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An evaluative study to find the correlation between semitendinosus graft dimension with respect to patient's anthropometry

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ABSTRACT

Background: A prospective study of a cohort of anterior cruciate ligament (ACL) reconstructed patients 7 years after surgery revealed degenerative radiographic changes in 95% of patients, and only 47% were able to return to their previous activity level following ACL reconstruction. **Aims and Objectives:** The aims of this study were to find the correlation between Semitendinosus graft dimension with respect to patients anthropometry such as age, height, weight, body mass index (BMI), and true leg length (TLL). **Materials and Methods:** The proposed study was the patients coming to orthopedics-outpatient department and emergency with 30 complete thickness ACL tears which were screened and recruited based on fulfillment of inclusion and exclusion criteria from January 2020 to August 2021 (20 months duration). The sample size was sufficient to draw conclusive findings. Correlation was calculated by Pearson correlation analysis. The Pearson product-moment correlation coefficient was a measure of the linear dependence between two variables X and Y. $P \leq 0.05$ was considered for statistically significant. **Results:** The age has positive correlation with graft length ($r = 0.11$) and relatively strong positive correlation with graft diameter ($r = 0.437$). Height has relatively strong positive correlation with graft length ($r = 0.4258$) and graft diameter ($r = 0.1375$). Weights have strong positive correlation with graft length ($r = 0.604$). TLL also had positive correlation with graft length (0.23) and graft diameter ($r = 0.1$). **Conclusion:** In selective cases, graft may be reinforced with additional Hamstring tendon harvest like gracilis or any alternative graft such as Bone–patellar tendon–bone (BPB) and Peroneus longus tendon autograft that may be taken to prevent graft failure and future complications. This current data can be a reference for surgeons in preoperative planning and counseling to patients about alternative autograft selection.

Key words: Anterior cruciate ligament; Anthropometry; Graft and semitendinosus

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INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction is the sixth most common procedure performed in orthopedics, and it is estimated that between 75,000 and 100,000 ACL repair procedures are performed annually in India alone.[1] The ACL has therefore been intensively studied and outcomes of ACL surgery have received considerable attention. This has included research on surgical technique factors such as tunnel position, graft choices, and fixation methods, as well as post-operative rehabilitation protocols.

A prospective study of a cohort of ACL reconstructed patients 7 years after surgery revealed degenerative radiographic changes in 95%[2,3] of patients, and only 47% were able to return to their previous activity level following ACL reconstruction.[4] However, it should be noted that some studies of long-term follow-up have more encouraging results. Järvelä et al.,[5] demonstrated tibiofemoral degenerative changes in only 18% of patients at 7 years follow-up post-ACL reconstruction with bone–patella–bone grafts. In addition, Roe et al.,[6] reported on a cohort of patients reconstructed with bone–patellar

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tendon–bone grafts and found an incidence of 45% with degenerative radiographic changes at 7 years follow-up, as well as an incidence of 14% with degenerative changes in a group with hamstring grafts. A thorough review of the anatomy and biomechanics of the normal ACL reveals key points regarding its complex role in stabilization of the knee joint. Improved awareness of the anatomy and biomechanical properties of the normal ACL may lead to improvements in techniques for ACL reconstruction and an associated improvement in outcomes over traditional results.

The ability to predict the length of the hamstring graft preoperatively is of great importance and may help the surgeon in the decision-making to achieve an acceptable diameter for the autograft in ACL reconstruction.[7]

Autograft selection is important for ACL reconstruction.[8] Anthropometric parameter that was first studied as a predictor of semitendinosus autograft size is also the strong predictor of semitendinosus autograft diameter and length. As semitendinosus autograft is the recent gold standard choice of graft in ACL reconstruction surgery due to easy harvesting techniques and lesser donor site morbidity, this study was helpful to increase the success of choosing this graft based on pre-operative anthropometric data.

Aims and objectives

The objectives of this study were to find the correlation between semitendinosus graft dimensions with respect to patients anthropometry such as age, height, weight, body mass index (BMI), and true Leg Length (TLL).

MATERIALS AND METHODS

The proposed study was an institution-based single-centered longitudinal study conducted at the Department of Orthopedics, "IPGME and R and SSKM Hospital" for 20 months duration after getting prior approval from the Institutional Ethical Committee with EIC Number "Memo No. IPGME and R/IEC/2020/584, Date: August 10, 2020" The patients attending Orthopedics-outpatient department and emergency with ACL injury were screened and recruited based after fulfilling the inclusion criteria. The study period was from January 2020 to August 2021 (20 months duration) and a sample size of 30 cases of full-thickness ACL Tear were taken.

Inclusion criteria

The following criteria were included in the study:

1. Adult Age group (20–60 years)
2. Type of injury: Full-thickness ACL tear
3. Fresh tear <3 weeks old to variable period
4. Those willing to participate in the study through signing of consent form.

Exclusion criteria

The following criteria were excluded from the study:

1. Patients with comorbid conditions not fit for surgery
2. Old age related degenerative tears
3. ACL tears with associated fractures of Tibia and Femur
4. Patient unwilling to undergo surgery
5. Multiligamentous laxity and injury.

This is an institution-based longitudinal study to find the correlation between two parameters, that is, ACL graft dimensions and patient's anthropometry. The parameters studied were the age of the patients (years), height of patient (using Stadiometer in centimeters), weight of patient (using weighing machine in kgs), BMI of patient (kg/m^2), true length of leg (from anterior superior iliac spine to the tip of medial malleolus tip in meters), graft diameter (mm), and graft length in (cm).

Patient's history was taken and name, age, and gender recorded. Mode and time of injury were noted. The affected limb was thoroughly examined to rule out multiligamentous laxity. The patients underwent thorough clinical examination with X-rays of the affected knee (anterior posterior [AP] and lateral views, ultrasonography of affected knee in selective cases, magnetic resonance imaging of the affected knee with both T1 and T2 weighted images. Before surgery, all patients were evaluated medically for hypertension, heart disease, diabetes, chronic obstructive pulmonary disease, cerebrovascular disease, and urinary tract infection to minimize any potential risk for surgery. Analgesics, antibiotics, and proper care of any associated injury and associated comorbidities, if any, were taken into consideration. Demographic and anthropometric data of all the patients who are admitted in the ward were taken (Case Record form).

Pre-operative preparations

All patients admitted and selected for operative method of treatment underwent the pre-operative work up as per standard protocol and written and informed risk consent for surgery and anesthesia were taken. The surgery can be performed under spinal anesthesia or general anesthesia.

Patient position

The patient is positioned supine on the operating table and the pneumatic tourniquet is placed as high as possible on the thigh to allow sufficient distance from the exit point of the Beath needles in the lateral thigh.

The tourniquet is inflated only during graft harvest. A thigh support is placed at the level of the tourniquet cuff, while a

foot bar is positioned at the end of the table to enable the knee to be fixed at 90° of flexion during surgery while at the same time still allowing free range of motion (ROM).

Skin incision (Figure 1)

A 3 cm oblique incision centered approximately 5 cm below the medial joint line, midway between the tibial tubercle and the posteromedial aspect of the tibia, is performed.

The sartorial fascia is incised, and the semitendinosus tendon is dissected and detached proximally with a tendon stripper.

The distal limb of the tendon is detached along with a tibial bone plug and periosteum with the use of an osteotome.

To achieve, the desired 7-cm quadrupled graft construct (2 cm inserted in the femoral tunnel, 3 cm intraarticular, and 2 cm inserted in the tibial tunnel), the required minimum tendon length would be 28 cm (range 28–30 cm).

Alternatively, semitendinosus tendons that are shorter than 28 cm can be prepared in a tripled configuration.

Graft harvest and preparation (Figure 2)

Quadrupled semitendinosus graft

All the muscle tissues attached to the tendon are removed with the use of a curette. Once devoid of excess tissues, the tendon is folded in a quadrupled fashion with Ethibond tied. Before suture placement on the tendon construct, the depth of the femoral tunnel is measured to determine the appropriate size of the Endobutton-Closed Loop to be used.

Once the proper size is chosen, the Endobutton is then positioned in the quadrupled construct's end. Both ends of the graft are then whipstitched using#5 non-absorbable sutures.

Measurement of the graft

Diameter follows, using 0.5-mm increment sizers to match this with the diameter of the femoral and tibial lengths and length is measured with a scale as shown in the figure once in place, the grafts are pre-tensioned and preconditioned prior to fixation with cyclical flexion and extension of the knee under maximum manual tension.

Arthroscopic ACL reconstruction (Figure 3)

A standard anterolateral portal is created through which the arthroscope is inserted followed by an anteromedial portal, where instruments can be introduced. While the graft is being prepared at the back table, tunnel preparations are completed. The tibial tunnel is prepared with the ACUFEX aimer and the femoral tunnel is drilled. Femoral fixation is achieved with the Endobutton connected to the graft, while tibial fixation is obtained with a titanium Fastlok device.

Rehabilitation protocol

From the 1st post-operative day, foot and ankle mobilizing exercises and static quadriceps exercises were started. Patients were allowed to bear weight on the affected limb as per pain tolerance keeping long knee brace on. Patients were encouraged to do knee bending as per pain tolerance from the 1st post-operative day. From the 14th post-operative day onward, active ROM exercises of the affected knee were started along with increased static and dynamic quadriceps strengthening exercises. Patients were encouraged to bear weight on the affected limb and independent ambulation without long knee brace was encouraged from 2 to 3 weeks onward.

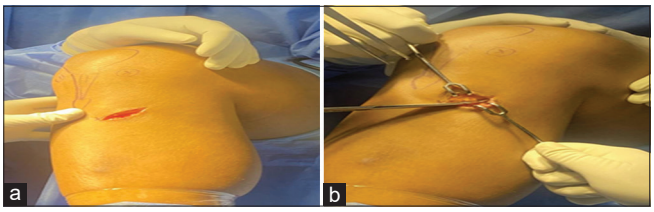

Figure 1: (a and b) Skin incision and graft harvesting

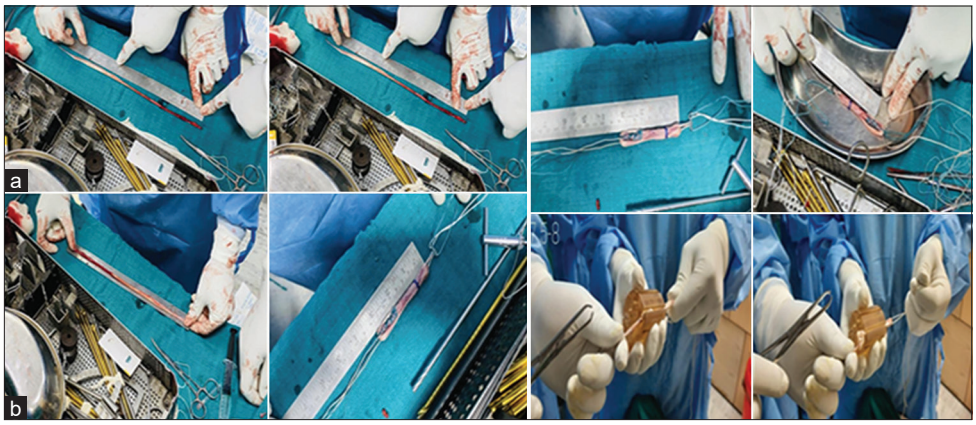

Figure 2: (a and b) Graft Sizing

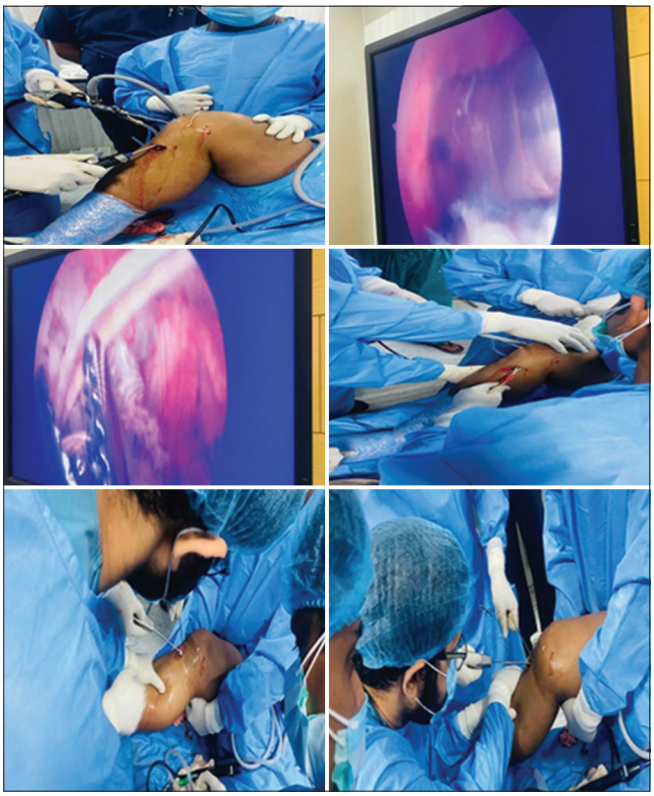

Figure 3: Arthroscopic anterior cruciate ligament reconstruction

Follow-up protocol

Sutures were removed 2 weeks after surgery. AP and lateral radiographs of the affected knee were obtained at post-operative 2 weeks, 4 weeks, 2 months, 3 months, 6 months, 1 year, and 2 years. On each visit patients were evaluated clinically for knee ROM, presence, or absence of pain, any wound site complications.

Statistical analysis

For statistical analysis, data were entered into a Microsoft excel spreadsheet and then analyzed by SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism version 5(2010). Data had been summarized as mean and standard deviation for numerical variables and count and percentages for categorical variables. Correlation was calculated by Pearson correlation analysis. The Pearson product-moment correlation coefficient was a measure of the linear dependence between two variables X and Y. P≤0.05 was considered for statistically significant.

RESULTS

This study consisted of 30 patients with

Mean value of age was 35.9 years, mean value of height was 173 cm, mean value of weight was 73 kg, mean values of BMI was 24.83 kg/m^2, mean TLL was –89.55 cm, mean graft diameter was 8 mm, and mean autograft length was 8 cm (Tables 1 and 2).

Table 1: Distribution of mean age, height, weight, BMI and true leg length

Parameters	Mean	Median±SD	Max	Min
Age (years)	35.9	26.5±7.82	48	18
Height (cm)	173	170±4.67	178	160
Weight (kg)	73	68.5±9.1	92	58
BMI (kg/m2)	24.83	24.23±2.98	34.21	20.7
True leg length (cm)	89.55	88.5±6.57	110	78

BMI: Body mass index

Table 2: Distribution of mean graft length and graft diameter

Parameter	Mean	Median±SD	Max	Min
Graft length (cm)	8	8±0.41	8.6	7.5
Graft diameter (mm)	8	7.8±0.38	8.8	7

About 26% (8) patients had average graft length of 8 cm, 21% patients had average graft length of 7.8 cm, 10% patients had average graft length of 8.25 cm, and 6% patients had average graft length of 8.5 cm.

No patient had graft length below 7 cm. No patient had graft diameter below 7.5 mm. From Pearson's correlation test and simple linear regression analysis (Table 3), we found that

Positive correlation was found in

The age has positive correlation with graft length (r=0.11) and relatively strong positive correlation with graft diameter (r=0.437). Height has relatively strong positive correlation with graft length (r=0.4258) and graft diameter (r=0.1375). Weight has strong positive correlation with graft length (r=0.604). TLL has positive correlation with graft length (0.23) and graft diameter (r=0.1).

Negative correlation was found in

Weight was negatively correlated with graft diameter (r=−0.016). BMI was negatively correlated with graft diameter (r=−0.116).

Autograft length

- Autograft length=0.0187×Age (years)+7.4362
- Autograft length=0.0429× Height (cm)+0.7736
- Autograft length=0.0313× Weight (kg)+5.815
- Autograft length=0.016×TLL (cm)+6.6733.

Autograft diameter

- Autograft diameter=0.0045× Age (years)+7.7649
- Autograft diameter=0.0051× Height (cm)+7.0512
- Autograft diameter=0.0049× TLL (cm)+7.4976.

Very young, short height, and light weight patient with short TLL measurements tend to have smaller autograft length, while very young heavy weight patient with higher BMI and shorter TLL had smaller autograft diameter in our study.

Table 3: Correlation of age, height, weight, BMI, and true leg length with graft length and graft diameter

Correlation of parameters	Pearson	P-value
Age		
Graft length	0.11	0.380
Graft diameter	0.437	0.3733
Height		
Graft length	0.4258	0.05
Graft diameter	0.1375	0.004
Weight		
Graft length	0.604	0.118
Graft diameter	–0.016	0.12
BMI		
Graft length	–0.71	0.19
Graft diameter	–0.116	0.198
True leg length		
Graft length	0.28	0.05
Graft diameter	0.1	0.05

BMI: Body mass index

Patients with body weight <58 kg, <160 cm in height, and <78 cm TLL should be considered at high risk for having semitendinosus autograft diameter <7 mm and length <7.5 cm.

DISCUSSION

Autograft selection is important for ACL reconstruction. Pre-operative selection should normally consider autograft volume, strength, donor site morbidity, availability, patient activity level, lifestyle, and personal preferences. The ability to predict the length of the hamstring graft preoperatively is of great importance and may help the surgeon in the decision-making to achieve an acceptable diameter for the autograft in ACL reconstruction.

This is a prospective study in 30 patients who underwent ACL reconstruction using semitendinosus autograft in our institution.

Pichler et al.,[9] Pinheiro et al.,[10] and Ma et al.,[11] showed that height is the best predictor among anthropometric data in hamstring graft size.

Moghamis et al.,[7] showed that patient's height and thigh length demonstrated a positive correlation with gracilis graft length (r=0.464, P=0.001, r=0.456, P=0.001, respectively) and semitendinosus graft length (r=0.541, P=0.000, r=0.578, P=0.000, respectively). While the patient's age was the only independent factor which had a positive correlation with the quadrupled hamstring graft diameter (r=0.412, P=0.004), multiple regression analysis showed that abdominal girth had a significant negative correlation with gracilis (P=0.04) and semitendinosus (P=0.006) graft thickness.

Pereira et al.,[12] showed a positive correlation between the height and total diameter of the quadruple graft (r=0.254; P=0.043), total length of the ST tendon (r=0.450; P<0.01), diameter of the double ST (r=0.270; P=0.031), triple ST (r=0.347; P=0.005), length of G tendon (r=0.249; P=0.047), and diameter of the double-G (r=0.258; P=0.039). However, age (r=−0.015; P=0.908), weight (r=0.165; P=0.193), and BMI (r=0.012; P=0.926) showed no correlation.

Kumar et al.,[13] study comprised 73 male participants whose mean age was found to be 33.7 years, mean height was 173.1 cm, mean weight was 71.2 kg, mean BMI was 23.7 kg/m^2, mean thigh circumference was 50.4 cm, and the obtained mean graft diameter was 8.0 mm. A strongly positive correlation was observed between height and the graft diameter (r=0.940, P=0.000) and thigh circumference and the graft diameter (r=0.769, P=0.000). In contrast, weight showed a moderately positive correlation with the graft diameter (r=0.514, P=0.000). A very weakly positive correlation was observed between the BMI of the subjects and the obtained graft diameters (r=0.236, P=0.045). However, no correlation was observed between the age and the final graft diameters (r=0.140, P=0.238). Subsequent linear regression analysis indicates that only height (R^2=0.883, P=0.000; strong) and the thigh circumference (R^2=0.591, P=0.000; moderate) share a significant predictive value for the obtained QHAG. Both height and thigh circumference together were good predictors for graft diameter as determined by multiple regression (F [2,70]=272.372, P<0.001), with an R^2 of 0.886.

We found that age, weight, height, and TLL have positive correlation with Semitendinosus graft length. While age, height, and TLL have a positive correlation with semitendinosus autograft length, height, and weight which have the strongest correlation with semitendinosus autograft length (R=0.425, P<0.05 and R=r=0.604, P≤0.05), whereas age has the strongest positive correlation with Graft Diameter (r=0.437, P<0.05). The age has very weak association with graft length variation, while TLL has weak association with graft diameter variation that is they do not correlate significantly with the length and diameter of the semitendinosus autograft.

TLL is the anthropometric parameter that was first studied as a predictor of semitendinosus autograft size is also a strong predictor of semitendinosus autograft diameter and length. In this study, the smallest diameter of the semitendinosus autograft was 7 mm. This is one of the advantages of using semitendinosus autografts in ACL reconstruction, where the minimum size to avoid revision surgery is considered as 7 mm. In addition, autograft size is considered as an important factor that influences

the outcome of surgery. The latest study considered that the autograft diameter of no <8 mm is considered as acceptable.

There was a 0.82 times lower likelihood of revision surgery with every 0.5-mm increase of autograft diameter. Semitendinosus also has nearly the same mean width (8.24 mm) as the native ACL (7–12 mm). The other advantage is that it lies superficially in the leg which makes it easy to harvest. All these points supported the conclusion of semitendinosus autograft as a safe and effective autograft alternative in ACL reconstruction surgery.

However, the use of semitendinosus autograft in our institution has just become popular in the recent years. Autograft length is an important component in the ACL reconstruction. An inadequate length may compromise fixation of the autograft in the tibia fixation component. Autograft length of <8 cm is associated with more complications. Thus, one should assure that functional length of the autograft must be 8 cm (2 cm in the femoral tunnel, 4 cm intra-articular, and 2 cm in the tibial tunnel) or more.

Tuman et al.,[14] and Hamner et al.,[15] showed the mean sizes of hamstring grafts range from 7.9 to 8.6 mm, and our results showed that the mean hamstring graft diameter was 8 mm.

We found that the mean of semitendinosus autograft length is 8 cm, this is considered as another advantage of semitendinosus autograft. Although there are differences between authors regarding the relationship of gender to autograft size, several studies have found that female have a risk of having a smaller semitendinosus autograft. We found a significant difference in the diameter and length of the semitendinosus autograft between male and female in this study. There were also statistically significant differences in age, weight, BMI, and TLL, in this study. It can't be identified that gender also affects the diameter and length of the semitendinosus autograft.

A cadaveric study by, Tan et al.,[16] has reported that the ACL in the Singapore Chinese was smaller than those reported in the Western literature and that the size of native ACL is shorter, narrower, and more vertical. Hence, in people who are short, the native ACL in this population was shorter and narrower. Our study also showed similar results, where patients who were young with short height and light weight, with short TLL, had smaller graft lengths.

Further, the research is needed to find out whether or not this equation can be applied to the general Indian population.

CONCLUSION

Age, height, weight, and TLL can be used to predict semitendinosus autograft length, while height and TLL can be used predict semitendinosus autograft diameter. Patients with body weight <58 kg, <160 cm in height, and <78 cm TLL should be considered at high risk for having semitendinosus autograft diameter <7 mm and length <7.5 cm. In these cases, graft may be reinforced with additional Hamstring tendon harvest like Gracilis or any alternative graft such as BPB, peroneus longus tendon autograft may be taken to prevent graft failure and future complications. This current data can be a reference for surgeons in pre-operative planning and counseling to patients about alternative autograft selection.

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Authors Contribution:
TD- Concept and design of the study, preparation of manuscript, review of the literature and revision of the manuscript; **DB-** Concept and Coordination and manuscript preparation; **KM-** Statistical analysis and data interpretation; **SS-** Data Collection and preparation of manuscript.

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