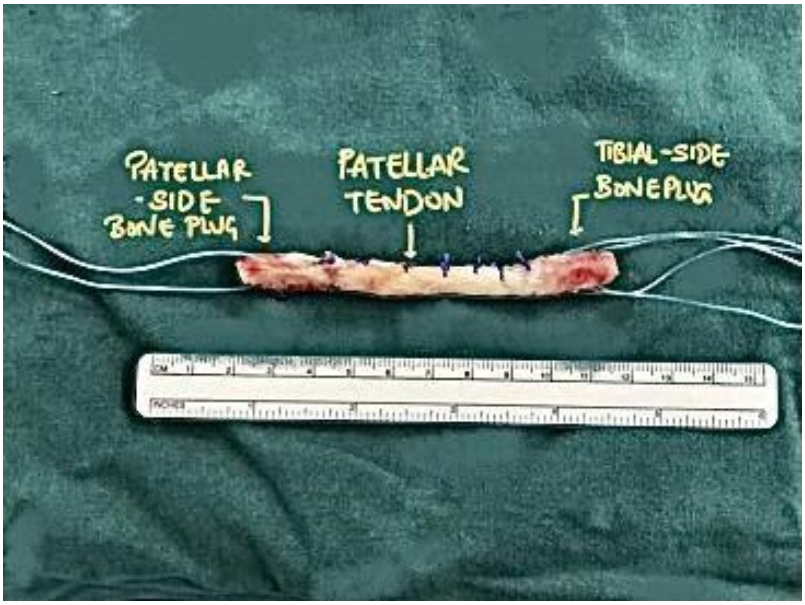


Fig. 20: BPTB Autograft

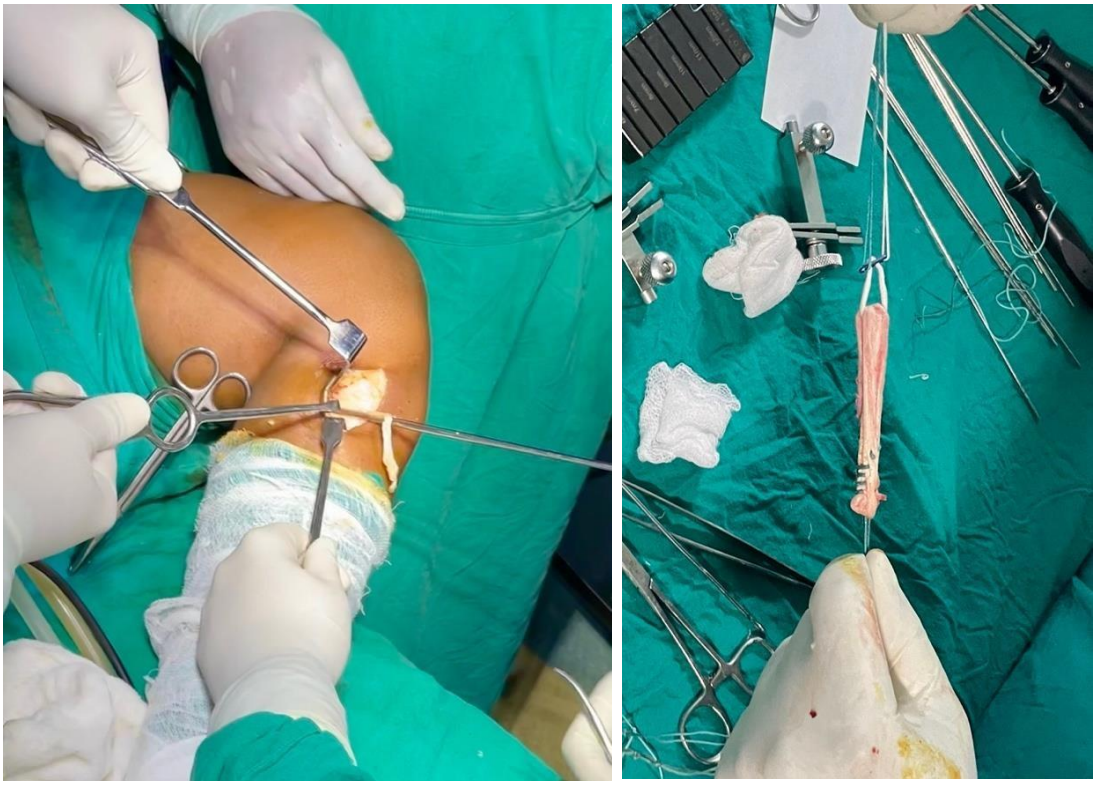


Fig. 21: Hamstrings Tendon Autograft harvest and preparation

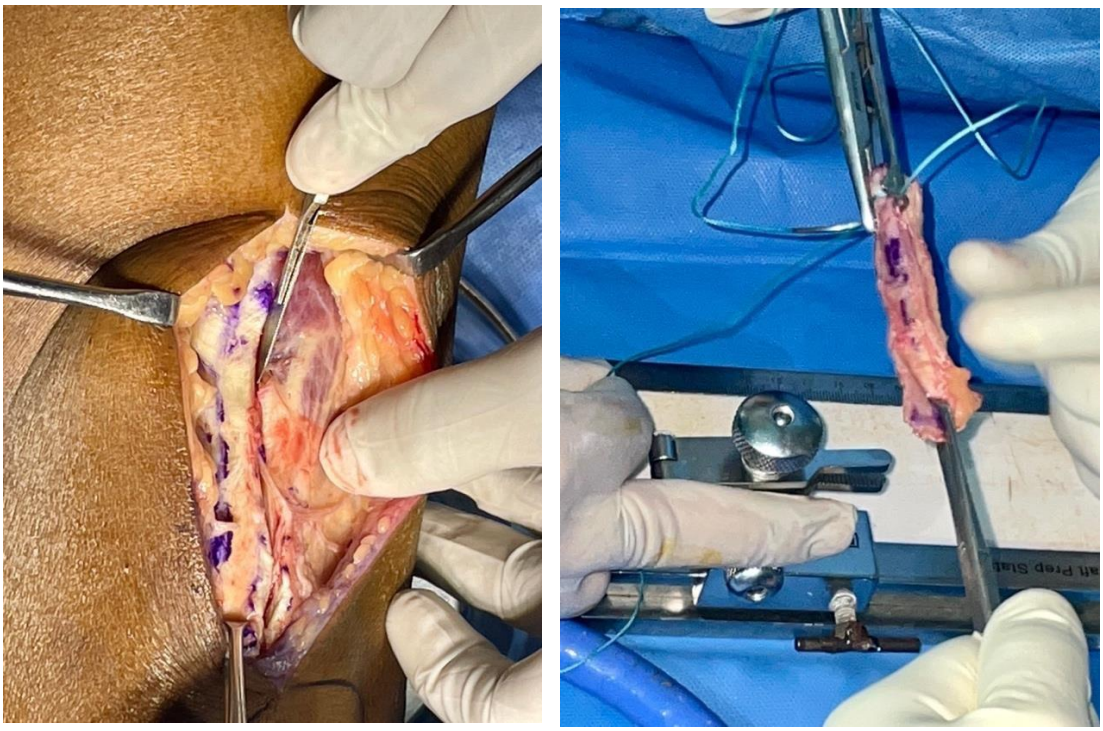


Fig. 22: All soft tissue Quadriceps tendon autograft harvest and preparation

Fig. 23: Peroneous longus graft harvest and preparation

Allografts:

Grafts (BPTB/HT/QT/PL) harvested from cadavers offer conceivable alternative to synthetic materials, especially for revision or multiple ligament injuries. Advantages include easy availability and no donor-site morbidity. Disadvantages include Immune reactions leading to synovitis and procurement-storage costs.

Synthetic Materials:

Prosthetic ligaments typically braided & woven different polymeric materials. They are almost discontinued due to disadvantages like low bio-compatibility leading to rupture, high cost and as it is not fixed inside the tunnel by interference screws and requires extra lateral incision for screws or staples. Materials used by different manufacturers include:

- Nylon
- Dacron
- Teflon
- Carbon Fiber

FIXATION METHODS AND IMPLANTS

There are three main types of fixation solutions for soft-tissue grafts:

1. **Headless Interference screws**

These direct-fixation tools aid in retaining the graft in place. It's put in-between the bone-tunnel & the graft. The titanium interference-screw and the bio-absorbable interference-screw are two varieties that are available.

The following are interference screw benefits:

- Low-profile
- enables intra articular placement

The dis-advantages are:

- Graft injury while the screw is being advanced
- Graft advancement on tension is application while insertion of screw
- Risk of the graft position change on screw advancement
- Risk of dropping screw in postero-lateral recess on insertion
- Blow-out of posterior condylar cortex
- Difficulty finding screw on revision if it was pushed deeply into the tunnel

Fig. 24: Titanium and Bio-degradable Interference screw

Bio-degradable screws:

They have strength of fixation comparable to titanium screws along-side ensures a regulated resorption and osteo integration to form architectural bone through hydrolysis. It is made up of 75% PLDLLA (Poly-d, l-lactic Acid) & 25% BCP (**Bathocuproine**).

Advantages of Bio-screws:

- Removal not necessary
- MRI Compatible

Dis-advantages of Bio-screws:

- Immune-reaction
- Visco-plastic Deformation weakening strength of the fixation

2. **Suspensory Extra cortical buttons**

Endobuttons and Tibial base plates follow this fixation solution.

Advantages:

- Small size
- Stable fixation
- Ease in placement
- Compatible to most auto-grafts
- Revision possible without any complication to tunnel

Dis-advantages:

- Wide-separation (fixation-points)

Tunnel widening due to; “windshield wiper effect” (graft movement in same direction to tunnel) & “Bungee effect” (graft movement at right angle to tunnel)

Endobutton: The endobutton aids in ensuring that the majority of the graft is contained within the tunnel. The centre two holes of the endobutton, which has four holes total, are used to form the loop for the quadrupled graft. The endobutton can be flipped with the help of the two peripheral holes that allow sutures to pass through. Withstanding cyclical stress is stronger than the interference screw.

Fig 25: Endo-button

Fig. 26: Tibia base plate

3. **Cross pins**

Other fixation tools are:

- Staple
- Polyester Tapes
- Suture-posts
- Screws with washers

In our studies, interference screws or tibial base plate were utilised on the Tibial side and Endo-button was used on the Femoral side.

DIFFERENT FEMORAL TUNNEL PREPARATION TECHNIQUES

Current concept of tunnel preparation prefers graft to be in isometric condition during knee movements i.e, not more than 1-2mm changes should be there between femoral and tibial attachments on flexion and extension. Far anterior placement of femoral tunnel makes it nonisometric and causes difficulties in flexion.

Access for Femoral tunnelling:

1. **Trans Tibial:** Fast and simple method. Tibial tunnel is crucial for the direction of Femoral tunnel. Direction can be undesirable (11 or 1 o' clock position while preferred direction is 10 or 2 o'clock)

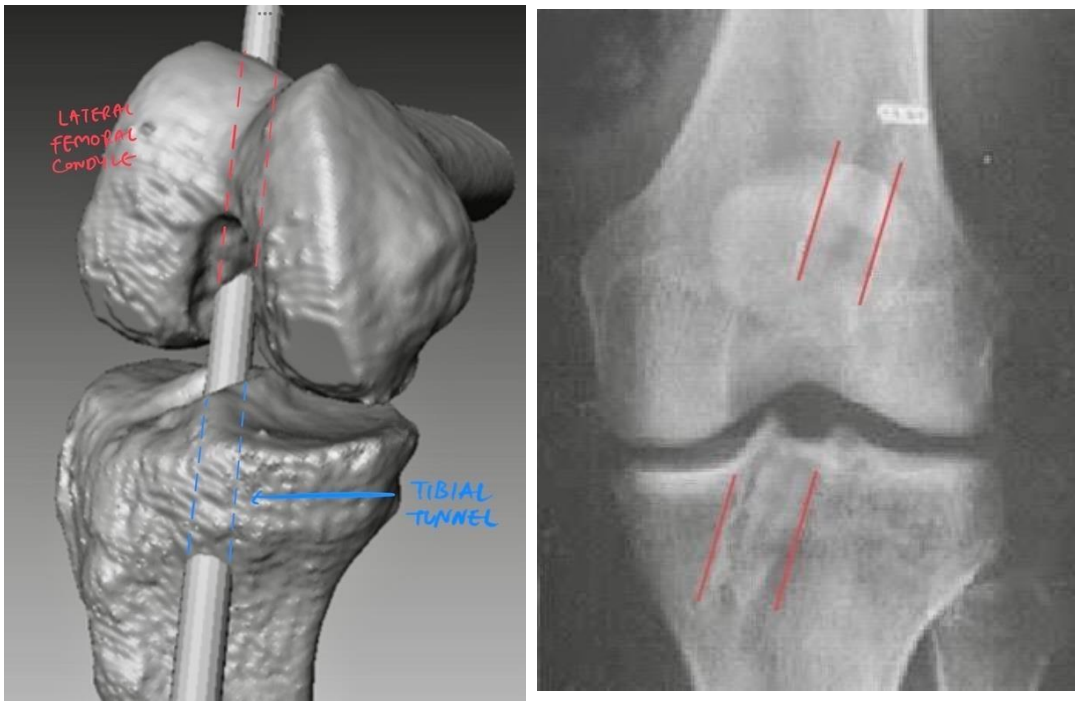


Fig. 27: Transtibial Femoral tunnelling

2. **Trans Portal:** Requires hyperflexion of knee. Can be done through medial instrumental portal or accessory far medial portal which can cause damage to Vastus medialis obliquous. Damage to Medial femoral condyle and its cartilage while drilling is possible.

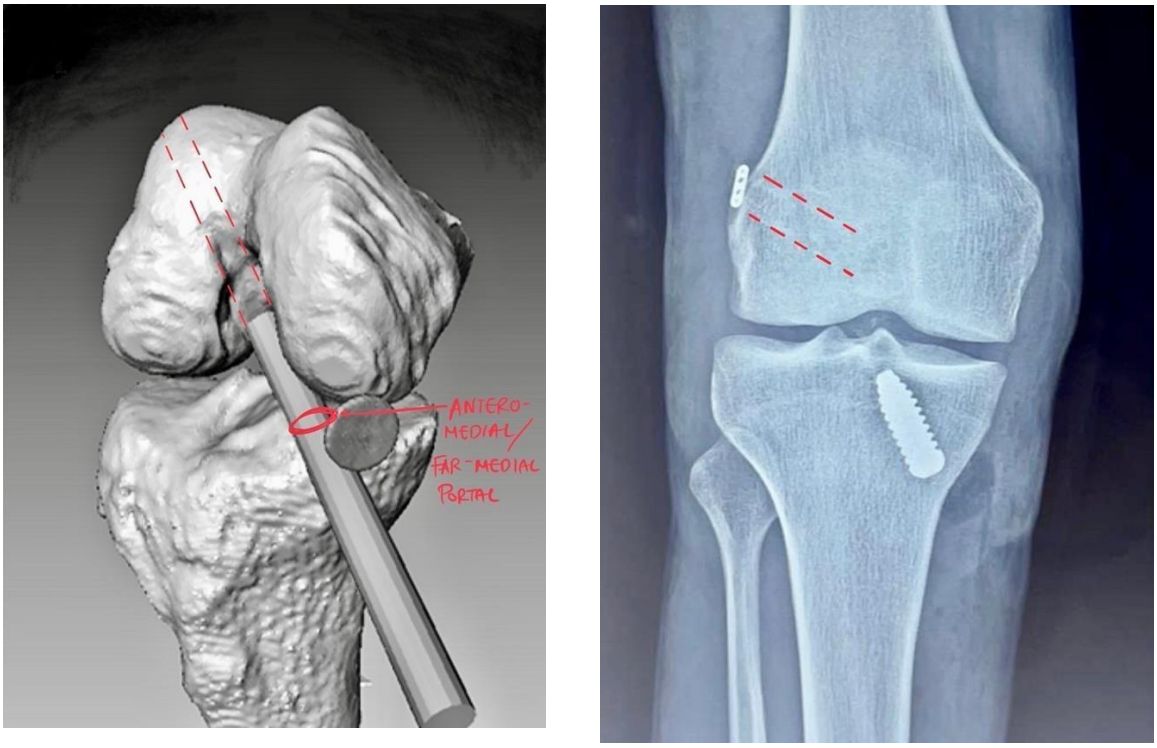


Fig. 28: Trans portal Femoral tunneling

3. **Tunnel placement through lateral incision:** Old practice not in use now days. Smaller incision required for interference screw while longer incision for headed screws with washers might be necessary.

POST OPERATIVE REHABILITATION PROTOCOL

Our post operative rehabilitation protocol consisted six phases:

1st Phase (0-14 Days):

- Quadriceps strengthening started from first day (static), dynamic and Straight leg raise as per tolerated, electric stimulation if poor strength of quadriceps.
- Mobilisation of Patella (superior-inferior)
- Ankle pumps
- Range of Movement increased as per tolerated up-till 90^0 by end of 2nd week, Full extension is also emphasized (by pillow under ankle and passive extension)
- Partial weight bearing with crutches started and as per tolerated, full weight bearing with or without crutches is achieved.

2nd Stage (2-10 weeks):

- Increase Range of movement gradually uptill 120^0 full ROM by end of 6th week. Bicycle ride emphasized to increase ROM.
- Discontinue crutches and full weight bearing mobilisation there should be no limp by end of 4th week.
- Increase Quadriceps strengthening by progress id dynamic and Straight leg raise with weights.
- Hamstrings curls with weights
- Extension of 90^0 to 40^0 with manual resistance by therapist.
- Start lunges at 8th week.

3rd Stage (3-4 months):

- Knee extension with high repetitions or low weight
- Isokinetic quadriceps exercises up-till full extension
- Slow and controlled drills for lateral sports

4th Stage (4-5 months):

- Start jogging, jump rope if no effusion, full ROM, stable knee with good quadriceps strength

5th Stage (5-8 months):

- Sports drills started including cutting and figure of eight
- Agility testing

6th Stage (>8 months):

Full return to sports if;

- ROM 0^0-130^0
- Good Hamstrings (90%) and Quadriceps (85%) strength
- Agility training sports specific to be finished
- Continue exercises thrice weekly

POST OPERATIVE COMPLICATIONS

EARLY:

- Pulmonary Embolism if torniquet time is extended above limit
- Haematoma collection at graft harvest site
- Infection
- Implant or instrument breakage causing matalliosis
- Residual laxity due to advancement of graft in tunnel, graft laceration by screw, screw breakage, Advancement of endobutton into soft tissue.

DELAYED:

- Residual laxity due to partial/complete graft tears, Ganglion cyst formation, detachment and soft tissue migration of endobutton
- Decrease in ROM due to arthrofibrosis, Graft impingement
- Deep vein thrombosis
- Residual pain due to CRPS, unattended meniscal tears, femoral condyle articular surface laceration by drilling
- Lack of quadriceps and/or hamstrings strength due to inadequate rehabilitation
- Extension lag
- Synovitis causing repetitive effusion of knee

LATE:

- Graft or implant failure requiring revision surgery
- Biceps femoris tendinopathy due to lack of hamstrings increases load on biceps femoris

METHODOLOGY

We have done a "Randomised Controlled Prospective study" conducted in BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura from December 2020 to November 2022.

In our study, 34 patients were involved, of whom 27 (79%) were male and 7 (21%) were female. 16 patients (47%) sustained a left side injury, whereas 18 patients (53%) sustained a right knee injury. A minimum of 12 months and a maximum of 21 months of follow-up achieved.

The Randomisation of this study was done through Lottery method. Out of 34 patients 50% (17 patients) were operated with Hamstrings tendon and rest 17 with Quadriceps tendon autograft.

All young and middle-aged patients who presented to the orthopaedic emergency and outpatient departments at the BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura with complaints of knee pain and giving away sensation following history of twisting or injury to the same side were examined thoroughly. The affected knee was assessed after the unaffected knee was inspected to determine ligament injuries in a relaxed patient lying supine.

To identify an ab-normal ACL, the following particular tests were carried out:

1. Lachmans test
2. Anterior Drawer
3. Pivot-shift

Associated structure injuries of knee were examined by:

1. Valgus & Varus-stress test (Collateral ligaments)
2. McMurray's & Apley's grind test (Meniscis)
3. Posterior Drawer (for PCL)

Regular X-rays of the afflicted knee were taken in both lateral and anteroposterior views. For confirmation, an MRI of the knee was performed in every case of ACL tears.

Inclusion criteria:

1. Patient aged 18 years and below 50 years.
2. Clinically and MRI confirmed Anterior cruciate ligament ruptures.
3. Patients willing for treatment and giving informed and written consent.

Exclusion criteria:

1. Patients aged below 18 years and above 50 years.
2. Anterior cruciate ligament ruptures associated with the meniscal injury, which needs meniscectomy.
3. Multi Ligament knee injuries.
4. Chondral injury to same knee
5. Associated neurovascular injury.
6. Polytrauma.
7. Patients medically unfit for surgery.
8. Skin infections at/near incision site

SAMPLING:

The anticipated Mean ± SD duration of surgery in Quadriceps Tendon and Hamstrings Tendon group 96.6±12 86.9±11.8 resp. (ref) the required minimum sample size is 21 per group (i.e., a total sample size of 42, assuming equal group sizes) to achieve a power of 80% and a level of significance of 5% (two-sided) for detecting a true difference in means between two groups[11].

$$\boldsymbol{N = 2\,[\frac{(Z_a + z_Q) * S}{d}]^2}$$

$\boldsymbol{Z_a}$ Level of significance=95%

$\boldsymbol{Z_Q}$--power of the study=80%

d=clinically significant difference between two parameters

SD= Common standard deviation

- Statistical Analysis
- The data obtained will be entered in a Microsoft Excel sheet, and statistical analysis will be performed using a statistical package for the social-sciences (Version 20).
- Results will be presented as Mean ± SD, counts and percentages, and diagrams.
- For normally distributed continuous variables between the two groups will be compared using Independent t-test for not normally distributed variables Mann Whitney U test will be used.
- Categorical variables between the two groups will be compared using the Chi-square test.
- $p<0.05$ will be considered statistically significant. All statistical tests will be performed two-tailed.

Pre Operative work-up:

Patients with Anterior Cruciate Ligament tears that have been clinically and radiologically confirmed were admitted to the Orthopaedics Department at the BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, in Vijayapura. Routine tests such as complete blood count, Blood sugar, CXR & Electro Cardiography were checked and a pre-anaesthetic examination was done.

Pre-operative Rehabilitation:

1. The knee joint's pre operative strength & ROM recorded.
2. Patients were taught static and dynamic quadriceps exercises while they were waiting for surgery.
3. Post-operative rehabilitation was explained to all patients.

Consent:

Each participant in this study received a detailed explanation of their injury, diagnosis, treatment options, complications associated with non-operative care and surgical intervention, intraoperative & post-op complications, damage to structures nearby, infections & movement restrictions.

All study participants gave their consent before getting surgery. Prior to the operation, all consents were obtained. The benefits and drawbacks of the treatment were thoroughly addressed to patients and attenders. Ratio of risk to benefit was explained.

Examination after anaesthesia & positioning:

In our study, patients underwent supine spinal/epidural anaesthesia. Anesthesia was used for the pivot shift test, Lachman test, anterior drawer test, and posterior drawer test. After soft padding, a pneumatic tourniquet was applied and placed in proximal thigh. Knee is kept little far from the usual operating table's distal breakpoint while the patient is lying on his or her back. The unaffected limb is set in an upright support. In each case, a preoperative dose of ceftriaxone + sulbactum(1.5 g) is administered as a preventive antibiotic before the tourniquet is inflated. Before inflating tourniquet, limb is kept up-right for exsanguination.

Fig. 29: Patient with pneumatic torniquet being examined post anaesthesia

Arthroscopy Portals[77]

Before joint distension, the portal entry locations need to be properly marked. Both femoral condyles, patella, its tendon and tibial tuberosity, tibia plateus are marked. Surgeon should draw landmarks & portals to make sure the portals are positioned appropriately.

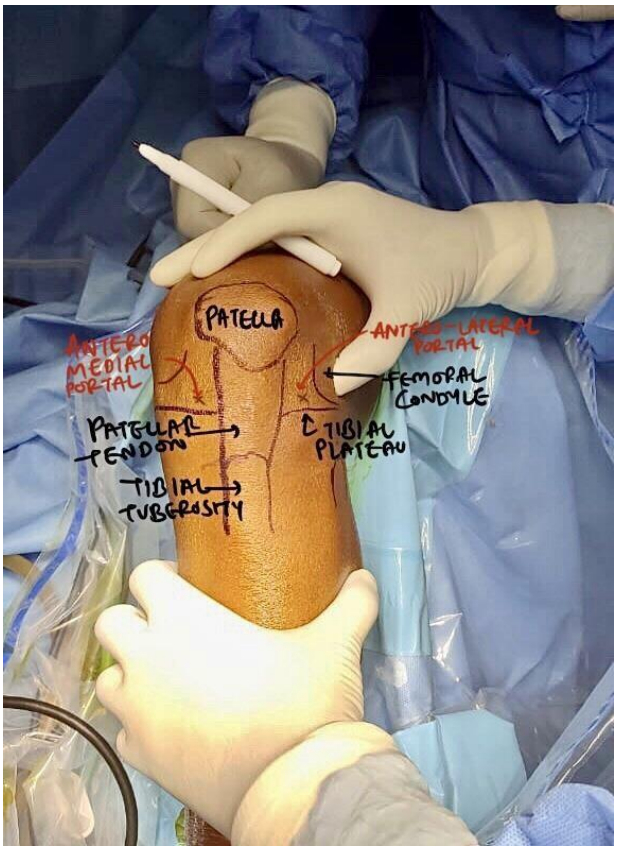


Fig 30: Skin marking

Portals used:

Antero-lateral portal: The surgeons usually perform diagnostic arthroscopy through this portal. With the exception of PCL & anterior horn of lateral-menisci, through this portal, you may see practically all of the knee joint's internal structures. This portal is situated 1 cm lateral to the patellar tendon and 1 cm superior to the lateral joint line. The inferior pole of the patella should be around 1 cm distal from the level of the portal.

Antero-medial port: It is primarily utilised to provide additional views of lateral-compartment & to use probe to palpate the medial & lateral compartments. The portal is positioned 1 cm medial to the patellar tendon, 1 cm distal to the inferior pole of the patella, and 1 cm superior to the medial joint line. A spiral needle can be inserted percutaneously and used to limit the exact location of the portal while being seen through the antero-lateral portal.

Accessory anteromedial portal:

An accessory portal medial to anteromedial portal with atleast 1 cm skin bridge between the two portals was made for Trans portal drilling of femoral tunnel.

Diagnostic Arthroscopy[77]**:**

A diagnostic arthroscopy was performed before the graft was harvested. Skin marking was done. Anterolateral port (viewing portal) is created with no. 11 blade at the level of the inferior pole of the patella, directly lateral to the patellar tendon, when the knee is flexed 90 degrees. Next, the scope is put in for diagnostic arthroscopy and all intra articular structures were visualised for any abnormality ACL tear is confirmed and other lesions if any i.e, meniscal tear or loose bodies.

The anteromedial (working) portal is then established when all abnormalities have been noted. Probing is done to confirm the diagnosis. The accompanying pathologies are treated in accordance, including the removal of loose bodies and meniscal repair for meniscal tears.

Hamstrings tendon autograft Harvest & Preparation:

An oblique incision is preffered one finger breadth medial to tibial tuberosity. The saphenous nerve's infrapatellar branch is less likely to sustain damage when the pes anserinus is exposed in a greater area thanks to the oblique incision. Through the same incision, graft harvesting & tibial tunnelling will be carried out.

Fingertips are used to distinguish the pes anserinus' superior boundary. The fascia is incised and this superior border is raised. Fingers extending from the top down can feel the tendons. The semitendinosus tendon is the one that is felt the least. Sartorius fascia is split in line with the tendons (gracilis & semi-tendinosus), being cautious to preserve the inner layer containing MCL. Gracilis is first hooked out with right-angled artery forceps, and subsequently the semitendinosus. To help with traction, a double loop knot was used to secure the tendon ends.

The knee is flexed to 90 degrees, and the tendons are dissected proximally utilising blunt dissection with the fingers up to the musculotendinous junction, removing accessory bands and adhesions as continuous traction is administered through the threads.

With the aid of scissors, the major band connecting the medial head of the gastrocnemius is often severed. It is proven that there shouldn't be any posterior dimpling over the gastrocnemius as the tendon is dragged distally.

With the help of the scissors, the tendon's distal end is released. Then, in-line with tendon, tendon-stripper is advanced across it, exerting traction by grasping the threads and keeping firm, constant, and gentle pressure. The stripper is retracted if resistance is encountered and adhesions are cut, the stripper is once again advanced to harvest the tendon. Graft master board is then covered with the harvested graft. With blunt-end of blade, any remaining muscle fibres are removed from the tendons.

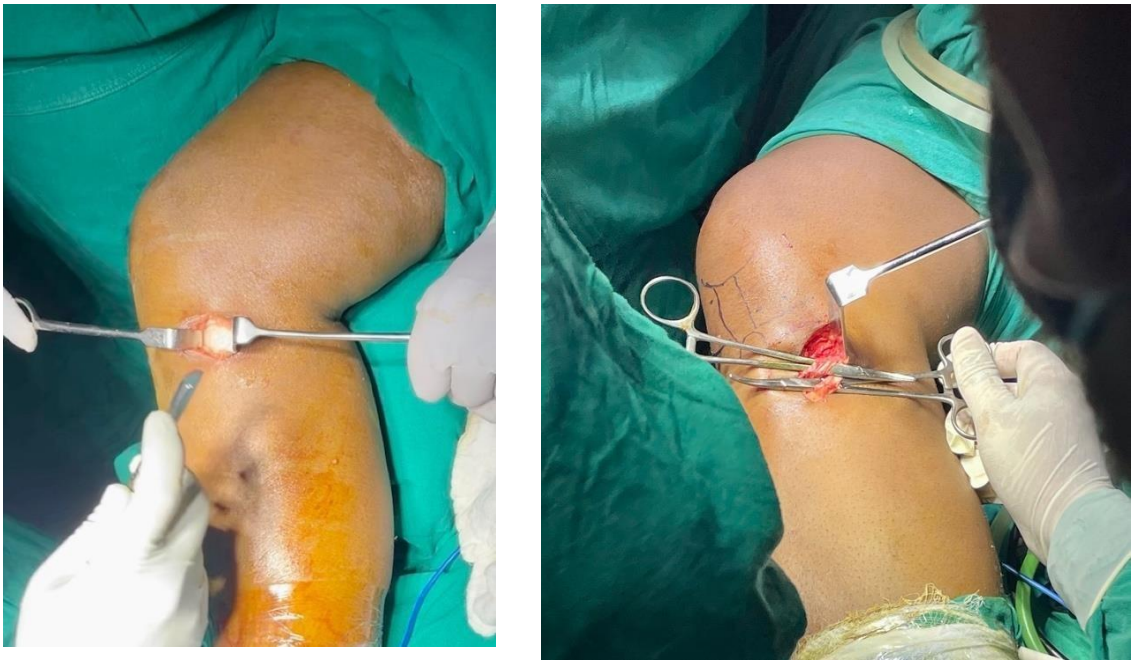


Fig. 31: Hamstrings graft harvest incision and Tendon Exposure

Fig. 32: Tendon adhesions removed and stripping by tendon-stripper

To ensure uniform size, the tendon ends are cut. There is a whipstitch at each end of the tendons. The tendon's two ends were sewn together for around 3–4 cm. The umbilical tape is looped over the two tendons. The graft sizer is then used on the composite graft. Most of our grafts were 4 or 5 tailed. The diameter of the tunnel should be the same as the smallest size sleeve so that a quadrupled graft may pass through it with the least amount of resistance.

The length of graft to be put into the tunnel is measured in order to guarantee correct placement of the graft when seen arthroscopically.

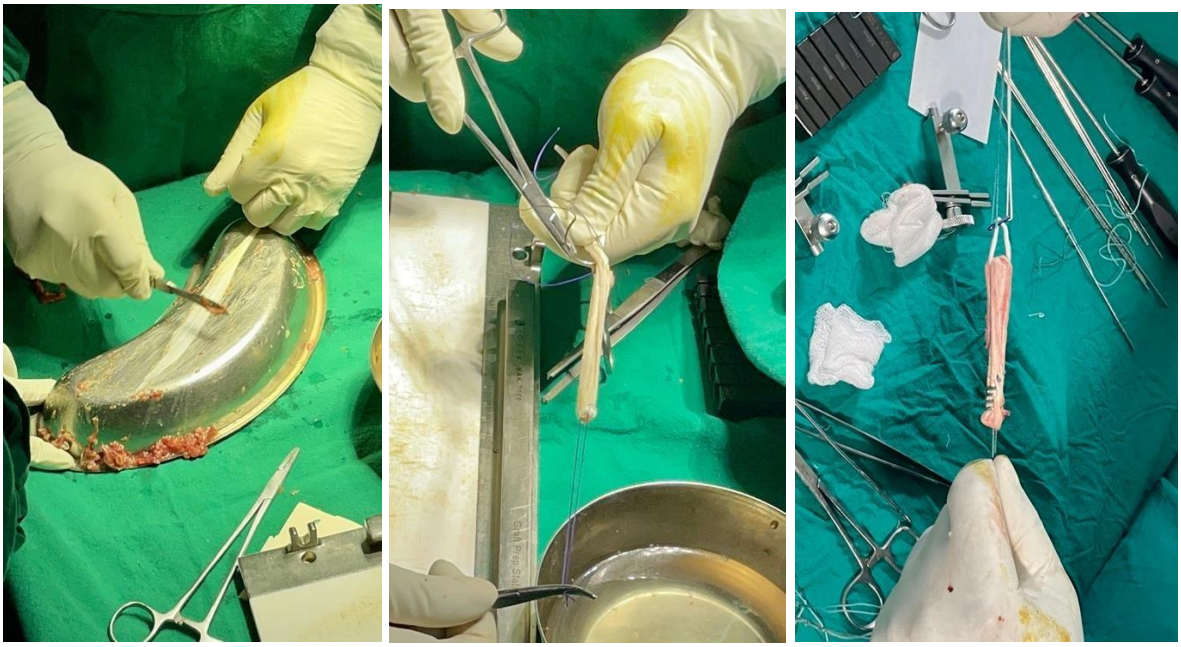


Fig. 33: Hamstrings graft preparation

Quadriceps Tendon Graft harvest and Graft preparation[78]:

It is standard to mark the femoral shaft 1.5 to 2 cm away from the midline of the proximal pole of the patella. Any remaining overlaying soft tissue on the anterior surface of the tendon is removed, together with the overlying paratenon. The low-profile quadriceps tendon harvest knife is a cutting tool that allows the surgeon to select the width and depth of graft harvest. Most patients are treated with blades that are 10 mm wide and 7 mm deep. The knife is inserted into the incision and pressed firmly down on anterior surface of central-portion of quadriceps tendon.

Once the spot on anterior thigh has been identified as the distal myotendinous junction of the rectus femoris, the knife is advanced proximally, incising the quadriceps longitudinally. Although we have found the retrograde "push" motion to be more predictable, an alternative technique that starts proximally and advances distally with a "pull" type motion can also be used. In order to prepare the graft for suture, the distal graft diameter will grow by 0.5 to 1 mm, so a no. 15-blade is used to carry the longitudinal incisions distally to the superior pole of the patella.

Since there is a thin layer of fat between the distal quadriceps tendon and the underlying capsule, deeper dissection should be avoided if only partial thickness graft to be harvested. Following the elevation of 3 cm of tendon, the tendon is whipstitched using a looped suture. Starting 2 cm from the patellar end of the graft, four throws are placed distally before the last throw is locked (by entering the tendon behind the last stitch and exiting the central portion of the tendon). Once the graft is harvested, the needle is kept in place for additional graft preparation. With tendon on the sutures and Metzenbaum scissors, additional proximal dissection can be carried out.

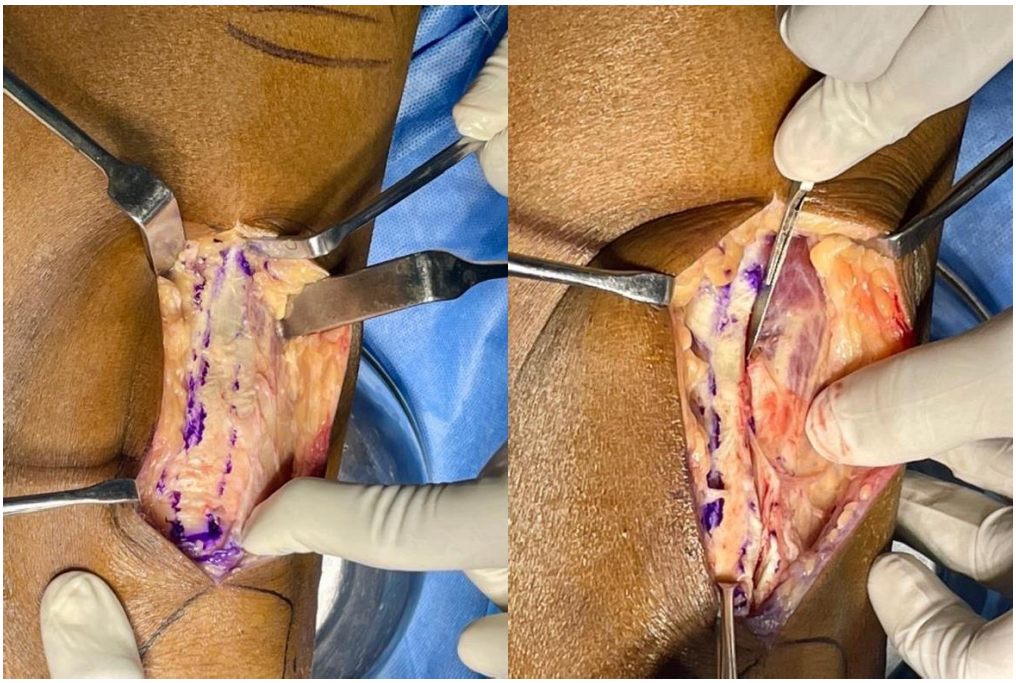


Fig. 34: All soft tissue Quadriceps tendon graft incision and Harvest

As the tendon is being stripped and severed, it's crucial to keep a tight grip on the sutures. For the vast majority of patients undergoing anatomic ACL restoration, a graft length of 7 cm is sufficient. If a partial-thickness graft was intended, the harvest site can be assessed for full-thickness rent by the arthroscopic examination (fluid off).

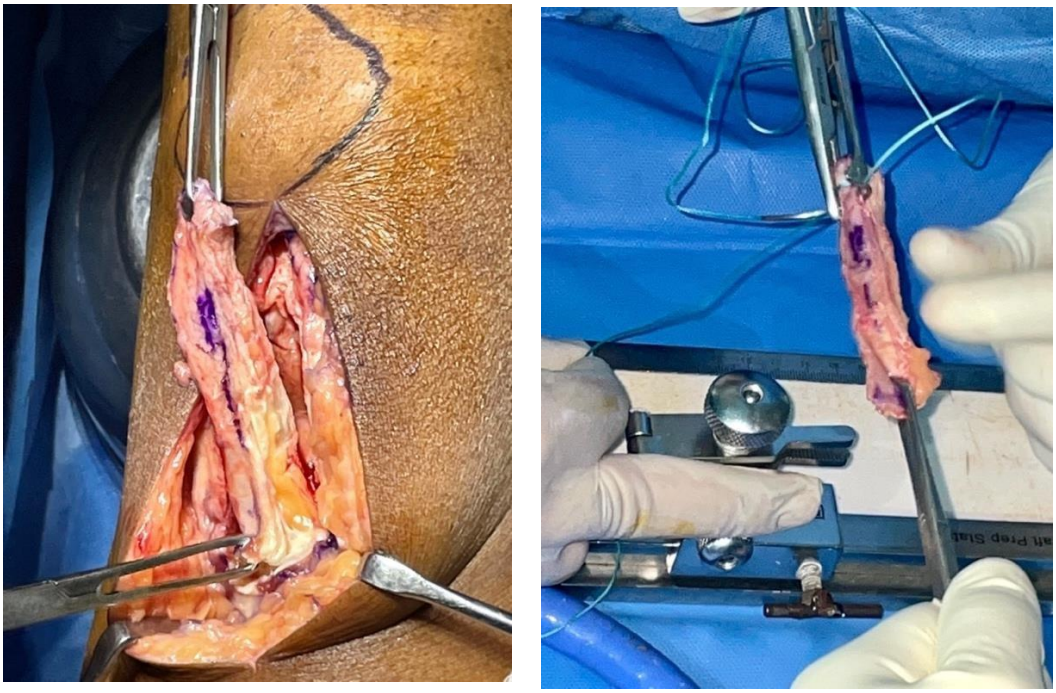


Fig.35: All soft tissue Quadriceps tendon graft Harvest and preparation

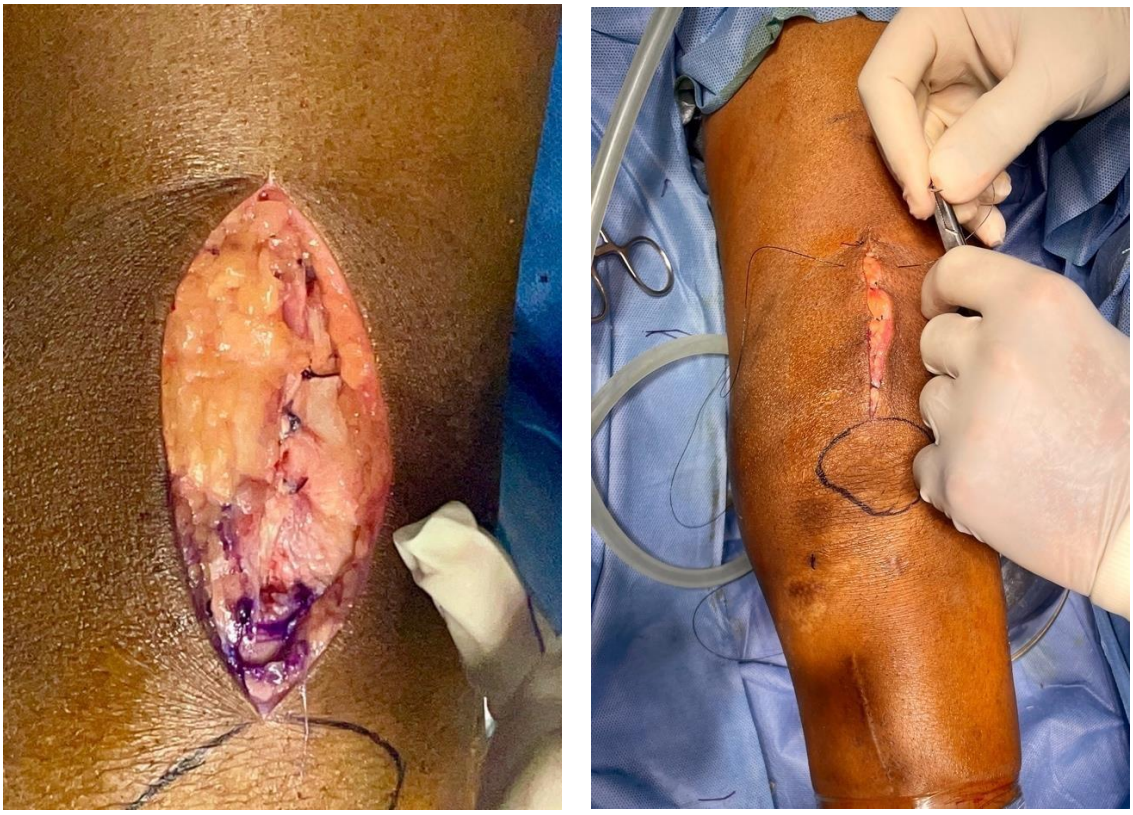


Fig. 36: All soft tissue Quadriceps tendon graft harvest site closure

Intra-articular preparation:

The joint cavity was visulized when the arthroscope was inserted through the anterolateral portal. The anteromedial portal is used to introduce the shaver blade, and the ligamentum-plicae, fat-pad & synovial reflection which obstruct full examination of medial side of lateral femoral condyle and ACL's tibial footprint are removed. The intact PCL should be protected from harm during the joint debridement.

Femoral tunnel preparation:

When knee is in flexion of 90^0, entry location of ACL can be seen on the lateral femoral condyle at its medial surface. In order to attain anatomical insertion point at lateral femoral condyle; Resident's ridge (Lateral intercondylar ridge) is identified and Bifurcate ridge is visualised (Fig.) Proximal and posterior cartilage margin are taken in consideration. By Femoral aimer or free hand beathed pin; entry is marked below resident's ridge and on bifurcate ridge confirming distance from posterior cartilage margin.

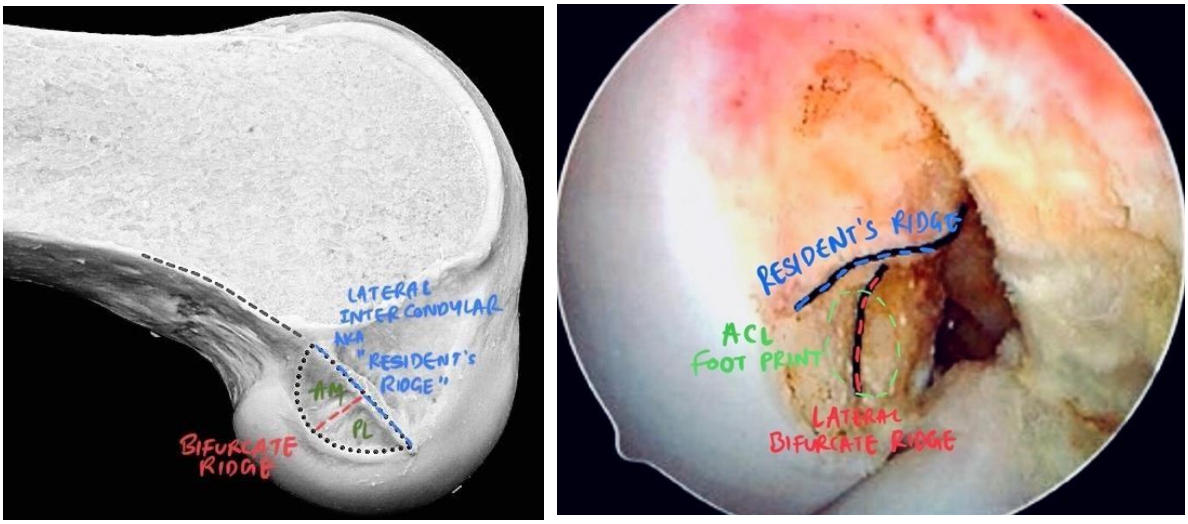


Fig. 37: ACL footprint seen grossly and through arthroscope

The entrance location is then drilled by beathed pin while in 120^0 knee hyperflexion, using femoral offset aimer device that has been placed through the anteromedial port. Drilling continues until the guide wire's tip is visible out of the skin..

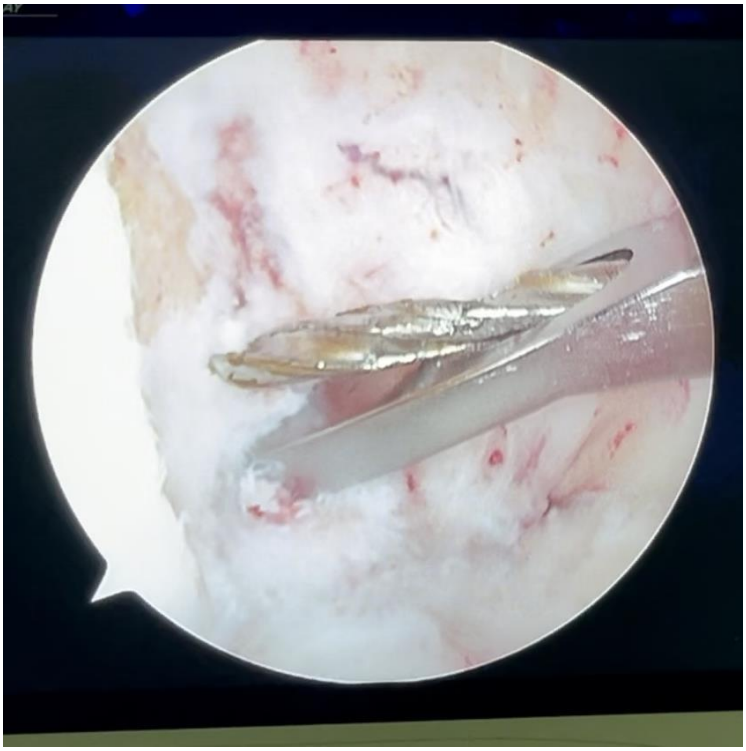


Fig. 38: Femoral aimer at ACL insertion

Femoral tunnel preparation starts with reaming with 4.5mm cannulated reamer on the guide pin which is drilled through accessory anteromedial portal in all our cases uptill the far cortex of lateral femoral condyle. The tunnel's length was then determined using a depth gauge. Sequential reaming till diameter of graft size was done keeping in mind the flipping radius of the endobutton used (In most of our cases we have used 15 mm fixed loop endobutton having 9 mm of flipping diameter) and keeping far cortex 4.5 mm for flipping of endobutton rest of the tunnel was reamed according to graft diameter.

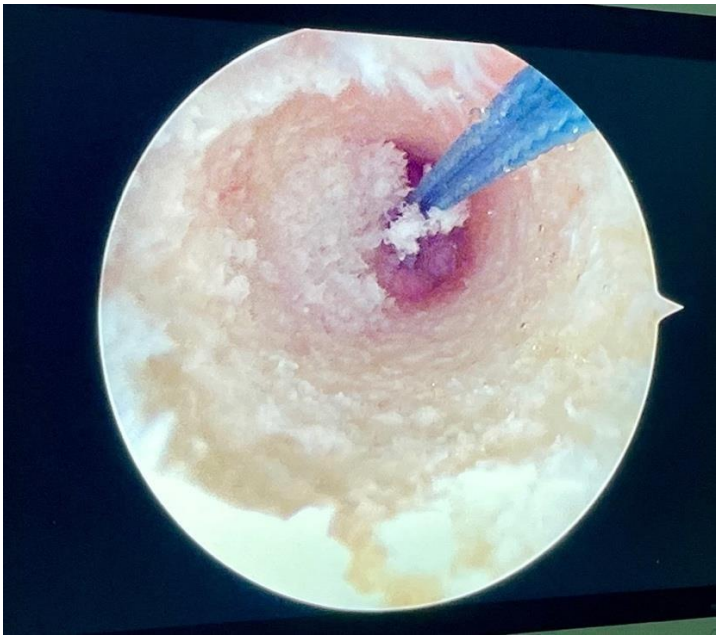


Fig. 39: Femoral-tunnel seen through antero medial portal post reaming

Tibial-tunnel preparation :

Tibial guide aids in creating the tibial tunnel. When the knee is bent 90 degrees, tip of tibial-guide is 2-3 mm posterior to posterior border of anterior-horn of the lateral-meniscus & slight medial to mid-line of ACL's tibial attach-ment region. Tibial tunnel is then reamed to the diameter of graft. The tunnel's edges are smoothened with a shaver to enhance proprioception, and the leftovers are left close to where the ACL attaches to the tibia.

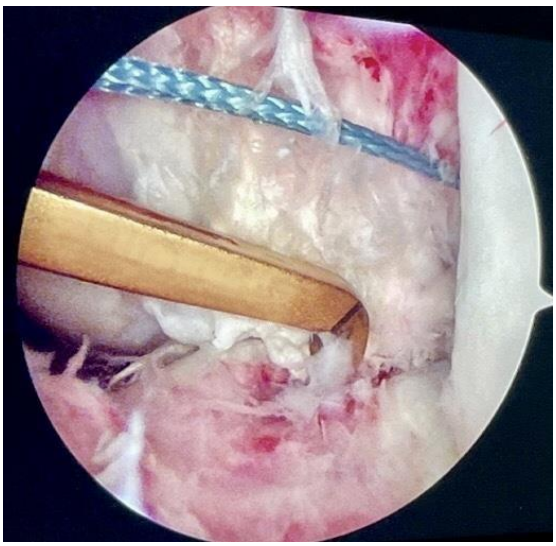


Fig. 40: Tibial jig at ACL footprint

Graft Passage and Fixation:

Once femoral socket is prepared ,the graft is secured to endobutton loop by passing the graft through the loop in case of hamstring graft or with fiber wire number 2-0 in case of quadriceps graft. In most of our cases we have used 15mm fixed loop endobutton. The flipping distance and the portion of graft to be put inside the femoral tunnel is marked with pencil marker. Preferabally 20mm of graft was kept in femoral tunnel. Once the calculated portion of graft is inside the tunnel; the endobutton is flipped and checked for the same by pulling the tibial side of the graft.

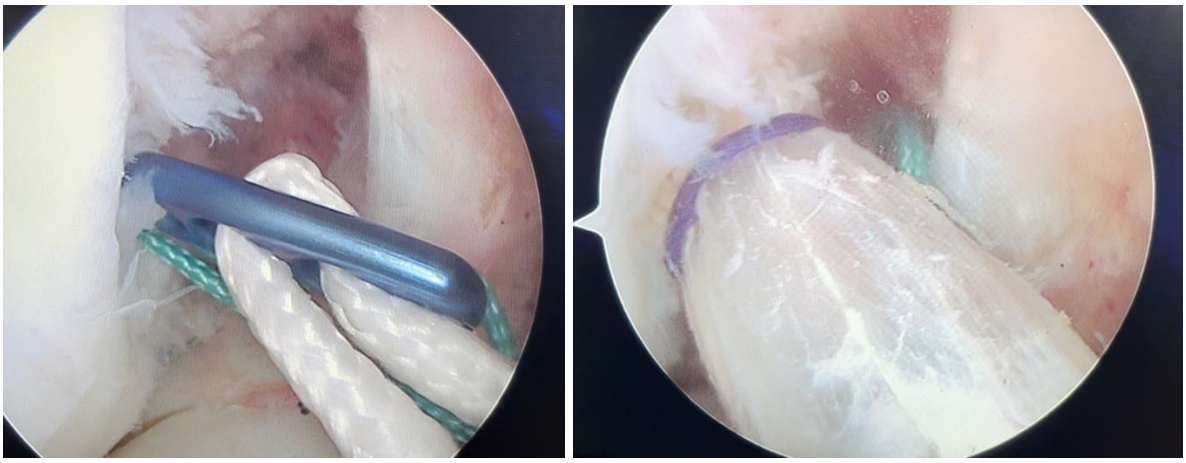


Fig 41: Endobutton followed by Hamstrings Graft pulled into femoral tunnel

Fig. 42: Endobutton followed by Quadriceps Graft pulled into femoral tunnel

The graft is cycled through 20 to 30 times of knee flexion and extension while being continuously pulled into the tibial tunnel. The graft is then arthroscopically visualised to check for any indications of alignment, impingement, etc. A Interference screw or tibia base plate is used to secure the tibial side of the graft with knee in 10 degree flexion and with posterior drawer.

The wounds and ports sutured in layers. Then a sterile dressing done. Knee brace immobilises the affected limb.

Post- Operative management:

First few days following surgery, immobilised in a knee-brace and limb-elevation were performed. Antibiotics were administered intravenously for three days following surgery. Second post-operative day, the wound was examined. Inspected on the second and seventh post-operative days. On the twelfth post-operative day, the sutures were removed. The process of rehabilitation began immediately.

Evaluation:

To ascertain the tunnel placement and positions of the implants, all patients had post-operative anteroposterior and lateral radiographs. Functional results were evaluated at six-week, 3 months, 6 months, and one-year intervals for the patients.

Patients were evaluated by **IKDC** and **Lysholm** Knee Scoring Scale.

IKDC subjective score has different parameters which gives score of 87 in total when summed. Parameters are subjective and gained by a questionnaire in particular format. Score is converted to percentage and used in that format to evaluate knee functions of the patient. A score of 100 is considered to indicate no restrictions on daily activities or athletic endeavours as well as the lack of symptoms.

Lysholm score is evaluated by 8 parameters:

1. Limp
2. Walking aid
3. Locking of knee
4. Instability
5. Pain
6. Swelling
7. Ability to climb stairs
8. Ability to Squat

The scores were given according to patient's ability to function with full function at 100 score. Scores were divided into excellent, good, fair and poor.

IKDC & Lysholm knee score formats are attached.

CASE ILLUSTRATION

CASE 1

8 years old case of chronic ACL deficiency was operated with Arthroscopic ACL reconstruction with Five tailed Hamstrings graft with Fixed loop endobutton for femoral side and Interference screw for Tibial side.

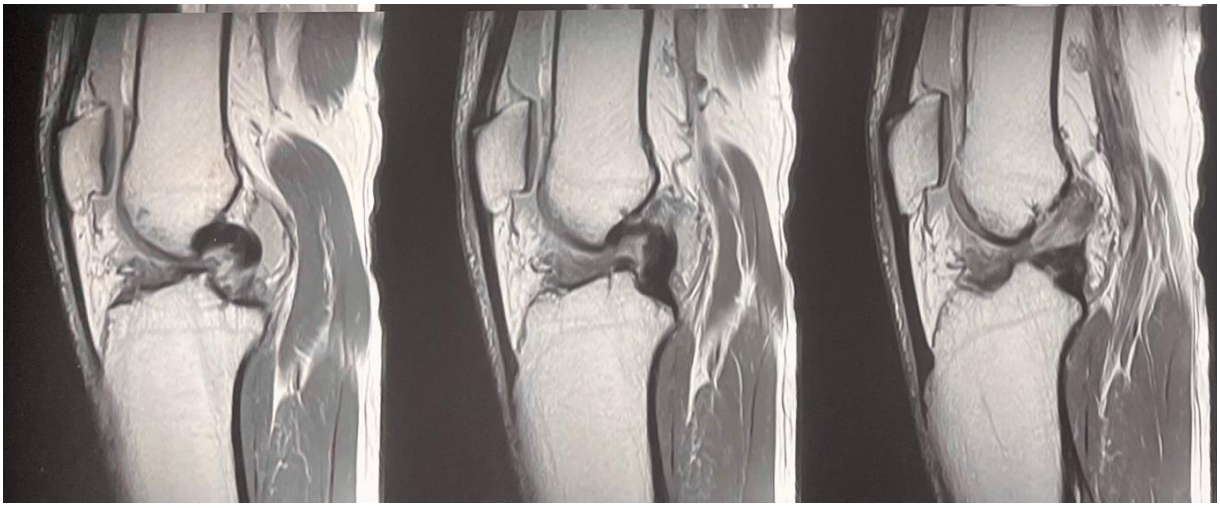


Fig. 43A: Preop MRI showing ACL deficiency

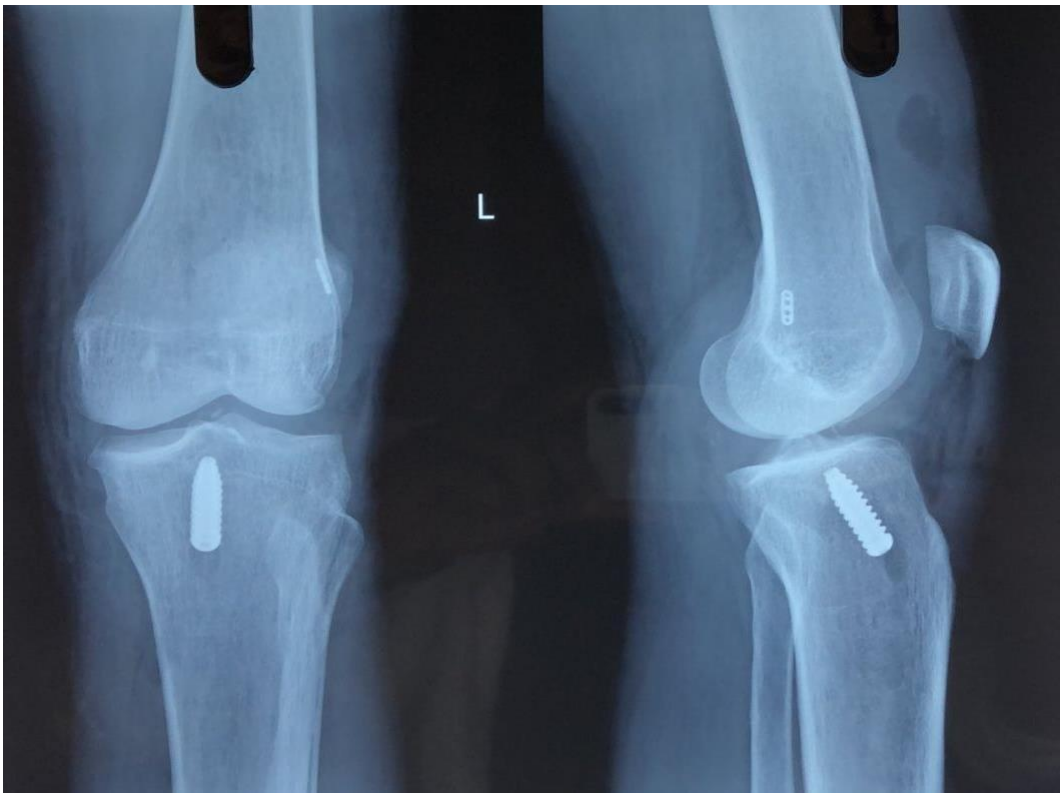


Fig. 43B: Post op radiograph with Endobutton and Titanium interference screw insitu

Fig 43C: Post operative knee ROM and SLRT

CASE 2

2 months old case of chronic ACL deficiency was operated with Arthroscopic ACL reconstruction with Quadriceps graft with Fixed loop endobutton for femoral side and Interference screw for Tibial side.

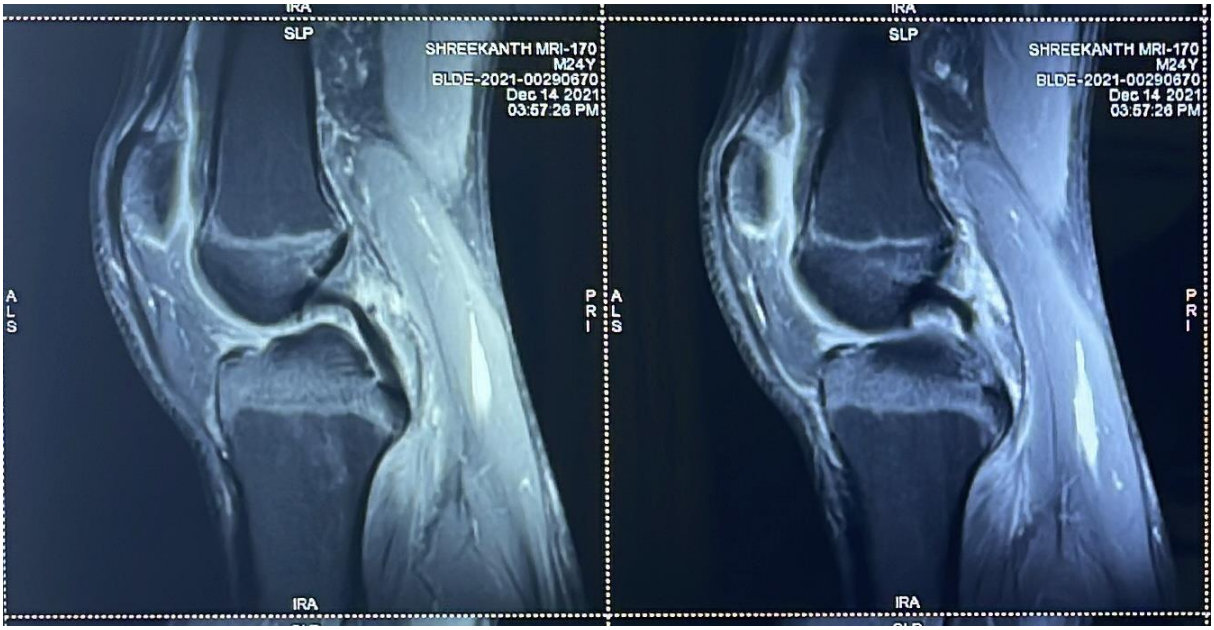


Fig. 44A: Preop MRI showing ACL deficiency

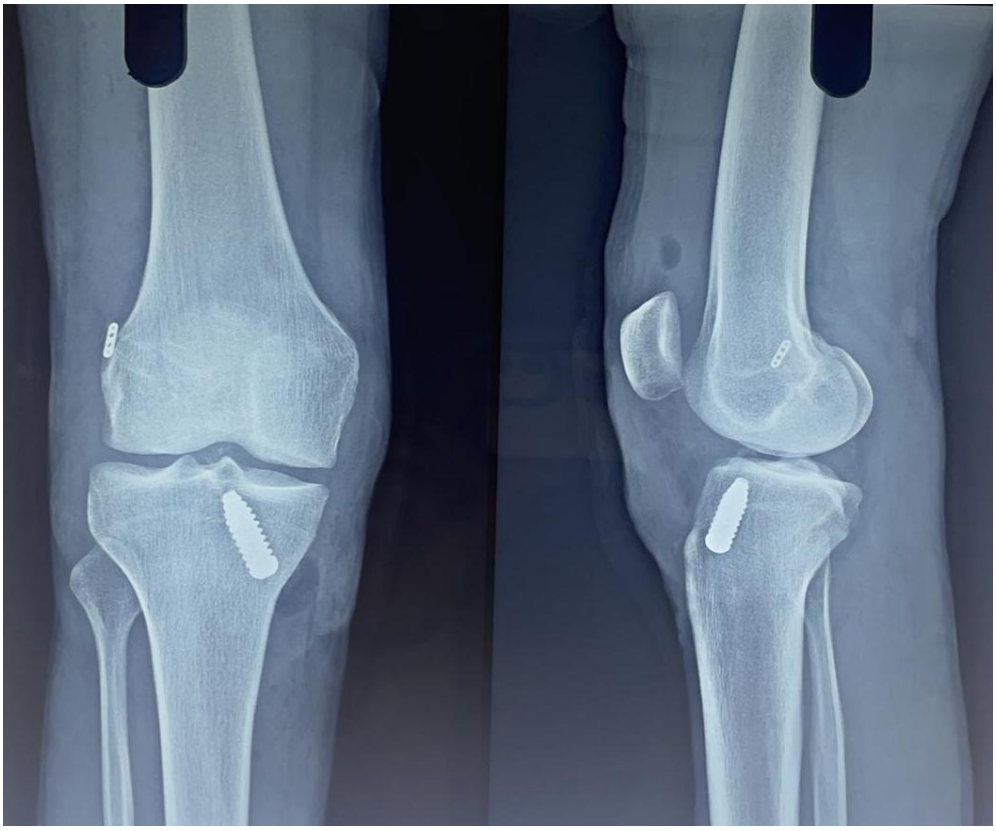


Fig. 44B: Post op radiograph with Endobutton and Titanium interference screw insitu

Fig 44C: Post operative knee ROM and SLRT

CASE 3

1 month old case of chronic ACL deficiency was operated with Arthroscopic ACL reconstruction with Four tailed Hamstrings graft with Fixed loop endobutton for femoral side and Tibial base plate for Tibial side.

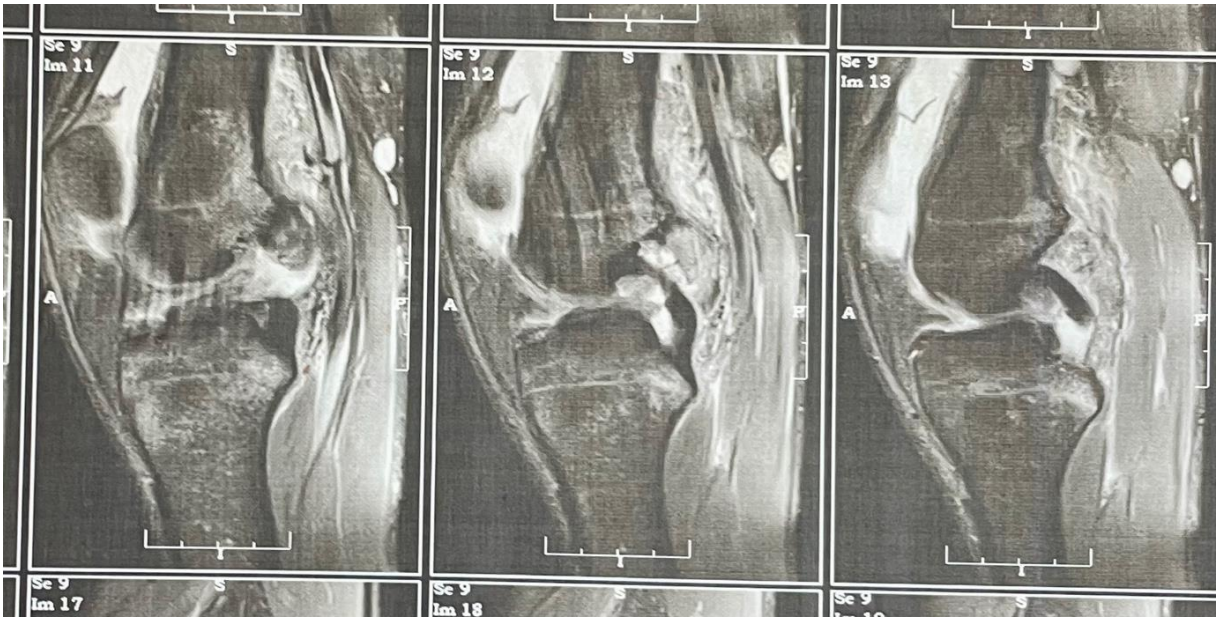


Fig. 45A: Preop MRI showing ACL deficiency

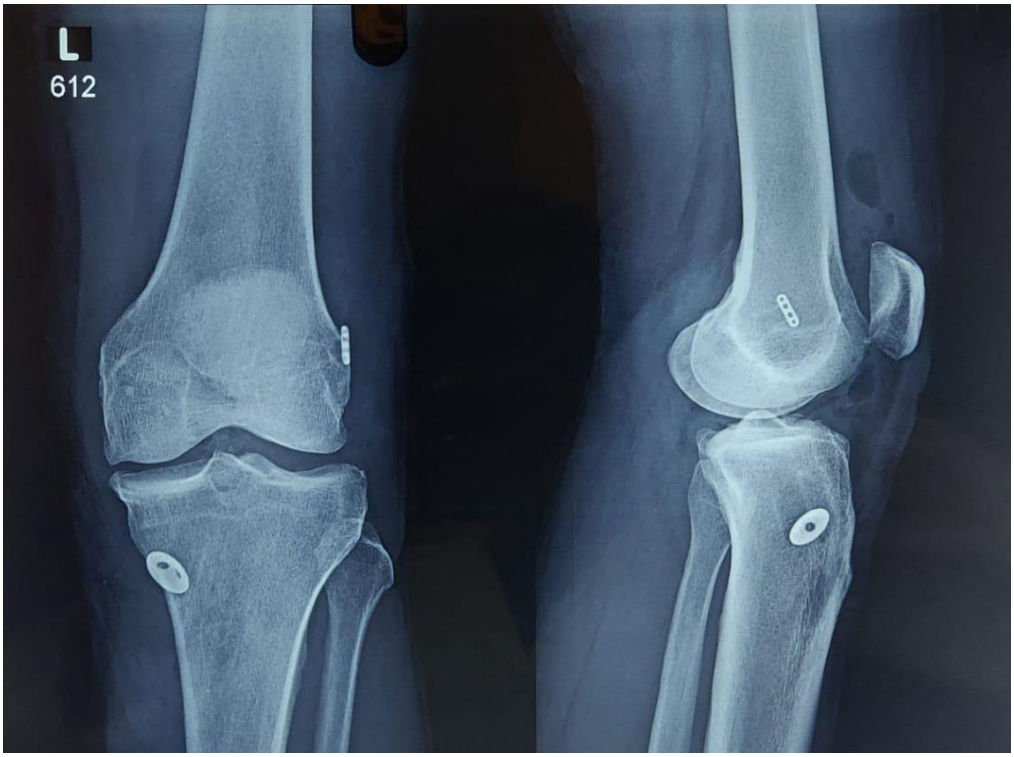


Fig. 45B: Post op radiograph with Endobutton and Tibial base plate insitu

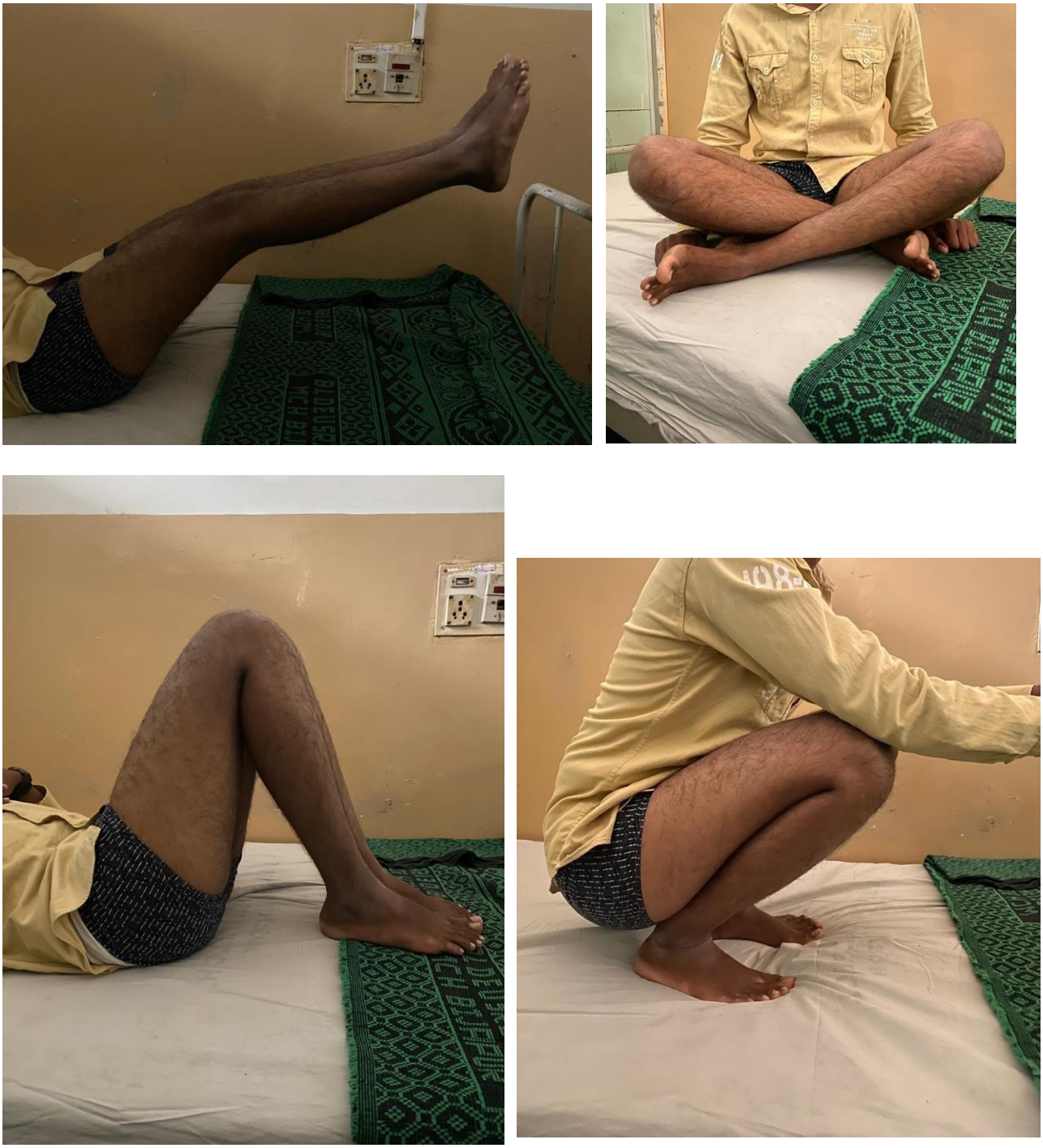


Fig. 45C: Post operative knee ROM and SLRT

CASE 4

15 days old case of chronic ACL deficiency was operated with Arthroscopic ACL reconstruction with Quadriceps graft with Fixed loop endobutton for femoral side and Tibial base plate for Tibial side.

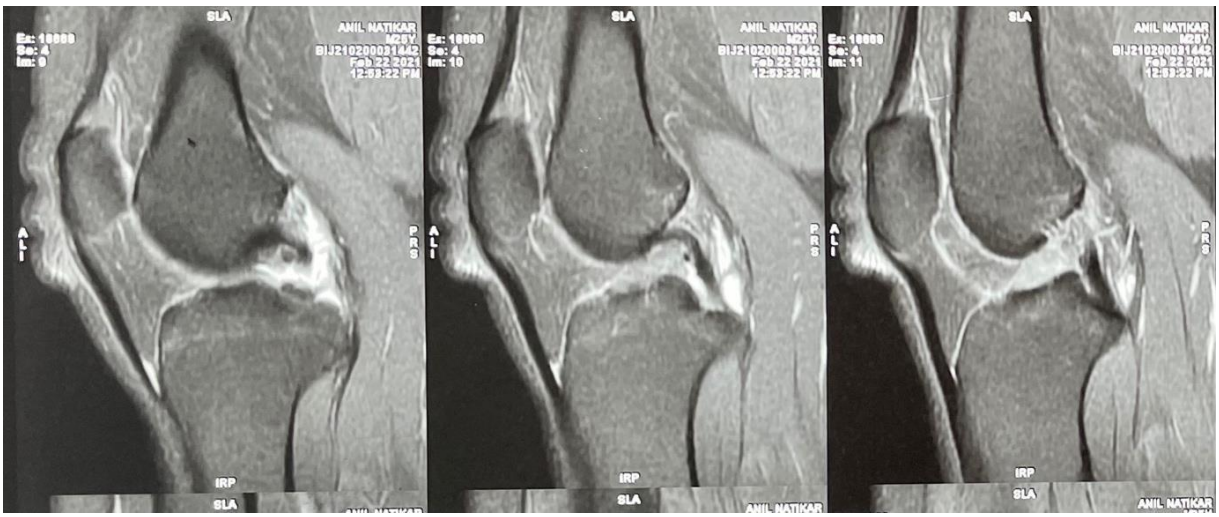


Fig. 46A: Preop MRI showing ACL deficiency

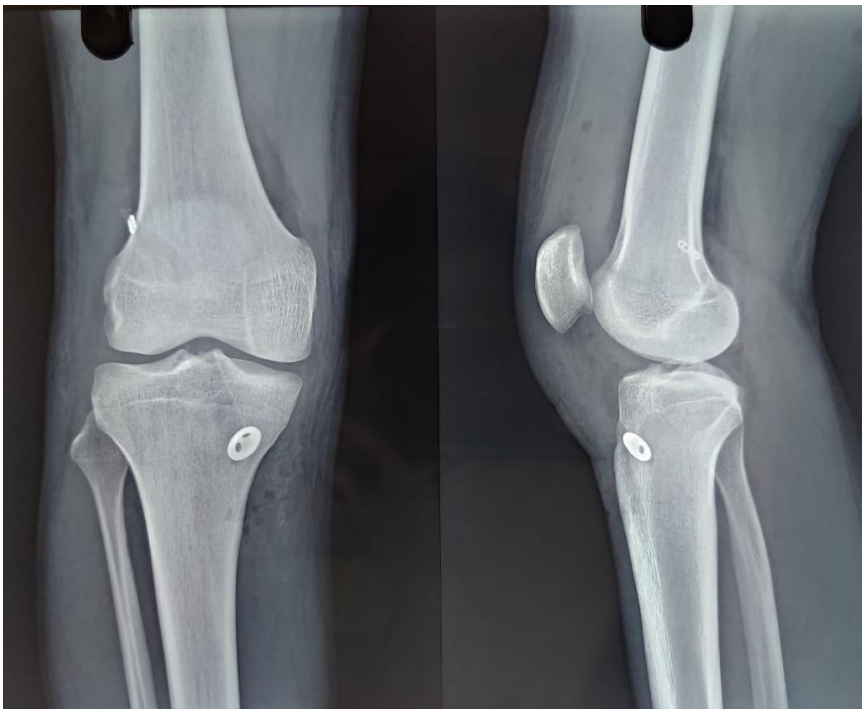


Fig. 46B: Post op radiograph with Endobutton and Tibial base plate insitu

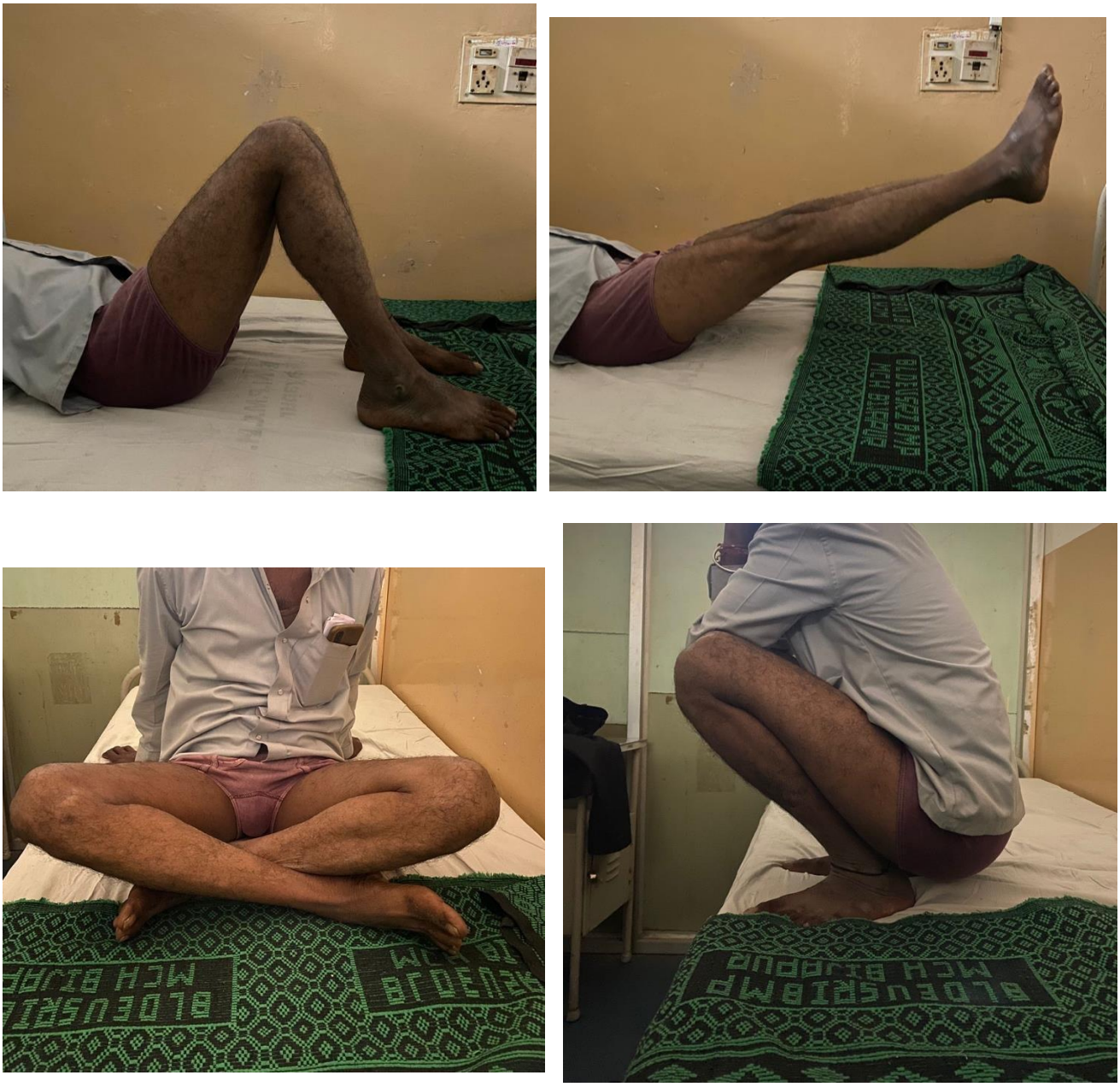


Fig. 46C: Post operative knee ROM and SLRT

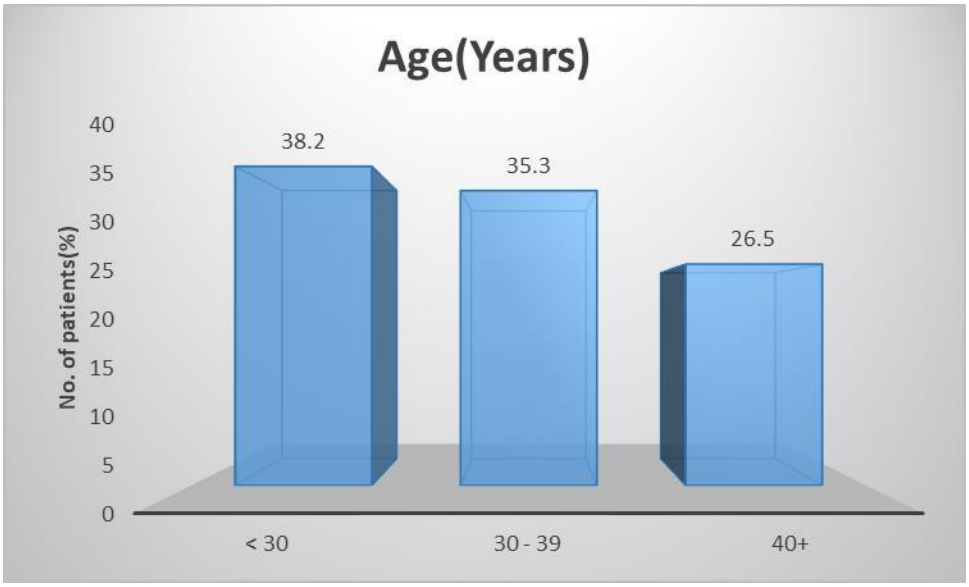
RESULTS

34 cases of Arthroscopic ACL Reconstruction were randomize into 2 groups with all baseline characters matched (17 with Hamstrings tendon autograft and rest 17 with Quadriceps tendon) and were followed up regularly for an period of 21 months maximum and 12 months minimum in BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapur (from December 2020 to November 2022).

Age Distribution:

Age(Years)	Hamstrings Group	Quadriceps group	No. of patients	Percentage
< 30	5	8	13	38.2
30 - 39	7	5	12	35.3
40+	5	4	9	26.5
Total	17	17	34	100

Table 1: Age distribution

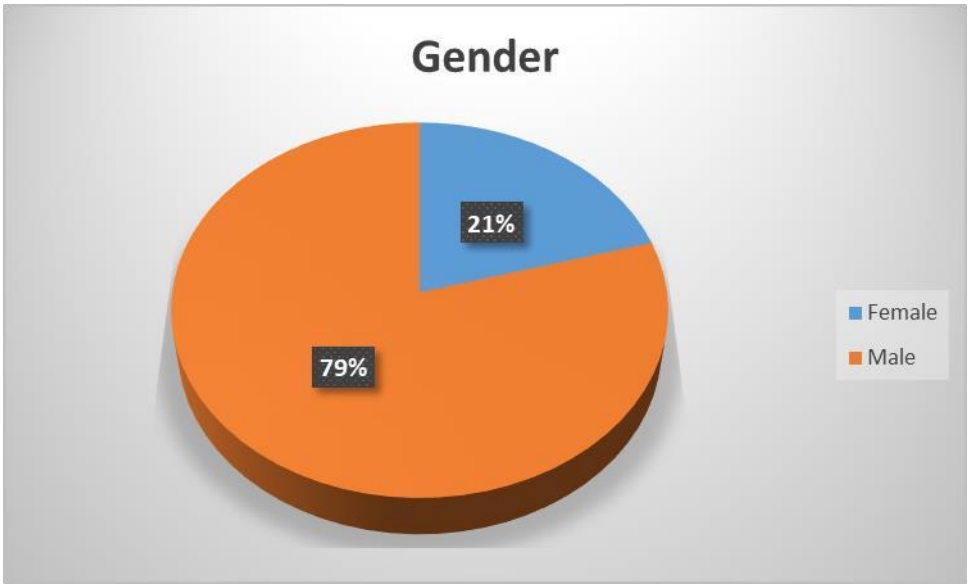


Most patients presented to us were young and in age group of below 30 years, out of 13 (38%) patients of this age group, 8 received quadriceps and 5 hamstrings graft. 12 patients were of 30-39 age group and rest 9 patients were from above 40 years age group.

Sex Distribution:

Gender	Hamstrings Group	Quadriceps group	No. of patients	Percentage
Female	3	4	7	20.6
Male	14	13	27	79.4
Total	17	17	34	100

Table 2: Sex distribution

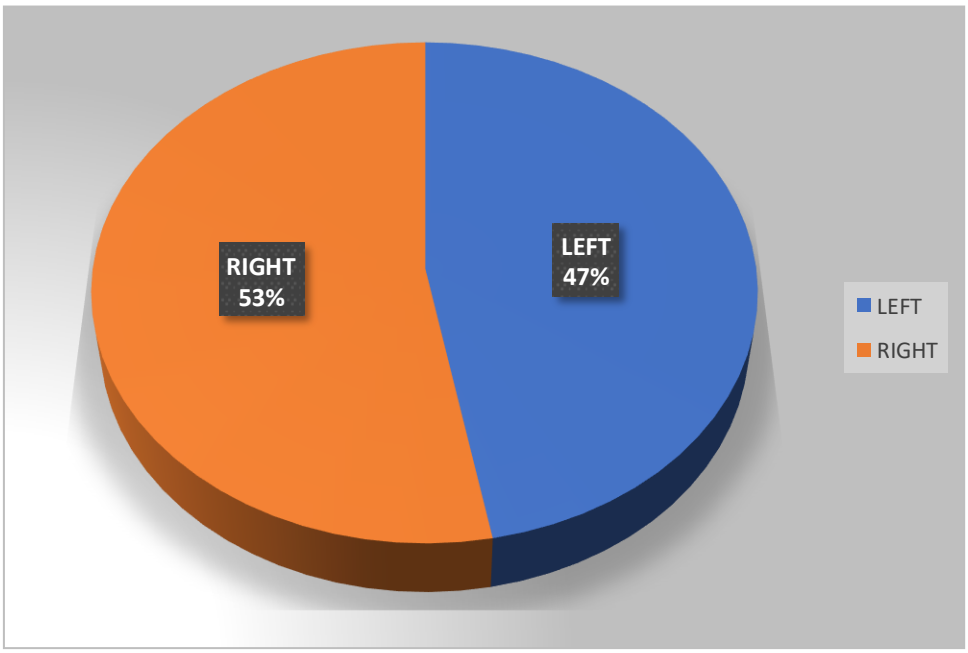


Males sustained this injury noticeably more than females. 27 of 34 operated for ACL reconstruction in our study were males, 14 of which received quadriceps while 13 hamstrings tendon autograft. 3 females got quadriceps and 4 hamstrings in our study.

Side involvement:

Side	Hamstrings Group	Quadriceps group	No. of patients	Percentage
LEFT	6	10	16	47.1
RIGHT	11	7	18	52.9
Total	17	17	34	100

Table 3: Side involvement

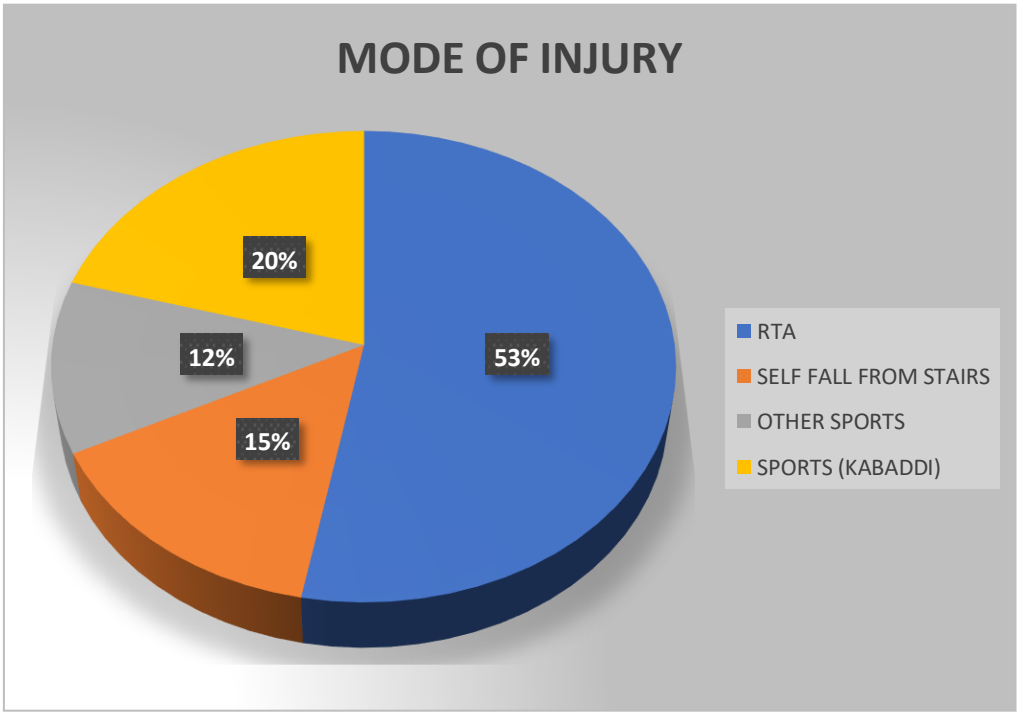


Right side(18 patients) was involved slightly more than left side(16 patients).

Mode of Injury:

MODE OF INJURY	Hamstrings Group	Quadriceps group	No. of patients	Percentage
RTA	10	8	18	52.9
SELF FALL FROM STAIRS	2	3	5	14.7
OTHER SPORTS	2	2	4	11.8
SPORTS (KABADDI)	3	4	7	20.6
Total	17	17	34	100

Table 4: Mode of Injury

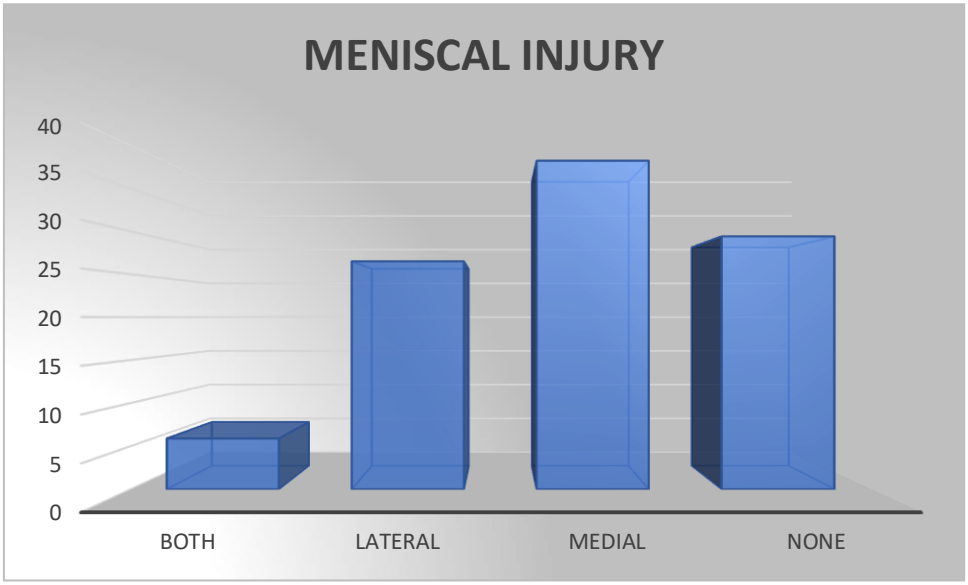


The most common mode to sustain the injury in our study was Road Traffic Accidents (53%) followed by sports (32%). 20% Kabaddi players and 12% of them were other sports and 20% were fall from stairs. We specifically mentioned kabaddi and other sports as it is frequently played sport in our rural population which are referred to our institute.

Associated Meniscal injuries:

MENISCAL INJURY	No. of patients	Percentage
BOTH	2	5.9
LATERAL	9	26.5
MEDIAL	13	38.2
NONE	10	29.4
Total	34	100

Table 5: Associated Meniscal injuries



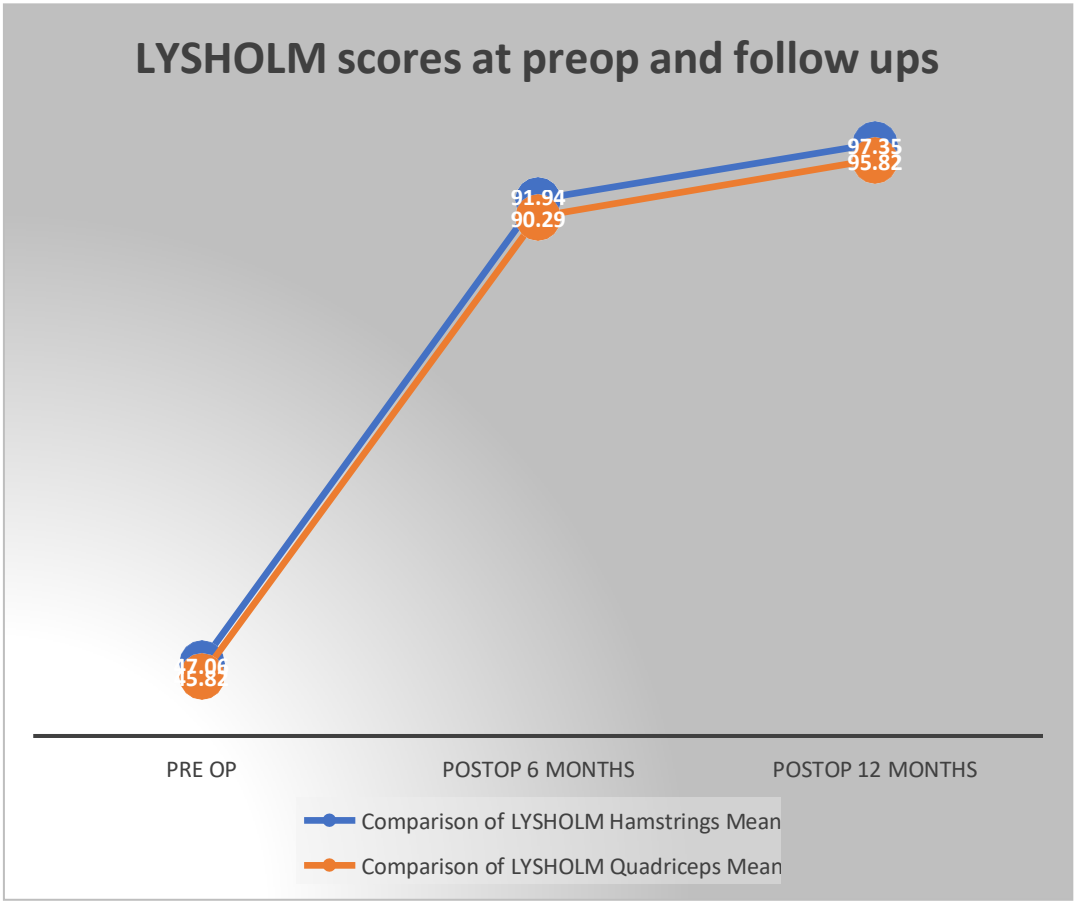
24 of 34 patients had an associated meniscal injury. Medial meniscus (38.2%) was injured more commonly than lateral(26%). The cases which underwent repair were simple tears and not complicated ones which required change in the rehabilitation protocol. Isolated ACL tear was present in 10 patients (29.4%).

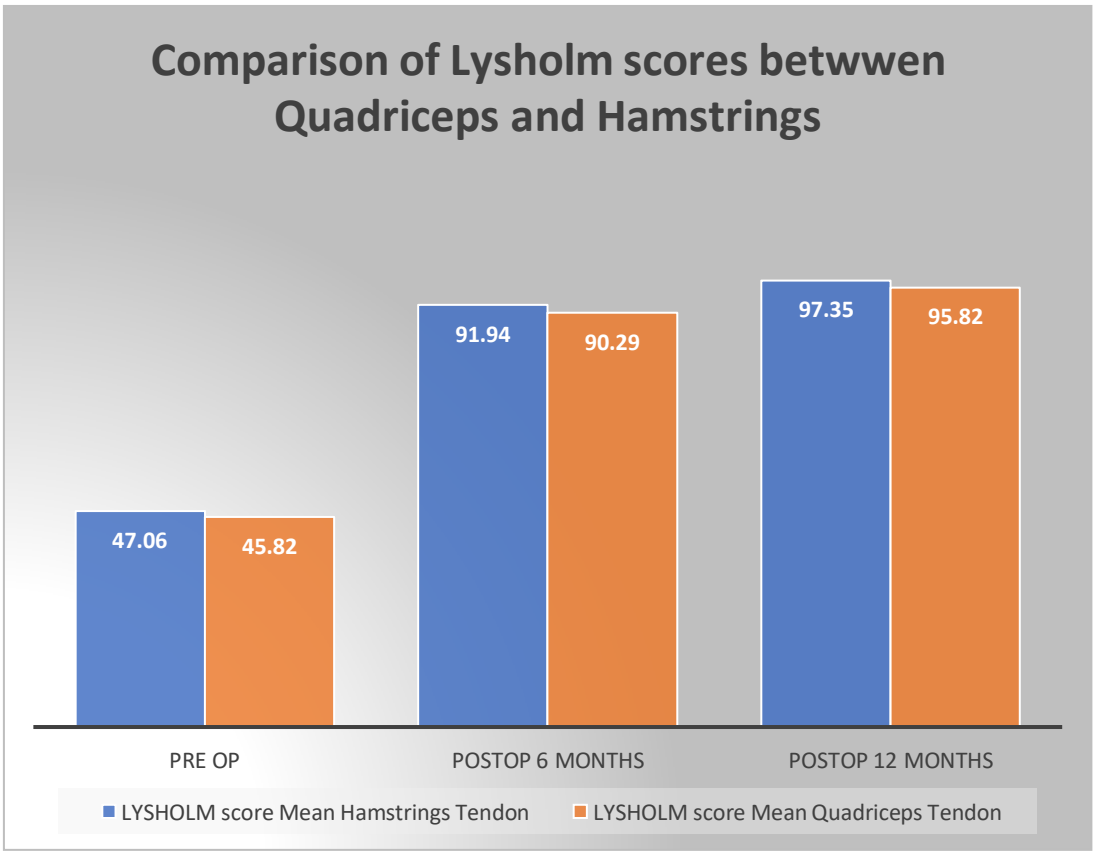
Median of injury to surgery time was 2 months with 1 at 25, 2 at 50 and 7.5months at 75 percentile. Functional outcomes as seen on lysholm and IKDC scores, were in negative correlation with injury to surgery time at 6 months (-0.258) and 12 months (-0.292) follow ups proving more the delay in injury to surgery worse the functional outcome.

Lysholm score:

Comparison of LYSHOLM	HAMSTRINGS		QUADRICEPS		Mann-Whitney U	P value
	Mean	Std. Deviation	Mean	Std. Deviation		
PRE OP	47.06	6.057	45.82	6.840	127.500	0.563
POSTOP 6 months	91.94	3.716	90.29	4.370		
POSTOP 12 months	97.35	2.805	95.82	3.414		
Statistically Insignificant						

Table 6: Lysholm score comparison



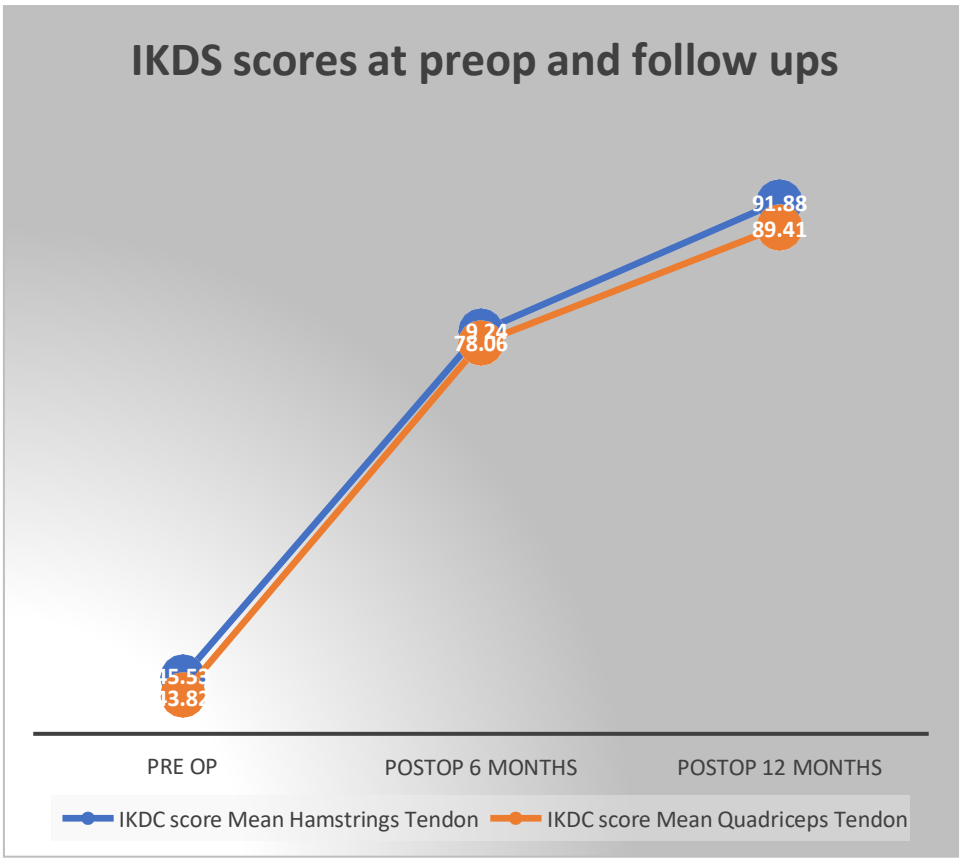


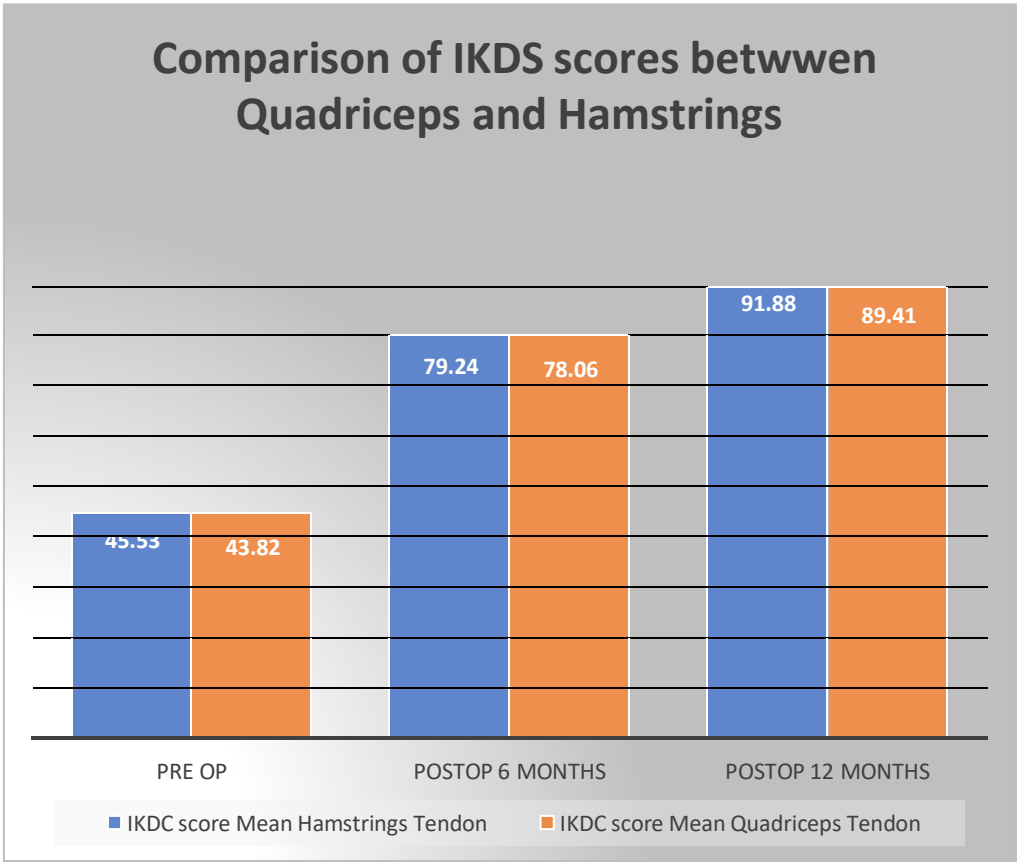
IKDC score:

	GRPS	Mean	Std. Deviation	Std. Error Mean
IKDC PREOP	HAMSTRINGS	45.53	6.345	1.539
	QUADRICEPS	43.82	7.117	1.726
IKDC POSTOP 6mo	HAMSTRINGS	79.24	7.742	1.878
	QUADRICEPS	78.06	7.284	1.767
IKDC POSTOP 12mo	HAMSTRINGS	91.88	7.279	1.765
	QUADRICEPS	89.41	7.027	1.704

	IKDC PREOP	IKDC POSTOP 6mo	IKDC POSTOP 12mo
Mann-Whitney U	107	121	102
Exact Sig. [2*(1-tailed Sig.)]	.205[b]	.433[b]	.150[b]

Table 7: IKDC scores comparison





Hence both Lysholm and IKDC score for Hamstrings and Quadriceps tendon autografts showed no significant difference at 6, and 12 months post operatively.

31 (91%) of our cases went back to the pre injury activity three (2 Hamstrings group and 1 Quadriceps group) of the 34 patients still had restriction of full movements restricting them from squatting and cross legged sitting. 16 (47%) of 34 patients returned back to sports activity rest 18 had mild pain and difficulty in cutting, acceleration and sudden stop from running.

Complications:

1. 2 patients were noted to have superficial infection of donor site in our study they were treated with IV Antibiotics; 1 patient from Hamstrings and 1 from Quadriceps group.
2. 3 patients complained of restricted range of movement due to poor compliance to post operative rehabilitation. Range of movements of 10 to 80 degrees which were increased by aggressive physiotherapy. 2 of them were from Hamstrings and 1 from Quadriceps tendon group.
3. 2 patients reported numbness over anteromedial aspect of the leg both were from Hamstrings tendon group.
4. None of our patients complained of unsatisfactory cosmetic appearance of post operative scar.
5. None of the cases had infection requiring debridement
6. None of the cases had graft laxity and failure at end of 1 year.

DISCUSSION

Only few studies have compared Quadriceps tendon versus hamstrings tendon autografts in ACL Reconstructions, We have done prospective randomised controlled trial in order to reduce slection bias.

34 patients with confirmed ACL tears were randomised and 17 received Quadriceps while rest 17 Hamstrings autograft during ACL reconstruction prospectively followed up for minimum 12 months. Similar study done by Adrial Todor et al. [50] published a study in 2019 showed retrospectively 72 patients out of which 39 were operated with quadricpes while 33 by hamstrings tendon with follow up of minimum 24 months. Pomenta Bastidas et al.[53] did non randomised comparative study including 52 patients (25 Quadriceps and 27 Hamstrings) with minimum 2 year follow up. Cavaignac E et al,[79] conducted a study including 86 patients of ACL tear 45 of them were operated with quadriceps and 41 with Hamstrings tendon and were followed up for minimum of 3 years.

We received no significant difference in functional outcomes between Quadriceps and hamstrings tendon autograft at our follow ups(6 and 12 months). Findings are similar to the study of Adrian Todor et al.[50] which concluded no significant difference in functional outcomes detected on KT 1000 arthrometer (p=0.326), Lysholm (p=0.299), Modified cincinatti score(p=0.665) and general SF-36 scores (p=0.588). 5 patients of quadriceps group reported unsatisfactory results while 8 Hamstrings group patients reported mild numbness on anteromedial aspect of leg. None of his patients required revisions or reoperations. Pomenta Bastidas et al.[53] in his study received no significant difference in Tagner (p=0.11) and IKDC (p=0.38) functional outcome scores between both the groups. 3 of their patients one quadriceps group required revision surgery of the donor site, rest 2 (1 each from quadriceps and hamstrings group) due to sports injury.

Cavaignac E et al,[79] in his study achieved significant difference in Lysholm (p=0.008), KOOS Symptoms (p=0.017) and KOOS sport (p=0.003) which were significantly better in quadriceps tendon group(mean lysholm=89.6%) than hamstrings tendon (mean lysholm=83.1%) group. 3 of their quadriceps group patients required revision (1x cyclope lesion, 1x for femoral screw removal

and 1 for cartilage injury) and one came with rerupture. In hamstrings group 2 reruptures were noted due to contact sports, 1 revision for arthrolysis.

CONCLUSION

- In young active adults, anatomic single bundle reconstruction with quadriceps tendon autograft gives as good functional results as quadrupled hamstring autograft.

Limitations of this study are:

- Sample size was small
- Follow-up duration was short, longer follow up is required in order to assess such procedures.
- Assessment was done by subjective scores only and no objective assessment was done in our study

2000 IKDC SUBJECTIVE KNEE EVALUATION FORM

Name: First Last **Date:**

Physician: **Date of Injury:**

SYMPTOMS*:

*Grade symptoms at the highest activity level at which you think you could function without significant symptoms, even if you are not actually performing activities at this level.

1. What is the highest level of activity that you can perform without significant knee pain?

- ◯ Very strenuous activities like jumping or pivoting as in basketball or soccer
- ◯ Strenuous activities like heavy physical work, skiing or tennis
- ◯ Moderate activities like moderate physical work, running or jogging
- ◯ Light activities like walking, housework or yard work
- ◯ Unable to perform any of the above activities due to knee pain

2. During the past 4 weeks, or since your injury, how often have you had pain?

	0	1	2	3	4	5	6	7	8	9	10	
Never	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Constant

3. If you have pain, how severe is it?

	0	1	2	3	4	5	6	7	8	9	10	
No pain	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Worst pain imaginable

4. During the past 4 weeks, or since your injury, how stiff or swollen was your knee?

- ◯ Not at all
- ◯ Mildly
- ◯ Moderately
- ◯ Very
- ◯ Extremely

5. What is the highest level of activity you can perform without significant swelling in your knee?

- ◯ Very strenuous activities like jumping or pivoting as in basketball or soccer
- ◯ Strenuous activities like heavy physical work, skiing or tennis
- ◯ Moderate activities like moderate physical work, running or jogging
- ◯ Light activities like walking, housework or yard work
- ◯ Unable to perform any of the above activities due to knee swelling

6. During the past 4 weeks, or since your injury, did your knee lock or catch?

◯ Yes ◯ No

7. What is the highest level of activity you can perform without significant giving way in your knee?

- ◯ Very strenuous activities like jumping or pivoting as in basketball or soccer
- ◯ Strenuous activities like heavy physical work, skiing or tennis
- ◯ Moderate activities like moderate physical work, running or jogging
- ◯ Light activities like walking, housework or yard work
- ◯ Unable to perform any of the above activities due to giving way of the knee

SPORTS ACTIVITIES:

8. What is the highest level of activity you can participate in on a regular basis?

- ○ Very strenuous activities like jumping or pivoting as in basketball or soccer
- ○ Strenuous activities like heavy physical work, skiing or tennis
- ○ Moderate activities like moderate physical work, running or jogging
- ○ Light activities like walking, housework or yard work
- ○ Unable to perform any of the above activities due to knee

9. How does your knee affect your ability to:

		Not difficult at all	Minimally difficult	Moderately Difficult	Extremely difficult	Unable to do
a.	Go up stairs	○	○	○	○	○
b.	Go down stairs	○	○	○	○	○
c.	Kneel on the front of your knee	○	○	○	○	○
d.	Squat	○	○	○	○	○
e.	Sit with your knee bent	○	○	○	○	○
f.	Rise from a chair	○	○	○	○	○
g.	Run straight ahead	○	○	○	○	○
h.	Jump and land on your involved leg	○	○	○	○	○
i.	Stop and start quickly	○	○	○	○	○

FUNCTION:

10. How would you rate the function of your knee on a scale of 0 to 10 with 10 being normal, excellent function and 0 being the inability to perform any of your usual daily activities which may include sports?

FUNCTION PRIOR TO YOUR KNEE INJURY:

	0	1	2	3	4	5	6	7	8	9	10	
Couldn't perform daily activities	○	○	○	○	○	○	○	○	○	○	○	No limitation in daily activities

CURRENT FUNCTION OF YOUR KNEE:

	0	1	2	3	4	5	6	7	8	9	10	
Cannot perform daily activities	○	○	○	○	○	○	○	○	○	○	○	No limitation in daily activities

0 IKDC Score

Print Form

Submit

LYSHOLM KNEE SCORING SCALE

This questionnaire is designed to give your Physical Therapist information as to how your knee problems have affected your ability to manage in everyday life Please answer every section and mark only the ONE box which best applies to you at this moment.

Name: _____ **Date:** _____

SECTION 1 - LIMP
- ☐ I have no limp when I walk. (5)
- ☐ I have a slight or periodical limp when I walk. (3)
- ☐ I have a severe and constant limp when I walk. (0)

SECTION 2 - Using cane or crutches
- ☐ I do not use a cane or crutches. (5)
- ☐ I use a cane or crutches with some weight-bearing. (2)
- ☐ Putting weight on my hurt leg is impossible. (0)

SECTION 3 - Locking sensation in the knee
- ☐ I have no locking and no catching sensation in my knee. (15)
- ☐ I have catching sensation but no locking sensation in my knee. (10)
- ☐ My knee locks occasionally. (6)
- ☐ My knee locks frequently. (2)
- ☐ My knee feels locked at this moment.. (0)

SECTION 4 - Giving way sensation from the knee
- ☐ My knee gives way. (25)
- ☐ My knee rarely gives way, only during athletics or vigorous activity. (20)
- ☐ My knee frequently gives way during athletics or other vigorous activities. In turn I am unable to participate in these activities. (15)
- ☐ My knee frequently gives way during daily activities. (10)
- ☐ My knee often gives way during daily activities. (5)
- ☐ My knee gives way every step I take. (0)

SECTION 5 – PAIN
- ☐ I have no pain in my knee. (25)
- ☐ I have intermittent or slight pain in my knee during vigorous activities. (20)
- ☐ I have marked pain in my knee during vigorous activities. (15)
- ☐ I have marked pain in my knee during or after walking more than 1 mile. (10)
- ☐ I have marked pain in my knee during or after walking less than 1 mile. (5)
- ☐ I have constant pain in my knee. (0)

SECTION 6 – SWELLING
- ☐ I have swelling in my knee. (10)
- ☐ I have swelling in my knee on1y after vigorous activities. (6)
- ☐ I have swelling in my knee after ordinary activities. (2)
- ☐ I have swelling constantly in my knee. (0)

SECTION 7 – CLIMBING STAIRS
- ☐ I have no problems climbing stairs. (l0)
- ☐ I have slight problems climbing stairs. (6)
- ☐ I can climb stairs only one at a time. (2)
- ☐ Climbing stairs is impossible for me. (0)

SECTION 8 – SQUATTING
- ☐ I have no problems squatting. (5)
- ☐ I have slight problems squatting. (4)
- ☐ I cannot squat beyond a 90deg. Bend in my knee. (1)
- ☐ Squatting is impossible because of my knee. (0)

Total: _____/100

Instructions: Please place a mark on the line to indicate the amount of pain you have had in your knee(s) in the past 24 hours.

RIGHT KNEE
No pain at all ——————————————— **Worst pain possible**

LEFT KNEE
No pain at all ——————————————— **Worst pain possible**

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SCHEME OF CASE TAKING:

CASE NO. :

FOLLOW UP NO. :

NAME :

AGE/SEX :

I P NO :

DATE OF ADMISSION :

DATE OF SURGERY :

DATE OF DISCHARGE :

OCCUPATION :

RESIDENCE :

Presenting complaints with duration :

History of presenting complaints :

Family History :

Personal History :

Past History :

Vitals

PR: RR:

BP: TEMP:

Systemic Examination:

Respiratory system -

Cardiovascular system -

Per abdomen -

Central nervous system -

Local examination:

Right/ Left Leg

Gait:

Inspection:

a) Attitude

b) Abnormal swelling

c) Shortening

d) Skin condition

e) Compound injury, if any

Palpation:

a) Swelling

b) Local tenderness

c) Bony irregularity

d) Abnormal movement

e) Crepitus/ grating of fragments

f) Absence of transmitted movements

g) Wound

Movements:	Active	Passive
Flexion		
Extension		

Intra Operative details:

Post Operative:

- Rehabilitation protocol as per the guidelines
- Functional outcome evaluation with:
    1. IKDC scores
    2. Lysholm score

INFORMED CONSENT FORM FOR PARTICIPATION IN DISSERTATION / RESEARCH

I, the undersigned,_____, S/O D/O W/O_____, aged ____years, ordinarily resident of_____do hereby state/declare that **Dr. RONAK KHATRI** of Shri. B. M. Patil Medical College Hospital & Research Centre has examined me thoroughly on_____at_____(place) and it has been explained to me in my own language that I am suffering from_____disease (condition) and this disease/condition mimic following diseases. Further Dr. RONAK KHATRI informed me that he/she is conducting dissertation/research titled **"FUNCTIONAL OUTCOMES OF PRIMARY ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION TREATED WITH QUADRICEPS TENDON VERSUS HAMSTRING TENDON AUTOGRAFT: A RANDOMIZED CONTROLLED STUDY"** under the guidance of **Dr. SANDEEP NAIK** requesting my participation in the study. Apart from routine treatment procedure, the pre-operative, operative, post-operative and follow-up observations will be utilized for the study as reference data.

The doctor has also informed me that during the conduct of this procedure, adverse results might encounter. Most of them are treatable but are not anticipated; hence there is a chance of aggravation of my condition. In rare circumstances, it may prove fatal despite the expected diagnosis and best treatment made available. Further Doctor has informed me that my participation in this study help in the evaluation of the results of the study, which is a useful reference to the treatment of other similar cases in the near future and also, I may be benefited from getting relieved from suffering or a cure of the disease I am suffering.

The Doctor has also informed me that information given by me, observations made/ photographs/ video graphs taken upon me by the investigator will be kept secret and not assessed by the person other than my legal hirer or me except for academic purposes.
The Doctor did inform me that though my participation is purely voluntary, based on the information given by me, I can ask for any clarification during the course of treatment/study related to diagnosis, the procedure of treatment, the result of treatment, or prognosis. I've been informed that I can withdraw from my participation in this study at any time if I want, or the investigator can terminate me from the study at any time from the study but not the procedure of treatment and follow-up unless I request to be discharged.

After understanding the nature of dissertation or research, diagnosis made, mode of treatment, I the undersigned Shri/Smt_____under my full conscious state of mind agree to participate in the said research/dissertation.

Signature of the patient:

Signature of doctor:

Witness: 1.

2.

Date:

Place:

MASTERCHART

	NAME	AGE (YEARS)	SEX	PATIENT ID	SIDE OF INJURY	MODE OF INJURY	INJURY TO SURGERY TIME (MONTHS)	GRAFT USED	MENISCAL INJURY	DOS	LYSHOLM PRE OP (%)	LYSHOLM POSTOP 3 mo(%)	LYSHOLM POSTOP 6 mo(%)	LYSHOLM POSTOP 12 mo(%)	IKDC PRE OP (%)	IKDC POSTOP 3mo (%)	IKDC POSTOP 6mo (%)	IKDC POSTOP 12mo (%)
1	GANESH	26	M	73604	LEFT	SPORTS (KABADDI)	1	QUADRICEPS	NONE	09/02/21	47	88	94	95	45	60	75	90
2	PRAGATI	36	F	92453	LEFT	RTA	1.5	HAMSTRINGS	MEDIAL	16/02/21	54	84	95	100	41	60	86	97
3	KASTURI	32	F	10837	LEFT	SPORTS (KABADDI)	1	HAMSTRINGS	LATERAL	23/02/21	49	80	94	100	61	64	79	96
4	SACHIN PUJARI	20	M	112724	RIGHT	SPORTS (KABADDI)	24	QUADRICEPS	MEDIAL	02/03/21	54	80	94	95	61	64	79	91
5	RAMESH	25	M	102775	RIGHT	SPORTS (FOOTBALL)	24	HAMSTRINGS	BOTH	05/03/21	42	64	86	94	45	62	67	80
6	SANTOSH	26	M	133788	LEFT	SELF FALL FROM STAIRS	12	QUADRICEPS	BOTH	12/03/21	38	64	81	86	41	61	67	78
7	SOMALINGAPPA	27	M	156628	RIGHT	RTA	6	HAMSTRINGS	LATERAL	26/03/21	54	88	95	100	41	66	86	97
8	SOMNATH	40	M	169268	RIGHT	SPORTS (FOOTBALL)	0.5	HAMSTRINGS	LATERAL	02/04/21	47	85	95	100	45	67	86	95
9	GAUTAM	26	M	10625	RIGHT	SELF FALL FROM STAIRS	3	HAMSTRINGS	MEDIAL	09/04/21	38	66	90	95	47	66	80	96
10	ARUN	25	M	19882	RIGHT	SPORTS (KABADDI)	1	QUADRICEPS	LATERAL	16/04/21	38	66	90	95	38	61	79	91
11	PRAKASH	38	M	30525	RIGHT	RTA	6	HAMSTRINGS	MEDIAL	23/04/21	51	69	90	99	47	66	80	96
12	RADHIKA	49	F	142898	RIGHT	RTA	0.5	HAMSTRINGS	MEDIAL	17/05/21	54	84	95	100	41	60	86	97
13	SHRUJAN	26	M	200646	LEFT	RTA	3	QUADRICEPS	MEDIAL	15/06/21	51	69	90	99	39	61	86	91
14	MANAVAR	42	M	196647	RIGHT	SELF FALL FROM STAIRS	0.5	QUADRICEPS	NONE	29/06/21	38	61	86	95	42	61	67	77
15	ESHWAR	45	M	91405	LEFT	SELF FALL FROM STAIRS	24	QUADRICEPS	MEDIAL	01/07/21	54	84	94	100	39	61	86	91
16	MAHANTESH	30	M	82665	LEFT	RTA	24	QUADRICEPS	NONE	14/07/21	47	85	94	95	45	60	75	90
17	DEEPA	38	F	107390	LEFT	RTA	24	QUADRICEPS	NONE	15/07/21	42	64	86	94	42	61	67	77
18	RAJESH	50	M	107265	LEFT	RTA	12	HAMSTRINGS	LATERAL	19/07/21	47	85	94	95	45	60	75	90
19	SIDDALINGAYYA	28	M	107004	RIGHT	RTA	0.5	QUADRICEPS	NONE	21/07/21	54	84	94	100	38	61	85	97
20	BHIMASHANKAR	24	M	130380	RIGHT	RTA	1	HAMSTRINGS	LATERAL	11/08/21	47	85	95	100	45	67	86	95
21	PRAVEEN TELI	40	M	96910	LEFT	RTA	96	HAMSTRINGS	NONE	17/08/21	38	64	86	94	41	61	67	78
22	TAMANNA	32	M	145532	RIGHT	RTA	1.5	QUADRICEPS	MEDIAL	18/08/21	38	80	94	95	45	64	85	95
23	PRAVEEN	36	M	143999	LEFT	SPORTS (KABADDI)	3	QUADRICEPS	MEDIAL	23/08/21	54	84	95	100	41	60	86	97
24	PRANESH	34	M	153738	RIGHT	SPORTS (FOOTBALL)	2	QUADRICEPS	MEDIAL	25/08/21	54	84	95	100	61	64	79	91
25	DINESH	36	M	154578	RIGHT	SPORTS (KABADDI)	0.5	HAMSTRINGS	LATERAL	26/08/21	42	64	86	94	61	64	79	96
26	HARISH	33	M	159667	RIGHT	RTA	1	QUADRICEPS	LATERAL	02/09/21	47	80	86	95	38	61	79	91
27	SWAPNA	31	F	162680	LEFT	SPORTS (FOOTBALL)	3	HAMSTRINGS	NONE	06/09/21	38	80	94	95	45	62	67	80
28	ANITA	47	F	162226	RIGHT	RTA	6	QUADRICEPS	LATERAL	08/09/21	38	66	90	95	47	66	80	96
29	VARSHA	23	F	162215	LEFT	SELF FALL FROM STAIRS	0.5	HAMSTRINGS	MEDIAL	13/09/21	49	80	94	100	41	60	86	97
30	VENKATESH	41	M	193530	RIGHT	RTA	1	HAMSTRINGS	NONE	30/09/21	54	80	94	95	45	64	85	95
31	SANTOSH	27	M	213641	LEFT	RTA	1.5	QUADRICEPS	NONE	19/10/21	38	61	86	95	38	61	85	97
32	PRASHANTH	26	M	205485	LEFT	RTA	1	QUADRICEPS	MEDIAL	23/10/21	47	80	86	95	45	62	67	80
33	MAHADEVAPPA	37	M	222932	LEFT	RTA	3	HAMSTRINGS	MEDIAL	26/10/21	54	84	94	100	38	61	85	97
34	DEEPAK	47	M	229575	RIGHT	SPORTS (KABADDI)	0.5	HAMSTRINGS	NONE	28/10/21	42	64	86	94	45	62	67	80

IEC/NO - 11/21
Date- 22/01/2021

B.L.D.E. (DEEMED TO BE UNIVERSITY)
(Declared vide notification No. F.9-37/2007-U.3 (A) Dated. 29-2-2008 of the MHRD, Government of India under Section 3 of the UGC Act, 1956)
The Constituent College
SHRI. B. M. PATIL MEDICAL COLLEGE, HOSPITAL AND RESEARCH CENTRE

INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The Institutional ethical committee of this college met on 11-01-2021 at 11 am to scrutinize the synopsis of Postgraduate students of this college from Ethical Clearance point of view. After scrutiny the following original/corrected and revised version synopsis of the Thesis has been accorded Ethical Clearance

Title: Functional outcomes of primary anterior cruciate ligament reconstruction treated with quadriceps tendon versus hamstring tendon autograft: A randomized controlled trial.

Name of PG student : Dr Ronak Khatri , Department of Orthopaedics

Name of Guide/Co-investigator : Dr Sandeep Naik, Associate.Professor of Orthopaedics

DR .S.V.PATIL
CHAIRMAN, IEC
Institutional Ethical Committee
B L D E (Deemed to be University)
Shri B.M. Patil Medical College,
VIJAYAPUR-586103 (Karnataka)

Following documents were placed before Ethical Committee for Scrutinization:

1. Copy of Synopsis / Research project
2. Copy of informed consent form
3. Any other relevant documents.

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