J Nepal Health Res Counc 2023 Jan-Mar;21(58): 34-9

Prediction of Hamstring Autograft sizes for Anterior Cruciate Ligament Reconstruction using Preoperative Magnetic Resonance Imaging

Prakash Shrestha,[1] Sunil Singh Thapa,[1] Deepak Prakash Mahara,[1] Sharma Paudel,[2] Arjun Lamichhane,[1] Tejendra Saud[1]

[1]Department of Orthopedic Surgery, Tribhuvan University Teaching Hospital, Kathmandu, Nepal, [2]Department of Radiology, Tribhuvan University Teaching Hospital, Kathmandu, Nepal.

ABSTRACT

Background: The purpose of this study is to determine whether preoperative magnetic resonance image measurements can predict the hamstring tendon autograft diameter during anterior cruciate ligament reconstruction.

Methods: We prospectively evaluated Forty-two patients with anterior cruciate ligament injury who underwent reconstruction using hamstring tendon autograft. Preoperative diameters and cross-sectional areas of the hamstring tendons were estimated using magnetic resonance imaging of the knee. Intraoperative diameters of the hamstring tendon graft were measured using a cylindrical graft sizer. We used Pearson's correlation test to compare the Preoperative and intraoperative graft size measurements. A possible cutoff value for the hamstring graft size was determined using Receiver operating characteristic analysis.

Results: The mean age of the patient in the study was 27.5 ± 8.5 years. There were statistically significant correlations between preoperative and intraoperative hamstring tendon graft measurements ($P < 0.001$). Our study found 13.3 mm^2 cross-sectional areas of combined gracilis + semitendinosus as the cutoff for predicting 7mm of quadrupled hamstring graft size with both sensitivity and specificity of 85.7 %, respectively.

Conclusions: We can conclude that preoperative magnetic resonance imaging measurements can predict the intraoperative graft size. This study can help in preoperatively planning for the graft choice.

Keywords: Anterior cruciate ligament; hamstring graft; magnetic resonance imaging; prediction

INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction is the current standard treatment of choice for a young patient with an ACL injury who wants to maintain an active lifestyle.[1] There are various graft options available for ACL reconstructions: bone-patellar tendon-bone (BPTB) autograft, hamstring tendon autograft, quadriceps tendon autograft, and multiple allograft sources. Hamstring autografts are more commonly preferred because of low postoperative pain, especially anterior knee pain, no violation of extensor mechanism, less quadriceps muscle atrophy, and low donor site morbidity.[1,2]

The recommended minimum graft diameter in single-bundle ACL reconstruction is 7mm. There is a risk of graft failure when the harvested hamstring graft is of insufficient diameter.[3-5] The hamstring tendon size varies between individuals, making it difficult to predict the hamstring graft size. Inadequate graft requires an alternate source for the graft.[6,7] Magnetic resonance imaging (MRI) of the knee is routinely done in cases of clinically diagnosed ACL tear before surgery to establish the diagnosis and look for other associated injuries. We thus conducted this study to determine whether the preoperative MRI measurements can predict the diameter of hamstring tendons during ACL reconstruction surgery and to assess the correlation between the MRI measurements and the intraoperative graft diameter.

METHODS

We prospectively conducted this study in the Department

Correspondence: Dr Prakash Shrestha, Department of Orthopedic Surgery, Tribhuvan University Teaching Hospital, Kathmandu, Nepal, Email: appalu99@gmail.com, Phone: +9779841624111.

of Orthopedics and Trauma surgery of the Institute of Medicine (IOM), Tribhuvan University Teaching Hospital, over 18 months period (January 2019 - July 2020) after ethical approval from the Institutional Review Committee (IRC) of IOM. Inclusion criteria for the study were patients with clinical and MRI-proven ACL injury, planned for ACL reconstruction using hamstring tendon autograft. Exclusion criteria were patients with ACL injury managed conservatively, undergoing ACL reconstruction using graft other than hamstring graft, and patients who had previously undergone ACL reconstruction. A total of 42 patients were selected based on the inclusion criteria. We took written consent from all the eligible patients after explaining the nature and implication of the study. MRI knees (1.5 or 3 teslas) of all 42 patients were evaluated to measure hamstring graft sizes by the same radiologist blinded to the intraoperative measurements. All the measurements were done using Syngo. Via software (Siemens Healthineers) under 2x magnified images to outline each tendon in the most precise and accurate manner.

In MRI, measurements were done on two different levels:

First at the level of physeal scar line of femur.

Second, at the level of the joint line

At these two levels, four diameters – maximum anteroposterior (AP) and mediolateral (ML) diameters were measured in T2 weighted axial images (Figure 1). Then we calculated the mean of all four diameters and defined it as the MR diameter of the individual tendon. The cross-sectional area measurements were done at the same two levels in the T2 weighted axial image using the freehand region of interest tool (Figure 2). The mean of two cross-sectional areas was calculated and taken as the MR cross-sectional area of the individual tendon.

a b

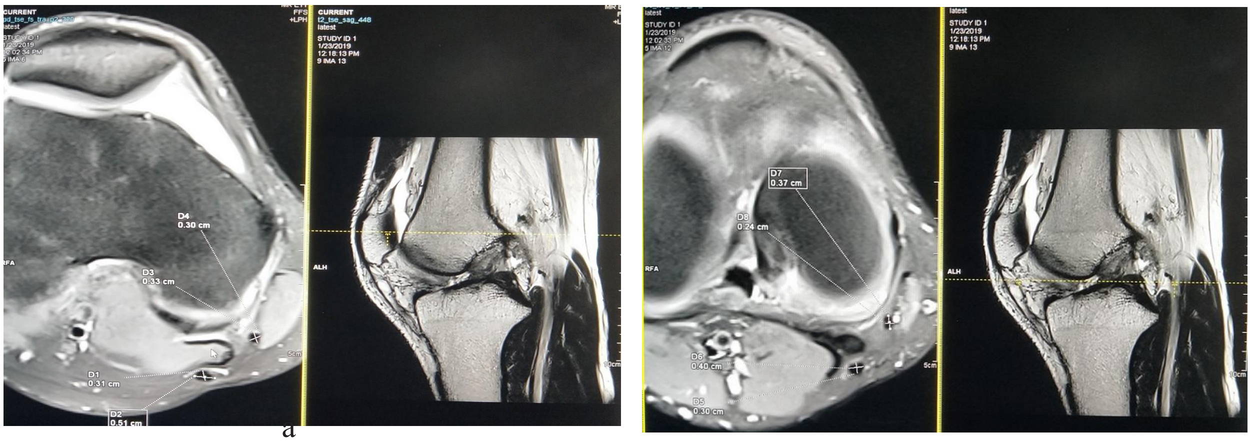

Figure 1.T2 weighted axial and sagittal MR images show the anteroposterior and mediolateral diameter of semitendinosus and gracilis at the level of (a) physeal scar line level and (b) the joint line.

a b

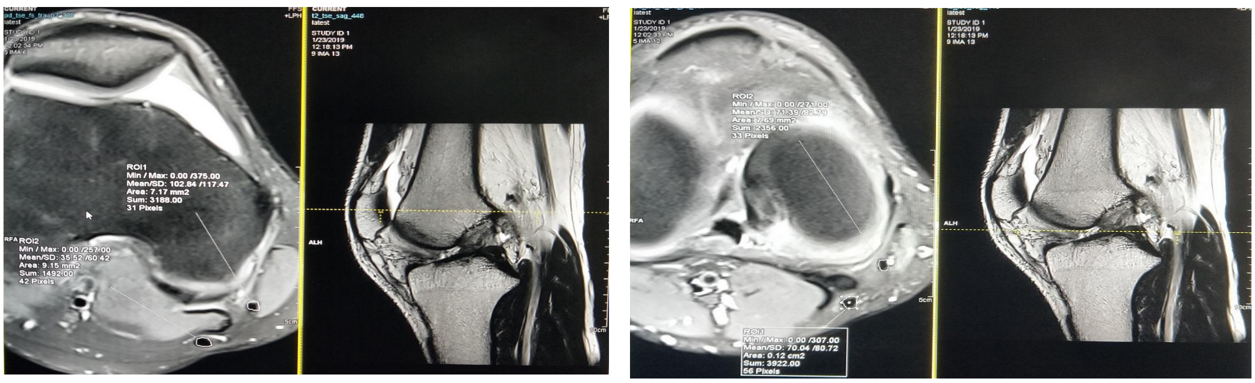

Figure 2.T2 weighted axial and sagittal MR images showing measurement of CSA of semitendinosus and gracilis at the level of (a) physeal scar line and (b) the joint line.

Intraoperatively during ACL reconstruction, an oblique anteromedial skin incision was given at the level of pes anserine insertion. A standard tendon stripper was used to free the tendon from their musculotendinous insertion, and the graft was harvested. After that, blunt removal of soft tissues from graft was done, and the diameter of gracilis and semitendinosus tendons were measured individually and combined (4 stranded) using a standard cylindrical graft sizer. The sizing tube used in our study had a minimum diameter of 4.5 mm with calibration of 0.5 mm. We made the individual graft of either 2 or 3 stranded to achieve the minimum diameter of the graft sizer. Then we divided the number of a fold made to get the diameter of the individual single-stranded graft. The same surgeon did all the intraoperative graft measurements and was unaware of the radiological measurements.

The statistical analyses were done with the help of the Statistical package for social services (SPSS) version 25. Pearson's correlation test was used to compare the preoperative MRI hamstring diameter, cross-sectional area, and intraoperative graft size measurements. Higher correlation coefficients indicate a more robust relationship among variables. Receiver operating characteristic (ROC) analysis was used to determine a cutoff value for the preoperative.

RESULT

Out of 42 patients included in this study, 34 (81%) patients were male, and the remaining 8 (19%) were female; the mean age of the patient was 27.5 years ± 8.5.

Table 1 shows the mean preoperative MRI measurements (diameter and CSA) and intraoperative graft measurements.

There was a moderate positive correlation between MRI diameters of gracilis, semitendinosus and gracilis + semitendinosus with intraoperative diameters of gracilis ($r = 0.574$, $p<0.001$), semitendinosus ($r=0.631$, $p<0.001$) and gracilis + semitendinosus ($r=0.628$, $p<0.001$) respectively. There was also a moderate positive correlation between MRI gracilis CSA with intraoperative gracilis diameter ($r=0.556$, $p<0.001$) and between MRI gracilis + semitendinosus CSA with intraoperative quadrupled hamstring diameter (($r=0.667$, $p<0.001$). There is a strong positive correlation between MRI semitendinosus CSA and intraoperative semitendinosus diameter ($r=0.716$, $p<0.001$).

Based on Receiver operating characteristic (ROC) analysis, the area under the curve (AUC) was found to be 0.865 for MR Gracilis + Semitendinosus CSA (Figure 3). The minimum desired graft size was 7 mm for 4-stranded gracilis + semitendinosus tendon grafts. MR cutoff value of the cross-sectional area for the minimum desired intraoperative quadrupled hamstring graft size was 13.3 mm^2 with both sensitivity and specificity of 85.7 %, respectively (Table 2).

Table 1. Mean preoperative MRI measurements and intraoperative hamstring graft sizes.

	Mean MRI Diameter (mm)	Mean MRI CSA (mm^2)	Mean Intraoperative graft size (mm)
Gracilis	2.80 ± 0.36	5.511 ± 1.42	1.83 ± 0.32
Semitendinosus	3.81 ± 0.52	10.595 ± 2.54	2.72 ± 0.46
Gracilis + Semitendinosus	6.61 ± 0.79	16.10 ± 3.70	7.28 ± 0.62

MRI, magnetic resonance imaging; CSA, cross-sectional area.

Table 2. Minimum MRI CSA required for a desired intraoperative graft size.

Graft	Graft size (mm)	Minimum MRI CSA required (mm^2) (cut-off)	Area under curve (AUC)	Stan-dard error	Sensi-tivity (%)	Speci-ficity (%)
Quadrupled hamstring graft	7	13.3	0.865	.072	85.7	85.7

MRI, magnetic resonance imaging; CSA, cross-sectional area.

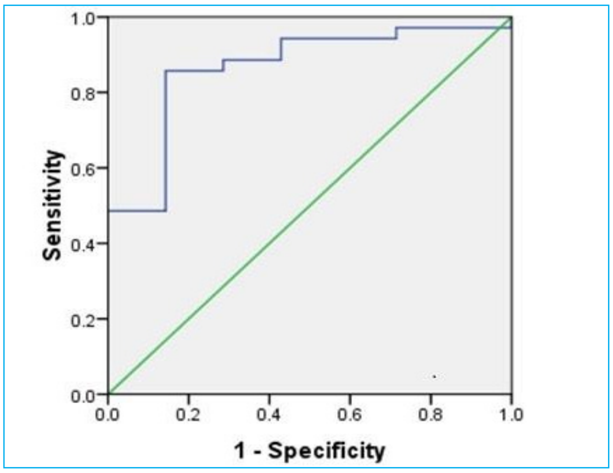

Figure 3. ROC curve for predicting four-stranded hamstring graft >= 7 mm.

DISCUSSION

Although various graft options are available for ACL reconstructions, hamstring autografts are commonly preferred because of low postoperative pain, especially anterior knee pain, no violation of extensor mechanism, less quadriceps muscle atrophy, and low donor site morbidity. Various studies were conducted to predict the hamstring graft size using anthropometric measures. However, there were conflicting results associated with these anthropometric variables, so there is a growing interest in MRI for predicting the hamstring graft sizes.[6-14]

Our study's mean MRI diameter of gracilis, semitendinosus, and gracilis + semitendinosus was smaller than the study done by Beyzadeoglu et al.[6] and Vardiabasis et al. [13] This difference could be due to different study populations and different measurement levels of tendon sizes. Similarly, the mean MRI CSA of gracilis, semitendinosus and gracilis + semitendinosus was also smaller compared to the study done by Beyzadeoglu et al. [6] and Grawe et al. [15] This difference in the result of MRI measurements of our study with other studies could be related to a lack of standardization with the imaging protocols and variations in measurement techniques. Specifically, the tool used to calculate the CSA, i.e., freehand region of interest tool where the outline of the tendon was traced manually. The efficacy and the reproducibility of this tool are unknown. Different landmarks (the level below versus above or at the physeal scar and the joint line) were used by a different study, making it difficult to compare results between studies. [6,7,12,14,16]

In our study, the mean intraoperative diameters of gracilis, semitendinosus, and quadrupled hamstring grafts were found to be 1.83 ± 0.325 mm, 2.72 ± 0.465 mm, and 7.28 ± 0.626 mm, respectively, which was similar to the study by Park SY et al.[17,18] conducted in South Korea. While the study done by Vardiabasis et al. [13] showed the mean gracilis, semitendinosus, and quadrupled hamstring diameters larger than our study. Beyzadeoglu et al. [6], Grawe et al. [15], and Galanis et al. [19] also in their study found the four-stranded semitendinosi + gracilis diameter larger compared to our study. The smaller diameter of the hamstring tendon in our study may be due to the smaller height of the Nepalese population. The difference in the intraoperative graft diameter also could be due to differences in sample size and variability in measurement technique.

Similar to our study, Vardiabasis et al. [13] and W. Chan et al. [14] found a significant correlation between MRI measured hamstring diameter with intraoperative hamstring autograft. However, the study done by Beyzadeoglu et al. [6] found no statistically significant correlation, which may be explained by the technique used to measure MR diameter, i.e., using the mean of MR diameters of the hamstring tendons to correlate with the intraoperative graft sizes. This method may not be accurate because of variable orientations and irregular shapes of individual tendons, and the MR tendon diameters were measured manually, tracing the tendon outline, which may vary in different settings.

However, similar to our study, Beyzadeoglu et al. [6] showed significant correlations between MRI cross-sectional areas of the hamstring tendon with intraoperative hamstring graft diameter. Galanis et al. [19] and Erquicia et al. [17] showed a stronger correlation with a correlation coefficient of 0.813 and 0.86, respectively. This higher correlation than our study may be due to a higher magnified MRI scanned image (4 times), which displays a higher sensitivity and specificity than a less magnified MR image.

Our study showed 13.3 mm^2 CSA as the cutoff for predicting 7 mm of quadrupled hamstring graft size performed under ×2 magnifications with both sensitivity and specificity of 85.7 %, respectively. Leiter J et al. [7] found 14.5 mm^2 as the cutoff for the graft of 7.5 mm with a sensitivity of 79% and specificity of 78%, which was comparable to our study. In comparison, Bickel et al. [12] predicted that combined CSA of gracilis + semitendinosus ≥18 mm2 on MRI corresponds to the intraoperatively measured tendon diameter of 7mm with 88% probability. In the study by Beyzadeoglu et al. [6], 18.4 mm^2 was found as the cutoff MR CSA under ×2 magnification to predict 7 mm of intraoperative quadrupled hamstring graft. In comparison, Erquicia et al. [17] predicted threshold values for combined gracilis + semitendinosus CSA for quadrupled hamstring graft with a minimum diameter of 8 mm as 25 mm2 and 17 mm2 under ×2 and ×4 magnifications, respectively. They found that the study done under ×4 magnifications was more accurate than those under ×2 magnification. [17] The difference in cutoff value may be explained by the differences in measurement technique, image magnification, sample size, and ethnic factors.

In their study, Park et al. [18] and Magnussen et al. [20] found that grafts smaller than 8mm had increased failures rates. At the same time, most other studies [4,21,22] cite a 7mm graft diameter to prevent graft failure. There were seven subjects whose quadrupled graft diameter was less than 7mm in our study. All 35 subjects had more than or equal to 7mm graft diameters. There were a few limitations of this study: small sample size, MRI measurements were performed by the same radiologist for each patient, and therefore, the inter-rater reliability of our measurements was not tested. The use of the freehand region of interest tool has not been validated. The sizing tube used to measure graft diameter had the minimum diameter of 4.5mm only with calibration of 0.5mm; results would have been more precise if the minimum diameter had been minor.

Our study has shown a significant correlation between MRI-measured hamstring graft sizes with the actual intraoperative hamstring graft as compared with other studies. Thus, using the preoperative MRI measurements, we would predict whether a patient undergoing ACL reconstruction using hamstring autograft would have a sufficient graft diameter or not so that proper preoperative planning about the graft source could be done preoperatively.

CONCLUSIONS

Our study revealed a significant positive correlation between the preoperative MRI measurements of hamstring tendon diameter and cross-sectional area with the intraoperative hamstring graft diameter. A total CSA of ≥ 13.3 mm^2 will provide a quadruple hamstring graft diameter of ≥ 7 mm. It is possible to predict the graft size using the cutoff value, which is valuable for the surgeon to improve the preoperative preparation regarding graft choice.

CONFLICT OF INTEREST

The authors declare no conflict of interest

REFERENCES

1. Kim HS, Seon JK, Jo AR. Current trends in anterior cruciate ligament reconstruction. Knee surgery & related research. 2013 Dec;25(4):165.[PubMed]
2. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. The American journal of sports medicine. 2003 Jan;31(1):2-11.[PubMed]
3. Charlton WP, Randolph DA, Lemos S, Shields CL. Clinical outcome of anterior cruciate ligament reconstruction with quadrupled hamstring tendon graft and bioabsorbable interference screw fixation. The American journal of sports medicine. 2003 Jul;31(4):518-21.[Article]
4. Challa S, Satyaprasad J. Hamstring graft size and anthropometry in south Indian population. Journal of clinical orthopedics and trauma. 2013 Sep 1;4(3):135-8. [PMC3880434]
5. Maeda A, Shino K, Horibe S, Nakata K, Buccafusca G. Anterior cruciate ligament reconstruction with multistranded autogenous semitendinosus tendon. The American journal of sports medicine. 1996 Jul;24(4):504-9. [PubMed]
6. Beyzadeoglu T, Akgun U, Tasdelen N, Karahan M. Prediction of semitendinosus and gracilis autograft sizes for ACL reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2012 Jul 1;20(7):1293-7. [PubMed]
7. Leiter J, Elkurbo M, McRae S, Chiu J, Froese W, MacDonald P. Using preoperative MRI to predict intraoperative hamstring graft size for anterior cruciate ligament reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2017 Jan 1;25(1):229-35. [PubMed]
8. Celiktas M, Golpinar A, Ozkan KO, Sutoluk Z, Çelebi K, Sarpel Y. Prediction of the quadruple hamstring autograft thickness in ACL reconstruction using anthropometric measures. Acta orthopaedica et traumatologica turcica. 2013 Jan 1;47(1):14-8. [PubMed]
9. Ma CB, Keifa E, Dunn W, Fu FH, Harner CD. Can preoperative measures predict quadruple hamstring graft diameter? The Knee. 2010 Jan 1;17(1):81-3. [PubMed]
10. Treme G, Diduch DR, Billante MJ, Miller MD, Hart JM. Hamstring graft size prediction: a prospective clinical evaluation. The American journal of sports medicine. 2008 Nov;36(11):2204-9. [PubMed]
11. Tuman JM, Diduch DR, Rubino LJ, Baumfeld JA, Nguyen HS, Hart JM. Predictors for hamstring graft diameter in anterior cruciate ligament reconstruction. The American journal of sports medicine. 2007 Nov;35(11):1945-9. [PubMed]
12. Bickel BA, Fowler TT, Mowbray JG, Adler B, Klingele K, Phillips G. Preoperative magnetic resonance imaging cross-sectional area for the measurement of hamstring autograft diameter for reconstruction of the adolescent anterior cruciate ligament. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2008 Dec 1;24(12):1336-41. [PubMed]
13. Vardiabasis N, Mosier B, Walters J, Burgess A, Altman G, Akhavan S. Can we accurately predict the quadruple hamstring graft diameter from preoperative magnetic resonance imaging?. Orthopaedic journal of sports medicine. 2019 Mar 26;7(3):2325967119834504. [PubMed]
14. Chan KW, Kaplan K, Ong CC, Schweitzer ME, Sherman OH. Using magnetic resonance imaging to determine preoperative autograft sizes in anterior cruciate ligament reconstruction. Bulletin of the NYU hospital for joint diseases. 2012 Oct 1;70(4):241. [PubMed]

15. Grawe BM, Williams PN, Burge A, Voigt M, Altchek DW, Hannafin JA, Allen AA. Anterior cruciate ligament reconstruction with autologous hamstring: can preoperative magnetic resonance imaging accurately predict graft diameter?. Orthopaedic journal of sports medicine. 2016 May 18;4(5):2325967116646360. [Article]

16. Cobanoglu M, Ozgezmez FT, Omurlu IK, Ozkan I, Savk SO, Cullu E. Preoperative magnetic resonance imaging evaluation of semitendinosus tendon in anterior cruciate ligament reconstruction. Indian journal of orthopaedics. 2016 Oct;50(5):499-504.[Article]

17. Erquicia JI, Gelber PE, Doreste JL, Pelfort X, Abat F, Monllau JC. How to improve the prediction of quadrupled semitendinosus and gracilis autograft sizes with magnetic resonance imaging and ultrasonography. The American journal of sports medicine. 2013 Aug;41(8):1857-63. [PubMed]

18. Park SY, Oh H, Park S, Lee JH, Lee SH, Yoon KH. Factors predicting hamstring tendon autograft diameters and resulting failure rates after anterior cruciate ligament reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2013 May 1;21(5):1111-8. https://pubmed.ncbi.nlm.nih.gov/22688502/

19. Galanis N, Savvidis M, Tsifountoudis I, Gkouvas G, Alafropatis I, Kirkos J, Kellis E. Correlation between semitendinosus and gracilis tendon cross-sectional area determined using ultrasound, magnetic resonance imaging and intraoperative tendon measurements. Journal of Electromyography and Kinesiology. 2016 Feb 1;26:44-51. https://pubmed.ncbi.nlm.nih.gov/26708406/

20. Magnussen RA, Lawrence JT, West RL, Toth AP, Taylor DC, Garrett WE. Graft size and patient age are predictors of early revision after anterior cruciate ligament reconstruction with hamstring autograft. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2012 Apr 1;28(4):526-31. https://www.sciencedirect.com/science/article/pii/S0749806311013156

21. Grood ES, Walz‐Hasselfeld KA, Holden JP, Noyes FR, Levy MS, Butler DL, Jackson DW, Drez DJ. The correlation between anterior‐posterior translation and cross‐sectional area of anterior cruciate ligament reconstructions. Journal of orthopaedic research. 1992 Nov;10(6):878-85. https://onlinelibrary.wiley.com/doi/pdf/10.1002/jor.1100100617

22. Conte EJ, Hyatt AE, Gatt Jr CJ, Dhawan A. Hamstring autograft size can be predicted and is a potential risk factor for anterior cruciate ligament reconstruction failure. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2014 Jul 1;30(7):882-90. https://pubmed.ncbi.nlm.nih.gov/24951356/