Outcome Of Arthroscopic Anterior Cruciate Ligament (Acl) Reconstruction Using Quadruple Hamstring Graft 6 Month Post-Operative Follow up

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ABSTRACT
BACKGROUND
The unprecedented rate of growth and development in our country have resulted in increase in the sports activities by the individuals. This has led to the increased accidental injuries to the knee joint, a major contributing factor to Anterior Cruciate Ligament (ACL) injury.Despite the serious nature of the injury, the patients expect relief from minimal surgical intervention resulting in arthroscopic ACL reconstruction.The use of hamstring tendon autograft has been perceived to have less post-operative morbidity enabling earlier return to activities by patients. Hence, the outcome following arthroscopic ACL reconstruction using hamstring graft 6 months after surgery was evaluated in this study.

Objective

Primary Objectives of the Study

(a) To assess the outcome following arthroscopic ACL reconstruction using the hamstring grafts.
(b) Establish co-relationship with International knee documentation committee (IKDC) and Lysholm and Gilquist knee scoring scale.

Material and Methods

(a) Source of Data:- 25 patients who underwent arthroscopic ACL reconstruction using hamstring tendon graft from march 2016 to march 2018 were included in this study. Patients were assessed pre-operatively and 6 months post-operatively.
(b) Establish co-relationship with International knee documentation committee (IKDC) and Lysholm and Gilquist knee scoring scale.

.**Results and Discussion**

Arthroscopic quadruple hamstring ACL reconstruction was performed to restore the functional stability in ACL deficient knees and restore the normal kinetics of the knee.

- Out of the 25 patients, 84% were male and 16 % were female.
- Left knee was involved in 28% of the patients and right knee in 72%. Even in the case of left knee injured, they were found to be right dominant.
- Mode of injury was predominantly from sports (52%), RTA (32%), and fall 16%.
- When the patients were observed after 6 months post surgery, swelling was present in 16%, pain in 16%, instability in 4 %, and sensory loss in 36%. However, no infection and locking were found in any of the patients.
- Frequency of associated injuries on MRI: MMIM 32%, LMIM 24%, MCLIM 8%, LCLIM 1%, and ACLIM 100%.
- Maximum ROM for pre-op was 0-80 and minimum 0-60. In the post-op, maximum was 0-140 and minimum 0-90.
- In the post-op, IKDC results showed that the frequency of normal patients was 10, nearly normal 14, and abnormal 1.
- LGS scoring was excellent for 11, good 11, and fair 3 patients.
- Out of the 11 excellent LGS score, 5 were normal and 6 were nearly normal; out of 11 good LGS, 5 were normal and 6 were nearly normal; and out of 3 fair LGS, 2 were nearly normal and 1 was abnormal.

.**Conclusion**

ACL reconstruction using quadruple stranded hamstring tendon graft provide an intrinsically stable knee with a full range of motion without any pain with restoration of function suggesting that the patients will be able to participate in unrestricted activities and sports.

KEYWORDS:-Anterior cruciate ligament, hamstring graft.

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LIST OF ABBREVIATIONS

ACL	Anterior cruciate ligament
ACLIM	Anterior cruciate ligament injury in MRI
AE	Affected leg extension
AF	Affected leg flexion
AMB	Anteromedial band
AKP	Anterior knee pain
DM	Dominant
DoA	Date of admission
DoS	Date of surgery
FFD	Fixed flexion deformity
IKDC	International Knee Documentation Committee
IL	Injured left
IR	Injured right
LAD	Ligament augmentation device
LCL	Lateral collateral ligament
LCLIM	lateral collateral ligament injury in MRI
LGS	Lysholm Gilquist scoring system
LMIM	Lateral meniscus injury in MRI

MCL	Medial collateral ligament
MCLM	Medial collateral ligament on MRI
MMIM	Medial meniscus injury in MRI
MRI	Magnetic resonance imaging
NE	Normal leg extension
NF	Normal leg flexion
OPD	Outpatient department
OP NO	OPD number
PCL	Posterior cruciate ligament
PCLIM	Posterior cruciate ligament injury in MRI
PLB	Posterolateral band
PTB	Patellar-tendon-bone
QPOT	Quadriceps patellar tendon over-the-top
ROM	Range of movement
ROMA	Range of movement on admission
ROM6	Range of movement at 6 months
RTA	Road traffic accident
SD	Standard deviation
SQ	Subjective questionnaire
ST	Semitendinosus tendon

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INTRODUCTION

Arthroscopic-assisted reconstruction of the anterior cruciate ligament (ACL) using hamstring grafts is a well known and widely accepted surgical procedure [1]. The use of hamstring tendon autograft has been perceived to have less post-operative morbidities[2]. The early post-operative complications were evaluated in this study[3].

In ACL reconstruction using hamstring graft, only few reports are available on the post-operative incidence and area of hypoesthesia[3-6].The ACL is an important restraint to anterior tibial translation and tibial rotation and contributes to the overall stability of the knee[7-9]. If an ACL insufficiency remains untreated, meniscal tear and cartilaginous damage of the joint may secondarily occur [(10,11)]. Therefore, ACL reconstruction is generally recommended for active younger people to restore joint stability and prevent secondary arthritis[12].

In a previous study, Lips Comb et. al[13] evaluated the peak torque value of hamstring strength after harvesting hamstring tendons and reported that no significant loss of hamstring strength occurred when the semitendinosus tendon and Gracilis tendon were used to reconstruct the ACL[12].

The semitendinosus and Gracilis tendon (STG) is found to be a very good autograft donor material, which may be used for the reconstruction of the ACL without disturbing the extensor mechanism.

In the case of patellar-tendon-bone (PTB) graft, the main disadvantages are problem with the extensor mechanism of the knee, loss of motion, patellar fracture and development of the chronic anterior knee pain. Due to the challenges with PTB graft, the STG tendon has become more popular as an alternative technique over the recent years[14-27].

Hamstring graft reconstruction is also not without challenges. It may pose hamstring weakness following ACL reconstruction[28] and the fixation in the tunnel can be longer with respect to bone-patellar tendon[29].

The present study is designed to analyze the post-operative outcome of arthroscopic ACL with quadrupled hamstring autograft filled with endobutton in the femoral tunnel and bio-interference screw in the tibial tunnel.

The muscular torque of the quadriceps and hamstrings, as well as their torque ratio (H/Q) is usually evaluated by the isokinetic test[32]. The H/Q ratio is conventionally calculated by dividing the maximum values of the flexion and the maximum values of the extension of the knee joint in angled speed and determined contraction modes. The same formula was used in the present study to evaluate the H/Q ratio.

The ACL is the primary ligament that limits the anterior translation of the tibia in relation to the femur. Subjects with ACL injury demonstrate laxity, an increase in tibia translation and knee instability[33].

The measurement of ACL laxity is clinically important from the preventive diagnosis of knee injury standpoint as well as for comparison of pre and post surgical reconstruction and conservative treatment. Generalized articular laxity can also be a risk factor for a number of skeletal muscle injuries[34].

OBJECTIVE

Primary Objective of the Study

To assess the outcome following arthroscopic ACL reconstruction using the hamstring grafts.

Secondary Objective

Establish co-relationship with IKDC and Lysholm and Gillquist knee scoring scale.

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Review of literature

Embryology

ACL formation has been observed in foetal development as early as 8 weeks, and two distinct bundles of the ACL are present at 16 weeks' gestation (Figure 1) [(35,36)]. A leading hypothesis holds that the ACL originates as a ventral condensation of the foetal blastoma and gradually migrates posteriorly with the formation of the intercondylar space[37]. The menisci are derived from the same blastoma condensation as the ACL, a finding that is consistent with the hypothesis that these structures function in concert[38]. Another proposed mechanism of foetal ACL formation is a confluence between ligamentous collagen fibres and fibres of the periosteum[39]. After the initial formation of the ligament, no major organizational or compositional changes are observed throughout the remainder of foetal development[36].

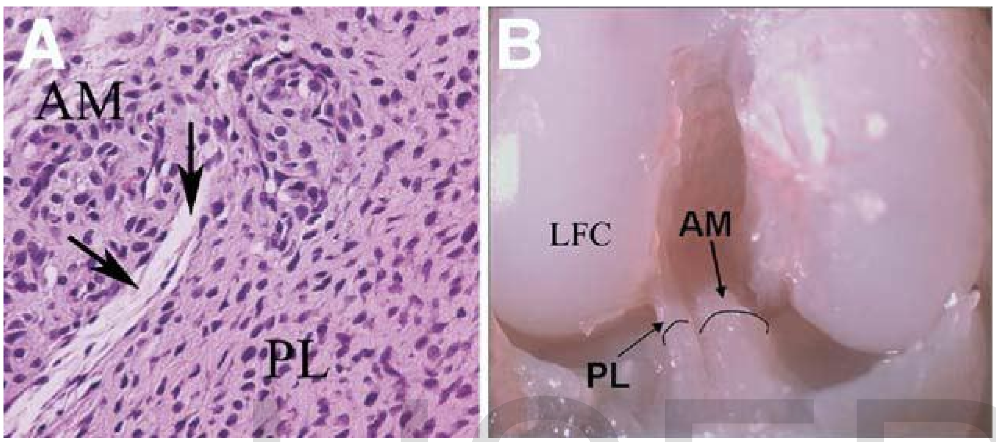

Figure 1. (A) Foetal ACL, sagittal cut. Arrows indicate the vascularised septum dividing the AM and PL bundles. (B) Gross 16-week specimen showing two distinct ACL bundles: AM and PL. H&E stain, 40X magnification. (LFC, lateral femoral condyle.

Anatomy

Insertion site anatomy

Anatomic studies have characterized the individual contribution so both the AM and PL bundles to the overall ACL architecture (Figure 2A and B). Odensten and Gillquist[40] described the femoral origin of the ACL as an ovoid area measuring 18 mm in length and 11 mm in width. Within this area, the AM bundle occupies a position located on the proximal portion the medial wall of the lateral femoral condyle, and the PL bundle occupies a more distal position near the anterior cartilage surface of the lateral femoral condyle. One series studied the digitized origin and the insertion of the AM an PL bundles and concluded that each bundle occupies approximately 50% of the total femoral origin, with cross- sectional areas of 47 ± 13mm² and 49 ± 13 mm² for the AM an PL bundles, respectively (41, 42).

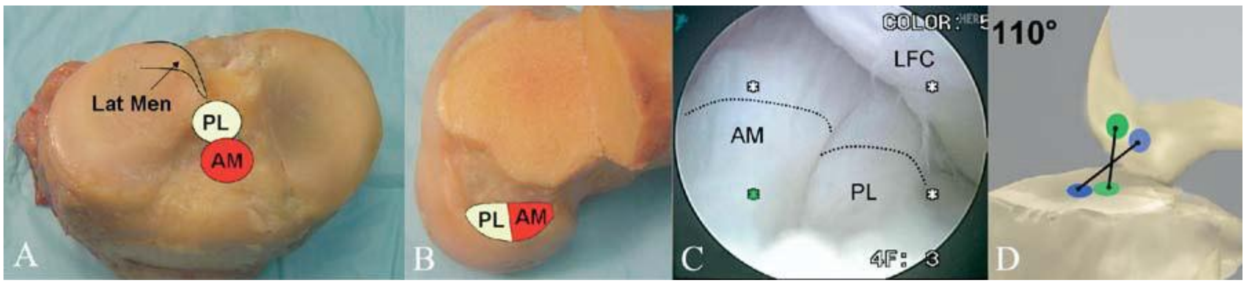

Figure 2: (A) Tibial insertion sites of AM and PL bundles. (Lat men, lateral meniscus.) (B) Femoral

insertion sites of AM and PL bundles. (C) Normal ACL shows two distinct bundles: AM and PL. (D) Crossing pattern of AM and PL bundles, with knee in 110° of flexion. This has been described by some authors as a "twisting" pattern

On the tibia, the insertions of the AM and PL bundles are located between the medial and lateral tibial spine, over a broad area stretching as far posterior as the posterior root of the lateral meniscus. The full ACL insertion has been described as an oval area measuring 11 mm in diameter in the coronal plane and 17 mm in the sagittal plant[43-45]. Within this area, the AM bundle insertion can be found in an anterior and medial position, whereas the PL bundle insertion is located posterior and lateral. Posteriorly, fibres of the PL bundles are in close approximation to the posterior root of the lateral meniscus itself. The overall size of the tibial insertion is approximately 120% of the femoral origin; however, as is the case with the femoral origin, the two bundles share approximately equal tibial insertion site areas; the AM bundle occupies 56 ± 21 mm², and the PL bundle occupies 53 ± 21 mm241.

ACL Bundle Anatomy

The size and length of each bundle are also unique. Studies have shown that the AM bundle is approximately 28 to 38 mm in length (40, 43). The PL bundle has been less well studied. Kummer and Yamamota[44] measured the PL bundle in 50 cadavers and found a mean length of 17.8 mm. Both the AM and PL bundles have a similar diameter. In addition, throughout the normal range of motion, a complex relation exists between the two bundles. In extension, the two bundles are oriented in parallel to the sagittal plane; however, as the knee is flexed, the PL bundle becomes crossed with respect to the AM bundle[45]. Furthermore, other authors have attempted to replicate this twisting pattern simply by twisting the ACL graft 90° before fixation (46, 47).

Vascular Supply

Contrary to popular belief, the major blood supply to the ACL does not originate from its bony attachments[48]. The ACL is supplied mainly by vessels that originate from the middle genicular artery, which leaves the popliteal artery and directly pierces the posterior capsule. Branches enter the synovial membrane at the junction of the joint capsule distal to the infrapatellar fat pad (48, 49). A few smaller, terminal branches of the lateral inferior geniculate artery may also contribute some vessels to this synovial plexus. The ligament is ensheathed by the synovial plexus along its entire length. Smaller, connecting branches penetrate the ligament and anastomose with a network of endoligamentous vessels that are oriented in a longitudinal direction and lie parallel to the collagen bundles within the ligaments [48,50].

Nerve Supply and Neural Receptors

The posterior articular nerve is the major neuro-bundle. Neurotracer studies have indicated that there are very few receptors in the ACL[51]. Monoclonal antibody stains demonstrated a maximum of 17 mechanoreceptors in the ACL of a 3-year old child .

The receptors found are primarily Ruffini receptors and the free nerve endings that are thought to function as stretch receptors and nociceptors, respectively[51]. In addition to their function as nociceptors, free nerve endings may serve as local effectors by releasing neuropeptides with vasoactive function. Thus, they may have a modulatory effect in normal tissue homeostasis or in remodelling of grafts[51].

Papastergiou et al. did a comparison between vertical and horizontal incisions in ACL reconstruction using hamstring grafts[52]. It was found that 39.7% had disturbed sensibility after a vertical incision, and a significant lower incidence of 14.9% after a horizontal incision. Furthermore, in the study by Papastergiou et al.[52] ,there was a reduction in incidence of hypoesthesia in the group with horizontal incision.

Portland et al. found a significantly better cosmetic result using an oblique incision following the Langer's skin lines[54].

Anatomical studies and the study by Papastergiou et al. suggest that an oblique or horizontal incision is preferable (53, 55-57). It is up to the surgeon to choose the incision that allows him the preferable access, but we found no literature supporting a vertical incision. Yet no studies have examined an incision in the safe zone described by Boon et
al.[55].

Anatomic Considerations

A thorough knowledge of the anatomic relationships of the hamstring tendons facilitates their harvest and reduces harvest-related morbidity. Potential complications include division of tendons, damage to the medial collateral ligament of the knee and neurological injury.

It has been noted that neurological injury is possible especially in the distribution of the saphenous nerve and its infrapatellar branch, presenting with parasthesia[58].

The semitendinosus and gracilis insert as a conjoined tendon onto anteromedial surface of tibia.

The sartorius lies superficial to these tendons proximally. Together these three tendons form the pes anserinus[59].

Commonly, the inferior fibres of semitendinosus form an accessory insertion more distally on tibia (this was noted to be present in 24 of 31 knees in a series)[60].

The saphenous nerve pursues a postero medial course towards the medial side of the knee and emerges between the sartorius and gracilis with the knee extended, the nerve is held taut against tendon with the knee flexed, and the tendon diminishes.

The infrapatellar branch arises proximal to where the saphenous nerve crosses the gracilis. This then curves beneath the patellar to supply the skin over the anterior surface proximal tibia. During tendon harvest, an oblique or transverse incision may reduce the risk of injury to the infrapatellar branch.

Also, during the harvesting of the hamstring flexing the knee and externally rotating the hip to relax the tension of the saphenous nerve on the tendon is important[59].

Functions of ACL are as follows [61,62]:

(c) Resists anterior tibial translation
(d) Prevents hyper extension
(e) Provides check to internal axial rotation and affords rotator tense control
(f) Secondary restraint resisting valgus and varus in all degree of flexion.

BIOMECHANICS

Anterior-Posterior Translation Control

The dynamic nature of the two bundles of the ACL during knee flexion demonstrates the complex role of the ACL in stabilization of the knee joint. However, initial biomechanical studies of the ACL focused mainly on its function of resisting anterior tibial translation [63,64]. From this work, we know that the in situ forces of the ACL vary considerably during the normal range of motion of the knee joint. With an anterior tibial load applied, the ACL shows high in situ forces between 0° and 30° flexion, with a maximum occurring at 15°. In situ forces are at their lowest point between 60° and 90°, with a minimum occurring at 90°.35 As previously mentioned, recent studies have also been completed to evaluate the individual roles of each bundle of the ACL in anterior-posterior translation. This has shown that the AM bundle has relatively constant levels of in situ forces during knee flexion, whereas the PL bundle is more variable, with high in situ forces at 0°, 15°, and 30° of flexion but rapidly decreasing in situ forces beyond these angles (Figure 3)[64].

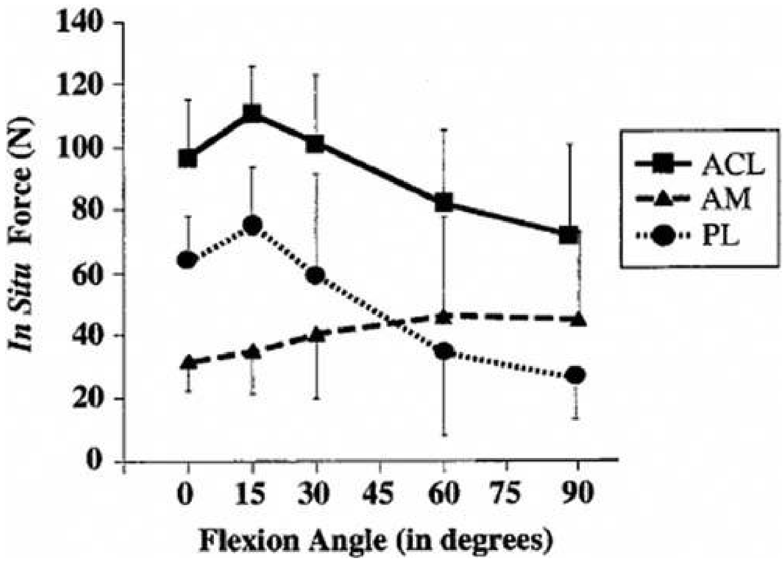

Figure 3. In situ forces of AM and PL bundles throughout knee flexion. (Reprinted with permission[35]).

Rotational Stability

Clinical experience has suggested that biomechanical considerations of anterior-posterior translation alone do not correlate with subjective evaluations of knee stability, as well as that a more complete evaluation of the role of rotational stability is relevant[65]. Therefore in recent years closer attention has been given to the rotational stabilizing function of the ACL[66-68] Included in the cadaveric study of 10 knees by Gabriel et al.37 was an analysis of a combined rotatory load of 10 Nm valgus and 5 Nm internal tibial torque at 15° and 30° of flexion. For the PL bundle, an in situ force of 21 N was recorded at 15° and 14 N at 30°. For the AM bundle, the in situ forces were 30 N and 35 N, respectively. This shows that both the AM and PL bundles contribute to rotational stability of the knee at these angles.

Tensioning Pattern

The change in alignment of the AM and PL femoral insertion sites allows the ACL to twist around itself as it is moved through a complete range of motion. This crossing pattern, along with the differences in the length of each bundle, has implications for the tensioning pattern of the entire ligament, as well as each bundle individually. In a study by Gabriel et al,[67] forces were measured in each bundle during an anterior load over several flexion angles, as well as for a combined rotatory load in valgus and internal tibial torque. The results showed that the PL bundle is tightest in extension (in situ force of 67 30 N), and as the knee is flexed, it becomes relaxed, whereas the AM bundle is more relaxed in extension and reaches a maximum tightness as the knee approaches 60° of flexion (in situ force of 90 17 N) [(67,69)] This tensioning pattern can be observed grossly as well in cadaveric and arthroscopic views of the bundles. The PL bundle is also observed to tighten during internal and external rotation[37]. In summary, the ACL consists of two distinct bundles, the AM and PL bundles, and these bundles contribute synergistically to the stability of the knee.

Graft Biomechanics

Strength is defined as “maximal resistance to strain before mechanical failure begins”[70] and is measured in newtons (N). Stiffness is defined as “resistance of a structure to deformation.”[70]. In this context, it would be defined as resistance to elongation. Stiffness is measured in N/mm. In 1984, Noyes et al[71] performed a biomechanical analysis of the ACL and other human ligament grafts. They found the strength of the normal ACL to be 1725 N. A 14-mm central one-third patellar tendon graft possessed a strength of 2900 N, which is 168% of normal ACL strength. However, the typical patellar tendon graft used in clinical practice today is approximately 10mm wide.

Extrapolation of their data estimates that the strength of a 10-mm central one-third patellar tendon graft is closer to 107%-120% of the normal ACL (72, 73).

In the same study, the authors demonstrated that a single-stranded semitendinosus tendon had a strength of 1216 N (70% of the normal ACL), and a single stranded gracilis tendon had a strength of 838 N (49% of the normal ACL)[71].

When used for ACL reconstruction, the hamstring tendon graft is typically quadrupled. Based on the data of Noyes et al,[71] the strength of a four-stranded hamstring graft should be 4108 N if the strength of each strand is assumed to be additive. This is approximately 238% of the strength of the normal ACL (71, 72) Recent biomechanical studies have confirmed that the strength of the quadrupled hamstring tendon graft is between 4090 N and 4213 N (73, 74)

In addition to the strength of a graft, its stiffness should also be considered. A graft that lacks stiffness may have a propensity to elongate, which could be manifest clinically as increased laxity. The stiffness of a 10-mm patellar tendon graft has been shown to be 455 N/mm[75] and the stiffness of the quadrupled hamstring tendon graft has been shown to be 776-954 N/mm (73, 74). Both grafts possess stiffness that exceeds that of the normal ACL (182-306 N/mm) (71, 76, 77).

Because a hamstring tendon graft is cylindrical in shape, it will have a greater cross-sectional area compared to a patellar tendon graft of similar width. The cross-sectional area of a 9-mm hamstring tendon graft is approximately 1.6 times that of a 10-mm patellar tendon graft. This results in a greater number of collagen fibres within the substance of the graft and across the joint[72].

In summary, the quadrupled hamstring tendon graft appears to possess superior biomechanical properties compared to the patellar tendon graft. However, in vitro studies have shown that the strength and stiffness of both grafts exceed that of the native ACL.

HISTORY OF LIGAMENT SURGERY

Primary Repairs

The earliest surgical attempts to address ACL deficiency focused on primary repair of the torn ligament. In 1900, Battle[78] described a successful outcome of one case at 2 years following repair. This concept was furthered by the report of a successful repair with 8-year follow up published by Mayo Robson in 1903[79]. Hey Groves[80] disagreed with the concept of primary repair, noting that the ruptured ligament often is torn or destroyed that "direct suture would have been utterly impossible." Instead, he recommended reconstruction with a fascia lata graft. In the United States, the major advocates of repair or reconstruction if necessary were Campbell in the 1930s and O'Donoghue in the l950s[81].

Despite the work of these early pioneers, from the 1930s through the 1960s the debate was less over primary repair versus reconstruction than it was over whether any procedure at all need be done. Prominent surgeons such as Hughston[82] and Quigley[83] stated that the ACL did not need repair if the associated meniscal and capsular pathology was appropriately addressed. They failed to recognize the importance of the ACL as the primary restraint to anterior translation of the tibia and the prevalence of isolated ACL rupture.

Renewed interest in primary repair came in the early 1970s. In 1972, Feagin[84] presented his initial success with repair in West Point cadets during the annual American Academy of Orthopaedic Surgeons meeting. This idea was supported by Macintosh[85] who described good results with suture repair of the ligament behind the lateral condyle—the so-called "over-the-top" repair. This repair was later modified by Marshall and quickly became the preferred surgical treatment[86].

However, interest in primary repair did not last long. Marshall abandoned primary repair alone in favour of a fascia lata augmented reconstruction[87]. The final blow came in 1976 when Feagin presented his 5-year follow up on the West Point cadets. Despite initial success, his patients had developed recurrent instability and progressive deterioration of function[84].

Extra-Articular Reconstructions

By 1970, it became clear that ACL deficiency led to functional disability and that some type of reconstruction was necessary to address this problem. Surgeons began to scientifically address the problem through ligament cutting studies (88-106) and mechanical testing. This led to the concept of "rotational instability of the knee" described by

Slocum and Larson[107]. They noted that a valgus and external rotation injury would result in disruption of the medial collateral ligament (MCL), posterior medial capsule, and ACL. However, they failed to recognize the importance of isolated ACL injury. Instead, surgical strategies were focused not on the ACL itself, but rather on treating the resultant anterior medial rotatory instability[107]. Several procedures were described to prevent subluxation of the tibia and hold it in a reduced and internally rotated position, including pes anserinus transfer, posterior medial capsular reefing, and advancement of the MCL to a more proximal and posterior position[108]. In 1973, Nicholas published his "five-in-one" technique. This was similar to Slocum's reconstruction with the addition of a medial meniscectomy and vastus medialis oblique advancement. This procedure was popular in the mid-1970s. Patients were then routinely casted for 6 weeks in a flexed and internally rotated position, which often led to significant motion loss. Although these procedures decreased rotational translation, they failed to address the clinical problem of anterior instability.

In 1971, Kennedy and Fowler[109] published an anatomic study that showed the ACL could be injured without involvement of the medial capsular structures. The following year, the "pivot shift phenomenon" was published by Galway et al.[110]. Hughston incorporated these findings into his rotational instability theory calling it "anterior lateral rotatory instability." He attributed this findings primarily to lateral capsular injury, which could be accentuated by ACL deficiency[97]. The emphasis then shifted to laterally based procedures designed to limit anterior subluxation of the tibia on the lateral side. Macintosh described an extra-articular reconstruction using a strip of the iliotibial (IT) band, which would later be referred to as the Macintosh 1. Other procedures using the IT band were simultaneously described by Losee et al,[111] Ellison,(112) and Andrews and Sanders[113]. Losee et al[111] described passing the IT hand through an extra-articular tunnel, through the lateral gastrocnemius, and then passing under the lateral collateral ligament. Both of these reconstructions involved detaching the IT band proximally. Ellison[112] described a "dynamic" reconstruction also using the IT band detached distally instead of proximally.

He routed this graft under the lateral collateral and fixed it distally. It was thought that the pull of the tensor fascia lata muscle would help stabilize the lateral side during activity.

Andrews gained much notoriety from his novel technique[2]. He recognized the importance of isometry and sought to create a reconstruction that would be taught in both flexion and extension. He did so by creating two slips of the IT band and securing them extra-articularly to a point on the lateral femoral condyle. These procedures reduced the pivot shift initially, but did not function dynamically and tended to stretch out and fail over time. Due to inconsistent long-term results, a high incidence of arthrofibrosis, and occasional varus instability from disruption of the normal lateral structures, these procedures began to fall out of favour.

Intra-Articular Reconstructions

By the early 1980s, the treatment of anterior instability began to focus more on the ACL than the capsular structures. The clinical importance of the Lachman test had recently been described by Torg et al.[114]. Noyes published his research, which clearly defined the ACL as the primary restraint to anterior subluxation of the tibia[90]. In response to these studies, surgeons began to modify their procedures to more anatomically address the deficient ACL, and intra-articular techniques began to be used. Insall was one of the first to pass grafts intra-articularly. He developed a dynamic technique, which was based on the work of Ellison[100]. He passed a proximally based strip of IT band intra-articularly and fixed it to a trough on the anterior aspect of the tibia. Macintosh modified his original procedure by extending the IT band over the top of the lateral femoral condyle and back down through an intra-articular tunnel in the tibia (Macintosh 2). The importance of intra-articular graft passage and an anatomic tibial tunnel had now been appreciated.

Macintosh later began using a strip of the quadriceps patellar tendon dissected off of the anterior aspect of the patella and left intact distally. The proximal end of the graft was passed through the notch and secured on the lateral aspect of the femur. This was known as the "quadriceps patellar tendon over-the-top" procedure (QPOT or Macintosh 3). The graft was not isometric and the thin pre-patellar tissue tended to stretch out, leading to failures. Therefore, the thinnest area often was augmented with either a folded down strip of quadriceps tendon (the popular Marshall Macintosh modification) or the addition of a synthetic material.

Palmer[61] described the use of a patellar tendon graft in his doctoral thesis in 1936. In the same year, Campbell described using the patellar tendon graft, but it was not widely used until intra-articular techniques were developed in the late l970s[115]. They used the medial third of the tendon left attached distally and passed it through tunnels in both the tibia and femur. The use of the central third was described by Jones in the 1960s[103]. The free bone-patellar tendon-bone graft was soon to follow.

Originally developed in Germany, its clinical effectiveness was demonstrated and popularized in the United States by Clancy[116]. Although he transitioned from a medial third to a free central third graft, he recommended augmenting this reconstruction with medial and lateral extra-articular reconstructions. A subsequent report by O'Brien et al[117] showed that the addition of a lateral sling was not necessary to achieve good results.

At the same time, interest in the use of other grafts was developing. In the early 1970s, several authors published the results of harvesting the medial meniscus for use as an ACL graft[100]. As late as 1980, this was still considered a reasonable option compared to patellar tendon grafts. Macey[118] originally described the use of the hamstring graft in 1939 much as it is used today. Zarins and Rowe[119] repopularized the use of hamstrings when they published their results of a semitendinosus reconstruction modified by adding a Macintosh 2 procedure. The hamstring was passed up the tibial tunnel and over the top to be secured to Gerdy's tubercle, while the IT band was passed over the top and down through the same tibial tunnel. Their combined reconstruction was widely used in the 1980s and gave excellent stability, but required open arthrotomies and significant dissection, which frequently resulted in pain and loss of motion.

Synthetic Reconstructions

The failures of primary repair and combined reconstructions led to the development of synthetic replacements for the ACL[104]. Even as modern intra-articular reconstructions were being developed, a synthetic replacement for soft-tissue grafts seemed appealing. It was believed that they would be stronger than soft-tissue grafts and would obviate the need for the associated larger dissection and donor site morbidity.

The first clinical trials used a polyethylene structure called the Polyflex. It failed quickly due to inadequate strength and poor incorporation into bone at the attachment sites. A porous Teflon graft known as the Proplast was designed to allow for better tissue ingrowths, but stretched out and failed in most patients by 1-2 years[102]. Various other synthetics using carbon fibre, Gore—Tex, Dacron, and polypropylene were tried 0.3. The polypropylene graft known as the Ligament Augmentation Device (LAD) was the only one to gain widespread use[106]. It often was used to augment other reconstructions such as the QPOT and later the hamstring tendons. These synthetics all failed as they tended to stretch or fragment over time. This led to recurrent sterile effusions, pain, and instability[120]. The demand for synthetic grafts was obviated by the newly reported success of the intra-articular reconstructions using free tissue grafts. The general consensus regarding the synthetic experience can be summed up in the words of Eriksson, "Like shoestrings, they eventually break"[121].

Arthroscopic-Assisted Procedures

When the intra-articular procedures were developed, they were performed using arthrotomies to ensure proper tunnel placement and passage of the graft under direct vision. Due to technological advances in the early 1980s, the arthroscope and the necessary instruments were becoming widely available. As surgeons began to gain greater facility with the scope, they sought modification to the existing reconstructions that would allow them to perform isolated intra-articular reconstructions?[122]. The free bone-patellar tendon-bone and hamstring grafts passed through appropriate bone tunnels became the standard reconstruction techniques[123].

Initially, these procedures were performed through a two-incision approach. This referred not only to an anterior tibial incision, but also an incision over the lateral aspect of the lateral femoral condyle. From the latter incision, dissection was carried around the posterior aspect of the condyle. A rear-entry guide was then placed around the posterior aspect of the condyle and allowed for outside-in drilling of the femoral tunnel[124]. The graft was then secured to the lateral femur with a staple, spiked washer, or interference screw placed from outside-in.Advances in arthroscopic guides to ensure proper tunnel placement and improvements in fixation techniques made the second incision on the lateral femur unnecessary. The single-incision or endoscopic technique became popular in the early 1990s when surgeons began to use intra-articular drilling of the femoral tunnel[92].

Surgeons using soft-tissue grafts did not have the problem of mismatch and were therefore less constrained in the sagittal orientation of their tibial tunnels. They did, how-ever, have to contend with other fixation issues (Figure 4). Initially, soft-tissue grafts were fixed on the lateral cortex of the femur by using over—a post fixation or the original endobutton design (Smith & Nephew Endoscopy, Andover, Mass). Hoher et al[96] have shown that fixing the graft farther away from the joint can lead to a significant "bun- gee-effect" that results in a higher degree of graft laxity.

Fixing the graft closest to the intra-articular end of the tunnel makes a functionally shorter graft with potentially greater stiffness and less overall stretch. To address this observation, modified metal and bioabsorbable soft-tissue screws and various bicortical fixation devices known as cross-pins were introduced. Therefore, many surgeons now favour this aperture near fixation. Clinical results are not significantly different between these techniques.

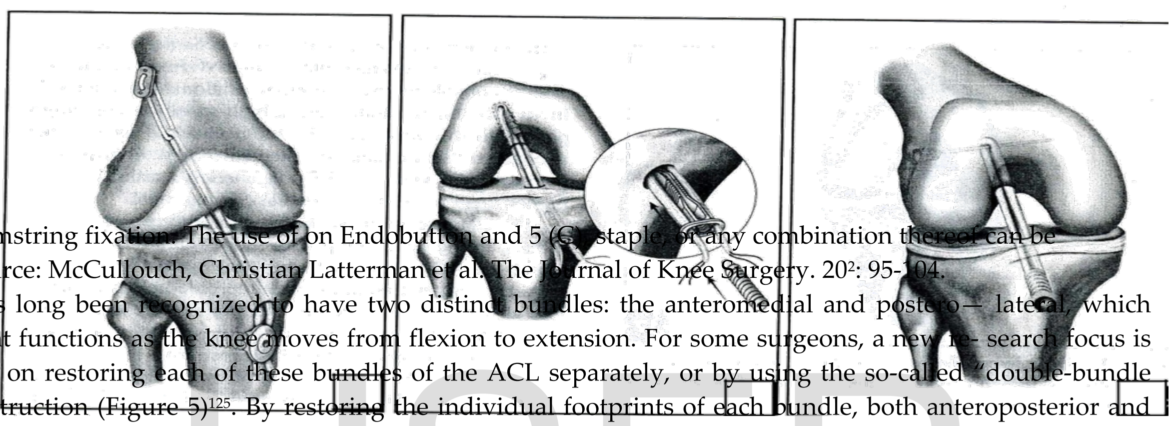

Figure 4. Hamstring fixation. The use of on Endobutton and 5 (G) staple, or any combination thereof can be effective. Source: McCullouch, Christian Latterman et al. The Journal of Knee Surgery. 20[2]: 95-104.

The ACL has long been recognized to have two distinct bundles: the anteromedial and postero— lateral, which have different functions as the knee moves from flexion to extension. For some surgeons, a new re- search focus is being placed on restoring each of these bundles of the ACL separately, or by using the so-called "double-bundle ACL" reconstruction (Figure 5)[125]. By restoring the individual footprints of each bundle, both anteroposterior and rotational stability can be more accurately addressed. Given the excellent clinical results of present single-bundle techniques, there is concern that the increased technical complexity and surgical trauma of a double-bundle reconstruction may outweigh the proposed benefits[9]. Although the short-term clinical results are promising[91], it remains to be seen whether potential improvements in kinematics translate to improved long-term clinical results.

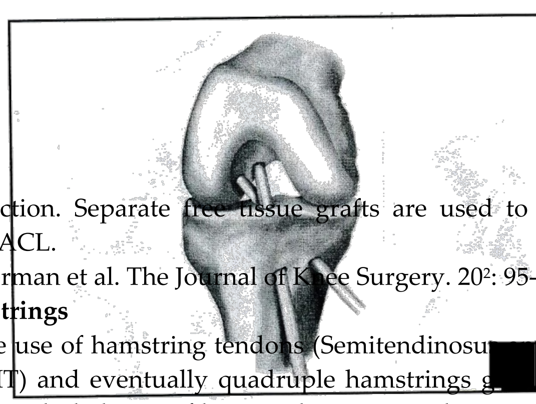

Figure 5. Double-bundle reconstruction. Separate free tissue grafts are used to recreate the anteromedial and posterolateral bundles of the native ACL.
Source: McCullouch, Christian Latterman et al. The Journal of Knee Surgery. 20[2]: 95-104.

New Technique - Quadruple Hamstrings

One of these graft alternatives is the use of hamstring tendons (Semitendinosu[redacted]d Gracilis). This began with the use of double hamstring grafts (2HT) and eventually quadruple hamstrings g[redacted] (4HT) in ACL reconstruction. The advantages of using 4HT grafts included ease of harvest, less anterior knee pain, less extension loss and equal strength and stability. Unfortunately, despite the recent increase in the number of randomized control trials and meta-analysis studies comparing the two graft choices, the answer to which graft choice is superior has yet to be answered.

As a result of improved fixation techniques, concerns of pull-out strength and stability have also been shown to be invalid. A recent meta-analysis by Prodromos[126], comparing stability between the two grafts (4HT and BPTB) found that the 4HT, using modern fixation techniques, was more stable (80% within 2mm of contra-lateral knee using KT 1000) than the BPTB technique using modern soft-tissue fixation on the tibia and endobutton (Smith and Nephew) fixation the femur. Another recent study showed no difference in stability between 4HT and BPTB as defined by Lachman, pivot shift and KT 1000 side-to-side difference > 5 mm[59].

The author used the 4HT graft. It is simple and reproducible with minimal harvest morbidity. Hamstring graft harvest can be done through a very small three centimeter vertical incision over the pes anserinus insertion two centimetres medial to the tibial tubercle. The tendons are usually palpable through the skin and allow for centralization of the incision. The tendons are identified, the sartorius fascia incised and the tendons delivered out of the wound while incising any attachments to the gastrocnemius musculature. When the tendons are delivered three to four centimetres out of the wound, usually all of the attachments have been released. An open tendon stripper is used leaving the distal tendon attached to bone. A gentle pull on the tendon and concomitant push on the tendon stripper prevents any tendon amputation (rarely a problem). The remainder of the procedure is done similar to BPTB technique. After cycling, the graft is tensioned. The graft is fixed using an endobutton on the femoral side and an Xtralock Screw on the tibial side. If purchase with the tibial fixation is a concern, a screw and washer is added and the individual hamstring strands are wrapped around a post and tied using high strength suture. It is important to whipstitch high strength suture (Herculon, Linvatec) or Fibrewire (Arthrex) on both ends of the tendon on the tibial side to prevent suture breakage and inadvertent cutting during interference screw fixation.

ASSESSMENT

Knee Laxity

Generally, if the side-to-side difference is less than 3 mm, the surgery is considered a success. If the difference is 3 to 5 mm, it is acceptable and if the difference is more than 5 mm, it is considered a graft failure. Soon[59] could not prove this in his case studies with 10 patients.

Sensory Changes

A study by Spicer et al[9] noted that areas of sensory change over the front of the knee were identifiable in 50% of patients and of these, 86% demonstrated sensory change in the distribution of the infra-genicular branch of the saphenous nerve. The postulated injury of the infra-genicular branch can occur during the skin incision, the initial exposure of tendon and drilling of tibial tunnel or during dissection of tendons proximally and during the passage of the tendon stripper, as never courses superficially to the gracilis. In his study, Soon[59] did not find his patients complain of any significant limitation of their sporting activities to work.

Anterior Knee Pain

It was suggested that anterior knee pain is less common with the hamstring method. Using hamstring tendons and thereby avoiding a direct approach to the front of the knee without interfering with the extensor mechanism should, in theory, reduce the incidence of anterior knee pain[154, 155]. In Soon's[59] study only 5% complained of significant pain that interfered with their sporting activities.

MATERIALS AND METHODS

TERIAL AND METHODS

SOURCE OF DATA

25 patients who underwent arthroscopic ACL reconstruction using hamstring tendon graft from march 2016 to march 2018 were included in this study. Patients were assessed pre-operatively and 6 months post-operatively.

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INCLUSION CRITERIA

(a) No previous ligament reconstruction performed
(b) Healthy contra-lateral knee
(c) No diagnosis of re-injury during the follow up period
(d) All skeletally mature patients with ACL injury

EXCLUSION CRITERIA

(a) Patient with ACL avulsion injury
(b) Patient with contra-lateral knee injury
(c) Patient with advanced degenerative changes in the knee. (i.e., Kellgral and Lawrence grade III)
(d) Concurrent and musculoskeletal condition e.g., hip or ankle injury

Surgical Technique
Initial Arthroscopy
The patient receives the intravenous antibiotics pre-operatively. After induction of anaesthesia, the patient is positioned supine with the operative leg in a leg holder and tourniquet on the upper thigh.
Diagnostic arthroscopy is performed through an anteromedial and anterolateral portals. Integrity of ACL, PCL meniscus cartilage covers over the tibial and femoral condoyle. Patella is inspected and any chondral or meniscal procedures are performed at this time (Figures 7 & 8).
A minimal soft-tissue notchplasty is performed for visualization purposes only.

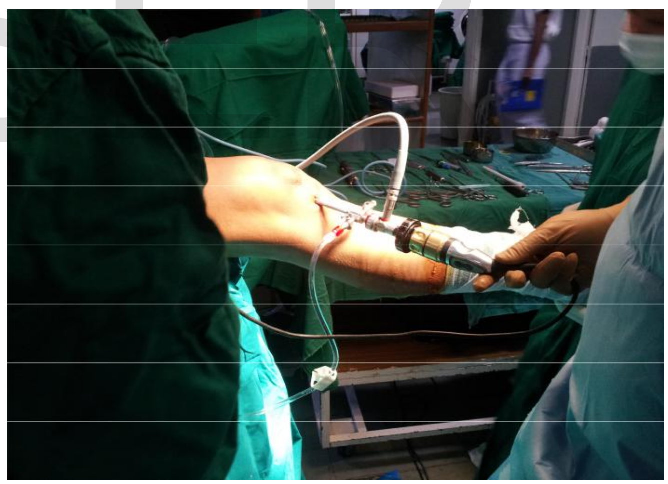

Figure 8. Diagnostic arthroscopy.

Figure 7. Patient positioning

Graft Harvest and Preparation

Make a 4-cm incision anteromedially on the tibia starting approximately 4 cm distal to the joint line and 3 cm medial to the tibial tuberosity (Figure 9).

Expose the pes anserinus insertion with subcutaneous dissection. Palpate the upper and lower borders of the sartorius tendon, and identify the palpable gracilis and semitendinosus tendons 3 to 4 cm medial to the tendinous insertion. Make a short

incision in line with the upper border of the gracilis tendon, and carry the incision just through the first layer, taking care not to injure the underlying medical collateral ligament. With Metzenbaum scissors, carry the dissection proximally up the thigh. Stay in the same plane, and maintain adequate exposure by using properly placed retractors. With a curved haemostat, dissect the gracilis and semitendinosus tendons from the surrounding soft tissues about 3 cm medial to their insertion onto the tibia.

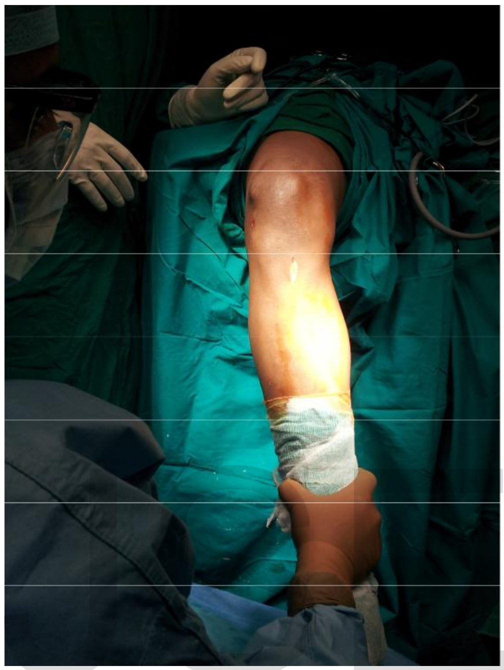

Figure 9. Skin incision for graft harvest

After carefully identifying each tendon, place an umbilical tape around the gracilis tension, place a double Krackow-type whipstitch with vicryl near the insertion of the tendon and release its fibrous extensions to the gastrocnemius and semimembranous muscles (Figure 10).

Palpate all sides of the tendon to ensure that no fibrous extensions before releasing it with an open-end tendon stripper. It firm resistance is felt, redissect around the tendons with a periosteal elevator and Metzenbaum scissors. Release the tendon proximally by controlled tension on the tendon, while advancing the stripper proximally. The muscle should slide off the tendon as the stripper is advanced proximally. Use the same

procedure e to release the semitendinosus tendon. Subperiosteally dissect the tendons medially to the insertion, and release them sharply. Do not damage or release the sartorius tendon. The surgical assistant prepares the tendons on the ACL Graftmaster on the back table. The Graftmaster allows for pretensioning and control of the tendons during preparation. Residual muscle tissue is stripped from the tendons with a blunt elevator.

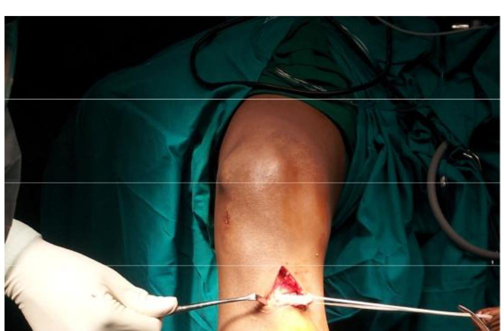

Figure 10. Identification of hamstring tendon.

Place a double Krackow-type whipstitch in both ends of each tendon with 2-0 nonabsorbable sutures. Fold both tendons in half to form four strands of tendons. Place a No. 5 nonabsorbable suture through the loop end of both tendons. Place a running, interlocking No. 2 nonabsorbable Krackow-type whipstitch in each end of each hamstring so that the graft can be passed as a single quadruple graft; use a No. 0 Vicryl running stitch to suture the terminal 3cm of the looped end (femoral side) together. The prepared graft is then placed under tension, covered by a wet saline gauze, for 20 to 30 minutes on the Graftmaster.

The graft is prepared and tensioned on a graft tensioning board while tunnels are prepared. The distal ends are whip-stitched with high strength suture (Figure 11-16).

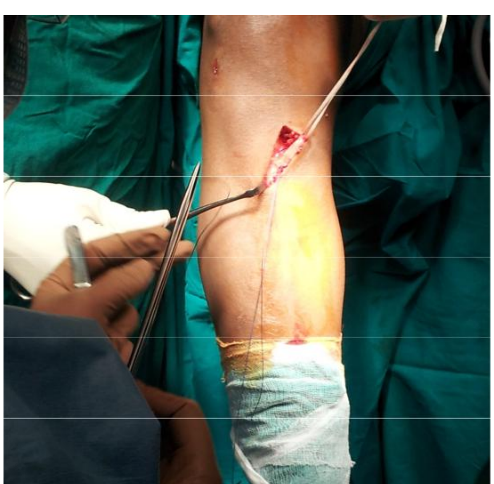

Figure 11. Suturing the distal end.

igure 12. Release of adhesions and soft-tissue tunnelling.

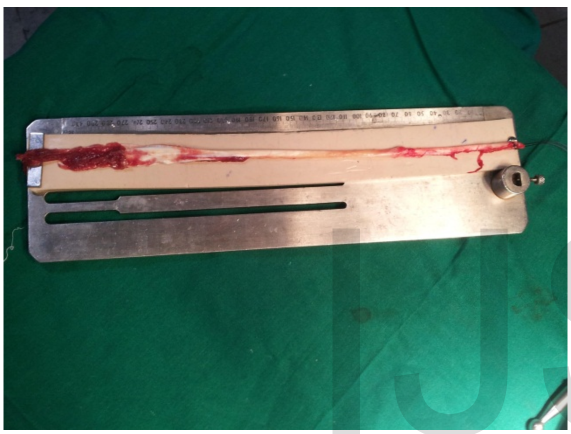

Figure 13. Harvested tendon

Figure 14. Prepared tendon

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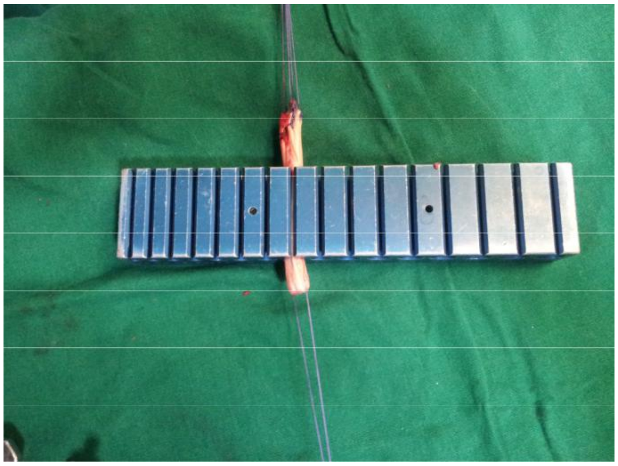

Figure 15. Graft sizing

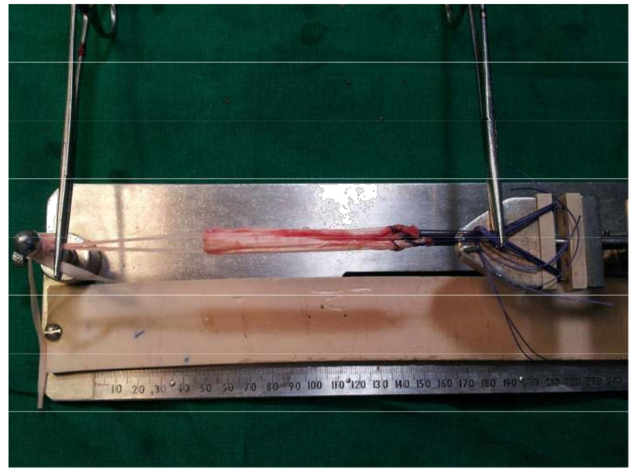

Figure 16. Prepared quadrupled graft under tension

Femoral Tunnel Preparation

New portal is made anterior to antero medial portal. The ACL guide is passed through this to the medial aspect of lateral femoral condyle. The position should be posterior and inferior to the medial surface. The guide wire is drilled through the femoral condyle to exit through the lateral aspect of thigh. The starting point is at 10:30 clock position on R knee, 1:30 clock position on the L knee approximately 8 mm lateral to the posterior cruciate ligament. The femoral tunnel is then reamed to a depth of 30 mm using the appropriate diameter reamer based on graft size. Double vicryl is taken and passed through femoral tunnel (Figure 17).

Figure 17. Femoral tunnel preparation

Tibial Tunnel Preparation

Tibial tunnel is made through the previous vertical incision made for the hamstring graft harvesting.

When placing the tibial guide, be aware of the intended tunnel length and direction so that the graft can be secured in physiometric, impingement-free position. Proper length and direction of the tunnel require a starting point approximately 1 cm proximal to the pes anserinus and about 1.5 cm medial to the tibial tuberosity to form a 30-50° angle with the shaft of the tibia. Intra-articular reference points that can serve as guides include the ACL stump, the inner edge of the anterior horn of the lateral meniscus, the medial tibial spine, and the posterior crucial ligament (PCL).

Next a cannulated reamer or trephine of the appropriate diameter is advanced over the guide pin and any retrieved bone is preserved for later tunnel grafting. The diameter of the reamer used for the tibial tunnel is determined by sizing the harvested hamstring graft. Tibial tunnel is prepared. Hook is passed and the vicryl wire pulled (Figure 18).

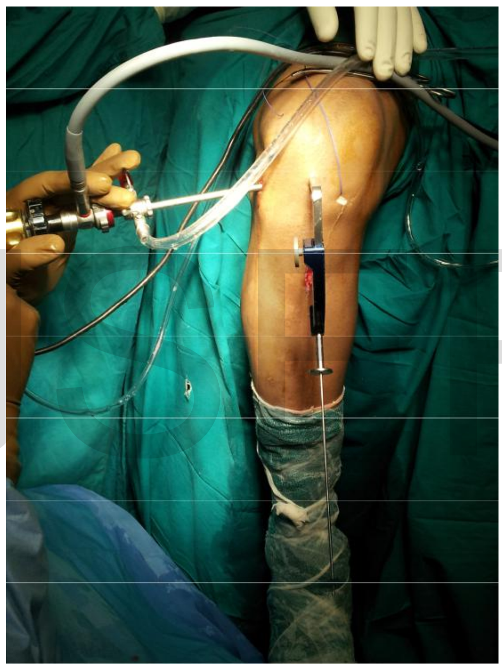

Figure 18. Tibial tunnel preparation

Graft Passage Fixation

One end of the endobutton is fixed to the graft and the other end to the vicryl wire. The four strands of endobutton are looped into vicryl. These strands are pulled retrograde through the tibial and femoral tunnel to exit through the lateral aspect of thigh (Figure 19).

Endobutton has two blue strands and two white strands. The blue strands of the endobutton are pulled initially retrograde through the femoral and tibial tunnel. The endobutton flip on the surface of the femur.

After that the white strands are subsequently pulled by bringing the graft into femoral and tibial tunnel and continuously pulled for the graft anchorage. Holding one end of graft cycling of knee is done to remove the slack of the graft (Figure 20).

The tibial side of graft is fixed by biointerferance screw. After that repeat diagnostic arthroscopy is done to see the tensioning and position of the graft. Stability is checked by the anterior drawer test. Closure is done (Figure 21).

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After tying a knot over the lateral femoral cortex and suturing [illegible], the excess guide suture is cut. Wound is closed in layers with 2-0 vicryl and skin staples. Compression dressing and knee extension brace is applied.

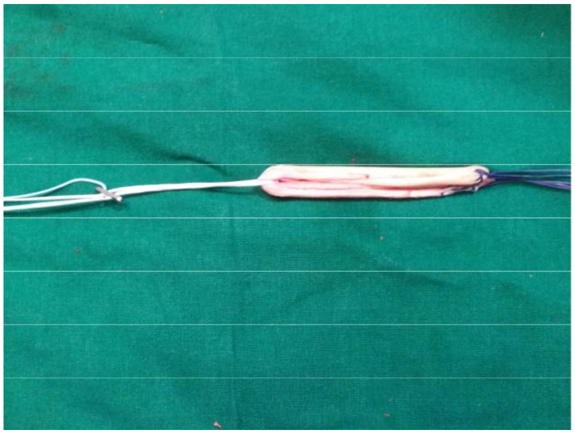

Figure 19. Endobutton fixed to graft

Figure 20. Graft passage and fixation

Figure 21. Tibial side fixation by biointerferance

RESULTS

	Frequency	Percent
Male	21	84
Female	4	16
Total	25	100

Table 1: Male-Female distribution

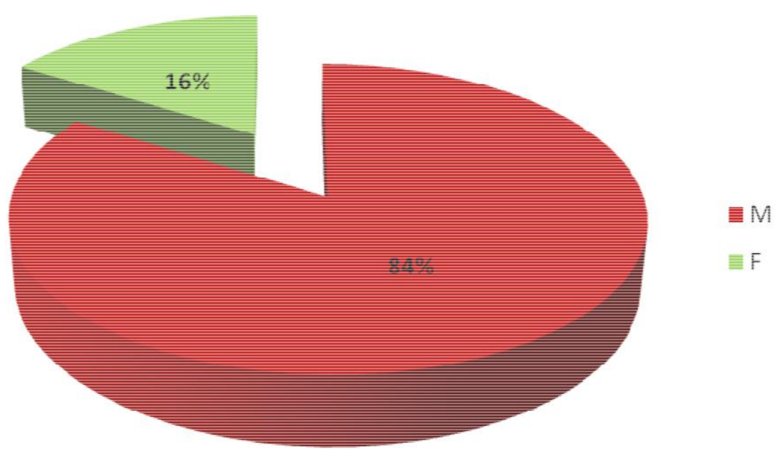

Figure 22. Male-Female distribution

	Frequency	Percent
Left	7	28
Right	18	72
Total	25	100

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Table 2: Side Injured

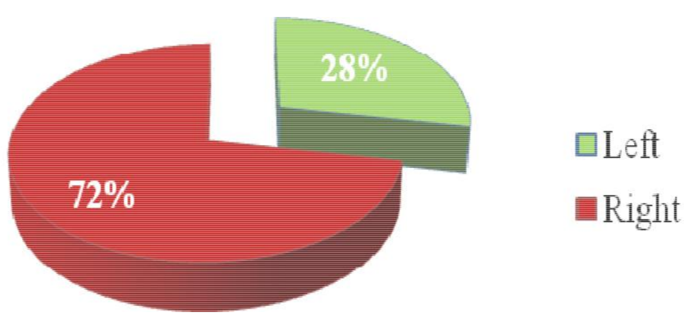

Figure 23. ***Side Injured***

	Frequency	Percent
Left	0	0
Right	17	100
Total	17	100

Table 3: Dominant Side Affected

	Frequency	Percent
Sports	13	52
RTA	8	32
Fall	4	16
Total	25	100

Table 4: Mode of Injury

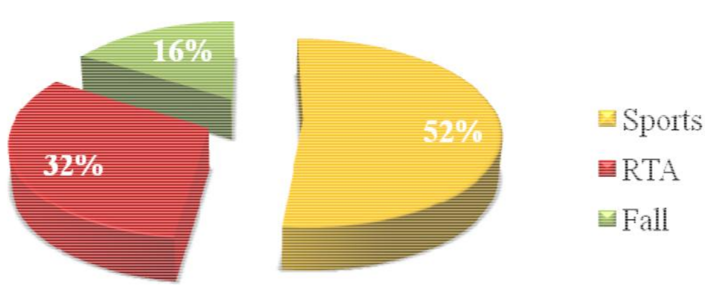

Figure 24. Mode of Injury

	Yes	Percent
Pain	4	16
Swelling	4	16
Instability	1	4
Locking	0	0
Infection	0	0
Sensory Loss	9	36

Table 5: Signs and Symptoms After Surgery

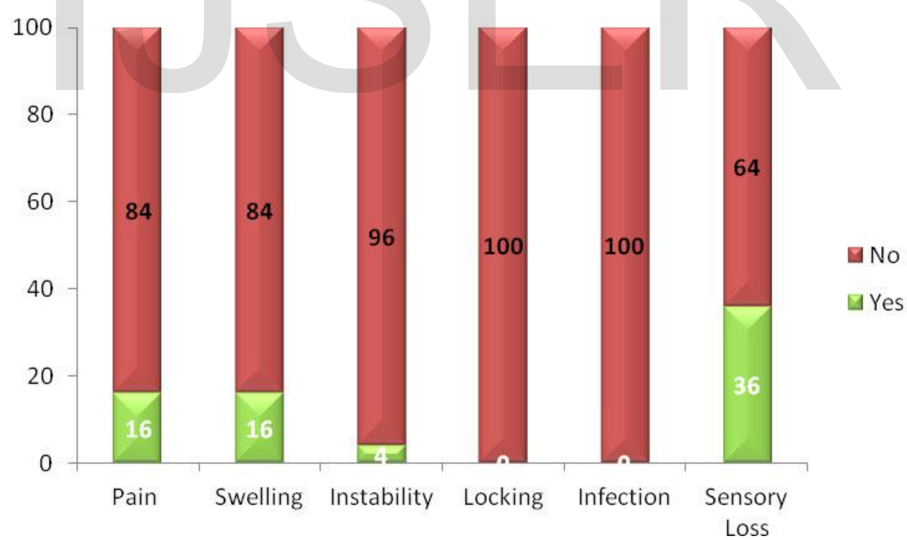

Figure 25. Signs and symptoms after surgery (given in %)

	Yes		No	
	Number	%	Number	%
MMIM	8	32	17	68
LMIM	6	24	19	76
MCLIM	2	8	23	92
LCILM	1	4	24	96
ACLIM	25	100	0	0
PCLIM	0	0	25	100

Table 6: Frequency of Associated Injuries on MRI

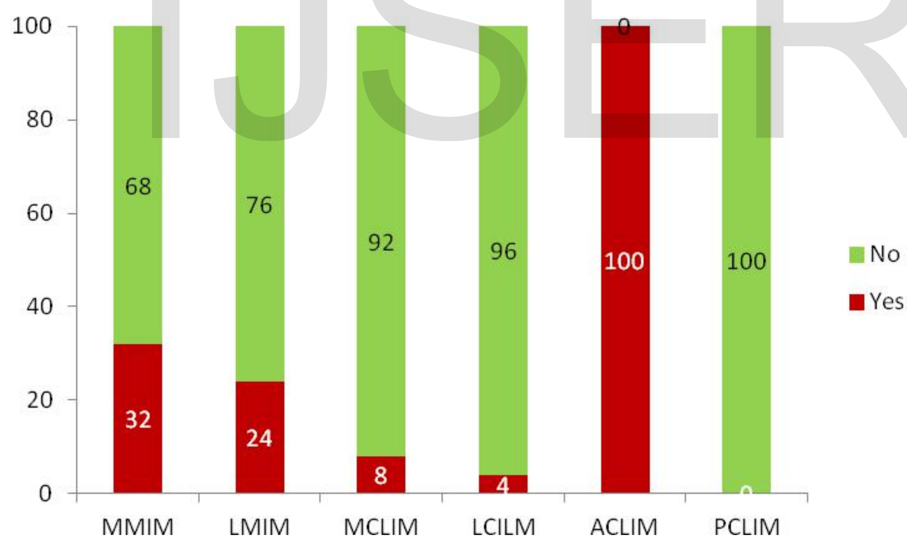

Figure 26. Frequency of associated injuries on MRI (given in %)

	N	Minimum	Maximum
ROMA	25	0-60	0-80
ROM6	25	0-90	0-140

Table 7: Range of Movements

Figure 27. Range of Movements

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	Frequency	Percent
Normal	10	40
Nearly Normal	14	56
Abnormal	1	4

Table 8: Post-Operative Outcome – IKDC Scoring System

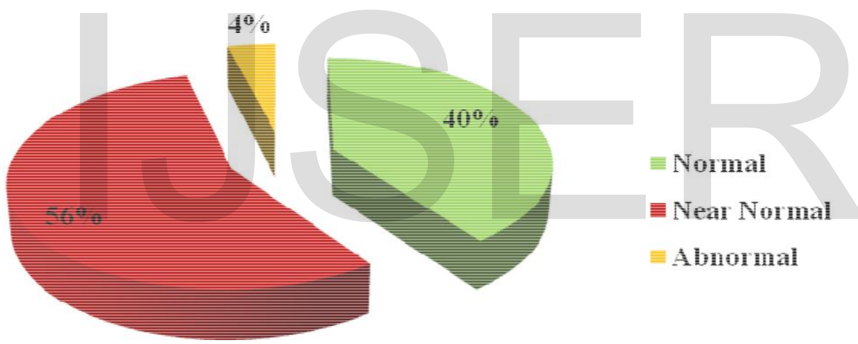

Figure 28. Post-Operative Outcome – IKDC Scoring System

9	36	16	64

Table 9: Sensory Loss After Surgery

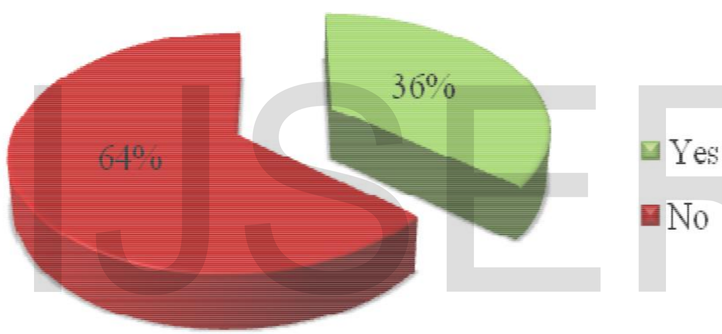

Figure 29. Sensory loss after surgery

	Frequency	

Excellent	11	44
Good	11	44
Fair	3	12

Table 10: Post-Operative LGS Scoring System

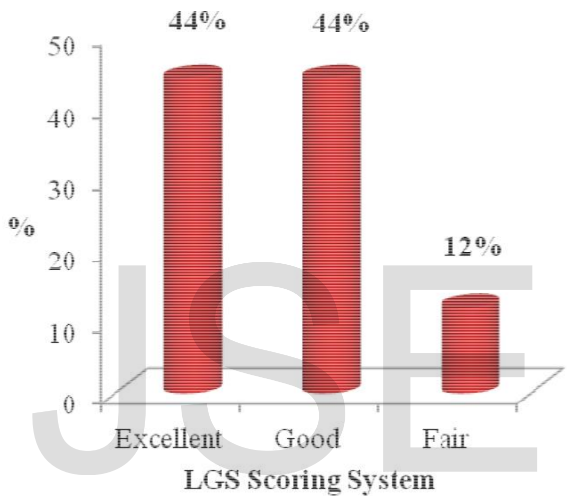

Figure 30. Post-operative LGS scoring system

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DISCUSSION

Arthroscopic ACL reconstruction is performed to restore the functional stability in ACL deficient knees and restore the normal kinetics of the knee. Increasing number of ACL reconstruction surgeries have been performed and there is an increasing expectation of a more rapid return to sporting activities and even return to activities of daily living, work and study.

Long term outcomes and post-op outcome following arthroscopic ACL reconstruction depends on graft selection .

This is a prospective study to assess the morbidity following arthroscopic ACL reconstruction using the quadruple stranded hamstring graft.

ANTERIOR KNEE SYMPTOM

Anterior Knee Pain (AKP)

It was suggested that anterior knee pain is less common with the hamstring method. Using hamstring tendons and thereby avoiding a direct approach to the front of the knee without interfering with the extensor mechanism should, in theory reduce the incidence for anterior knee pain[59].

In the study by Soon et al[59] 13 patient with complaints of anterior knee pain, however, only 4 (5%) complained of significant pain that interfered with their sporting activities and the other 9 experienced pain only with strenuous activity (for example, after running 5 km).

Soon et al[59] in a retrospective study, 2% had significant symptoms of anterior knee pain that caused limitation with daily activities and 12% had pain during kneeling. It was noted that kneeling was the activity most likely to cause pain. However, most patients were asymptomatic with most normal activities.

In our study, out of 25 patients, 4 complained of anterior knee pain. However, only two complained of pain that interfered with sporting activities and other 2 experienced pain only with strenuous activities, for example, after running 2 kms.

Patello-femoral pain, quadriceps weakness and flexion contracture are shown to be related[131]. Sachs et al[131] noted that AKP is s frequent complication at about 25% incidence and is related to both residual extension loss and quadriceps weakness. They felt that it is essential to regain complete ROM and immediate full extension to avoid patella-femoral symptom and anterior knee pain.

In our patients, there were no significant problems with the achievement of extension and quadriceps strength and hence we postulate that the small number of patients with significant knee pain is due to early achievement of extension and quadriceps strengthening.

Knee Laxity

A study[55] has shown that the majority of variance in IKDC was accounted for by the patients' symptoms and laxity.

Generally, if the side-to-side difference is less than 3 mm, the surgery is considered a success. If the difference is 3-5 mm, it is acceptable and if the difference if more than 5 mm it is considered as graft failure.

In this study, it was noted that one patient with a side-to-side difference of more than 5 mm and his IKDC scores was grade C and abnormal (Table 11 & Figure 31).

However, this result is seen only 6 months after surgery and may not be indicative of the final outcome of the patient after 1 year. Hence, we may have to read the result cautiously.

Sensory Change

A study by Spicer et al[6] noted that areas of sensory change over the front of the knee were identifiable in 50% of the patients and of these, 86% demonstrated sensory change in the distribution of the infra-genicular branch of the saphenous nerve. The postulated injury of the infra-genicular branch can occur during the skin incision, the initial exposure of tension and drilling of tibial tunnel, or during dissection of tendons proximally and during the passage of the tendon stripper, as the nerve courses superficially to the gracilis.

In our study, sensory change was noted in nine patients, i.e., 36% (Table 9 & Figure 29). To harvest hamstring graft, vertical incision was used. But Papastergiou et al. did a comparison between vertical and horizontal incisions in ACL reconstruction using hamstring grafts[53]. It was found that 39.7% had disturbed sensibility after a vertical incision, and a significant lower incidence of 14.9% after a horizontal incision. Furthermore, in the study by Papastergiou et al.[53], there was a reduction in incidence of hypoesthesia in the group with horizontal incision

In the current study, sensory loss was followed for 6 months after surgery. However, according to Kjaergaard[161], the patients will recover within 1 year after the surgery. Since we have not followed for 1 year, we will not be able to conclude on the sensory loss at this point.
Anatomical study and the study by Papastergiou et al. Suggest that an oblique or an horizontal incision is preferable[53, 55, 162, 163].

Infection

None of the patient had superficial or deep infection 6 month post-operatively (Table 5 & Figure 25).

Swelling

Swelling was present in 4 patients out of 25. Their IKDC grade was either abnormal (1 patient) or nearly normal (3 patients) (Table 5 & Figure 25).

SUMMARY

25 patients who underwent ACL reconstruction surgery using quadruple hamstring tendon graft were included in this study.

- Out of the 25 patients, 84% were male and 16 % were female.
- Left knee was involved in 28% of the patients and right knee in 72%. Even in the case of left knee injured, they were found to be right dominant.
- Mode of injury was predominantly from sports (52%), RTA (32%), and fall 16%.
- When the patients were observed after 6 months post surgery, swelling was present in 16%, pain in 16%, instability in 4 %, and sensory loss in 36%. However, no infection and locking were found in any of the patients.
- Frequency of associated injuries on MRI: MMIM 32%, LMIM 24%, MCLIM 8%, LCLIM 1%, and ACLIM 100%.
- Maximum ROM for pre-op was 0-80 and minimum 0-60. In the post-op, maximum was 0-140 and minimum 0-90.
- In the post-op, IKDC results showed that the frequency of normal patients was 10, nearly normal 14, and abnormal 1.
- LGS scoring was excellent for 11, good 11, and fair 3 patients.
- Out of the 11 excellent LGS score, 5 were normal and 6 were nearly normal; out of 11 good LGS, 5 were normal and 6 were nearly normal; and out of 3 fair LGS, 2 were nearly normal and 1 was abnormal.

CONCLUSION

This is a prospective study to assess the outcome following arthroscopic ACL reconstruction using the quadruple stranded hamstring grafts.
25 patients who underwent ACL reconstruction surgery using quadruple hamstring tendon graft were included in this study.
Clinical features like pain and sensory loss were also assessed.
Within the limitation of expertise available at our institute, the following conclusions were drawn:

- Using IKDC scoring, nearly normal were 14, normal were 10 and abnormal 1.
- 4 patient (16%) presented with anterior knee pain.
- Sensory loss was noted in 9 patients (36%) at the end of 6 months following surgery.
- Swelling was present in 4 patients (16%).

ACL reconstruction using quadruple stranded hamstring tendon graft provide an intrinsically stable knee with a full range of motion without any pain suggesting that the patients will be able to participate in unrestricted activities and sports.

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ANNEXURE – I

PROFORMA FOR REGISTRATION OF SUBJECTS FOR DISSERTATION

1	NAME OF THE CANDIDATE & ADDRESS	Dr. HARDIK PAWAR SPECIALIST ORTHOPAEDIC SURGEON DNB Orthopaedics CHARUSAT HOSPITAL ANAND
2	NAME OF THE INSTITUTION	CHARUSAT HOSPITAL ANAND
3	COURSE OF STUDY AND SUBJECT	Orthopaedics
5	TITLE OF THE TOPIC	outcome following arthroscopic Anterior Cruciate Ligament (ACL) reconstruction using hamstring graft - 6 months post-operative follow up.

PROFORMA FOR ANTERIOR CRUCIATE LIGAMENT INJURY

PART 1

ISSN 2229-5518

Name:		Code:	
Age:		Follow-up: 6m	
Sex:		Hospital No.	
Address		OP:	
Phone No:		Email address:	
DoA:		DoS:	

NATURE OF INJURY

Level I	**Level II**	**Level III**	**Level IV**
Jumping, pivoting, hard cutting: Basket ball , Soccer, Volley Ball	Lateral motion (less jumping/hard cutting) base B, Racquet sports, skiing	Straight ahead activity: Jogging, running, swimming	others
Occupation	Occupation	Occupation	Occupation
Activity comparable to level sports (strenuous)	Heavy manual work, climbing, working on uneven surface	Light manual work	Activities of daily living (no sports/desk/job)
Indication for surgery	Instability		
	Pain		
	Swelling		
	Locking		
	Others		

PHYSICAL EXAMINATION

Test	**OPD/emergency**	**EUA**	**Follow-up**
Lachman			
Anterior drawer			
Pivot shift			

Associated injury		**Clinical**	**MRI**	**Arthroscopy**	**Treatment**
Meniscus	Medial				
	Lateral				
MCL					
LCL					
PCL					
Others					

SURGICAL DETAILS

1.Incision	Straight midline/ oblique antero-lateral	
2.Graft	Semitendinosus	

	and gracilis			
	Length	To pull		
		Prolene/vicryl/SS wire		
		Prolene/SS wire/ vicryl		
		Prolene/SS wire/ vicryl		
Semitendinosus and gracilis				
3.Notchplasty	Yes/no	Bone/soft tissues		
4.Tunnel & interference screw/crosspin	Size	Screw endobutton	Size	make
Tibia				
Femur				
5.Duration of surgery		Tourniquet time		
6.Robert Jones compression bandage		Yes/no		
7.Knee brace/slab (knee flexed to 30°)		Yes/no		

Comments

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FUNCTIONAL ASSESSMENT

1. Girth of thigh

At 5 & 15 cm from superior pole of patella extended knee (compare normal knee

	Pre-op	Difference	Follow up (6m)	
	Normal	Affected	Normal	Affected
5 cm				
15 cm				
2. Range of motion	Pre-op	Difference	Follow up (6m)	
	Normal	Affected	Normal	Affected
Flexion				
Extension				
Extensor lag				

3. IKDC	Follow up (6m)
a. Knee symptom	
b. Pain	
c. Swelling	
d. Giving way	
e. Motion	
f. Stability/laxity	
g. Crepitus	
h. Morbidity at donor site	
i. Hop index	
j. Reduction of joint space on x-ray	

Normal-A, nearly normal-B, abnormal-C, severely abnormal-D

A. International Knee Documentation committee (IKDC)

IKDC Grade	Pre-operative	Post operative after 6 months
A (Normal)	0	9
B (Nearly Normal)	0	42
C (Abnormal)	25	5
D (Severely abnormal)	51	0

IKDC Grade	Pre-operative	Post operative after 6 months
A (Normal)		
B (Nearly Normal)		
C (Abnormal)		
D (Severely abnormal)		

SEVEN GROUPS	**FOUR GRADES** **A** **Normal**	**B** **Nearly Normal**	**C** **Abnormal**	**D** **Severely Abnormal**	**Group Grade ABCD**
1.Effusion	None		Mild	Moderate	
Severe					
2.Passive Motion Deficit					
Lack of extension	<3^0		3 to 5^0	6 to 10^0	
>10^0					
Lack of flexion	0 to 5^0		6 to 15^0	16 to 25^0	
>25^0					
3.Ligament Examination (manual , instrumented, x-ray)					
Lachman (25^0 flex)(134N)		-1 to 2mm	3 to 5mm(1*)	6 to 10mm(2*)	
>10mm(3*)					
		<-1to -3		<-3 stiff	
Lachman (25^0 flex)		-1 to 2mm	3 to 5mm	6 to 10mm	
>10mm					
manual max					
Anterior endpoint		firm		soft	
Total AP Translation					
(25^0 flex)	0 to 2mm		3 to 5mm	6 to 10mm	
>10mm					
Total AP Translation					
(70^0 flex)	0 to 2mm		3 to 5mm	6 to 10mm	
>10mm					
Posterior Drawer Test					
(70^0 flex)	0 to 2mm		3 to 5mm	6 to 10mm	
>10mm					
Med Joint Opening					
(20^0 flex/ valgus rot)	0 to 2mm		3 to 5mm	6 to 10mm	
>10mm					
Lat Joint opening					
(20^0 flex/ varus rot)	0 to 2mm		3 to 5mm	6 to 10mm	
>10mm					
External Rotation Test					
(30^0 flex prone)		<5^0	6 to 10^0	11 to 19^0	

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$>20^0$				
External Rotation Test				
(90^0 flex prone)	$<5^0$	6 to 10^0	11 to 19^0	
$>20^0$				
Pivot Shift	equal	+glide	++(clunk)	
+++(gross)				
Reverse Pivot Shift	equal	glide	gross	
marked				
4.Compartment				
Findings				
Crepitus Ant.				
Compartment	none	moderate	mild pain	>mild
pain				
Crepitus Med.				
Compartment	none	moderate	mild pain	>mild
pain				
Crepitus Lat.				
Compartment	none	moderate	mild pain	>mild
pain				
5.Harvest Site				
Pathology	none	mild	moderate	
severe				
6.X-ray Findings				
Med. Joint Space	none	mild	moderate	
severe				
Lat. Joint space	none	mild	moderate	
severe				
Patellofermoral	none	mild	moderate	
severe				
Ant. Joint Space (sagittal)	none	mild	moderate	
severe				
Post. Joint Space(sagittal)	none	mild	moderate	
severe				
7.Functional Test				
One Leg Hop				
(% of opposite side)	>90%	89 to 76%	75 to 50%	
<50%				

**Final Evaluation

IKDC SUBJECTIVE 2000 FORM

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 basket ball 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?

10 9 8 7 6 5 4 3 2 1 0

Never . . . .

Constant

3. If you have pain, how severe is it?
   - 10 9 8 7 6 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 basket ball 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.
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 basket ball 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.
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 basket ball 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.

9.How does your knee affect your ability to:

		Not difficult at all	Minimally difficult	Moderately difficult	Extremely difficult	Unable to do
a	Go upstairs	4	3	2	1	0
b	Go downstairs	4	3	2	1	0
c	Kneel on the front of your knee	4	3	2	1	0
d	Squat	4	3	2	1	0
e	Sit with your knee bent	4	3	2	1	0
f	Rise from a chair	4	3	2	1	0
g	Run straight ahead	4	3	2	1	0
h	Jump and land on your involved leg	4	3	2	1	0
i	Stop and start quickly	4	3	2	1	0

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

FUNCTION PRIOR TO YOUR KNEE INJURY:

Couldn't perform daily activities

0 1 2 3 4 5 6 7 8 9 10

no limitation in daily activities

CURRENT FUNCTION OF YOUR KNEE:

Couldn't perform daily activities

0 1 2 3 4 5 6 7 8 9 10

no limitation in daily activities

COMPLICATION

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Donor site morbidity	**Comment**	**Pre-operative**	**Post operative after 6 months**
Superficial infection	Yes/No		
Deep infection	Yes/No		
Pain	Yes/No		
Numbness	Yes/No		
Subjective opinion	Yes/No		
Anterior knee pain	Yes/No		
Distal femur fracture	Yes/No		
Neuro – vascular injury	Yes/No		
Graft laceration during screw fixation	Yes/No		
Bone plug fracture	Yes/No		
Traction suture laceration by screw	Yes/No		
Posterior wall fracture	Yes/No		
Bone plug fracture	Yes/No		
Short hamstring harvesting	Yes/No		
Graft impingement	Yes/No		
Neuro vascular injury	Yes/No		
Osteoarthrosis	Yes/No		
Damage to medial collateral ligament of knee	Yes/No		

SUBJECTIVE QUESTIONNAIRE

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Subjective questionnaire	**Comment**	**Pre-operative**	**Post operative after 6 months**
a) Feeling of looseness	Yes/No		
b) Swelling	Yes/No		
c) Pain	Yes/No		
d) Limitation of motion	Yes/No		
e) giving way	Yes/No		
Dissatisfied / Satisfied			

STABILITY/ASSESSMENT

Stability/assessment	**Pre-operative**		**Post-operative (6m)**	
	N	**A**	**N**	**A**
Kt-1000 arthometer				
(normal) <3mm				
>3-4 mm				
>4-5 mm				
>5-6 mm				
(Abnormal)				
Done by maximum manual excursion and the knee flexed to 30°. Force 89 Newton load				

REHABILITATION (CHAPMAN)

Phase		Follow up
Pre-operative		**Post-operative (6m)**
Immediate post-op		
Achieved/notachieved/comment		
6 m after operation		
Achieved/notachieved/comment		

ACTIVITY LEVEL

Level	Sports	Occupation	Pre-operative	Post-operative (6m)
I	Yes/No	Yes/No		
II	Yes/No	Yes/No		
III	Yes/No	Yes/No		
IV	Yes/No	Yes/No		

LYSHOLM AND GILLQUIST KNEE SCORING SCALE

Lysholm and Gillquist Knee scoring scale		**Pre-op**	**Post-op (6m)**
Limp[5]	5		
None	(5)		
Slight or periodical	(3)		
Severe and constant	(0)		
Support[5]			
None	(5)		
Stick or crutch	(2)		
Weight bearing impossible	(0)		
Locking[15]			
No locking and caching sensation	(15)		
Caching but no locking	(10)		
Locking			
Occasionally	(6)		
Frequency	(2)		
Locked joint on examination	(0)		
Instability[25]			
Never giving way	(25)		
Rarely during athletics or other severe exertion	(20)		
Occasionally in daily activities	(10)		

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Often in daily activities	(5)		
Every step	(0)		
Pain[25]			
None	(25)		
Inconstant & severe during exertion	(20)		
Marked during exertion	(15)		
Marked on or after walking >2km	(10)		
Marked on or after walking < 2km	(5)		
Constant	(0)		
Swelling[10]			

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None	(10)		
On severe exertion	(5)		
On ordinary exertion	(2)		
Constant	(0)		
Strain climbing[10]			
No problem	(10)		
Slightly impaired	(5)		
One step at a time	(2)		
Impossible	(0)		
Squatting[5]			
No problem	(5)		
Slightly impaired	(4)		
Not beyond 90^0	(2)		
Impossible	(0)		
TOTAL	**100**		

<65 Poor, > 65-83 Fair, > 84-94 Good, >95 Excellent

ANNEXURE – II

POST OPERATIVE ACL REHABILITATION PROTOCOL

(ADAPTED FROM WILK'S PROTOCOL)

Phase	**Criteria**	**Goals**	**Exercises**
Phase I [redacted] Immediate Weeks 0-2		□Protest graft fixation □Establish quadriceps control □Independent ambulation □Weight bearing to tolerance with crutches □Diminish joint swelling and pain	□Ankle pumps □Passive knee extension □Active and passive knee flexion to 90° by day 5 □Quadriceps isometric setting □Knee extension 90°-40° □SLR (three-way)
Phase II Early rehabilitation Weeks 2-4	Quadriceps control passive ROM 0-90°	□Full passive knee extension □Muscle training □Restore proprioception □Increase knee flexion □Brace discontinued after 3 weeks if SLR and walking is good	□SLR (four planes) □Leg press □Knee extension 90°-40° □Quadriceps isometric setting □Half squats 0-40° (closed chain kinetic) □Bicycling □Assisted hamstring curls weight shifts ROM 0-115°
Phase III Controlled	Active ROM 0-115°	□Knee ROM (0-125°)	□Progress isometric

ambulation Weeks 4-6		☐Improve lower extremity strength ☐Enhance proprioception, balance and neuro muscular control ☐Restore limb confidence and function	strengthening program ☐Leg press ☐Knee extension 90°-40° ☐Wall squats ☐Bicycling ☐Hamstring curls ☐Lateral and forward lungs ☐Lateral step-ups and step-overs ☐Wall slides ☐Proprioception drills ☐Wobble-board or tilt-board balance ☐Stair climbing
Weeks 6-10		☐Increase ROM up to 135°	☐Continue all exercises ☐Bicycling ☐Stair climbing ☐Plyometric and stretching drills ☐Active quadriceps setting and graded weights
Phase IV Advance activity Weeks 10-16	Activity ROM 130° or greater	☐Normalize lower extremity strength ☐Enhance muscle power and endurance ☐Improve neuro muscular control ☐Perform selected sports-specific drills	☐Continue all exercises

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Phase V Return to activity Weeks 16-22	Full ROM quadriceps bilateral comparison ≥100% hamstring bilateral comparison ≥80%	□□□□□□□□□□□□□□□□□□□□□□□□□ normal activities □Achieve maximum strength and endurance	□□□□□□□□□□□□□□□□□□□ exercises □Stationary on the spot jogs □Strengthen quadriceps and hamstring with graded weights □Improve neuromuscular control
Months 6-9			□Continue stationary jogs □Cycling □Strengthening exercise for quadriceps and hamstring □Start mild jogging from 6th month to normal jogging at the end of 9th month
Phase III Controlled ambulation Weeks 4-6	Active ROM 0-115°	□Knee ROM (0-125°) □Improve lower extremity strength □Enhance proprioception, balance and neuro muscular control □Restore limb confidence and function	□Progress isometric strengthening program □Leg press □Knee extension 90°-40° □Wall squats □Bicycling □Hamstring curls □Lateral and forward lungs □Lateral step-ups and step-overs □Wall slides □Proprioception drills □Wobble-board or tilt-board balance □Stair climbing
Weeks 6-10		□Increase ROM up to 135°	□Continue all exercises □Bicycling □Stair climbing □Plyometric and

			stretching drills ☐Active quadriceps setting and graded weights
Phase IV Advance activity Weeks 10-16	Activity ROM 130° or greater	☐Normalize lower extremity strength ☐Enhance muscle power and endurance ☐Improve neuro muscular control ☐Perform selected sports-specific drills	☐Continue all exercises

Phase V Return to activity Weeks 16-22	Full ROM quadriceps bilateral comparison ≥100% hamstring bilateral comparison ≥80%	☐Gradual return to normal activities ☐Achieve maximum strength and endurance	☐Continue all exercises ☐Stationary on the spot jogs ☐Strengthen quadriceps and hamstring with graded weights ☐Improve neuromuscular control
Months 6-9			☐Continue stationary jogs ☐Cycling ☐Strengthening exercise for quadriceps and hamstring ☐Start mild jogging from 6^{th} month to normal jogging at the end of 9^{th} month

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