Original Article
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Preoperative Templating of Bone-Patellar Tendon-Bone Graft for Anterior Cruciate Ligament Reconstruction: A Morphometry-Based Graft Harvest Method

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Background: Knowledge of anatomy and morphometry of the patella and patellar tendon is crucial for the selection of bone-patellar tendon-bone (BTB) graft for anterior cruciate ligament reconstruction. Graft tunnel mismatch in BTB graft especially in patients with patella alta or baja can result in compromised fixation for the bone-to-bone healing. This complication can be avoided by proper templating of graft using parameters measured from magnetic resonance imaging (MRI). The study aimed to derive morphometric data from MRI and predict the suitability of BTB graft preoperatively.

Methods: MRI of 1,002 knees was chosen from database after applying the eligibility criteria, which included individuals in the age group of 18–50 years (both sexes) with the intact patella and patellar tendon. Individuals with pathologies of the knee joint and associated structures such as patellar fracture/dislocations, fractures of the distal femur and proximal tibia, and avulsion of the quadriceps tendon or patellar tendon were excluded. For analysis, 1.5 Tesla, proton density, and fat-suppressed sequences of sagittal and axial sections of T2-weighted MRI images were used.

Results: Mean age of the 1,002 patients was 35.45 years and there were 290 women and 712 men. Respective measurements were as follows: patella length, width, and thickness, 40.3 mm, 40.2 mm, and 18.6 mm, respectively; patellar tendon length, width, and insertional thickness, 45.2 mm, 27.2 mm, and 5.7 mm, respectively; Insall-Salvati ratio, 1.13; overall graft length, 90.2 mm; and effective tendon length, 26.1 mm.

Conclusions: A simple MRI analysis can give us valuable inputs on BTB graft morphometry. The values can also help us with the near-perfect graft harvest. The intraoperative complication of graft tunnel mismatch can be avoided by predicting the overall graft length, effective tendon length, tibial tunnel length, and patellar position using the measured parameters on MRI.

Keywords: *Bone patellar tendon bone grafts, Anterior cruciate ligament, Magnetic resonance imaging, Preoperative period, Graft tunnel mismatch*

The anterior cruciate ligament (ACL) is one of the most common ligaments to be injured in the knee, which require arthroscopic reconstruction. There are a variety of graft choices for ACL reconstruction (ACLR). Bone-patellar tendon-bone graft (BTB) and hamstring grafts (semitendinosus gracilis) are most commonly used. A survey published by an ACL study group in 2021[1] studied the evolution of ACLR graft choice over three decades.

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According to their data, in the early 1990s, the most frequent graft choice (nearly 90%) for primary ACLR was BTB autograft. Later, hamstring tendon autografts increased in popularity (currently, over 50%), followed by BTB autograft (just under 40%). Other scientific shreds of evidence[2-4] prove the resurgence of BTB graft. A graft-tunnel mismatch is a condition in which the ACL BTB autograft does not match the intra-articular and tunnel length. It can result in compromised fixation for bone-to-bone healing when using a BTB autograft. The use of BTB autografts in a patient with patella baja or alta can increase the likelihood of graft tunnel mismatch. Proper preoperative planning can help avoid graft tunnel mismatch.[5] In view of the increase in the use of BTB as a graft option for ACLR, knowledge of anatomy and morphometry of the patella and patellar tendon is crucial for understanding the pathologies, as well as predicting the choice of autografts in an individual.[6]

Though studies involving X-ray-based patellar indices are ample in number, there is very little data available on magnetic resonance imaging (MRI)-based measurements.[7,8] MRI is the gold standard imaging modality in detecting ACL injury with 97% sensitivity and 100% specificity with an added advantage to rule out other concomitant injuries around the knee joint.[9] Knowledge of appropriate graft source and graft size is vital for a surgeon to avoid both inadequate harvest and or need for augmentation.[6]

The primary objective of our study was to assess the dimensions of the patella and patellar tendon on MRI and derive morphometric data from the study population. The secondary objective was to suggest or give recommendations on how these dimensions will help in the preoperative templating of BTB graft. The secondary objective of the study was to determine if the BTB graft can be used as a graft option in a patient using the dimensions from MRI. By applying the dimensions from the primary objective, parameters like overall graft length (OGL), patella position, tunnel length, effective tendon length (ETL), and size of the tibial bone plug with extension can be estimated and checked for the feasibility of the graft in a patient prior to surgery.

These preoperative measurements would help to decide if harvesting the patellar tendon is feasible or not prior to surgery. These parameters would also provide surgeons with a clearer understanding of expected graft sizes and the thickness of the patella to harvest accurate bone blocks to avoid graft harvest complications, and aid in calculating the appropriate tunnel lengths. Proper preoperative planning reduces operative time and decreases complication rates. Hence, we hypothesized that measuring the overall graft dimensions in an MRI film would aid in avoiding the graft tunnel mismatch and provide a better postoperative outcome.

METHODS

Approval was obtained from the Ethics Committee of Sri Ramachandra Institute of Higher Education and Research (No. CSP/MED/19/JUL/54/92). The informed consent was waived.

This retrospective study analyzed the MRI films of knee joints taken between June 2014 and December 2020 from Picture Archiving and Communication System (PACS) of our institute. Various patella and patellar tendon indices were measured. Inclusion criteria were individuals in the age group of 18–50 years (both men and women) with an intact patella and patellar tendon. Individuals with pathologies of the knee joint and associated structures such as patellar fracture/dislocations, fractures of the distal femur and proximal tibia, and avulsion of quadriceps tendon or patellar tendon were excluded from the analysis. Following an initial screening process, knees of 1,002 individuals met the eligibility criteria and were chosen for analysis, and 1.5 tesla, proton density, and fat-suppressed sequences of sagittal and axial sections of T2-weighted images were picked up for the measurement of variables.

The list of parameters measured and radiological reference points of measurement on MRI of each variable is given in Table 1. ETL was measured on the patellar tendon as the distance between the tip of the inferior pole of the patella to a horizontal line drawn 5 mm below the proximal tibial plateau. From the measured values, we derived a few other parameters using the formulas from the existing literature pertaining to the BTB graft, which are listed in Table 2. Insall-Salvati (IS) ratio was measured by dividing the patellar tendon length (PTL) by the length of the patella. OGL was calculated by adding 2.5 cm for the patellar bone plug and 2 cm for the tibial bone plug to the PTL.[10,11] All measurements were made by a single radiologist (SL). Descriptive statistics including mean, range, and two standard deviations of all the study parameters were done for all the recorded variables and tabulated using the Microsoft Excel application.

RESULTS

A total of 1,002 MRI films (579 right knees and 423 left knees) were studied. There were 290 women and 712 men with a mean age of 35.45 years (Table 3). The dimensions

Table 1. Radiological Reference Points of Measurement of Study Parameters

Anatomical part/parameter	Dimension	MRI measurement
Patella	Length (Fig. 1A)	Longest length in a sagittal section
	Width (Fig. 1B)	At the mid-portion in an axial section
	Thickness (Fig. 1B)	At the mid-portion in an axial section
Patellar tendon	Length (Fig. 3)	From the inferior posterior insertion of the tendon to the patella to the superior posterior insertion of the tendon to the tibia
	Width (Fig. 2B)	At the mid-portion of PT in an axial section
	Thickness (Fig. 2B)	At the mid-portion of PT in an axial section
Patellar tendon at the inferior pole of the patella	Insertional width	At the insertion in an axial section
	Insertional thickness	At the insertion in an axial section
Patellar tendon at the tibial tuberosity	Insertional width (Fig. 2B)	At the insertion in an axial section
	Insertional thickness (Fig. 2B)	At the insertion in an axial section
Estimated intra articular ACL length	Effective tendon length (Fig. 5)	Measured on the patellar tendon as the distance between the tip of the inferior pole of the patella to a horizontal line drawn 5 mm below the proximal tibial plateau

MRI: magnetic resonance imaging, PT: patella thickness, ACL: anterior cruciate ligament.

Table 2. List of Parameters Derived from Magnetic Resonance Imaging Data

Derived parameter	Formula
Insall Salvati ratio	PTL / length of the patella
OGL	PTL + 2.5 cm (patellar bone plug) + 2 cm (tibial bone plug)
Length of the tibial bone plug with an extension	OGL – 2.5 cm – effective tendon length

PTL: patellar tendon length, OGL: overall graft length.

Table 3. Demographic Data

Parameter	Value
Mean age (yr)	35.45
Male : female	712 : 290
Knee (right : left)	579 : 423

of the patella and patellar tendon are given in Table 4. The average length of the patella was 40.3 mm, patella width was 40.2 mm, and the thickness of the patella was 18.6 mm (Fig. 1). The measured average length of the patellar tendon was 45.2 mm, width was 27.2 mm, and thickness was 5.7 mm (Fig. 2). The average insertional width and thickness of patellar tendon at the inferior pole of the patella and tibial tuberosity were 28.9 mm and 5.5 mm and 24.7 mm and 5.9 mm, respectively. The average IS ratio was 1.13 (Fig. 3). Patella alta was found in 330 (33 %) patients and 60 (6%) had patella baja. The average OGL was 90.2 mm (Fig. 4), ETL was 26.1 mm (Fig. 5), length of the tibial bone plug with extension (to avoid graft tunnel mismatch) was 39.1 mm. These derived parameters (Table 5) will aid in the preoperative templating of the BTB graft. Fig. 6 shows the harvested BTB graft with tibial tongue.

DISCUSSION

Graft templating prior to ACLR can ease the graft harvest, as well as help the surgeons negate intraoperative complications such as graft tunnel mismatch. Graft-tunnel mismatch is encountered in approximately 13% of all BTB reconstructions,[12] which may lead to intraoperative or postoperative complications. If the graft is relatively long, it will compromise the integrity of interference screw fixation. In contrast, a short graft may result in the blind placement of the tibial interference screw. This can lead to screw divergence, graft laceration, or articular penetration.[13] A recent study comparing the outcomes of BTB and hamstring grafts showed the resurgence of BTB graft as a primary option and found no significant difference in

Table 4. Dimensions of Patella and Patellar Tendon on MRI

Anatomical part/parameter	Dimension	Measured value on MRI (mm)
Patella (mm)	Length (Fig. 1A)	40.3 ± 0.7
	Width (Fig. 1B)	40.2 ± 0.8
	Thickness (Fig. 1B)	18.6 ± 0.4
Patellar tendon (mm)	Length (Fig. 3)	45.2 ± 1.3
	Width (Fig. 2B)	27.2 ± 0.5
	Thickness (Fig. 2B)	5.7 ± 0.5
Patellar tendon at the inferior pole of the patella (mm)	Insertional width	28.9 ± 0.5
	Insertional thickness	5.5 ± 0.3
Patellar tendon at the tibial tuberosity (mm)	Insertional width (Fig. 2B)	24.7 ± 0.5
	Insertional thickness (Fig. 2B)	5.9 ± 0.2
Approximate intra-articular ACL length (mm)	Effective tendon length (Fig. 5)	26.1 ± 1.1

Values are presented as mean ± standard deviation.
MRI: magnetic resonance imaging, ACL: anterior cruciate ligament.

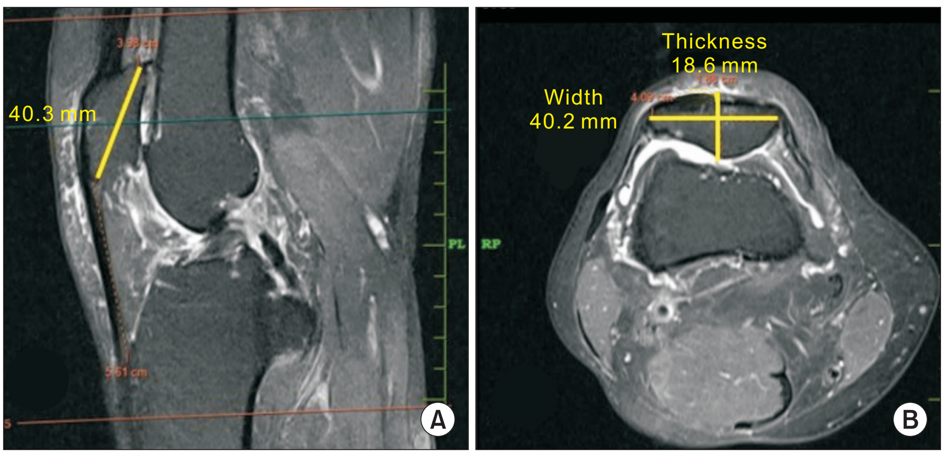

Fig. 1. Dimensions of patella. (A) Patellar height. (B) Patella width and thickness.

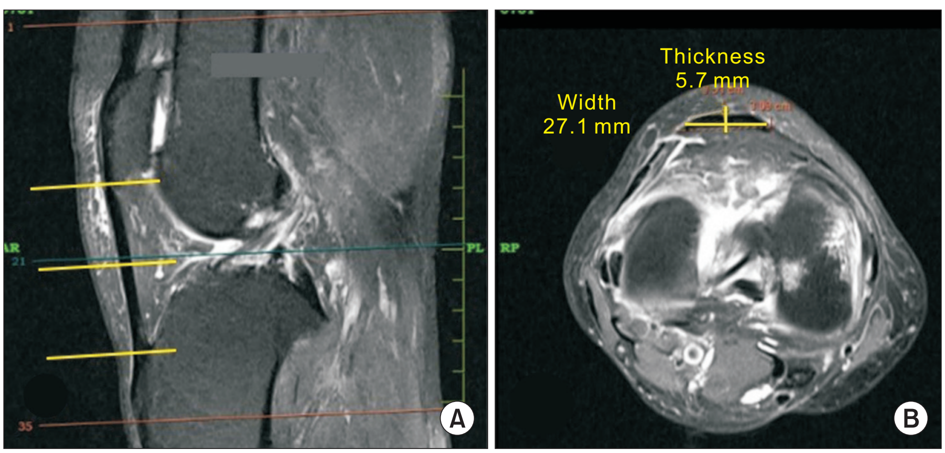

Fig. 2. Dimensions of patellar tendon (A) at three levels. (B) Patellar tendon width and thickness at tibial insertion.

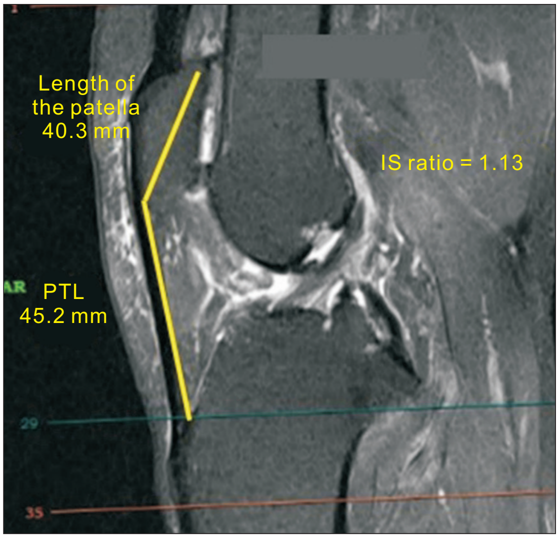

Fig. 3. Insall-Salvati ratio measurement. IS: Insall-Salvati, PTL: patellar tendon length.

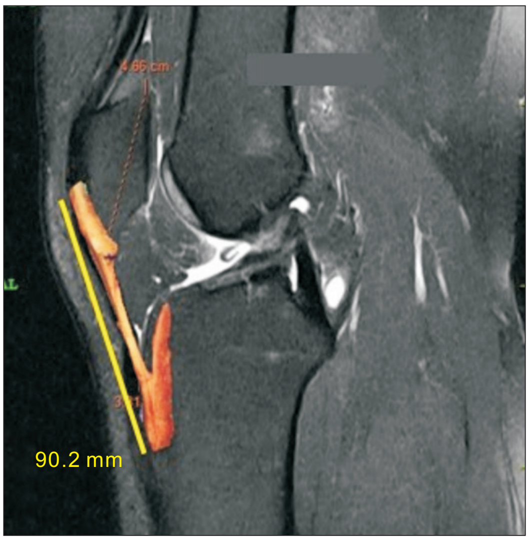

Fig. 4. Illustration of bone-patellar tendon-bone with bone plug over magnetic resonance imaging (overall graft length).

the knee outcome scores (Lysholm score and International Knee Documentation Committee score) at the end of 18 months.[14] MRI is a simple tool that can aid in calculating the expected graft sizes. Though MRI was previously used to determine the patella height in terms of IS ratio,[8] it has been seldom used to calculate the graft size for an ACLR. Agarwal et al.[6] systematically reviewed and explored the utility of preoperative MRI as a tool for predicting intraoperative graft size for several graft options used in ACLR. This review analyzed the following two studies that used MRI to predict BTB graft size.[15,16] Zakko et al.[15] showed moderate to good accuracy of the MRI and intraoperative

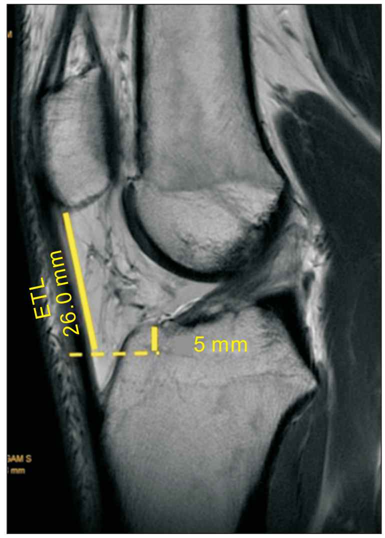

Fig. 5. Measurement of effective tendon length (ETL).

Table 5. Derived Parameters from Magnetic Resonance Imaging Data

Parameter	Value
Insall Salvati ratio	1.12 ± 0.38
Patella alta : patella baja	330 : 60
Overall graft length (mm)	90.2 ± 1.37
Length of the tibial bone plug with an extension (mm)	39.1 ± 1.1

Values are presented as mean ± standard deviation.

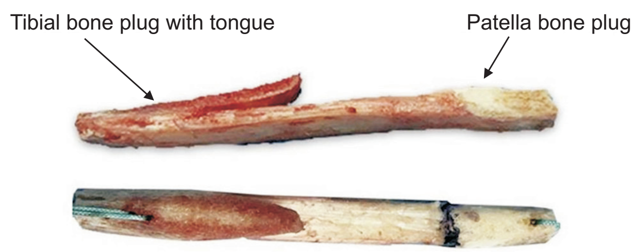

Fig. 6. A bone-patellar tendon-bone graft.

graft measurements in their study. Chang et al.[16] established the normative data in 147 knees, as well as demonstrated that the preoperative MRI assessment of patellar tendon dimensions could be a valuable tool with satisfactory accuracy and reliability when the autologous patellar tendon was considered as the graft source for ACLR in the South Korean population.

The primary objective of the study to establish descriptive data on the patella and patellar tendon dimensions was achieved. Zakko et al.[15] in the United States established a PTL of 48.5 mm, patellar tendon thickness (PTT) of 4.3 mm, and patella thickness (PT) of 21.1 mm in 62 knees, whereas Chang et al.[16] measured a PTL of 41 mm and PT of 4.3 mm in 55 knees. A cadaveric study done in 14 cadaveric knees by McAllister et al.[17] examined the dimensions using three modalities: radiographic, standard MRI, and three-dimensional MRI. In addition, further autogenous BTB was harvested from all knees, a tendinous portion of the graft was measured using a ruler, and a linear regression analysis was performed for all the imaging techniques. They concluded that MRI is less accurate than radiographs for PTL alone. In their study, the actual PTL was 45.2 mm (radiographic, 47.5 mm; standard MRI, 50.1 mm; and three-dimensional MRI, 44.4 mm). This difference could be because the study was done on cadavers and might be due to the obliquity of the plane of imaging relative to the plane of the patellar tendon. Despite the shortcomings of standard MRI mentioned in the above study, MRI still remains the only valuable non-invasive method for graft templating. Our study showed the respective dimensions of PTL = 45.2 mm, PTT = 5.79 mm, and PT = 18.7 mm, which is close to the previously reported values. The IS ratio was observed to be 1.12 with approximately 33% of them having high riding patella and 6% having patella baja.

Our secondary objective of BTB graft templating can be done using other measured parameters. Graft tunnel mismatch is a frequently encountered problem when the graft is too long or too short.[18] Between the years 1990–1998, there was a lot of research on BTB as it was a widely used graft option in that particular period. Again it has gained popularity in recent times with the advances in surgical techniques. Several authors have quoted the importance of the correct measurement of the anatomical structures around the patella as an essential requirement for the proper execution of surgical technique, especially the tunnel lengths.[10,11,18-21] Several formulas have been validated to calculate the tunnel length with the help of PTL and other dimensions (Table 6): the "N + 7 rule" proposed by Miller and Hinkin,[20] "Rule 50" formula by Kenna et al.[11] and Hazzard et al.,[22] "N+2 rule" by Olszewski et al.,[10] "Blumensaat line" method by Meijer et al.,[21] and "OGL + 10" by Rozell and Sennett.[23] This mandates the use of MRI to measure the required parameters to predict the feasibility of using BTB graft for ACLR. In our study, we also measured the insertional width and thickness of PT at both the patella and tibia, which have been seldom reported in other studies. The OGL can be predicted by adding PTL + 2.5 cm (patellar bone plug) + 2 cm (tibial bone plug).[10,11)]

Table 6. Formulae to Calculate Tunnel Length

Study	Proposed formula for tunnel length calculation
Miller and Hinkin (1996)[20]	N + 7 rule (N-patellar tendon length)
Olszewski et al. (1998)[10]	N + 2 (N-patellar tendon length)
Meijer et al. (2018)[21]	Blumensaat line method
Rozell and Sennett (2017)[23]	OGL + 10
Kenna et al. (1993)[11], Hazzard et al. (2021)[22]	Rule 50: graft length – 50 mm = tibial tunnel distance needed (set on tibial drill guide)

OGL: overall graft length.

We authors with our surgical expertise and knowledge in ACLR over the years have developed the term ETL, which approximates the intra-articular graft length of ACL. Surgical site marking of joint line can help the surgeon to arrive at a tentative stop point of patella bone plug cuts using the sagittal saw. This is also marked by the slimy dip of the mid-anterior cortex of the tibia, which can also be palpated or visualized by retracting the tendon. On MRI, it can be measured on the patellar tendon as the distance between the tip of the inferior pole of the patella and a horizontal line drawn 5mm below the proximal tibial plateau (Fig. 5). The anterior cortex dip was consistently between 5 mm and 8 mm when visualized on MRI. We arrived at a mean ETL of 26.1 mm in the 1,002 knees, which was similar to the previously quoted values of intra-articular length of ACL in the study of Shaffer et al (n = 34, 26.3 mm),[24] Denti et al.[19] (n = 59, 20.44 mm), and Miller and Olszewski[25] (n = 18, 23.56 mm). With our experience using this method, we never reported any incidence of graft tunnel mismatch in our patients who underwent a BTB harvest. Yet, the intraoperative correlation of ACL length with the templating values obtained from MRI warrants further research using randomized control trials for greater understanding. The limitations of the study are as follows: it was a retrospective study and the anthropometry data could not be traced; there is a possibility of intraobserver variability in measuring the MRI parameters; the intraoperative correlation was not examined; and the higher incidence of patella alta might be due to the imaging done in knee extension. The descriptive data obtained on the patella and patellar tendon morphometry will assist in future studies, which aim at preoperative graft templating prior to ACLR.

A simple MRI analysis can give us valuable inputs on BTB graft morphometry. The values can also help us with the near-perfect graft harvest. The intraoperative complications of graft tunnel mismatch can be avoided by predicting the OGL, ETL, tibial tunnel length, and patellar position using the measured parameters on MRI.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Arnold MP, Calcei JG, Vogel N, et al. ACL study group survey reveals the evolution of anterior cruciate ligament reconstruction graft choice over the past three decades. Knee Surg Sports Traumatol Arthrosc. 2021;29(11):3871-6.
2. Hospodar SJ, Miller MD. Controversies in ACL reconstruction: bone-patellar tendon-bone anterior cruciate ligament reconstruction remains the gold standard. Sports Med Arthrosc Rev. 2009;17(4):242-6.
3. Kim SJ, Choi CH, Kim SH, et al. Bone-patellar tendon-bone autograft could be recommended as a superior graft to hamstring autograft for ACL reconstruction in patients with generalized joint laxity: 2- and 5-year follow-up study. Knee Surg Sports Traumatol Arthrosc. 2018;26(9):2568-79.
4. Arida C, Tsikrikas CG, Mastrokalos DS, Panagopoulos A, Vlamis J, Triantafyllopoulos IK. Comparison of bone-patella tendon-bone and four-strand hamstring tendon grafts for anterior cruciate ligament reconstruction: a prospective study. Cureus. 2021;13(11):e19197.
5. Eskew JR, Miles D, Davis F, Bruce J. Graft tunnel mismatch in anterior cruciate ligament reconstruction with bone-patellar tendon-bone grafts. J Orthop Surg Tech. 2020;3(1):123-9.
6. Agarwal S, de Sa D, Peterson DC, et al. Can preoperative magnetic resonance imaging predict intraoperative autograft size for anterior cruciate ligament reconstruction?: a systematic review. J Knee Surg. 2019;32(7):649-58.
7. Phillips CL, Silver DA, Schranz PJ, Mandalia V. The measurement of patellar height: a review of the methods of imaging. J Bone Joint Surg Br. 2010;92(8):1045-53.
8. Biedert RM, Tscholl PM. Patella alta: a comprehensive review of current knowledge. Am J Orthop (Belle Mead NJ). 2017;46(6):290-300.
9. Jarbo KA, Hartigan DE, Scott KL, Patel KA, Chhabra A. Accuracy of the lever sign test in the diagnosis of anterior cruciate ligament injuries. Orthop J Sports Med. 2017;5(10):2325967117729809.
10. Olszewski AD, Miller MD, Ritchie JR. Ideal tibial tunnel length for endoscopic anterior cruciate ligament reconstruction. Arthroscopy. 1998;14(1):9-14.
11. Kenna B, Simon TM, Jackson DW, Kurzweil PR. Endoscopic ACL reconstruction: a technical note on tunnel length for interference fixation. Arthroscopy. 1993;9(2):228-30.
12. Verma NN, Dennis MG, Carreira DS, Bojchuk J, Hayden JK, Bach BR Jr. Preliminary clinical results of two techniques for addressing graft tunnel mismatch in endoscopic anterior cruciate ligament reconstruction. J Knee Surg. 2005;18(3):183-91.
13. Yanke A, Ellman MB, Sherman SL, Bach Jr BR. Graft-tunnel mismatch in bone-tendon-bone ACL reconstruction: prevention and treatment. Tech Orthop. 2012;27(2):153-7.
14. Janani G, Suresh P, Prakash A, Parthiban J, Anand K, Arumugam S. Anterior knee pain in ACL reconstruction with BPTB graft: is it a myth?: comparative outcome analysis with hamstring graft in 1,250 patients. J Orthop. 2020;22:408-13.
15. Zakko P, van Eck CF, Guenther D, Irrgang JJ, Fu FH. Can we predict the size of frequently used autografts in ACL reconstruction? Knee Surg Sports Traumatol Arthrosc. 2017;25(12):3704-10.
16. Chang CB, Seong SC, Kim TK. Preoperative magnetic resonance assessment of patellar tendon dimensions for graft selection in anterior cruciate ligament reconstruction. Am J Sports Med. 2009;37(2):376-82.
17. McAllister DR, Bergfeld JA, Parker RD, Grooff PN, Valdevit AD. A comparison of preoperative imaging techniques for predicting patellar tendon graft length before cruciate ligament reconstruction. Am J Sports Med. 2001;29(4):461-5.

18. Miller MD. Editorial Commentary: anterior cruciate ligament graft tunnel mismatch: the long and short of it. Arthroscopy. 2018;34(8):2444-5.

19. Denti M, Bigoni M, Randelli P, et al. Graft-tunnel mismatch in endoscopic anterior cruciate ligament reconstruction: intraoperative and cadaver measurement of the intra-articular graft length and the length of the patellar tendon. Knee Surg Sports Traumatol Arthrosc. 1998;6(3):165-8.

20. Miller MD, Hinkin DT. The "N + 7 rule" for tibial tunnel placement in endoscopic anterior cruciate ligament reconstruction. Arthroscopy. 1996;12(1):124-6.

21. Meijer K, Saper M, Joyner P, Liu W, Andrews JR, Roth C. Minimizing graft-tunnel mismatch in allograft anterior cruciate ligament reconstruction using Blumensaat's line: a cadaveric study. Arthroscopy. 2018;34(8):2438-43.

22. Hazzard S, Lonati D, Kolosky M, Asnis P. Rule 50: a reproducible technique to minimize graft-tunnel mismatch during ACL reconstruction using bone-tendon-bone (BTB) graft. Tech Orthop. 2021;36(4):445-8.

23. Rozell J, Sennett B. Sports tips & tricks: technical evaluation of ACL graft dimensions: staying out of trouble. Univ Pa Orthop J 2017;27:90-92.

24. Shaffer B, Gow W, Tibone JE. Graft-tunnel mismatch in endoscopic anterior cruciate ligament reconstruction: a new technique of intraarticular measurement and modified graft harvesting. Arthroscopy. 1993;9(6):633-46.

25. Miller MD, Olszewski AD. Cruciate ligament graft intra-articular distances. Arthroscopy. 1997;13(3):291-5.