Prediction of Semitendinosus and Gracilis Tendon Lengths and Diameters for Double Bundle ACL Reconstruction

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Abstract

Although double bundle anterior cruciate ligament (ACL) reconstruction with hamstring autograft tendons has been reported frequently, some patients may not have enough semitendinosus and gracilis tissue to make satisfactory diameter and length grafts or allow secure graft fixation. The purpose of this study was to evaluate double bundle ACL reconstruction feasibility with hamstring autograft tendons and correlate this feasibility with patient height, weight, and body mass index (BMI).

One hundred consecutive patients undergoing ACL reconstruction with hamstring autograft tendons were evaluated. Preoperative height, weight, and BMI were documented for each patient. Our team measured semitendinosus and gracilis tendon lengths intraoperatively. Graft diameters were measured after doubling each tendon. Three double bundle ACL reconstruction techniques were defined that were felt to allow satisfactory graft diameters and lengths, and that would allow secure fixation of the grafts.

There were moderate correlations between patient height and graft lengths and diameters. There were poor correlations between patient weight and BMI, and graft lengths and diameters. The likelihood of having enough semitendinosus and gracilis tendon tissue for double bundle ACL reconstruction was 57%, 39%, and 88% for each of the 3 described technique constructs respectively.

Double bundle anterior cruciate ligament (ACL) reconstruction has enjoyed recent gains in popularity. Several investigators have proposed that double bundle ACL reconstruction better reproduces knee anatomy and rotational stability than single bundle ACL reconstruction.[1-7]

Double bundle ACL reconstruction techniques have been reported with use of autograft and allograft tendons. Most clinical reports of autograft double bundle ACL reconstruction have used hamstring autograft tendons. These double bundle ACL reconstruction techniques have significant variations. It is unclear whether all patients have enough semitendinosus and gracilis tissue for double bundle ACL reconstruction. Because it may be useful to be able to predict whether a given patient will have enough semitendinosus and gracilis tissue for double bundle ACL reconstruction prior to surgery, this study was conducted. Although other studies have attempted to predict hamstring tendon graft diameter and length for single bundle reconstructions, no reported study has attempted to make these predictions for double bundle ACL reconstruction using clinical measures.[8-11] Thus, the purpose of this study is to evaluate correlations between patient height, weight, body mass index (BMI), and sex with semitendinosus, and gracilis lengths and diameters for double bundle ACL reconstruction.

Materials and Methods

The study included 100 consecutive patients undergoing ACL reconstruction with hamstring autograft tendons. Preoperative data collection included patient sex, height, weight, and BMI. Institutional review board approval was obtained.

Through a small incision near their tibial insertions, the semitendinosus and gracilis tendons were sharply incised at their tibial insertions. Careful dissection was performed to debride any soft-tissue attachments to the tendons along their course. The typical semitendinosus gastrocnemius fascial attachments were carefully sectioned. Both tendons were detached at their myotendinous junctions with a closed tendon stripper.

Muscle was removed from each tendon with a blunt elevator. Any thin wispy end of either tendon was resected. The length of each tendon was measured. Each tendon was doubled so that the free ends matched up. A number 2-0 caliber suture was folded over the looped end of each tendon. The tendons were individually measured in commercial sizing cylinders that were arranged in 0.5 mm increments.

Because there are various options for deploying these 2 tendons for double bundle ACL reconstruction, several scenarios were considered to assess whether adequate tendon diameters and lengths were present. First, a common configuration in-

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Figure 1. Doubled semitendinosus to be used for one ACL bundle and doubled gracilis to be used for the other ACL bundle.

Figure 2. Construct 1 Drawing.

Figure 3. Semitendinosus tendon that is at least 270 mm long.

Figure 4. Scissors demonstrating position to cut the semitendinosus into 2 halves.

Figure 5. Semitendinosus tendon that has been cut into 2 parts.

Figure 6. The 2 parts of the semitendinosus tendon that are doubled to each be used for a different ACL bundle.

volves the use of a doubled semitendinosus for the anteromedial bundle and a doubled gracilis for the posterolateral bundle (**Figures 1, 2**). This will be termed construct number 1. Feasibility regarding diameter was evaluated for a minimum 5 mm diameter gracilis and a 6 mm diameter semitendinosus. Semitendinosus and gracilis length was not felt to be an issue for this configuration.

A second common construct (construct number 2) would involve cutting the semitendinosus to obtain 2 grafts. These 2 semitendinosus grafts would be doubled (**Figures 3-7**).[7,12,13] Each one would serve as a separate ACL graft bundle. This would necessitate a semitendinosus tendon that is 270 mm long. It was postulated that cutting the tendon at the appropriate position would result in doubled grafts that are 55 mm and 70 mm long. Feasibility regarding length was evaluated for a minimum 270 mm long semitendinosus graft.

Construct number 3 would involve tripling the semitendinosus and the gracilis grafts to obtain satisfactory diameters for the 2 bundles (**Figures 8, 9**). The tripled semitendinosus would be used for the anteromedial bundle and the tripled gracilis would be used for the posterolateral bundle. Tripling the grafts

Figure 7. Construct 2 Drawing.

Figure 8. Tripled semitendonosis to be used for 1 ACL bundle and tripled gracilis to be used for the other ACL bundle.

Figure 9. Construct 3 Drawing.

would compromise graft lengths. Feasibility regarding length was evaluated for a minimum 175 mm long gracilis tendon and a 220 mm long semitendinosus. It was postulated that after tripling tendons of such lengths, the tripled constructs would be approximately 55 mm and 70 mm long. This would allow for approximately 20 mm of graft in each of the 4 tunnels.

Statistical analysis was performed to evaluate correlations between height, weight, BMI, and sex, and semitendinosus and gracilis diameters and lengths. Pearson correlation coefficients were computed for these purposes.

Results

Pearson correlation coefficients for height, weight, and BMI with graft diameters and lengths are listed in **Tables 1-4**. Patient height had moderate correlations with semitendinosus and gracilis diameters and lengths. Patient weight and BMI had poor correlations with semitendinosus and gracilis diameters and lengths.

Construct One

Regarding construct number 1, all patients had long enough tendons to make this construct feasible. This construct was deemed feasible if a given patient's doubled gracilis was at least 5 mm in diameter. When this was the case, their doubled semitendinosus was always at least 6 mm in diameter.

Fifty-seven total patients (57%) had doubled gracilis tendons with diameters greater than or equal to 5 mm. If someone were at least 70 inches tall, then the likelihood that they would have a gracilis to make this construct feasible was 78% (35 of

45 patients). If someone were 65 inches tall or less, then the likelihood that they would have a gracilis to make this construct feasible was 32% (10 of 31 patients).

For surgeons who may desire that both the semitendinosus and gracilis tendons measure 6 mm in diameter or greater when doubled, this construct would not be very feasible. Four patients (4%) had doubled gracilis tendons that were greater than or equal to 6 mm in diameter. Three of these patients were at least 70 inches tall.

Construct Two

A total of 39 patients had semitendinosus tendons long enough to cut into 2 grafts. If someone were 70 inches tall or greater, then the likelihood that their semitendinosus was long enough to cut into 2 grafts was 62% (28 of 45 patients). If someone were less than 70 inches tall, then the likelihood that their semitendinosus was long enough to cut into 2 grafts was 20% (11 of 55 patients).

Table I. Correlations Between Height, Weight, BMI, and Semitendinosus Graft Diameter

	Correlation Coefficient	P-Value
Height (in)	0.43	P < 0.001
Weight (lbs)	0.38	P < 0.001
Body Mass Index (kg/m²)	0.185	0.065

Table II. Correlations Between Height, Weight, BMI, and Semitendinosus Graft Length

	Correlation Coefficient	P-Value
Height (in)	0.59	P < 0.001
Weight (lbs)	0.33	P = 0.001
Body Mass Index (kg/m²)	0.002	0.99

Table III. Correlations Between Height, Weight, BMI, and Gracilis Graft Diameter

	Correlation Coefficient	P-Value
Height (in)	0.41	P < 0.001
Weight (lbs)	0.44	P < 0.001
Body Mass Index (kg/m²)	0.29	0.009

Table IV. Correlations Between Height, Weight, BMI, and Gracilis Graft Length

	Correlation Coefficient	P-Value
Height (in)	0.51	P < 0.001
Weight (lbs)	0.33	P = 0.001
Body Mass Index (kg/m²)	0.07	0.49

Construct Three

A total of 88 patients had tendons long enough to triple. If someone were 66 inches tall or greater, then the likelihood that their tendons were long enough to triple was 93% (64 of 69 patients). If someone were 65 inches tall or less, then the likelihood that their tendons were long enough to triple was 77% (24 of 31 patients).

Discussion

This study revealed the likelihood of having enough hamstring autograft tissue from a given patient's knee to perform double bundle ACL reconstruction with hamstring autograft tendons with 3 possible techniques. When considering using the semitendinosus and gracilis tendons for separate graft bundles and to have a gracilis tendon diameter of at least 5 mm, 57% of patients had enough hamstring tendon graft tissue. When considering cutting a semitendinosus into 2 grafts, doubling each portion and utilizing each portion as a separate graft bundle, 39% of patients had long enough semitendinosus tendons to perform this technique. When considering tripling the semitendinosus and gracilis tendons and utilizing each as a separate graft bundle, 88% of patients had enough tissue.

Further, this study demonstrated moderate correlations between patient height and semitendinosus, and gracilis tendon diameter and length. Conversely, patient weight and BMI had poor correlations with semitendinosus and gracilis tendon diameter and length.

Double bundle ACL reconstruction has been supported in numerous biomechanical and clinical studies.[1-7,14-17] It has been reported that double bundle ACL reconstruction better restores anatomy and provides better rotational control than single bundle ACL reconstruction. The great majority of techniques in published reports of double bundle ACL reconstruction have utilized hamstring autograft tendons. The constructs in these reports have varied substantially.

A handful of clinical comparison studies between double and single bundle ACL reconstructions have revealed some superior outcomes measures for double bundle ACL reconstruction.[3-7,14-17] Suomalainen and colleagues[14] prospectively compared single bundle to double bundle ACL reconstruction with hamstring autograft tendons. Doubled semitendinosus and gracilis tendon grafts were fixed with interference screws. There were significantly more graft failures in the single bundle group at 2-year follow-up, but no differences between groups regarding arthrometer laxity measurements, pivot-shift tests, and clinical outcomes scores.

Izawa and colleagues[15] prospectively compared quadrupled semitendinosus autograft single bundle ACL reconstruction with double bundle ACL reconstruction utilizing a semitendinosus autograft cut in half lengthwise and then doubled to obtain 2 separate grafts. They found significantly less laxity for the double bundle ACL group with the Slocum anterolateral rotatory instability test and the K-2000 arthrometer. There

were no differences found regarding pivot-shift test and clinical outcomes scores.

In another prospective, randomized study, Ibrahim and colleagues[4] evaluated doubled semitendinosus and gracilis tendon autografts for single bundle ACL reconstruction versus double bundle ACL reconstruction. Although no differences were found between groups for clinical outcomes scores, double bundle ACL reconstruction demonstrated less laxity with the Lachman test and arthrometer measurements.

Some studies have revealed no outcomes differences between double and single bundle ACL reconstructions.[18,19] Park and colleagues[18] prospectively compared single and double bundle ACL reconstruction utilizing hamstring autograft tendons. The single bundle group graft constructs were double semitendinosus and gracilis tendons. The double bundle group constructs were tripled semitendinosus and gracilis tendons to create 2 separate grafts. No differences were found between the groups at 2-year follow-up for pivot-shift testing, arthrometer measurements, and clinical outcomes scores.

Song and colleagues[19] compared single versus double bundle ACL reconstruction with tibialis anterior tendon allografts. Despite better intraoperative anterior and rotational stability in the double bundle group, 2-year outcomes revealed no differences in Lachman tests, pivot-shift tests, and clinical outcomes scores.

Despite some favorable clinical results, some of these techniques may not be considered optimal by ACL surgeons. For example, a common technique reported involved splitting the semitendinosus tendon in half, doubling each half, and utilizing the 2 parts for the 2 ACL bundles.[7,12,13] These techniques often utilized tibial-sided fixation such as post fixation. This was likely necessitated by short grafts. Although post fixation is considered an acceptable tibial fixation in ACL reconstruction, it may not provide the strength and stiffness that some surgeons desire for accelerated postoperative rehabilitation.

Another commonly reported technique involves utilizing the semintendinosus for 1 ACL bundle and the gracilis for the other graft bundle.[4,5,6,14] Although this provides sufficient length for the grafts, the gracilis diameter may be quite small. Some surgeons may not desire one of the graft bundles to be a petite graft due to concerns over graft strength and stiffness.

Because of these concerns, this study was undertaken to evaluate and attempt to make some predictions regarding hamstring autograft diameters and lengths with respect to double bundle ACL reconstruction. It may be useful for surgeons who choose to embark on double bundle ACL reconstruction with hamstring autograft tendons to be able to predict preoperatively which patients may have enough graft tissue for double bundle ACL reconstruction. Realizing that there are different techniques for double bundle ACL reconstruction, 3 constructs were described and evaluated for double bundle ACL reconstruction feasibility. It was postulated that simple measurements such as height, weight, and BMI would be practical measures for most surgeons.

Prior studies have evaluated hamstring autograft tendon diameters and lengths for single bundle ACL reconstruction based on patient heights and weights.[8,9,10,11] Tuman and colleagues[9] found positive correlations between hamstring autograft tendons and patient height and weight in a medical record review. In a prospective evaluation of 50 patients, Treme and colleagues[10] found strong correlations between height and graft length, and weight and graft diameter. In a prospective study of 100 patients, Schwartzberg and colleagues[11] demonstrated a strong correlation between patient height and hamstring graft length, and a moderate correlation between patient weight and hamstring graft diameter. Xie and colleagues[8] showed strong correlations for height and weight with graft length. They found strong correlations for semitendinosus diameter with weight and gender.

Regarding preoperative magnetic resonance imaging (MRI) hamstring graft size predictions, Bickel and colleagues[20] demonstrated a strong correlation between gracilis and semitendinosus MRI cross-sectional area and hamstring tendon graft diameter for single bundle ACL reconstruction. Evaluation and prediction of graft diameter in double bundle ACL reconstruction with hamstring autograft tendons was performed with an MRI study.[21] Wernecke and colleagues[21] showed positive correlations between MRI cross sectional area measurements of semitendinosus and gracilis tendons with intraoperative measures.

This study is the only study utilizing patient body measurements to evaluate hamstring autografts for double bundle ACL reconstructions. The study provides surgeons with data for 3 possible double bundle ACL reconstruction constructs. It demonstrates percentage likelihoods that patients will have enough hamstring autograft tissue in a given leg for these 3 constructs. Because there were moderate correlations between height and semitendinosus, and gracilis graft diameters and lengths, surgeons can consider the likelihood that patients who are quite short or quite tall may have enough hamstring tissue for one of the double bundle ACL reconstruction constructs.

There are several limitations to this study. First, only semitendinosus and gracilis tendon autografts were evaluated. Other autografts could be added to allow more tissue for double bundle ACL reconstruction for a given patient. Such autografts could include patellar tendon, quadriceps tendon, and contralateral knee semitendinosus and gracilis tendons. Ipsilateral semitendinosus and gracilis tendons only were chosen since this is the most common graft selection for double bundle ACL reconstruction in the literature.

Another limitation involves the 3 double bundle ACL reconstruction constructs chosen. There are likely other methods for performing double bundle ACL reconstruction. However, these are reported techniques or techniques that employ common ACL reconstruction graft fixation principles. Further, assumptions were made regarding minimum graft diameters and lengths for the constructs. These assumptions were made to utilize graft diameters that the author deems ample and graft lengths that allow for high strength fixation.

Last, the amount of hamstring autograft tissue available is not the only limiting factor in the performance of double bundle ACL reconstruction. Other potential limiting factors

that were not evaluated in this study include tibial and femoral insertion sizes and intercondylar notch volumes.

Conclusion

This study provides surgeons with data to evaluate the likelihood of having enough hamstring autograft tissue to perform double bundle ACL reconstruction with 1 of 3 described reconstruction techniques. There are moderate correlations between patient height and semitendinosus, and gracilis graft diameters and lengths that can be helpful when contemplating double bundle ACL reconstruction.

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