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Comparison of functional outcome of arthroscopic anterior cruciate ligament reconstruction using an autologous four- strand single semitendinosus tendon versus semitendinosus and gracilis tendon graft

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Abstract
Objectives: There is no consensus about the optimal graft choice for anterior cruciate ligament (ACL) reconstruction. The present study was aimed to compare the clinical and functional results of reconstruction of ACL by using an autologous four strand semitendinosus tendon versus semitendinosus and gracilis graft.
Design: Prospective Randomized control trial.
Study Done At: Orthopaedics Department BPS Govt. Medical College for women, Khanpur, Sonipat.
Materials and Methods: In the present study, 58 patients were included. Mean age of the patients in the ST group was 27.34 ± 6.28 years and that in the STG group was 26.34 ± 5.19 years. Road traffic accident was the most common mode of injury and most common symptom at presentation was knee pain. It was found that among all patients included in the study, 48.3% had 4 to 8 months since the time of injury. Mean time since injury was 6.59 ± 2.7 months in the ST group and 6.42 ± 2.2 months in the STG group.
Results: LKSS and IKDC values were significantly higher in the ST group as compared to STG group at 2 and 8 weeks post-operatively. Later on, at all follow up points, the mean LKSS and IKDC were similar in the two study groups. Anterior drawer and Lachman test showed no statistical difference between the two study groups. Since ACL reconstruction using quadrupled ST is more technically demanding than doubled STG and with there being no difference in outcomes, no compulsory advice should be made on the former technique.
Summary: Since ACL reconstruction using quadrupled ST is more technically demanding than doubled STG and with there being no difference in outcomes, no compulsory advice should be made on the former technique.

Keywords: arthroscopic anterior cruciate ligament reconstruction, autologous four- strand single semitendinosus tendon, gracilis tendon graft

Introduction
ACL reconstruction is generally involves replacing a graft in place of ruptured ACL. However, no consensus could be obtained on how and from where to select the most suitable graft. Native grafts may be taken from the patellar tendon, hamstring tendon (semitendinosus and gracilis), or quadriceps tendon, or an allograft may be used. Achilles or patellar tendon are usually used to provide allografts, but the quadriceps, hamstring, and tibialis tendons may also be used as per the choice of the surgeon. No single graft has demonstrated a superior functional and clinical outcome [1]. The three most common grafts are the patellar tendon graft, the hamstring tendon graft, and the allograft. Patellar graft may be advantageous as by providing an increased initial strength and stiffness compared with the normal ACL and potential bone-to-bone healing in the femoral and tibial tunnels made during surgery, early graft fixation is promoted [2]. Systematic reviews confirm that reconstruction using the patellar tendon graft results in greater anterior knee pain compared with other grafts [3]. Such pain usually resolves after the first year. Patellar tendon grafts provide greater stability than traditional hamstring grafts, but this may no longer be the case with four stranded hamstring grafts. Moreover, patellar tendon grafts may increase the long-term risk for osteoarthritis of the knee [4].

The hamstring graft has several advantages. Patellar tendon morbidity and thus primarily anterior knee pain can be avoided by using hamstring tendon. A systematic review found that hamstring donor site pain usually resolved by three months, while hamstring strength returned to normal by 12 months [5]. Brown *et al.* demonstrated that the hamstring graft is stronger and stiffer when quadruple strands are used [6]. Eight-stranded tendon grafts [7] and double-bundle reconstructions [8] appear to yield greater strength and stability. Patellar tendon grafts include a portion of bone at either end, while hamstring grafts are comprised entirely of tendon [9]. As hamstring grafts need healing between a tendon and an osseous tunnel, initial fixation may be slower and ultimately weaker than the bone-to-bone healing of a patellar tendon graft, although techniques like endobutton have been developed to address this.

However, hamstring graft can cause considerable decrease in knee flexion and tibial rotation strength due to the harvesting of both hamstring tendons [10]. Thus, the importance of harvesting gracilis tendons in ACL reconstruction has been debated in many research studies, doubting the role of the gracilis tendon in hamstring graft technique [11]. Furthermore, previous studies indicate that harvesting the gracilis tendon autograft is not only ineffective in the motor control and stability of the knee, but also inefficacious regarding the kinetic muscle torque involved in knee flexion [12]. Some research studies, using subjective and functional evaluations, have demonstrated no significant differences between harvesting semitendinosus ten- don and semitendinosus and gracilis [13].

Therefore, this study was done to examine and compare the results of the ACL reconstruction using only semitendinosus autograft (ST) and the combined use of semitendinosus and gracilis (ST/G).

Materials and Method

This study was conducted on patients undergoing reconstruction of ACL ligament at the Department of Orthopaedics, Bhagat Phool Singh Government Medical College for Women, Khanpur Kalan, Sonepat for a period of 18 months. This study was approved by Institutional Ethical committee. A separate informed consent was obtained from patients before being included in the study. Patients were mandated for the age in the 20 to 45 year without pre-existing arthritis, symptomatic unilateral anterior cruciate ligament tear, Patients with clinical or radiological evidence of anterior cruciate ligament tear.

Patients with bilateral anterior cruciate ligament tears, Multi ligamentous injury of knee, Patients with other systemic diseases (diabetes mellitus, hypertension) were not included in the study.

Sampling: The sample size was calculated based on previous studies by Kyung *et al*. and Witvrouw *et al.* Using Master 2.0 software the calculations were done. With the power of study being 80%, and alpha error at 5%, sample proportion 0.32 and with confidence interval 95% the sample size was calculated to be 29 patients in each group and total sample size was calculated as 58. Simple random sampling was used and was collected using computerized generated by simple random number table.

Study Design: In this present prospective interventional study, 58 eligible patients were included. At baseline, pre-operative clinical functional score by Lysholm Gillquist score and IKDC score were noted. The patients were then randomized to undergo ACL reconstruction either by autologous four strand ST tendon or a ST and gracilis tendon graft. Post-operatively all patients underwent clinical functional assessment at 2 weeks, 8 weeks, 12 weeks and 24 weeks.

Surgical Technique: For majority of patients, spinal anesthesia was preferred as it allows for adequate joint exposure, complete muscle relaxation and tourniquet pain is minimal, but the choice depended on patients' general condition and the preference of the patient and operating surgeon. Once the patient was anesthetized, an examination under anesthesia was performed. A systemic physical examination with the patient anesthetized can give important additional information. The subject was positioned in the supine position on the operation table. A tourniquet was placed, high-up on the proximal thigh of the operative extremity. The shorter and thicker the thigh, the more proximal the tourniquet was placed. A distal support placed on the table, kept the knee flexed at an angle 90 degree. The operative leg is then thoroughly scrubbed, from the level of the tourniquet down to the foot, with 10%w/v iodine solution and then painted with ioprep 7.5w/v solution. A standard surgical drape is then placed under the leg and secured at the thigh with a towel clip. The entire surgical field is then covered with a water proof sheet. The foot is then thoroughly painted and covered with a stockinet, which is secured by wrapping a bandage around it. The prepared leg is then exsanguinated by using a sterile Esmarch, from the foot upto the thigh, and then the tourniquet is inflated.

Arthroscopic portals: In all our patients, arthroscopic ACL reconstruction was obtained through the anteromedial portal technique (anatomical reconstruction). Anterolateral portal is the standard viewing portal where the arthroscope was first inserted and is usually located in the palpable lateral 'soft spot', approximately 1.5 cm above the lateral joint line and adjacent to the lateral margin of the patellar tendon as shown in figure 1.

ACL graft preparation: An oblique incision was placed over the medial border of the proximal tibia, about one centimeter above the 'pes anserius'. The Sartorius fascia was split transversely and the semitendinosus and gracilis tendons were identified. These tendons were then separated from its tibial attachment with a #11 blade. Using a tendon stripper, doubled gracilis and semitendinosus tendons in ST/G group or quadrupled semitendinosus in ST group were harvested and 4 strands made to make atleast 8mm diameter and 7.5cm length in ST and 9 cm in STG in patients according to their study group. The tendons were then cleared off their muscle fibers and then fastened together with 'whip-stich' sutures using 2 ethibond. The prepared graft was then mounted on a graft preparation board and pre-tensioned.

Femoral and tibial tunnel: Remnants of the torn ACL were carefully inspected and an attempt was made to preserve large tibial stumps and ACL fibers with intact connections from the tibia to the femur. In our study, an endobutton was used for the femoral fixation in all cases. First we used a 4 mm drill Bit to drill a tunnel through the lateral femoral cortex with the help of femoral offset. The depth of drilling was calculated by deducting the preferred endobutton length from the initial tunnel length and then adding 10mm; required for the

endobutton to flip. While viewing through the anterolateral portal, ACL tip aimer jig was inserted at a 55° angle through the anteromedial portal into the knee joint. Position the tip of the aimer, 2–3 mm anterior to the posterior margin of the anterior horn of the lateral meniscus and slightly medial to mid-line of the ACL footprint of tibial attachment.

Graft passage: Using an arthroscopic probe or grasper, we retrieved the suture loop that was left in the ACL femoral tunnel and pulled the suture out of the knee joint through the tibial tunnel. The endobutton was then flipped and tension was applied to the free end of the graft. The knee was then put around 15 degree flexion with posterior drawer and the free end of the graft was attached to the proximal medial tibia with bio screw or suture disc. In case of semi T G, bioscrew / titanium interference screw was used and for semi T both bioscrew and suture disc were used. Post operative xray as shown in figure 2.

Fig 1: Incision made over pes anserinus and passing of ethibond and endobutton

Fig 2: Post - Operative X-rays

Obeservation and Results

Functional Assessments: Functional assessments of all patients included in the study was done pre-operatively for baseline scores and then post-operatively at 2 weeks, 8 weeks, 12 weeks and 24 weeks.

Lysholm Knee Scoring Scale: The purpose of the Lysholm Knee Scoring Scale is to assess the results of knee ligament surgery [14]. Evaluation on this scale is based on 8 items: limping, support, stair's climbing, walking, squatting, thigh atrophy, instability, and locking. Each response to the 8 items is assigned an arbitrary score. These scores are administered by clinicians in collaboration with the patient. Scores are assigned on an increasing scale from 0- 100 with 100 being interpreted to mean no symptoms. Percentage scores are grouped into four major categories: below 64 poor, 65-85 fair, 845-94 good, and 95-100 excellent [15].

International Knee Documentation 2000 score (IKDC) [16]: The IKDC scale was evaluated by summing the scores for the individual items and then transforming the score to a scale that ranges from 0 to 100. To calculate the final subjective IKDC score simply add the score of each item and divide by the maximum possible score which was 87.

Subjective IKDC score = [Sum of items/Maximum possible score] × 100

The score is interpreted as a measure of function such that higher scores represent higher levels of function and lower levels of symptoms. A score of 100 is interpreted to mean no limitation with activities of daily living or sports activities and the absence of symptoms.

Data Collection and Statistical Analysis: Using a pre-designed, semi-structured patient related data were collected. Demographic data like age and gender were noted for all patients. Clinical information such as mode and age of injury, x-ray findings were noted. Pre-operative (baseline) and post-operatively all patients underwent clinical functional assessment at 2 weeks, 8 weeks, 12 weeks and 24 weeks. Descriptive variables were expressed as mean and standard deviation for quantitative variables and frequency and percentages for qualitative variables. The qualitative (gender and complications) variables were compared using the chi-square and Fisher's exact tests. For the nonparametric variables (Lysholm Gillquist score and IKDC score), we used the Mann–Whitney U test for comparison. The statistical analysis was done with SPSS Version 21.0 (SPSS Inc, USA) and p value less than 0.05 was taken as statistically significant.

Results: During the study period, we included 58 patients. There underwent ACL reconstruction with either by autologous four strand ST tendon or a ST and gracilis tendon graft. In the present study, 58 patients were included. Mean age of the patients in the ST group was 27.34 ± 6.28 years and that in the STG group was 26.34 ± 5.19 years, with not statistical difference between them (p value = 0.67). The most common age group was less than 30 years of age (65%), in the ST group it comprised 69% of all patients and in the STG group it comprised 62%.

In the present study, 89.66% of the patients were males (n=52) and rest being females. There were 27 males in the ST group and 25 males in the STG group. The gender distribution in the two study groups was similar (p value = 0.72).

History at the time of presentation to the hospital revealed road traffic accident was the most common mode of injury in our patients (67.24%). In the ST group 72% and in the STG group 62% had a road traffic accident. Sports injury was seen among 32.76% of the patients. The distribution of patients according to the mode of injury was similar among the two patient group (p value = 0.92).

Right side was involved in 82.7% of all patients. Patients in the ST group had right side involved in 79.3% of the patients and in the STG group right side was involved in 86.2%, the distribution was statistically not significant (p value = 0.71).

The most common symptom at the time of presentation was knee pain (39.66%), while instability and knee locking was observed equally among the patients. The distribution of presenting symptoms were also similar between the two study groups (p value = 0.88).

We examined the patients for any associated injuries. Medial meniscal injury was found in a total of 41 patients, while lateral meniscal injury was found in only 10 patients in the study. Among the ST group 72% had medial meniscal injury, while lateral meniscal injury was found in only 14% of the patients. Among patients in the STG group, 69% had the medial meniscal injury while only 21% had lateral meniscal injury. The distribution of these associated injuries were not statistically different between the two study groups.

Time since injury was enquired from the patients. It was found that among all patients included in the study, 48.3% had 4 to 8 months since the time of injury. Mean time since injury was 6.59 ± 2.7 months in the ST group and 6.42 ± 2.2 months in the STG group, the difference of which was statistically not significant (p value = 0.64). Among patients in both the ST and STG group, 48.3% had time since injury of 4 to 8 months, 27.6% had time since injury of less than 4 months and 24.1% had time since injury of more than 8 months.

IKDC was assessed in the patients pre-operatively and post-operatively at 2 weeks, 8 weeks, 12 weeks and 24 weeks. The above describes how the mean IKDC values changed over different points of follow up. We observed the mean IKDC to be similar in both the study groups at baseline (pre-operatively). At 2 weeks, we observed the mean IKDC to be significantly higher in the ST group as compared to STG group (38.76 ± 4.6 vs 34.33 ± 3.4; p value <0.001). Similar observation was made at 8 weeks as well. Later on, at all follow up points, the mean IKDC was similar in the two study groups.

LKSS was assessed in the patients pre-operatively and post-operatively at 2 weeks, 8 weeks, 12 weeks and 24 weeks. The above describes how the mean LKSS values changed over different points of follow up. We observed the mean LKSS to be similar in both the study groups at baseline (pre-operatively). At 2 weeks, we observed the mean LKSS to be significantly higher in the ST group as compared to STG group (40.34 ± 5.5 vs 37.66 ± 3.6; p value <0.05). Similar observation was made at 8 weeks as well. Later on, at all follow up points, the mean LKSS was similar in the two study groups.

Anterior Drawer test was assessed in the patients pre-operatively and post-operatively. The above compared proportion of patients in various grades pre- and post-operatively in the two study groups. Pre-operatively, in the ST group, 17.2% of the patients were in Grade 3, 82.8% were in Grade 2, while in the STG group, 13.8% were in Grade 3 and 86.2% were in Grade 2. The difference in proportions was not statistically significant (p value = 1.00). Post- operatively, in the ST group 3.4% were in Grade 2, 13.8% in Grade 1 and 82.8% in Grade 0. In the STG group, 3.4% were in Grade 2, 17.2% were in Grade 1 and 79.3% were in Grade 0. The difference in the proportion of patients in various grades in the two study groups was not statistically significant (p value = 0.98).

Lachman test was assessed in the patients pre-operatively and post-operatively. The above compared proportion of patients in various grades pre- and post-operatively in the two study groups. Pre-operatively, in the ST group, 13.8% of the patients were in Grade 3, 79.3% were in Grade 2, 6.9% in Grade 1 and none in Grade 0 while in the STG group, 20.6% were in Grade 3 and 72.4% were in Grade 2, 6.9% were in Grade 1 and none in Grade 0. The difference in proportions was not statistically significant (p value = 0.63). Post-operatively, in the ST group 6.9% were in Grade 2, 51.7% in Grade 1 and 41.4% in Grade 0. In the STG group, 10.34% were in Grade 2, 55.17% were in Grade 1 and 34.48% were in Grade 0. The difference in the proportion of patients in various grades in the two study groups was not statistically significant (p value =0.78).

Pivot test was assessed in the patients pre-operatively and post-operatively. The above compared proportion of patients in various grades pre- and post-operatively in the two study groups. Pre-operatively, in the ST group, 17.2% of the patients were in Grade 2, 72.4% were in Grade 1, 10.3% in Grade 0 while in the STG group, 24.14% were in Grade 2 and 65.52% were in Grade 1, 10.3% were in Grade 0. The difference in proportions was not statistically significant (p value = 0.77). Post-operatively, in the ST group none were in Grade 2, 20.7% in Grade 1 and 79.3% in Grade 0. In the STG group, one patient was in Grade 2, 27% were in Grade 1 and 68.97% were in Grade 0. The difference in the proportion of patients in various grades in the two study groups was not statistically significant (p value =0.71).

Discussion

In the present study, mean age of the patients in either of the study groups was similar, with the most common age group being less than 30 years of age (65%). Also, 89.66% of the patients were males (n=52) and rest being females. Lee *et al.* compared the functional outcomes including muscle strengths between single ST and ST-G harvesting. Mean age of the patients in their study was 27.4 ± 6.6 years and 26.9 ± 7.3 years in ST and STG groups respectively, with male female ratio of 57:3 and 57:5 respectively. Karimi-Mobarake *et al.* [21] included patients with mean age of 28.8 ± 8.2 years and 29.7 ± 7.9 years in the ST and STG group respectively. Kyung *et al.* reported the mean age in the ST and ST/G groups were 28.0 and 31.3 years, respectively. Ardern *et al.* reported that the ST-G group comprised 20 males and 10 females with a mean age of 28.7 years at final follow-up, and the ST group comprised 15 males and 5 females with a mean age of 27.2 years at final follow-up. A recent meta-analysis comparing patient-reported outcomes and functional knee parameters of ACL reconstruction surgery with ST and ST-gracilis grafts found that mean patient age ranged from 20 to 31 years, with vast majority of studies reporting more numbers of male than female patients. Furthermore, in our study, road traffic accident was the most common mode of injury in our patients (67.24%) and rest having sports injury. The etiology underlying ACL injury varies significantly by country, with the vast majority being related to sporting injury in the USA, Western Europe and Scandanavia [17] whereas 58% were associated with a sporting injury, 26% with an RTA, and 16% were related to other nonsporting injuries in an Indian cohort [18].

We examined the patients for any associated injuries. Medial meniscal injury was found in a total of 41 patients, while lateral meniscal injury was found in only 10 patients in the study. Among the ST group 72% had medial meniscal injury, while lateral meniscal injury was found in only 14% of the patients. Among patients in the STG group, 69% had the medial meniscal injury while only 21% had lateral meniscal injury. Kyung *et al.* [22] found that there were 27 cases of meniscus injury and six cases of MCL injury in the ST group

and 21 cases of meniscus injury and two cases of MCL injury in the ST/G group. Partial meniscectomy and meniscus reconstruction was performed in 13 and 14 cases, respectively, in the ST group, and they were performed in 15 and six cases, respectively, in the ST/ G group. MCL injuries were treated conservatively in both groups.

Time since injury was enquired from all our patients, mean time since injury was 6.59 ± 2.7 months in the ST group and 6.42 ± 2.2 months in the STG group, the difference of which was statistically not significant (p value = 0.64). Kyung *et al.* found that the mean time from injury to index surgery in the ST and ST/G groups were 5.8 and 6.0 months, respectively. Karimi-Mobarakeh *et al.* found that the time between injury and surgery was 2. 7 ± 1.9 and 2.8 ± 1.6 months. Barenius *et al.* reported that the mean days between injury and reconstruction was 84 days and 91 days in the STG and ST group respectively.

We assessed the functional outcome of our patients in the two study groups using IKDC and LKSS pre-operatively and post-operatively at 2, 8, 12 and 24 weeks. We observed the mean IKDC to be similar in both the study groups at baseline (pre-operatively). At 2 weeks and 8 weeks, we observed the mean IKDC to be significantly higher in the ST group as compared to STG group. Later on, at all follow up points, the mean IKDC was similar in the two study groups. Karimi-Mobarakeh *et al.* [21] found no significant differences in the IKDC subjective score side-to-side between the two groups (80.8 ± 6.8 vs 83.5 ± 6.3, p value = not significant). Similarly, Arden *et al.* found that the outcome measures of the IKDC, knee laxity, isokinetic knee flexor peak torque and range of motion were not significantly different in ST and ST/G groups. Gracilis harvest had no positive or negative effect on the outcome measures of ACLR according to the findings of Barenius *et al.* [19]. Niki *et al.* demonstrated that the IKDC improved in patients undergoing either ST or STG grafting but there was no significant difference among the patients in the two groups. Inagaki *et al.* [20] also found that after 2 years of follow-up, no significant differences in the functional outcome as assessed by IKDC in patients undergoing ST or STG grafting. In addition, we observed the mean LKSS to be similar in both the study groups at baseline (pre-operatively). At 2 weeks, and 8 weeks we observed the mean LKSS to be significantly higher in the ST group as compared to STG group. Later on, at all follow up points, the mean LKSS was similar in the two study groups. Similar results were reported by Kyung *et al.* [22] also found that LKSS was not significantly different among either ST or STG group of patients. Inagaki and colleagues also demonstrated similar functional outcomes.

One major concern regarding ACL reconstruction with hamstring tendon is loss of knee flexion strength. Gifstad *et al.*, in a 7-year follow-up study of the patients who had undergone ACL reconstruction, found that total flexion work decreased more among the patients in the ST/ G group than those in bone–patellar tendon–bone (BPTB); however, anterior knee pain was observed in BPTB more than with the ST/G. This was observed especially during the first few years following the operation. Conversely, two other review articles suggest that semitendinosus and gracilis tendons regenerated among a significant number of patients who had undergone ACL reconstruction with the ST/G technique. However, there is doubt as to whether the regeneration occurs at the anatomic site and whether or not this affects knee flexion strength. Janssen *et al.* observed 22 patients who had undergone ACL reconstruction with 4S- HT for 1 year and used an MRI to assess tendon regeneration. They reported the regeneration of gracilis tendons in all the patients and the regeneration of semitendinosus tendons in 14 of the 22 patients. This regeneration of tendons had no significant effect on the scores of IKDC, Tegner, Lysholm, KT-1000, or the isometric and isokinetic tests of hamstring muscles.

Even though both the patient related outcomes (IKDC and LKSS) were comparable in both the study groups in our study and shown previously as well, side-to-side differences in flexor peak torque have been shown to be significantly higher in the ST-G graft at lower angular velocities, indicating that the gracilis muscle plays a greater role on knee flexion torque at lower angular velocities. This has been validated by the presence of higher surface electromyogram signals at slower velocities during isokinetic test. While multiple studies highlighted that ST alone appears to have an added advantage over ST-G grafts with respect to rotational weakness, they too concluded a lack of clinical differences. Still, these statistical differences have not translated into clinical significance as the patient related outcomes have consistently been reported to be similar between the two surgical procedures.

Conclusion

Our results show that patients who underwent ST graft had significantly higher IKDC and LKSS at only 2 and 8 weeks post-operatively, further assessments showed no difference. Other than this no other assessment method could identify.

superiority of one surgical technique over the other. If stability could be maintained similarly in both the study groups (based on anterior drawer and Lachman test), it can be suggested that good functional outcomes can be obtained from ST graft without the gracilis tendon for ACL reconstruction. Since ACL reconstruction using quadrupled ST is more technically demanding than doubled STG and with there being no difference in outcomes, no compulsory advice should be made on the former technique. However, with enough experience, one might advise the ST over STG method due to its' lesser invasiveness. Future prospective randomized controlled trials are needed to assess the functional outcomes using objective tools with a longer follow up period.

References

1. Foster TE, Wolfe BL, Ryan S, *et al*. Does the graft source really matter in the outcome of patients undergoing anterior cruciate ligament reconstruction? An evaluation of autograft versus allograft reconstruction results: a systematic review. Am J Sports Med 2010;38:189.
2. Miller SL, Gladstone JN. Graft selection in anterior cruciate ligament reconstruction. Orthop Clin North Am. 2002;33:675.
3. Li S, Su W, Zhao J, *et al*. A meta-analysis of hamstring autografts versus bone-patellar tendon-bone autografts for reconstruction of the anterior cruciate ligament. Knee. 2011;18:287.
4. Pinczewski LA, Lyman J, Salmon LJ, *et al*. A 10-year comparison of anterior cruciate ligament reconstructions with hamstring tendon and patellar tendon autograft: a controlled, prospective trial. Am J Sports Med 2007;35:564.
5. Poolman RW, Farrokhyar F, Bhandari M. Hamstring tendon autograft better than bone patellar-tendon bone autograft in ACL reconstruction: A cumulative meta-analysis and clinically relevant sensitivity analysis applied to a previously published analysis. Acta Orthop.

2007;78:350.
6. Brown CH Jr, Steiner ME, Carson EW. The use of hamstring tendons for anterior cruciate ligament reconstruction. Technique and results. Clin Sports Med. 1993;12:723.
7. Zhao J, He Y, Wang J. Double-bundle anterior cruciate ligament reconstruction: four versus eight strands of hamstring tendon graft. Arthroscopy. 2007;23:766.
8. Schreiber VM, Van Eck CF, Fu FH. Anatomic Double-bundle ACL Reconstruction. Sports Med Arthrosc. 2010;18:27.
9. Poolman RW, Abouali JA, Conter HJ, Bhandari M. Overlapping systematic reviews of anterior cruciate ligament reconstruction comparing hamstring autograft with bone- patellar tendon-bone autograft: why are they different? J Bone Joint Surg Am. 2007;89:1542.
10. Kim JG, Yang SJ, Lee YS, Shim JC, Ra HJ, Choi JY. The effects of hamstring harvesting on outcomes in anterior cruciate ligament-reconstructed patients: a comparative study between hamstring-harvested and -unharvested patients. Arthroscopy 2011;27(9):1226-1234
11. Gobbi A, Domzalski M, Pascual J, Zanazzo M. Hamstring anterior cruciate ligament reconstruction: Is it necessary to sac- rifice the gracilis? Arthroscopy. 2005;21(3):275-280
12. Yosmaoglu HB, Baltaci G, Ozer H, Atay A. Effects of additional gracilis tendon harvest on muscle torque, motor coordination, and knee laxity in ACL reconstruction. Knee Surg Sports Traumatol Arthrosc 2011;19(8):1287-1292
13. Barenius B, Webster WK, McClelland J, Feller J. Hamstring tendon anterior cruciate ligament reconstruction: Does gracilis tendon harvest matter? Int Orthop. 2013;37(2):207–212
14. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. The American journal of sports medicine. 1982 May;10(3):150-4.
15. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS- ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). Arthritis care & research. 2011 Nov;63(S11):S208-28.
16. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P *et al*. Development and validation of the international knee documentation committee subjective knee form. The American journal of sports medicine. 2001 Sep;29(5):600-13.
17. Englund M, Eriksson K, Forssbland M, Frobell R, Kvist J, Herbertsson P. Swedish ACL Register. Annual Report; The Swedish National Knee Ligament Register. X Base, 2014.
18. Jacob KM, Oommen AT. A retrospective analysis of risk factors for meniscal co- morbidities in anterior cruciate ligament injuries. Indian J Orthop 2012;46:566-9.
19. Barenius B, Webster WK, McClelland J, Feller J. Hamstring tendon anterior cruciate ligament reconstruction: does gracilis tendon harvest matter?. International orthopaedics. 2013 Feb;37(2):207-12.
20. Inagaki Y, Kondo E, Kitamura N, Onodera J, Yagi T, Tanaka Y *et al*. Prospective clinical comparisons of semitendinosus versus semitendinosus and gracilis tendon autografts for anatomic double-bundle anterior cruciate ligament reconstruction. Journal of Orthopaedic Science. 2013 Sep;18(5):754-61.
21. Karimi-Mobarakeh M, Mardani-Kivi M, Mortazavi A, Saheb-Ekhtiari K, Hashemi-Motlagh K. Role of gracilis harvesting in four-strand hamstring tendon anterior cruciate ligament reconstruction: a double-blinded prospective randomized clinical trial. Knee Surgery, Sports Traumatology, Arthroscopy. 2015 Apr;23(4):1086-91.
22. Kyung HS, Lee HJ, Oh CW, Hong HP. Comparison of results after anterior cruciate ligament reconstruction using a four-strand single semitendinosus or a semitendinosus and gracilis tendon. Knee Surgery, Sports Traumatology, Arthroscopy. 2015 Nov;23(11):3238-43.