Prediction of Hamstring Tendon Autograft Diameter and Length for Anterior Cruciate Ligament Reconstruction

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Abstract

The purpose of this study was to determine whether common physical measurements in patients undergoing anterior cruciate ligament (ACL) reconstruction with autologous hamstring tendon could be used to predict autograft length and diameter.

One hundred nineteen consecutive patients undergoing hamstring autograft ACL reconstruction had these preoperative measurements taken: age, height, weight, bilateral leg length, and bilateral thigh girth 5 and 10 cm proximal to the superior pole of the patella. Correlations between these measurements and graft length and diameter were evaluated.

There was a strong correlation between leg length and hamstring autograft length (r = .73, P<.001). Weight (r = .51, P<.001) and leg length (r = .42, P<.001) had only moderate correlations with graft diameter. All other correlations were weak. Regression analysis demonstrated that leg length can be used to predict hamstring autograft tendon length to within 20 mm and that weight can be used to predict graft diameter to within 1.2 mm using regression equations.

In conclusion, several simple measurements correlate with doubled semitendinosus and gracilis tendon autograft length and diameter. This new information may prove useful to surgeons who want hamstring autografts of a certain diameter or of a long length.

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Anterior cruciate ligament (ACL) reconstruction is a common orthopedic procedure.[1,2] The use of bone–patella tendon–bone autografts for ACL reconstruction is a successful, time-tested technique.[1-4] However, the potential graft harvest site morbidity associated with these autografts has lead to development of alternative graft sources.[1] Various autograft and allograft tissues have been used. Four-stranded hamstring autografts have been demonstrated to be successful grafts for ACL reconstruction.[1-5]

"Can hamstring autograft length and diameter be predicted with simple preoperative measurements?"

Diameters and lengths of doubled semitendinosus and gracilis autografts can vary significantly.[6] In some cases, such as when performing ACL reconstructions in heavier athletic patients, surgeons may want larger-diameter grafts. Revision ACL reconstructions often pose special challenges when a larger-diameter graft is used.[7] Hamstring autografts of longer length may also be useful for some surgeons. Fixation techniques outside the tibial tunnel (eg, staples and some proprietary fixation devices) require that the grafts exit the tibial tunnels for a certain distance.

To our knowledge, there is no method for determining hamstring autograft diameter and length before ACL surgery. Preoperative estimation of hamstring autograft diameter and length may allow surgeons the opportunity to choose an alternative graft if the potential hamstring autograft specifications will not meet their desires for a given patient.

Although preoperative 30° flexion lateral x-rays of the knee have been shown to be accurate predictors of patella tendon length,[8] we are unaware of any study that has attempted to predict the diameters or lengths of hamstring autografts for ACL reconstruction using simple patient measurements obtainable in the office.

In the study reported here, we evaluated whether simple preoperative measurements correlated with diameters and lengths of doubled semitendinosus and gracilis tendon autografts.

Methods and Materials

One hundred nineteen consecutive patients undergoing ACL reconstruction using hamstring autograft tendons were included in the study. Several pre-

Table I. Summary of Results

	Mean Measurements (Ranges)					
	Height (59-78 in)	Weight (102-320 lb)	Leg Length (74-116 cm)	Age (13-58 y)	Graft Length (100-170.5 mm)	Graft Diameter (6.5-10 mm)
Females (n = 54)	63.25	143.48	85.58	24.41	119.75	7.52
Males (n = 65)	64.86	190.75	93.99	26.36	134.18	8.17

operative measurements were obtained for each patient. Measurements of height and weight were obtained at the surgery center. Thigh girth measurements were made on each lower extremity with a measuring tape at distances of 5 and 10 cm from the superior poles of the patellae with the knees in extension. Leg-length measurements of the involved leg were taken by measuring the distances from the anterior superior iliac spines to the medial malleoli.

The hamstring tendon autografts were harvested in a uniform fashion by Dr. Schwartzberg. The semitendinosus and gracilis tendons were detached from their insertion into the proximal tibia. The ends were whip-stitched, and a closed tendon stripper was used to detach the tendons from their musculotendinous junctions. After blunt removal of muscle, the 2 tendons were folded to form a 4-stranded graft. The functional length of the graft was measured. This functional length was determined after both tendons were folded, and the length that included all 4 arms of the tendon graft was used. This equates to half the length of the shorter of the 2 tendons—the reason being that tibial-sided fixation needs to include all 4 strands of the graft to be effective.

Graft diameter was determined after the free ends of each graft were whip-stitched with No. 2 nonabsorbable suture. The grafts were passed through sizing cylinders on a sizing block with incremental size changes of 0.5 mm. The smallest-size tube that the graft could be passed through was considered the graft diameter.

Statistical analysis was performed, including regression analysis to determine correlations between age, weight, height, leg length and thigh girth, and measured graft diameters and lengths. Stepwise algorithms were also used to select significant predictors of graft length and diameter. Regression equations were generated to attempt to predict graft diameter and length based on given measurements.

Results

There were 54 females and 65 males in the study. Leg lengths ranged from 74 to 116 cm, and weight ranged from 102 to 320 lb. Table I summarizes the results.

Correlations with graft length are summarized in Table II. There was no statistical difference in correlation between thigh girth of affected and unaffected legs, so only measurements of affected legs were included.

Table II. Correlation Between Graft Length and Specified Characteristics

Characteristic	*r*
Age	.0584
Weight	.4376
Height	.5750
Leg length	.7343
Involved ~5 cm	.2034
Involved ~10 cm	.1231

Table III. Correlation Between Graft Diameter and Specified Characteristics

Characteristic	*r*
Age	-.0437
Weight	.5118
Height	.3903
Leg length	.4177
Involved ~5 cm	.3462
Involved ~10 cm	.3447

Leg length had the strongest correlation with graft length ($r = .73$, $P<.001$). Regression analysis was performed for leg length with respect to graft length ($r^2 = .54$). The regression equation that allows prediction of graft length based on leg length is Graft Length = –12.79 + (1.557 × Leg Length). This is based on 95% confidence intervals (CIs) with a graft length of ±20 mm (95% CI, ±20 mm).

Correlations with graft diameter are summarized in Table III. Patient weight most strongly correlated with graft diameter ($r = .51$, $P<.001$). Leg length correlated less with graft diameter ($r = .42$, $P<.001$). However, these measurements alone were insufficient for predicting graft diameter.

Regression analysis was again performed once with all variables and again using a stepwise algorithm. In stepwise selection, weight ($P<.001$) and leg length ($P = .02$) were significant predictors of graft diameter when used in combination ($r^2 = .31$, $P<.001$). The regression equation using both weight and leg length as predictors is Graft Diameter = 4.80 + (0.07 × Weight) + (0.21 × Leg Length). The 95% CI when using leg length and weight (within the given parameters) to predict graft diameter is ±1.2 mm (CI 95%, ±1.2 mm).

Discussion

ACL reconstruction with hamstring autograft tendons is a popular procedure in orthopedics.[1-5] Various minimum diameters and lengths of doubled semitendinosus and gracilis autografts may be important to some surgeons and may be critical for certain surgical techniques and procedures.

Hamada and colleagues[6] measured the cross-sectional area of the semitendinosus tendon in 79 patients with ACL

rupture to evaluate the precision of magnetic resonance imaging in determining hamstring cross-sectional area and to correlate body size with cross-sectional area. They found that there was a slight correlation between body weight and cross-sectional area of the semitendinosus. There was also a slight correlation between patient height and length of the semitendinosus.

Yasumoto and colleagues[9] evaluated 28 patients who underwent ACL reconstruction. Preoperative 3-dimensional computed tomography (CT) images of the semitendinosus were obtained to predict length and diameter of the harvested tendon. There was a positive correlation between CT-measured graft length and actual graft length, but there was no correlation between CT-measured cross-sectional area and the cross-sectional area of the harvested graft.

We evaluated correlations of numerous easy preoperative measurements with diameters and lengths of doubled semitendinosus and gracilis autografts for ACL reconstruction, but only a few correlations with graft diameter and length were useful. First, patient leg length was strongly correlated with graft length. With use of 95% CIs, a regression equation was calculated that allows leg length to predict graft length within 20 mm.

Patient weight demonstrated moderate correlations with graft diameter. A somewhat lesser correlation was found with leg length and graft diameter. With regression analysis and stepwise selection, leg length and weight together were significant predictors of graft diameter. Graft diameter is correlated with both leg length and patient weight, and this was statistically significant. With 95% CIs, the calculated regression equation can be used to predict the diameter of the graft to within 1.2 mm given the leg length and the weight of the patient.

The ability to predict graft diameter and length may be useful for certain surgical techniques. Longer graft lengths may necessary for tibia-sided fixation outside the tibial tunnel. It would be helpful to know if a given patient's hamstring autograft would be long enough to allow this type of fixation. If the expected graft length were inadequate, the surgeon could choose an alternative graft type. Further, maximum graft diameters might be desired for revision ACL reconstruction. Previous tunnels and methods of fixation may necessitate a larger-diameter graft in a revision situation. If this were the case, an estimated hamstring graft diameter could aid in graft selection.

> **"The ability to predict graft diameter and length may be useful for certain surgical techniques."**

The main limitations of this study involve the accuracy of some preoperative measurements. Measuring leg length from the anterior superior iliac spine to the medial malleolus is not the most accurate way to measure leg length.[10] Also, measurements of weight did not take into account percent body fat. A measure of lean body mass may have demonstrated different results. However, the chosen measurements for the study were simple ones that could be performed with ease in an office setting.

Conclusions

Doubled semitendinosus and gracilis graft length for ACL reconstruction is strongly associated with leg length. For techniques that necessitate it, graft length can be predicted after measuring leg length. Further, graft diameter can be predicted with measurements of leg length and patient weight. Although these calculations are not precise, we feel that the graft data obtained may be valuable for preoperative planning for ACL reconstruction with hamstring autograft tendons.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

References

1. Freedman KB, D'Amato MJ, Nedeff DD, Kaz A, Bach BR Jr. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. *Am J Sports Med*. 2003;31(1):2-11.
2. Feller JA, Webster KE. A randomized comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction. *Am J Sports Med*. 2003;31(4):564-573.
3. Hamner DL, Brown CH, Steiner ME, Hecker AT, Hayes WC. Hamstring tendon grafts for reconstruction of the anterior cruciate ligament: biomechanical evaluation of the use of multiple strands and tensioning techniques. *J Bone Joint Surg Am*. 1999;81(4):549-557.
4. Woo SLY, Kanamori A, Zeminski J, Yagi M, Papageorgiou C, Fu FH. The effectiveness of reconstruction of the anterior cruciate ligament with hamstrings and patellar tendon: a cadaveric study comparing anterior tibial and rotational loads. *J Bone Joint Surg Am*. 2002;84(6):907-914.
5. Williams RJ III, Hyman J, Petrigliano F, Rozental T, Wickiewicz TL. Anterior cruciate ligament reconstruction with a four-strand hamstring tendon autograft. *J Bone Joint Surg Am*. 2004;86(2):225-232.
6. Hamada M, Konsei S, Mitsuoka T, Abe N, Horibe S. Cross-sectional area measurements of the semitendinosus tendon for anterior cruciate ligament reconstruction. *Arthroscopy*. 1998;14(7):696-701.
7. O'Neill DB. Revision arthroscopically assisted anterior cruciate ligament reconstruction with previously unharvested ipsilateral autografts. *Am J Sports Med*. 2004;32(8):1833-1841.
8. McAllister DR, Bergfeld JA, Parker RD, Grooff PN, Valdevit ADC. A comparison of preoperative imaging techniques for predicting patellar tendon graft length before cruciate ligament reconstruction. *Am J Sports Med*. 2001;29(4):461-465.
9. Yasumoto M, Deie M, Sunagawa T, Adachi N, Kobayashi K, Ochi M. Predictive value of preoperative 3-dimensional computer tomography measurement of semitendinosus tendon harvested for anterior cruciate ligament reconstruction. *Arthroscopy*. 2006;22(3):259-264.
10. Baylis WJ, Rzonca EC. Functional and structural limb length discrepancies: evaluation and treatment. *Clin Podiatr Med Surg*. 1988;5(3):509-520.

This paper will be judged for the Resident Writer's Award.