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Research Article

A Prospective Observational Study on Quadriceps Tendon as a Graft for Anterior Cruciate Ligament Reconstruction: Surgical Technique and Graft Dimensions

Mahesh B. Shinde[1,*], Mihir R. Patel[2], Bibhas DasGupta[3], Atharva Sharma[4], Kshitij Sarwey[4], Sanket Jethliya[4], Shreyas Revankar[4], Deepanshu Garg[4], Rohan Bahl[4], Samreen Chunawala[5], Sidharth Mitra[5], Juily Satam[4], Yash Nav Singh[5], Kiara Thakur[5]

[1] Assistant Professor, Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India
[2] Additional Professor, Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India
[3] Professor, Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India
[4] Senior Resident, Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India
[5] Medical Student, Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India

[*] Corresponding author: Mahesh B. Shinde; Department of Orthopedics, H.B.T Medical College and Dr R.N. Cooper Hospital, Mumbai, India. Tel: +91-7983134784
Email: mahesh.shinde.1466@gmail.com

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Abstract

Background: The quadriceps tendon (QT) graft provides better biomechanical strength, less donor site morbidity, and adjustable size, despite the fact that hamstring and bone-patellar tendon-bone (BPTB) grafts are frequently utilized. Recent research indicates similar results of other grafts, despite early reservations. In order to validate the QT graft's efficacy and dependability in clinical settings, this study will detail the surgical procedure for anterior cruciate ligament (ACL) repair and evaluate its three main dimensions: length, diameter, and thickness.

Methods: Fifty patients with ACL injuries who received QT transplants participated in this 24-month prospective research. Patients with isolated ACL injuries and a normal body mass index (BMI) between the ages of 20 and 50 were eligible. Grafts were harvested, processed, and their thickness, diameter, and length were measured. Suspensory fixation was done and anatomical tunnels were made. The following day, rehabilitation got underway. A proforma was used to collect and analyze the data. Informed consent and institutional ethics approval were acquired.

Results: In a study of 50 patients with ACL restoration, 84% had QT grafts of appropriate length (mean: 28.7 cm), while 70% had sufficient quadrupled lengths (mean: 7 cm). The majority of grafts' diameter (96%, mean: 8.6 mm) and thickness (94%, mean: 6.8 mm) fell within the acceptable parameters. These findings show that QT grafts consistently produced adequate dimensions for ACL restoration, demonstrating their dependability and efficacy.

Conclusion: The QT graft offers a consistent, adequate tissue source for ACL reconstruction, ideal for active patients needing strong, durable grafts.

Keywords: Arthroscopy; Grafts; Quadriceps Muscle; Semitendinosus; Anterior Cruciate Ligament

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Background

Anterior cruciate ligament (ACL) injuries are becoming increasingly prevalent, particularly among athletes (1). Arthroscopic reconstruction is currently regarded as the standard of care for managing these injuries (2). The most commonly used autografts for ACL reconstruction include the semitendinosus, gracilis, bone-patellar tendon-bone (BPTB), and quadriceps tendon (QT) grafts (3). Each graft option has inherent limitations (4).

BPTB grafts, although widely used, are associated with anterior knee pain - especially during kneeling - and potential complications such as patellar tendon rupture or patellar fracture (5). Hamstring autografts offer advantages including preservation of quadriceps function, reduced anterior knee pain, and a lower risk of patellar complications compared with BPTB grafts (6). However, harvesting the semitendinosus and gracilis tendons may result in complications such as saphenous nerve injury, donor-site pain, medial collateral ligament (MCL) injury, premature graft amputation, and transient hamstring weakness (7). A thorough understanding of anatomy and meticulous harvesting techniques is essential to minimize these risks and improve outcomes. Despite numerous graft options, the optimal graft choice remains a subject of ongoing debate (8).

Although the QT was first described as an ACL graft in 1984, its use has gained increasing popularity in recent years (9). The QT graft exhibits excellent biomechanical properties, with an ultimate failure load ranging from 2119 to 2352 N - exceeding that of the native ACL (1725-2160 N) and comparable to hamstring grafts (up to 4090 N). It is also nearly twice as stiff as the native ACL (466.2 N/mm vs. 242 N/mm). Studies have shown that QT grafts demonstrate the highest stiffness modulus and the most organized collagen fiber alignment compared with BPTB and hamstring tendon grafts (10), whereas hamstring tendons show the lowest modulus and the least organized collagen structure. These biomechanical characteristics support the QT as a strong and reliable graft option for ACL reconstruction (11).

The QT can be harvested as a partial-thickness graft,

often using minimally invasive techniques, allowing customization of graft dimensions while minimizing anterior knee pain (12). However, potential harvest-related complications such as patellar fracture or inadequate graft length must be considered. Short-term studies report graft failure rates and patient-reported outcomes comparable to those of hamstring and BPTB autografts (13). The relatively low donor-site morbidity of the QT makes it an attractive option for both primary and revision ACL reconstruction, particularly when tunnel size or positioning necessitates a larger graft (14). Nevertheless, some studies have reported persistent postoperative quadriceps weakness following QT harvest (15).

Overall, current evidence suggests that QT autografts offer lower donor-site morbidity with clinical outcomes comparable to other commonly used autografts (16). However, long-term, high-quality studies are required to identify patient populations that may benefit most from QT use. Given its superior strength, customizable dimensions, reduced anterior knee pain, and favourable maturation characteristics, the QT represents a promising graft choice for ACL reconstruction.

The aim of this study is to describe the surgical technique of ACL reconstruction using the QT graft and to measure graft dimensions, including length, diameter, and thickness.

Methods

This is a 24-month prospective observational study (anatomical feasibility study) of 50 patients with ACL tears who have been identified and operated on. The institutional ethics [Institutional Review Board (IRB)] committee (HBTMC/IEC/017-2025/R1/RP/335/07072025/26-dated 07/07/2025) provided approval. Data were gathered using the clinical history proforma, and patient information was documented at a tertiary care facility. The study comprised patients who presented to the orthopedic department using predetermined inclusion and exclusion criteria.

The study comprised patients with solitary ACL injuries, ACL tears with or without accompanying meniscus injuries (single cruciate ligament damage), fused epiphysis, and age groups ranging from 20 to 50 years. Patients with open injuries, associated posterior cruciate ligament (PCL) injury, MCL or lateral collateral ligament (LCL) injuries, ACL re-injury, ipsilateral lower limb fractures around the knee, and prior surgery on or around the same knee were excluded. Patients who volunteered to participate in the study provided signed informed consent.

Preoperative evaluation involved assessing general health and thoroughly examining the affected knee. Patient's anteroposterior (AP) and lateral views of the affected knee were carried out along with magnetic resonance imaging (MRI).

The patient was induced under spinal anesthesia. A tourniquet was applied with appropriate pressure and time. The patient was placed in the supine position, with the well leg supported on a soft pillow. The operative leg was prepped to allow full flexion and extension during the procedure. The entire limb was scrubbed. Draping was done to isolate the surgical field. The tourniquet was inflated to a pressure of 300 mmHg. Surface anatomical landmarks were palpated and marked as the patella, patellar tendon, medial and lateral joint line, medial and lateral femoral condyles, tibial crest, and posteromedial edge of the tibia (Figure 1).

Figure 1. Surface landmarking

Standard portals were made as the anterolateral portal, anteromedial portal, and accessory anteromedial portal. Diagnostic arthroscopy was done to confirm an ACL tear.

Tendon Harvest for the Quadriceps: A 3 cm incision was made 3 cm proximal to the patella's superior pole, halfway between the quadriceps' medial and lateral margins. Blunt dissection was done to expose the glistening white fibres of the QT. Five centimeters laterally from where the vastus medialis obliquus (VMO) muscle inserts, a single-fiber split incision was made. Figure 2 shows a partial thickness graft of the superficial quadriceps, which is 5 mm thick.

Figure 2. Incision and distal graft harvest

For easier access, the knee was extended, and the incision was made all the way distally to the patella's superior pole. Sharp dissection was used to remove the tendon from the patella's superior pole. A closed stripper was used to extract the tendon (Figure 3).

Figure 3. Graft harvesting

Graft Preparation: The harvested tendon was hydrated, trimmed, and adipose tissue and muscle fibres were stripped off. The two ends were whip-stitched using a number two non-absorbable suture. It was then measured using a scale and sizing block. Tendon length was measured, and it was folded twice on itself to make it quadrupled. Dimensions of graft, including diameter, thickness, and length, were measured (Figure 4).

Figure 4. Graft measurement

Ends were reinforced, and the four strands were secured together with non-absorbable sutures. The wound was closed with sutures, and a post-op dressing was done (Figure 5).

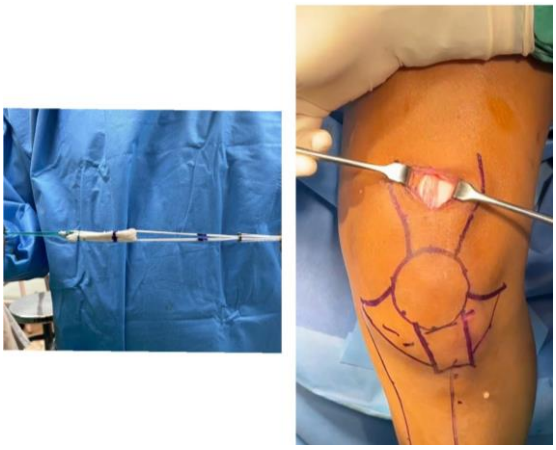

Figure 5. Final graft with donor site

Tunnel Creation: The femoral tunnel was drilled first, using the native ACL footprint as a guide for anatomical placement, followed by the tibial tunnel. Tunnel sizes matched the graft diameter.

Graft Insertion and Fixation: It involved passing the graft through the tibial tunnel first, followed by the femoral tunnel. Suspensory fixation of the quadriceps graft was done both on the femur and tibia. Graft was tensioned with the knee in flexion. Stability was checked arthroscopically. Wound was closed over layers. Rehabilitation included quadriceps strengthening, and knee range of motion (ROM) exercises were started gradually the next day after surgery.

Statistical Analysis: A case record (proforma) was filled out by an investigator using the interview technique. The QT graft dimensions were entered and compiled in Microsoft Excel and were analyzed. The collected data were tabulated in an Excel sheet under the guidance of a statistician. No hypothesis testing was intended as it was a technique and anatomical feasibility study. Statistical analysis was conducted using means and standard deviations (SDs) of the measurements for each group via SPSS software (version 22.0, IBM Corporation, Armonk, NY, USA).

Results

In this study, 50 patients underwent ACL reconstruction using QT grafts. Of these, 38 were men and 12 were women, reflecting the higher incidence of ACL injuries in men, consistent with existing literature. The mean patient age was 28 years, representing a predominantly young and physically active population. Injuries occurred more frequently in the right knee than the left. Sports-related activities were the most common mechanism of injury, underscoring the elevated risk of ACL tears among athletes and individuals engaged in high-demand physical activities (Table 1).

Table 1. Demography

	Value
Mean age (year)	28
Gender [n (%)]	
Men	38 (76)
Women	12 (24)
Side [n (%)]	
Right	30 (60)
Left	20 (40)
Mechanism of injury [n (%)]	
Sports	25 (50)
Road traffic accident	15 (30)
With a meniscus injury	10 (20)
Total	50 (100)

With respect to QT graft length, 84% of patients had grafts within the recommended range of 26-30 cm, considered optimal for adequate graft strength and fixation. A smaller proportion of grafts measured less than 26 cm (6%), while 10% exceeded 30 cm. The mean graft length was 28.7 cm, indicating consistent harvesting of appropriately sized grafts (Table 2).

Table 2. Quadriceps tendon (QT) graft length

QT graft length (cm)	n (%)
<26	3 (6)
26-30 (recommended range)	42 (84)
>30	5 (10)
Total	50 (100)

Mean quadriceps tendon (QT) graft length: 28.7 cm
QT: Quadriceps tendon

After quadrupling the graft to enhance thickness and strength, 70% of grafts measured within the recommended length of 6.5-7.5 cm. Additionally, 18% measured between 5.5 and 6.5 cm, 4% were shorter than 5.5 cm, and 6% exceeded 7.5 cm. The mean quadrupled graft length was 7.0 cm, supporting the adequacy of graft size for reconstruction (Table 3).

Table 3. Quadriceps tendon (QT) graft length when quadrupled

QT graft length (quadrupled) (cm)	n (%)
<5.5	2 (4)
5.5-6.5	10 (20)
6.5-7.5 (recommended range)	35 (70)
>7.5	3 (6)
Total	50 (100)

Mean quadriceps tendon (QT) graft length (quadrupled): 7 cm
QT: Quadriceps tendon

Regarding graft diameter, 96% of QT grafts were within the recommended range of 7-11 mm, with the remaining 4% exceeding this range. Notably, no graft measured less than 7 mm in diameter. The mean graft diameter was 8.6 mm, which falls within the optimal range for providing sufficient biomechanical strength and stability (Table 4).

Table 4. Quadriceps tendon (QT) graft diameter

QT graft diameter (mm)	n (%)
<7	0 (0)
7-11 (recommended range)	48 (96)
>11	2 (4)
Total	50 (100)

Mean quadriceps tendon (QT) graft diameter: 8.6 mm
QT: Quadriceps tendon

Graft thickness measurements showed that 94% of grafts were within the recommended range of 6-11 mm. Only 2% were thinner than 6 mm, while 8% exceeded 11 mm. The mean graft thickness was 6.8 mm, further confirming the suitability of graft size and quality for successful ACL reconstruction (Table 5).

Table 5. Quadriceps tendon (QT) graft thickness

QT graft length (cm)	n (%)
<6	1 (2)
6-11 (recommended range)	47 (94)
>11	2 (4)
Total	50 (100)

Mean quadriceps tendon (QT) graft thickness: 6.8 mm
QT: Quadriceps tendon

Overall, these findings indicate that QT grafts harvested in this study were generally of appropriate length, diameter, and thickness to meet surgical requirements, supporting their use as a reliable option for ACL reconstruction.

Discussion

ACL tears are increasingly common due to rising participation in sports and a growing number of road traffic accidents (RTAs). Common graft options for ACL reconstruction include hamstring tendons, BPTB, and QT grafts. QT grafts represent a reliable option for ACL reconstruction because of their high stiffness and well-organized collagen architecture. They are nearly twice as stiff as the native ACL and demonstrate an ultimate failure load ranging from 2119 to 2352 N.

This study evaluated QT graft characteristics in 50 patients undergoing ACL reconstruction, providing insight into graft dimensions and patient demographics. The predominance of male patients (n = 38, 76%) aligns with established epidemiological data indicating a higher incidence of ACL injuries in men, likely related to greater participation in high-impact sports and physically demanding activities. The mean patient age of 28 years reflects the typical demographics affected by ACL injuries – young, active individuals with high functional demands requiring durable graft choices. Similar age distributions have been reported by Johnson et al., who documented a mean age of 26.3 years and a median age of 25 years, with patients ranging from 17 to 48 years (17). In their study, most patients were between 15 and 25 years of age, with men accounting for 92% of cases.

Gong et al. evaluated 25 patients aged 17-43 years (mean age: 25.8 years) and reported sports-related injuries in 68%, falls in 24%, and RTAs in 8% of cases (18). The higher incidence of right-sided ACL injuries observed in our cohort may be related to limb dominance or activity-specific movement patterns, although further investigation is required to confirm this association. Tayeb et al. similarly reported a predominance of right-sided ACL injuries (62.5%) (19), while Krüger-Franke et al. observed associated lateral and medial meniscal tears in 55% and 45% of patients, respectively (20).

Analysis of QT graft dimensions in our study revealed that most harvested grafts met recommended parameters for length, diameter, and thickness. Specifically, 84% of grafts measured 26-30 cm in length, with a mean length of 28.7 cm, indicating adequate tissue availability for robust graft construction. After quadrupling, 70% of grafts fell within the optimal length range of 6.5-7.5 cm, with a mean of 7 cm, supporting secure fixation and appropriate graft tension. Krebs et al. reported a mean QT length of 83.3 ± 14.4 mm (range: 63-108 mm) (21), while Dworsky-Fried et al. documented an average QT length of 8.1 cm (SD: 1.3, range: 5.6-9.3 cm), confirming the consistency of QT graft dimensions across populations (22).

Graft diameter, which has been associated with postoperative stability and reduced failure rates, was within the recommended range of 7-11 mm in 96% of cases, with a mean diameter of 8.6 mm. Dworsky-Fried et al. reported a comparable weighted mean QT graft diameter of 8.9 mm (SD: 0.7, range: 7.8-10.4 mm), further supporting the reliability of QT graft sizing (22). Graft thickness in our study predominantly ranged between 6 and 11 mm, with a mean thickness of 6.8 mm. Xerogeanes demonstrated that the QT was nearly twice as thick as the patellar tendon, allowing for customizable graft diameters and making it suitable for both primary and revision ACL reconstructions (23). Lee et al. reported that an 8-mm QT graft provided greater ultimate tensile strength than a 10-mm patellar tendon graft, and even a 6-mm QT graft demonstrated comparable strength, indicating that narrower QT grafts could still offer sufficient biomechanical stability (24).

Overall, these findings support the QT as a reliable graft option with favorable dimensions that meet surgical requirements for ACL reconstruction. Compared with hamstring and patellar tendon grafts, QT grafts offer adequate length and volume with potentially lower donor-site morbidity. Additionally, the consistency of QT graft dimensions may facilitate surgical planning and contribute to improved clinical outcomes.

Limitations of this study include the relatively small sample size and lack of long-term clinical follow-up, which is necessary to correlate graft dimensions with functional results and graft survivorship. Future research should also compare QT graft outcomes with other autografts in diverse populations to better define its role in ACL reconstruction.

Conclusion

The QT graft provides a reproducible and adequate tissue source for ACL reconstruction, particularly suitable for active patients requiring durable grafts with optimal biomechanical properties.

- Ethics approval and consent to participate: Ethics committee approval was taken from IRB.
- Consent for publication: Consent was taken from all the participants.
- Availability of data and materials: The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare no conflict of interest in this study.

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