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Technical Notes

Prediction of graft length by body height in anatomic double-bundle anterior cruciate ligament reconstruction

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Introduction

Anatomic double-bundle (DB) anterior cruciate ligament (ACL) reconstruction has a theoretical advantage and can result in effective restoration of rotational stability.[1,2] In anatomic DB ACL reconstruction, the semitendinosus and gracilis (STG) tendons are commonly used grafts.[3–5]

However, Tadokoro et al.[6] evaluated patients who underwent ACL reconstruction with hamstring graft, and the isometric peak torque was reduced to 49.1% when the isometric hamstring strength was examined in a prone position at 110 degrees of flexion. Gobbi et al.[7] compared the internal rotation peak torque between patients who underwent ACL reconstruction with semitendinosus (ST) tendon alone and patients who underwent ACL reconstruction with STG tendons at one year after surgery. They reported that the internal rotation torque deficit was significantly higher in the STG group, demonstrating that only ST tendon should be used when performing ACL reconstruction with hamstring tendon. In our institution, anatomic DB ACL reconstruction is usually performed using only ST tendon autograft. However, it is unknown when the ST tendon is too short to prepare the grafts of antero-medial bundle (AMB) and postero-lateral bundle (PLB).

Because the femoral tunnel position in anatomic ACL reconstruction was more posterior in arthroscopic view than in isometric ACL reconstruction and the tibial tunnel position was more anterior in arthroscopic view, the length of intra-articular graft was getting longer and the graft in the tibial bone tunnel was relatively shorter.[11] As a result, the suture of the graft sometimes appeared in the intra-articular exit of the tibial tunnel in clinical situation (Fig. 1). However, there was no study to evaluate the required length of the graft for anatomic DB ACL reconstruction.

The purpose of this study was to investigate the intra-articular graft length and the length in the bone tunnels after anatomic DB ACL reconstruction with ST tendon, and predict the required length of ST tendon.

Materials and methods

From May 2013 to December 2015, 266 consecutive patients underwent anatomic DB ACL reconstruction with hamstring tendon at the author's hospital. Preoperatively the authors recorded patient height. At one week after surgery, all knees were routinely scanned by computed tomography (CT) for another study.[8] The ethics review board of Meiwa Hospital approved this study [No. 29–12].

Surgical procedure

All surgeries were performed by the three senior authors (M.Y., A.M., K.S.) under general anesthesia. One half of ST tendon was doubled for AMB reconstruction, and the other half of ST tendon was also doubled for PLB reconstruction. Both ends were firmly sutured side-by-side (approximately 15 mm in length) using No. 2 Ultrabraid (Smith and Nephew, Andover, MA). The length of AMB and PLB grafts was then measured. The composite tendon graft was fixed with an EndoButton CL (Smith and Nephew, Andover, MA) proximally and a post screw distally. An

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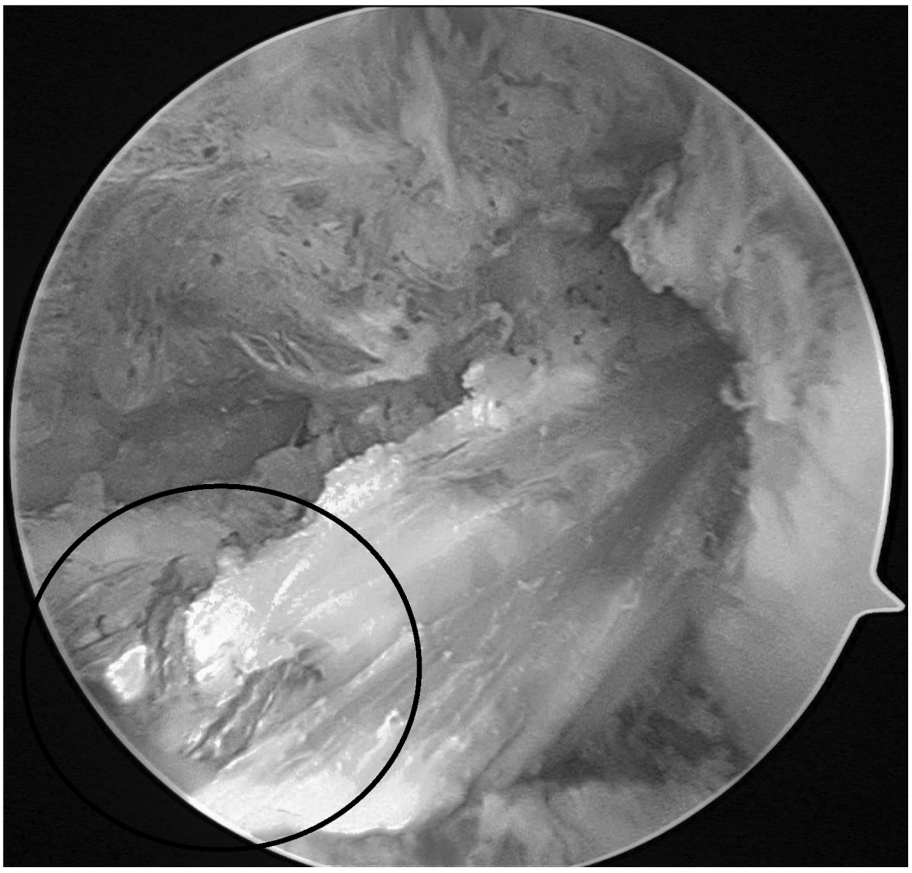

Fig. 1. The suture of the graft appeared in the intra-articular exit of tibial tunnel (circle).

appropriately sized EndoButton CL was selected so that the graft length in the femoral tunnel was above 10 mm.

Inclusion criteria

1) Anatomic DB ACL reconstructions were performed with ST tendon alone.
2) The femoral tunnels of AMB and PLB were located between the resident's ridge and the posterior articular cartilage margin of the lateral femoral condyle on the 3-D CT image (Fig. 2).[9]
3) The tibial tunnel of AMB was located just lateral to the medial intercondylar ridge and just posterior to the anterior ridge, and the tibial tunnel of PLB was located just lateral to the medial intercondylar ridge and between the tibial tunnel of AMB and the anterior intertubercular ridge on the 3-D CT image (Fig. 2).[10]

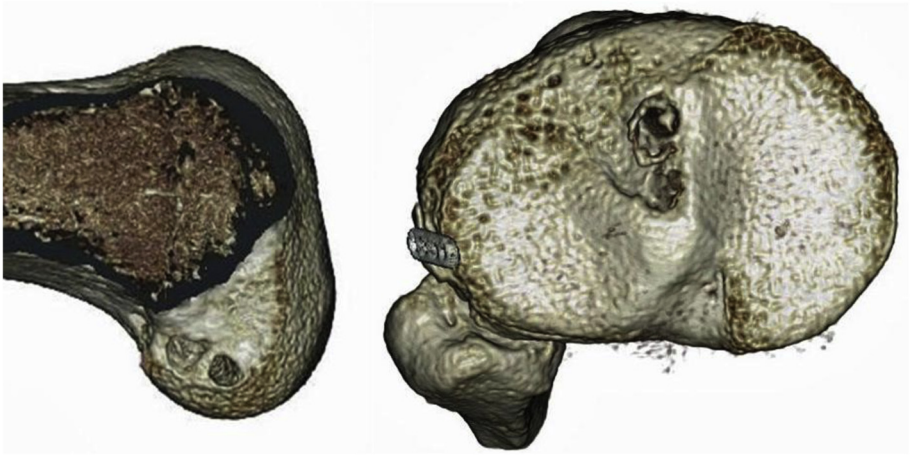

Fig. 2. The femoral tunnels were located between the resident's ridge and the posterior articular cartilage margin of the lateral femoral condyle. The tibial tunnel of AMB was located just lateral to the medial intercondylar ridge and just posterior to the anterior ridge, and the tibial tunnel of PLB was located just lateral to the medial intercondylar ridge and between the tibial tunnel of AMB and the anterior intertubercular ridge.

4) The tunnel coalition of AMB and PLB did not occur. If the tunnel coalition did occur, it would be difficult to measure the intra-articular graft length accurately.

Methods

CT data was reconstructed parallel to the longitudinal axis of the intra-articular graft, and the length of the intra-articular graft was then measured (Fig. 3).

The graft length in the femoral tunnel was calculated by the lengths of the femoral bone tunnel and the EndoButton CL. The graft length in the tibial tunnel was calculated by the lengths of the whole graft, the graft in the femoral tunnel, and the intra-articular graft (Fig. 4).

Statistical analysis

The Pearson correlation coefficient was used to correlate the intra-articular graft length and patient height with the significance level set at $P < 0.05$. When a significant interaction was detected, a linear regression analysis was performed. A post hoc power analysis was performed to ensure adequate power was obtained to support the conclusions.

Results

A total of 178 patients were enrolled. The average intra-articular graft lengths of AMB and PLB were 36.3 mm and 25.2 mm respectively (Table 1). The average difference between AMB and PLB length was 11.1 mm. The average lengths in the tibial tunnel of both AMB and PLB were 18.0 mm and 18.3 mm respectively.

There was a statistically significant correlation between the intra-articular graft length and patient height (Fig. 5).

Intra-articular AMB length (mm) = 0.31 × height (cm) − 14:
$R = 0.65$, $p < 0.0001$

Intra-articular PLB length (mm) = 0.27 × height (cm) − 19.3:
$R = 0.55$, $P < 0.0001$

The post hoc power analysis showed a power was 0.99. To make the graft length in the femoral tunnel more than 10 mm and the graft length in the tibial tunnel more than 15 mm, the required length of ST tendon can be estimated with use of above equation.

Discussion

This retrospective study focused on prediction of the required length of ST tendon in anatomic DB ACL reconstruction with ST tendon alone, and investigated the intra-articular graft length and the length in the bone tunnels. Brown et al.[12] collected intra-articular length of the anterior cruciate ligament from magnetic resonance imaging. They found a strong positive correlation between intraarticular length of the ACL and patient height. Because they assessed the correlation between actual ACL length and patient height, we believed that our study was based on more clinical situation. This is the first study to show that the required length of ST tendon can be predicted from patient height because the intra-articular graft length was statistically significant and correlated to patient height.

In the present study, the average difference between AMB and PLB length was 11.1 mm. Hollis et al.[13] showed that the AM portion was 34.4 mm and the PL portion was 22.5 mm at 0 deg flexion of cadaveric knees. Therefore, we suggest that the graft for AMB is prepared 1 cm longer than the graft for PLB.

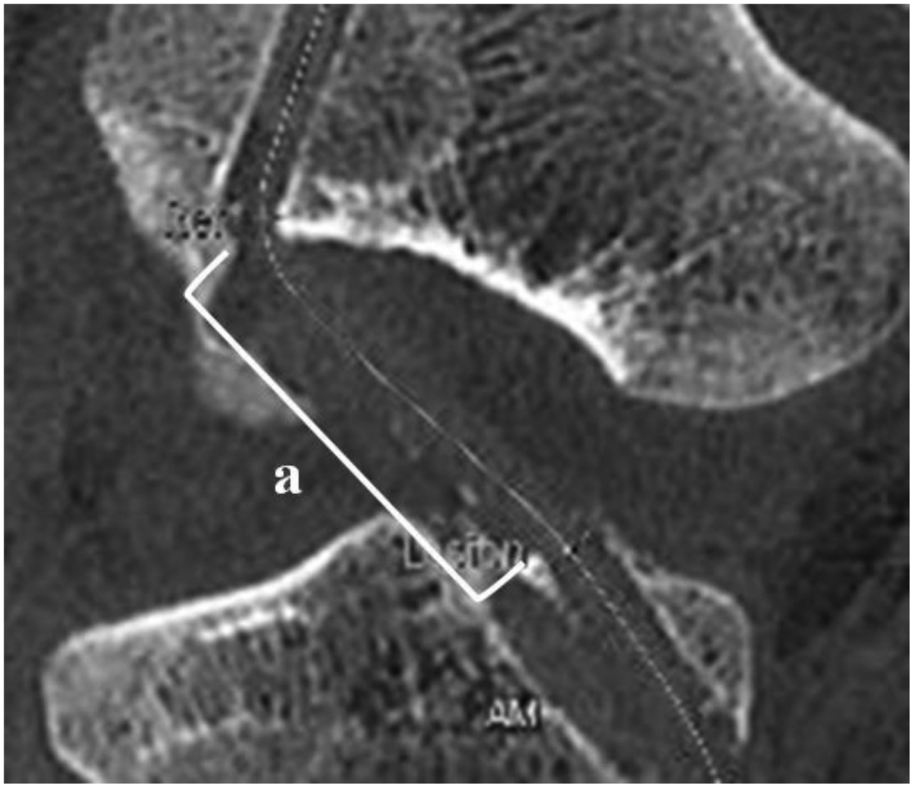

Fig. 3. The length of the intra-articular graft (a).

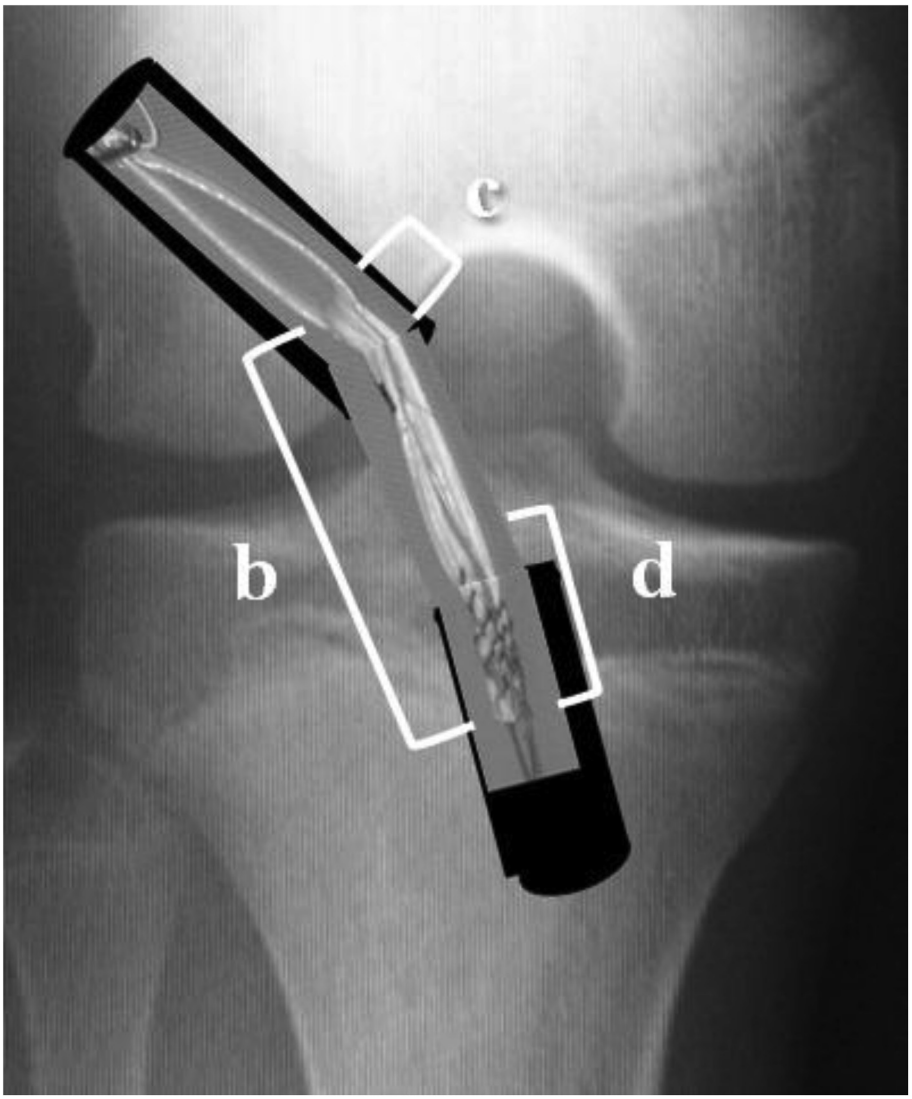

Fig. 4. The length of the whole graft (b), the graft length in the femoral tunnel (c), the graft length in the tibial tunnel (d). In this study, an appropriately sized EndoButton CL was selected so that the graft length in the femoral tunnel was above 10 mm.

Table 1
The average difference between AMB and PLB length was 11.1 ± 2.9 mm. In 14 cases the graft length in the tibial tunnel was less than 10 mm.

	AMB	PLB
Intra-articular graft length (mm)	36.3 ± 4.1	25.2 ± 4.2
Graft length in the tibial tunnel (mm)	18.0 ± 4.7	18.3 ± 5.6

The Authors selected an appropriately sized EndoButton CL so that the graft length in the femoral tunnel was above 10 mm. Regarding the previous studies dealing with the graft length in the bone tunnel, Qi et al.[14] suggested that lowering the amount of the intratunnel graft below a minimum of 15 mm should be avoided. However, Yamazaki et al.[15] compared graft having a length of 15 and 5 mm within the bone tunnel. They showed that there is no negative correlation between short graft length in the bone tunnel and the resulting knee kinematics and structural properties. In the present study, a minimally acceptable length of intra-tunnel tendon graft to allow satisfactory early tendon-bone healing was set more than 10 mm.

In the tibial tunnel, the sutures wrapping the tendon affected the tendon-bone healing as a barrier that hinders the formation of fibrous connection between the tendon and the bone tunnel.[14] So, this study determined the appropriate graft length in the tibial tunnel was set more than 15 mm. There is no consensus on the required length in the bone tunnel, and further study is needed.

There are limitations in this study as follows. First, 48 patients (18%) were excluded in this study because the femoral and tibial tunnels were not located in the anatomic position, or tunnel coalition did occur. The position of the femoral and tibial tunnels depended on the surgeons. So, there was variation in the position of the femoral and tibial tunnels. However, cadaveric studies showed that the length of the ACL ranges between 31 mm and 39 mm.[16–18] Therefore, the authors believe that the intra-articular graft length in the present study was approximately equal to the length of a normal ACL, and the position of the femoral and tibial tunnels was approximately equal to the ACL insertion. Second, this study only examined a correlation between the intra-articular graft length and patient height. Nuelle CW et al.[19] showed that patient height and weight were strongly correlated to final quadrupled

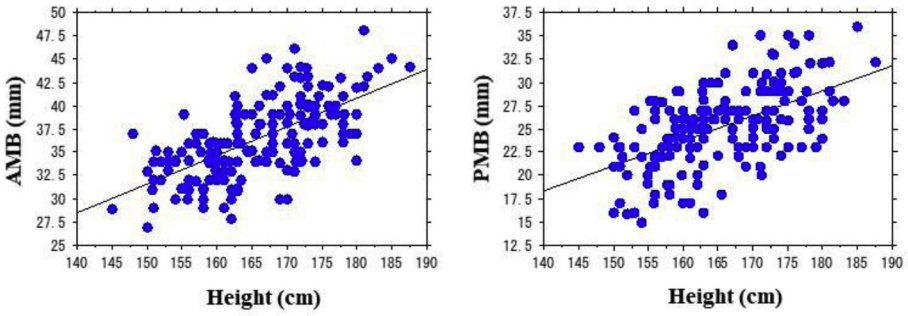

Fig. 5. The intra-articular graft length was statistically significant and correlated to patient height (AMB: R = 0.65, p < 0.0001; PLB: R = 0.55, P < 0.0001). The post hoc power analysis showed a power was 0.99.
Intra-articular AMB length (mm) = 0.31 × height (cm) − 14.4
Intra-articular PLB length (mm) = 0.27 × height (cm) − 19.3.

semitendinosus construct diameter and length. Treme G et al.[20] suggested that strongest correlations for hamstring graft lengths were height and leg length measurements. Though measurement parameter was different, the previous studies were compared with weight and leg length, and further study is mandatory.

Conclusion

The graft for AMB should be prepared 1 cm longer than the graft for PLB. It is possible to estimate the length of intra-articular graft based on patient height; therefore, if the length of ST tendon would be shorter than the required length, harvesting the gracilis tendon could be an alternative approach.

Conflicts of interest

The authors have no conflicts relevant to this article.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.asmart.2018.01.001.

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