Original Article

Anatomic Anterior Cruciate Ligament Reconstruction Using Rectangular Bone−Tendon− Bone Autograft Versus Double-Bundle Hamstring Tendon Autograft in Young Female Athletes

Takaki Sanada, M.D., Hiroshi Iwaso, M.D., Ph.D., Atsushi Fukai, M.D., Ph.D., Eisaburo Honda, M.D., Hiroki Yoshitomi, M.D., and Miyu Inagawa, M.D.

Purpose: To assess the clinical outcomes comparing rectangular bone−tendon−bone (BTB) grafts and double-bundle hamstring tendon (HM) grafts used for anatomic anterior cruciate ligament (ACL) reconstruction in young female athletes. **Methods:** From January 2014 to November 2017, young female athletes 20 years or younger who underwent primary ACL reconstructions by a single surgeon were identified. Patients with concomitant injuries, not being a regular sports participant, the existence of contralateral ACL reconstruction, and who did not have a minimum of 1-year follow-up were excluded. We searched the rate and time for return-to-play, clinical outcomes including chronological instrumental side-to-side tibial translation difference, and muscle strength. Second ACL injury rates between the 2 groups during follow-up period were evaluated. **Results:** Twenty-seven BTB ACL reconstructions and 29 HM ACL reconstructions were performed. The mean follow-up periods were 35.2 months in the BTB group and 33.8 months in the HM group. The BTB group showed better knee stability in mean side-to-side translational difference via arthrometric testing of 0.6 mm in the BTB versus 1.7 mm in the HM group at 5 months ($P = .01$) and 1.1 mm and 2.0 mm at 12 months, respectively ($P = .02$). There was no significant side-by-side difference in quadriceps muscle strength ratio, but the hamstring muscle strength was significantly better in the BTB group. The graft reinjury rate in the BTB group and the HM group was 0% (0/27) and 10.3% (3/29) ($P = .09$), respectively. In contrast, contralateral ACL injuries occurred in 17.3% (4/27) of the BTB group and 3.5% (1/29) of the HM group ($P = .12$). **Conclusions:** For young female athletes aged 20 years or younger, the BTB group had better knee instrumental stability than the HM group without range of motion loss or knee extensor muscle strength deficit. Although there was no statistical significance in terms of second ACL injury, we observed fewer graft rerupture and an increasing rate of contralateral ACL injuries in the BTB group. **Level of Evidence:** Level III, retrospective comparative study.

Anterior cruciate ligament (ACL) injuries increasingly are occurring in young athletes.[1] In general, female athletes have a 3 to 7 times greater risk for primary ACL injuries than male athletes.[2-4] Moreover, young female athletes are also at a high risk for second ACL injuries while playing sports after returning to play.[5,6] Graft selection for the ACL reconstruction is a considerable issue relating to ACL reconstruction. Essentially, among current autograft selection for the ACL reconstruction, bone−patellar tendon−bone grafts and hamstring tendon or quadriceps tendon graft have been well used and compared clinically.[7,8] Although there was a reported result that the bone−patella tendon−bone and hamstring tendon autografts provide high subjective and objective scores with good patient satisfaction,[9] bone−tendon−bone (BTB) grafts have greater incidences of postoperative anterior knee pain and kneeling discomfort when compared with hamstring tendon grafts.[9,10] BTB grafts also resulted in quadriceps muscle strength deficiency and the loss of

From the Department of Sports Orthopedic Surgery, Kanto Rosai Hospital, Kawasaki, Japan.

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Address correspondence to Takaki Sanada, M.D., 1-1 Kizuki Sumiyoshi-cho, Nakahara-ku, Kawasaki city, Kanagawa pref, 211-8510, Japan. E-mail: sanasana511@gmail.com

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extension range of motion.[11,12] On the contrary, hamstring autografts resulted in weakened knee flexion muscle strength compared with the BTB autograft[13] and had an increased risk of deep infections.[14] Second-look arthroscopy indicated subclinical posterolateral bundle injuries in the double-bundle hamstring reconstructions.[15] The hamstring autograft was seen as a greater risk selection for an ACL reconstruction procedure due to graft re-rupture rate.[16-19] Concerning the instrument laxity of the tibial translation in general population, some reports mentioned that the BTB graft did indicate a superior evaluation compared with the hamstring autograft[13,20-22]; however, others proved no difference.[19,23]

In studies that quantified a young female population, the BTB graft reconstruction provided better anterior translation stability and lower reinjury rate than the hamstring reconstruction.[24,25] The purpose of the study is to assess the clinical outcomes comparing rectangular BTB grafts and double-bundle hamstring tendon (HM) grafts used for anatomic ACL reconstruction in young female athletes. It was hypothesized that the use of BTB graft in young female athletes would be associated with a lower risk of the second ACL injury and better knee muscle function than hamstring graft.

Methods

From January 2014 to November 2017, a total of 56 young female athletes who underwent primary ACL reconstruction were included in the study. They qualified at least 1-year clinical follow-ups for the physical examination including instrumental measurement tests and isokinetic muscle strength tests and also qualified more than 2 years of consecutive follow-ups as either outpatients or by telephone questionnaire by the corresponding author (T.S). The graft selection was dependent on each patient and her parents' decision after an adequate discussion with the corresponding author of surgeon. We investigated the rate and time to return-to-sports, second ACL injuries, and clinical outcomes. In the series, return-to-sports was defined as participating in a typical practice on their previous team or returning to the same sport at the same activity level on another team. Graft reruptures and contralateral ACL ruptures were defined as the state of stopping sports activity due to increase anterior tibial laxity in the knee, that was then confirmed by magnetic resonance imaging findings or arthroscopic investigation. The institution review board in the hospital approved the survey of this retrospective study.

Surgical Technique

A single surgeon (T.S) of the corresponding author performed all surgical procedures. The BTB group was reconstructed by using the ipsilateral rectangular BTB autograft. The femoral tunnel was created via the transportal method in the anatomic position and the tibial tunnel made in a rectangular tunnel was directed parallel to the graft. The cross-sectional area of the rectangular femoral socket and tibial tunnel were created in the size of 6 × 10 mm in the anatomic position (Fig 1A). The bone plug of rectangular autograft was formed to fit the bone tunnel then inserted into the bone socket (Fig 1B). The mean length of the plug was 13.4 (range 12-16) mm. The graft was fixed with an ENDOBUTTON (Smith & Nephew, Inc., Andover, MA) and linked to the bone plug with suture button tape (Arthrex, Naples FL) on the femoral side and the tibial bone plug end was stacked with 3 folded #5 polyethylene braids. The BTB graft tied to the tibial post screw and washer (Meira GTS, Nagoya, Japan). The applying tension was a total of 60 or 80 N to the graft at full knee extension position. In contrast, the HM group graft source was the semitendinosus tendon or semitendinosus and gracillis tendons from the ipsilateral extremity. The tendon divided into 2 grafts prepared as the anteromedial and the posterolateral bundles. The femoral tunnels were created via the transtibial technique into the anatomic position (Fig 2A). The grafts were fixed on the femoral side with ENDOBUTTON CL (Smith & Nephew) until December 2015 and with TightRope RT (Arthrex) starting January 2016. The tibial graft ends were fashioned with #2 polyethylene braids by whip-stich sutures (Fig 2B). The graft fixation to the tibial end was the same procedure as the BTB graft, fixation to the screw post at the same tension in full knee extension position. We confirmed the growth plates status of all young patients from post-operative CT (Fig 1C and 2C).

Rehabilitation

Postoperative rehabilitation in the 2 groups were done in the same protocol. Physical therapy was initiated from the second day after the surgery, with the patient wearing a hinged knee orthosis. The patients started walking with full weight-bearing as tolerated and started gradual range of motion by slowly increasing the angle toward the full range until they reached full flexion at 4 months after surgery. Jogging training began at 2 months after surgery. They participated in sport activities from 5 months aiming to return to the competitive level of sports participation at 8 months when they have qualified for the goal of quadriceps and hamstring muscle recovery. We set the goal of muscle recovery to be that the knee extension and flexion peak-torque comparing to the contralateral intact extremity is more than 80% via the isokinetic dynamometer (Biodex system3, New York, NY) to return-to-play.

Statistical Analysis

For the statistical analysis, EZR (Jichi Medical University Saitama Medical Center, Saitama, Japan), which is a modified method from R (The R Foundation, Vienna,

Fig 1. A femoral bone tunnel was created in a 6- × 10-mm cross-sectional area in the anatomic position (black arrows) (A). The rectangular femoral bone plug (black arrows) was inserted and fixed by the suspensory device (B). The growth plate of this 14-year-old athlete was closed at tibial side and femoral growth plate almost closed (C).

Austria) was used. We used Mann−Whiney *U* tests or the Student *t* test for continuous variables (return-to-play, KneeLax3 arthrometry, Tegner activity score, muscle strength) and the Fisher exact test and χ^2 test for categorical variables (range of motion loss, manual instability test, complications, second ACL injury rate) to compare the 2 groups. We defined that a *P* value of less than .05 as being statistically significant different in the series. A sample size calculation was done using second ACL injury rate. If the injury rate in group 1 is 0.03 and group 2 is 0.2, then the study will have a power of 80% to yield a statistically significant result with 5% risk of an error, the propose sample size is 66 patients for each group.

Results

Young female athletes who underwent ACL reconstruction by a single surgeon (T.S.) were identified. Inclusion criteria were female patients who underwent primary ACL reconstruction and who were aged 20 years or less at the time of surgery. Exclusion criteria were the existence of concomitant injuries, not being a regular sports participant, the existence of contralateral ACL reconstruction, and who did not have a minimum of 1-year follow-up. Of the 56 young female athletes who underwent primary ACL reconstruction, either the rectangular BTB autograft or the HM autograft was used. The group size for reconstruction with the BTB group was 27 and the group size for hamstring autograft (HM group) was 29. The mean times to follow-up after surgeries were 34.2 (range 24-60) months in the BTB group and 33.8 (range 24-60) months in the HM groups ($P = .74$). There were no partial ruptures in the series.

There was no significant difference between the 2 groups in regard to age and height. There were a variety of sports in which the patients participated, mostly basketball, which comprised 41.1% of all sports, followed by volleyball, handball, and badminton. These 4 sports comprised 71.4% of the total participants of the series of investigation (Table 1).

Intraoperative data are displayed in Table 2. Concomitant intrajoint cartilage lesion and meniscal injury that required additional procedures were not

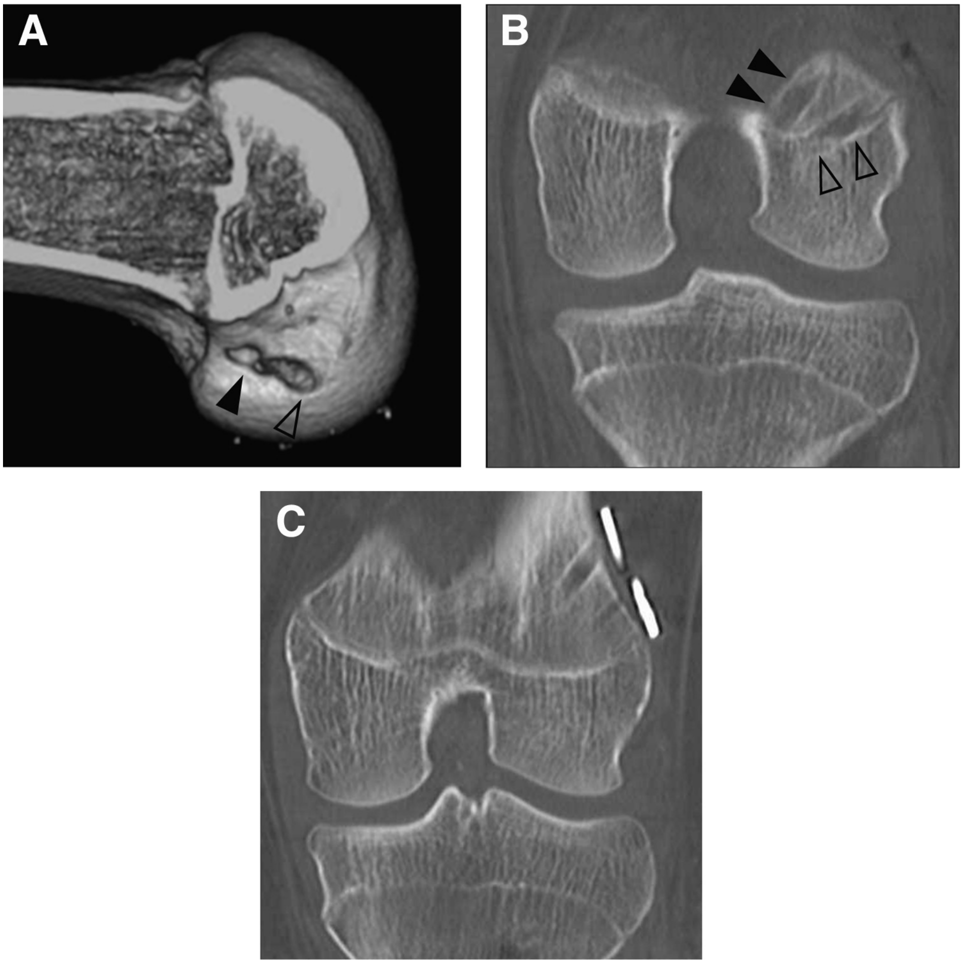

Fig 2. Anteromedial bone tunnel (black arrow) and posterolateral bone tunnel (open arrow) were set in the anatomic position (A). The grafts were fixed by the suspensory device into the anteromedial (black arrows) and the posterolateral (open arrows) bone tunnels (B). The growth plate of this 12-year-old athlete, who was the youngest patient in the series, was adequately closed at tibial side and femoral growth plate almost closed (C).

significantly different between the groups. One patient in the BTB group underwent simultaneous medial collateral ligament repair (Table 2).

In total, 92.6% of female athletes from the BTB group and 86.2% from the HM group were able to return to previous sports. Two athletes from the BTB group and 4 from the HM group did not return to play within the follow-up period. These 4 athletes no longer played sports because their high school season had already ended at the estimated time of return-to-play after surgery. The other 2 athletes from the HM group were skiers who had just started their first year on a competitive collegiate ski team. Both of the 2 beginners quit competitive skiing after surgery. There is no significant difference of mean time for return-to-play between the 2 groups ($P = .40$) (Table 3).

Concerning second ACL injuries after primary reconstruction, there were no statistically significant difference in graft ruptures ($P = .09$) or contralateral ACL injuries ($P = .13$) in the 2 groups. However, no graft ruptures occurred in the BTB group (Table 4).

In regard to clinical outcomes 1-year postoperation, there were no statistical differences for the ratio of knee range of motion nor clinical outcome scores. There was no difference in the ratio for negative Lachman test or negative pivot shift test by the N-test maneuver (Table 5). However, according to the chronological side-to-side laxity difference via the Knee lax3 evaluation, BTB reconstruction contributed better instrumental stability than the HM group at the periods of 5 ($P = .01$) and 12 months ($P = .02$) (Fig 3).

Also, we investigated chronological quadriceps and hamstring muscle strength after the surgeries. Side-to-side isokinetic quadriceps muscle strength ratio had no difference between the BTB group to the HM group muscle strength from 5 to 12 months after surgery (Fig 4 A and B). In contrast, hamstring muscle strength was significantly greater in the BTB group than the HM group from 5 to 12 months after surgery at 60°/s ($P < .001$) and at 12 months after surgery at 180°/s ($P = .05$) (Fig 5 A and B).

Discussion

In the study, we found that the BTB reconstruction had better knee instrumental stability than the HM reconstruction without range of motion loss or muscle

Table 1. Demographic Data for Patients in the BTB and the HM Groups

	BTB Group (n = 27)	HM Group (n = 29)	*P* Value
Age, y, mean (min-max)	16.3 (13-20)	16.5 (12-20)	.63
Height, cm, mean (min-max)	160.9 (150-170)	159.7 (150-172)	.43
Weight, kg, mean (min-max)	56.2 (48-77)	53.3 (43-63)	.05
Time to follow-up, mo, mean (min-max)	35.2 (24-63)	33.8 (24-60)	.62
ROM extension loss >3°, % (N)	7.4% (2/27)	10.3 % (3/29)	.7
ROM flexion loss >5°, % (N)	22.2% (6/27)	27.6% (8/29)	.64
Side-to-side difference (mm, mean (min-max)	5.5 (2.2-10.5)	5.6 (2.4-10)	.82
Tegner activity score, mean (min-max)	7.3 (6-10)	7.0 (6-9)	.16
Lysholm score, mean (min-max)	79.9 (60-95)	77.2 (61-95)	.24
IKDC, % (n)			
A	0% (0)	0% (0)	
B	0% (0)	3.4% (1)	.33
C	55.6% (15)	58.6% (17)	.62
D	44.4% (12)	37.9% (11)	.45
Sports, n			
Basketball	12	11	
Volleyball	3	5	
Handball	3	1	
Badminton	2	3	
Cheerleading	2	1	
Soccer	2	1	
Judo	2	0	
Dance	1	0	
Alpine skiing	0	2	
Track and field	0	2	
Tennis	0	1	
Softball	0	1	
Martial arts	0	1	

BTB, bone−tendon−bone; HM, double-bundle hamstring tendon; IKDC, International Knee Documentation Committee.

strength deficit in young female athlete. A study among young female athletes aged between 15 and 25 years by Shakked et al.[24] reported that there were no subjective functional outcomes difference between the 2 types of grafts but a greater rate of graft injury and greater laxity in the hamstring reconstruction surgeries. Another study by Salem et al.[25] reported that female athletes younger than 20 years old had a lower graft rupture rate but a greater risk of kneeling pain in the BTB reconstruction group. While our outcomes are consistent with the previous literature results, the present study provides new information observing postoperative muscle strength differences between the 2 grafts in this specific population. Another feature of our study is that a single surgeon performed all reconstruction surgeries, while the previous 2 studies showed results of procedures performed by plural surgeons. Uniformizing each surgical technique by one surgeon is a better method to reduce methodologic and technical bias among surgeons.

Referring to the graft reruptures after ACL reconstruction surgery, no rupture occurred using the BTB graft in our study. On the contrary, 10.3 % of the hamstring graft procedures resulted in graft ruptures.

Table 2. Intraoperative Findings and Procedures for the Patients

	BTB Group (n = 27)	HM Group (n = 29)	*P* Value
Medial meniscus			
Suture, % (n)	37.0% (10)	31.0% (9)	.63
Meniscectomy, % (n)	0% (0)	0% (0)	
Lateral meniscus			
Suture, % (n)	37.0% (10)	44.8% (13)	.55
Meniscectomy, % (n)	3.7% (1)	10.3% (3)	.33
Cartilage lesion (ICRS >2)	3.7% (1)	0% (0)	.29
Ligament injury			
MCL	3.7% (1)	0% (0)	.29
Other ligaments	0% (0)	0% (0)	

BTB, bone−tendon−bone; HM, double-bundle hamstring tendon; MCL, medial collateral ligament.

Table 3. Rate and Time for Return-to-Play

	BTB Group (n = 27)	HM Group (n = 29)	*P* Value
% Return-to-play, % (n)	92.6% (25)	86.2% (25)	.44
Time for return-to-play, mo, mean (min-max)	8.4 (6-15)	9.0 (6-20)	.4

BTB, bone–tendon–bone; HM, double-bundle hamstring tendon.

However, the difference was not statistically significant (*P* = .09). Previous literature follows this same trend, Shakked et al.[24] detected that the risk of revision surgery after ACL reconstruction was greater in the hamstring graft compared with the BTB graft with largest risk group being the young athletes aged from 15-19 years. Salem et al.[25] surveyed BTB and hamstring reconstruction, focusing on young female population; they also concluded that ACL reconstruction with BTB leads to fewer graft rupture when compared with hamstring in female patients aged 15 to 20 years.

We assume there are 2 main reasons for lower revision rates of the BTB graft. First, the BTB autograft earns early graft maturation compared with the hamstring autograft. According to human ACL graft ligamentization process, the maturation stage is initiated from 9 to 10 months in BTB graft; on the contrary, the hamstring reconstruction demonstrated maturation stage initiation from 18 months.[26] Since the risk sustaining of an ACL graft rupture has been the greatest in the first 12 months after reconstruction,[27] earlier maturation should have the potential to reduce graft injury after reconstruction in early stages. Second, preservation of hamstring muscle strength has a positive effect in preventing graft reruptures. A risk of graft injury after ACL reconstruction was related to the hamstring to quadriceps muscle strength ratio deficit.[28] The authors assumed that the hamstring muscles act as agonists to the ACL by resisting the anterior tibial displacement.[28] In our study, BTB reconstruction preserved significantly greater hamstring muscle strength compared with the HM reconstruction group in all of the physical examination follow-ups. Therefore, a high hamstring-to-quadriceps strength ratio may decrease the risk of graft rupture.

While Leys et al.[19] additionally referred to high contralateral ACL injuries in the BTB reconstruction group, the same trend of ipsilateral graft rerupture and contralateral ACL rupture was observed in our study results with a young female population. In our series, contralateral ACL injury occurred in 17.3% of ruptures in the BTB group and 3.5% of ruptures of the HM group with no significant difference. The reason for the common trend of a greater contralateral ACL injury

Table 4. Second ACL Injuries

	BTB Group (n = 27)	HM Group (n = 29)	*P* Value
Graft reinjury, % (n)	0% (0)	10.3% (3)	.09
Contralateral ACL injury, % (n)	17.3% (4)	3.5% (1)	.13

ACL, anterior cruciate ligament; BTB, bone–tendon–bone; HM, double-bundle hamstring tendon.

Table 5. Clinical Outcomes 1 Year After Surgery

	BTB Group (n = 26)	HM Group (n = 26)	*P* Value
ROM extension loss >3°, % (n)	7.7% (2/26)	23,1% (6/26)	.12
ROM flexion loss >5°, % (n)	11.5% (3/26)	7.7% (2/26)	.64
Tegner activity score, mean (min-max)	7.3 (5-10)	6.7 (5-9)	.12
Lysholm score, mean (min-max)	98.2 (80-100)	98.5 (85-100)	.76
A	84.6% (22)	80.8% (21)	.71
B	15.4% (4)	19.2% (5)	.71
C	0% (0)	0% (0)	
D	0% (0)	0% (0)	
Lachman test, % (n)			
0	96.2% (25)	92.3% (24)	.55
1	3.8% (1)	7.7% (2)	.55
2	0% (0)	0% (0)	
3	0% (0)	0% (0)	
Pivot shift test, % (n)			
0	84.6% (22)	92.3% (24)	.38
1	15.4% (4)	7.7% (2)	.38
2	0% (0)	0% (0)	
3	0% (0)	0% (0)	

BTB, bone–tendon–bone; HM, double-bundle hamstring tendon; IKDC, International Knee Documentation Committee. ROM, range of motion.

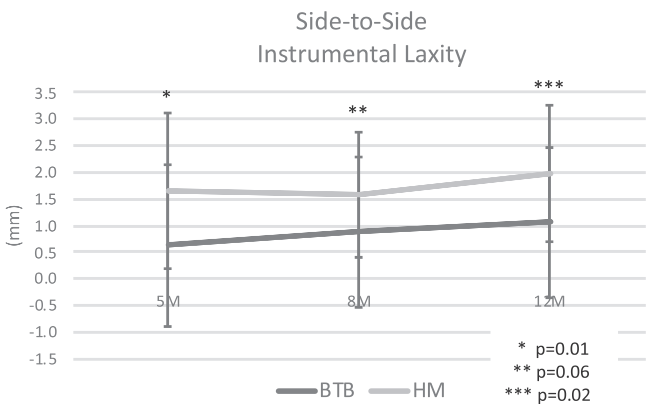

Fig 3. Side-to-side anterior instrumental knee laxity (mean and standard deviation) between the BTB and the HM groups at 5, 8, and 12 months after surgery. The mean side-to-side translational difference was 0.6 ± 1.5 mm in the BTB versus 1.7 ± 1.5 mm in the HM group at 5 months (*P* = .01), 0.9 ± 1.4 versus 1.6 ± 1.2 mm at 8 months (*P* = .06), and 1.1 ± 1.4 mm versus 2.0 ± 1.3 mm at 12 months (*P* = .02), respectively. (BTB, bone–tendon–bone; HM, double-bundle hamstring tendon.)

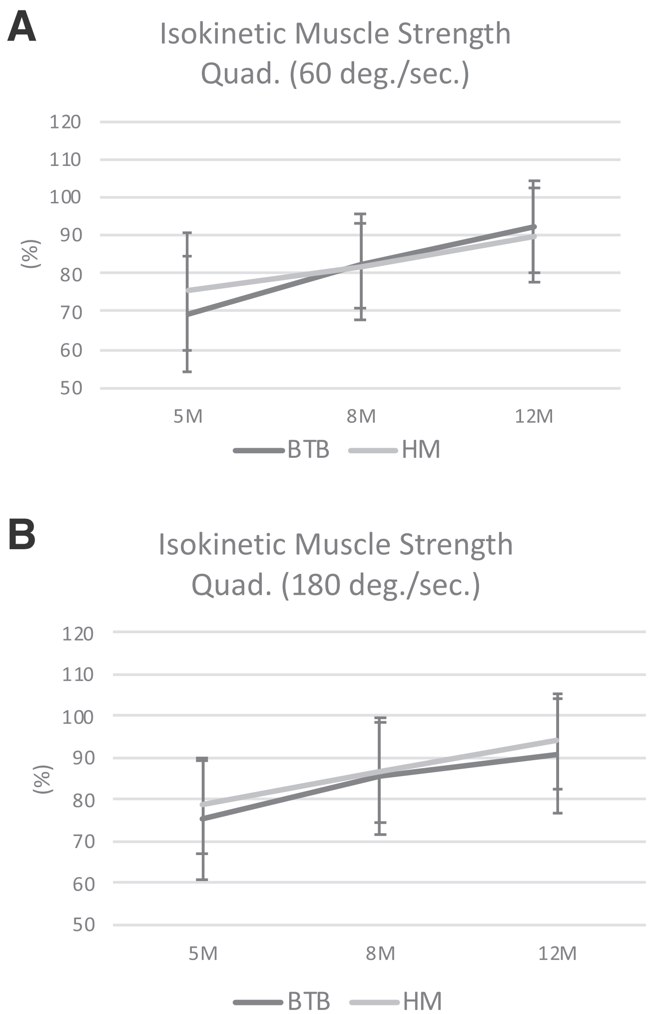

Fig 4. The isokinetic quadriceps muscle strength ratio of the reconstructed knee to the healthy knee in the angle velocity 60°/s (A) and 180°/s (B) at 5, 8, and 12 months after surgery (mean and standard deviation). In 60°/s, the muscle ratio was 69.3 ± 15.4% in the BTB group versus 75.3 ± 15.6% in the HM group at 5 months (*P* = .16), 82.2 ± 11.3% versus 81.9 ± 14.1% at 8 months (*P* = .93), and 92.3 ± 12.0% versus 90.1 ± 12.3% at 12 months (*P* = .53), respectively. In contrast, the quadriceps muscle ratio in 180°/s was 75.2 ± 14.3% in the BTB group versus 78.7 ± 11.5% in the HM group at 5 months (*P* = .29), 85.9 ± 13.9% versus 86.6 ± 11.8% at 8 months (*P* = .85), and 90.6 ± 13.6% versus 94.0 ± 11.5% at 12 months (*P* = .34), respectively. (BTB, bone−tendon−bone; HM, double-bundle hamstring tendon.)

rate in the BTB group was undetermined in our study. A possibility for lower performance or functional recovery of reconstructed knee could be due to BTB graft-site morbidity, which may require compensatory reliance performance to the contralateral normal knee.

Concerning postoperative knee laxity between hamstring and BTB in the general population, previous studies have found no difference in manual laxity examination.[29,30] Focusing on the instrumental knee laxity after ACL reconstruction, in some reports authors showed patellar tendon ACL reconstruction led to less anterior knee instrumental laxity and less rotational instability than hamstring ACL reconstruction.[18,19] In contrast, a recent comparison study referring to instrumental side-to-side tibial translation difference the authors concluded that there was no significant difference between the BTB with the hamstring autograft.[20] Even among young female athletes, Shakked et al.[24] proved better stability in instrumental laxity, Lachman, and pivot shift test in the BTB reconstruction group, whereas Salem et al.[25] indicated no difference in the groups. Our anatomic procedure, targeting the

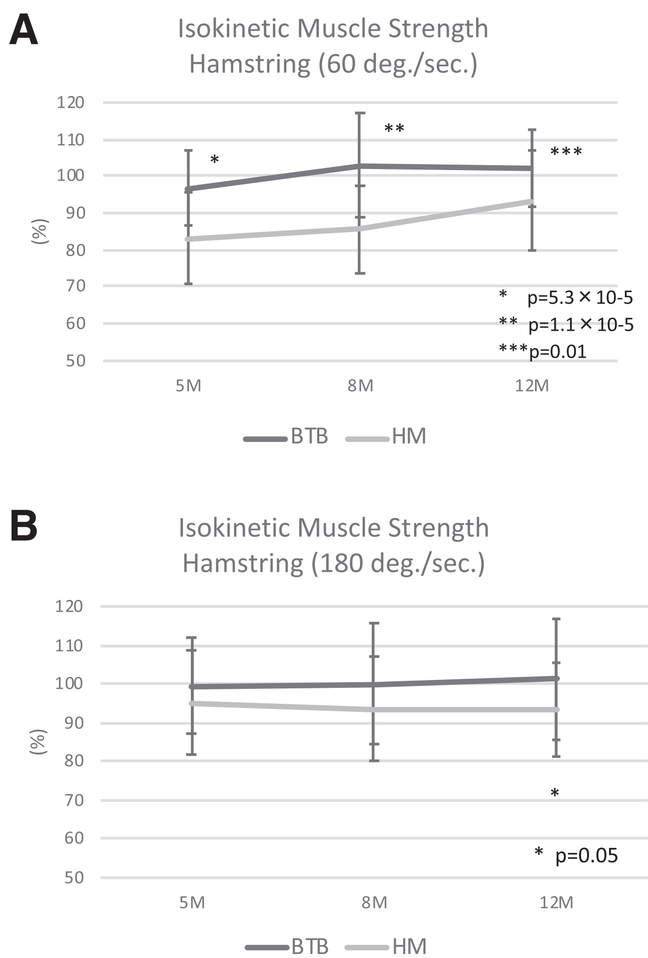

Fig 5. The isokinetic hamstring muscle strength ratio of the reconstructed knee to the healthy knee in the angle velocity 60°/s (A) and 180°/s (B) at 5, 8, and 12 months after surgery (mean and standard deviation). The hamstring muscle ratio in 60°/s was 96.6 ± 10.1% in the BTB group versus 83.1 ± 12.4% in the HM group at 5 months ($P < .001$), 102.9 ± 14.3% versus 85.6 ± 11.9% at 8 months ($P < .001$), and 102.0 ± 10.4% versus 93.3 ± 13.5% at 12 months ($P < .001$), respectively. In 180°/s, the hamstring muscle ratio was 99.4 ± 12.4% in the BTB group versus 95.0 ± 13.6% in the HM group at 5 months (*P* = .21), 100.0 ± 15.5% versus 93.5 ± 13.3% at 8 months (*P* = .11), and 101.4 ± 15.6% versus 93.3 ± 12.0% at 12 months (*P* = .05), respectively.

same population, secured superior instrumental stability in the BTB group in comparison with the HM group.

Muscle strength demonstrated by knee extension and flexion is a keystone in measuring performance and outcome after ACL reconstruction.[31] The BTB graft reconstruction in the general population showed a greater deficit in extensor muscle strength and lower deficit in flexor strength than the hamstring reconstruction. Also, the graft-site morbidity associated with muscle strength deficit appeared to be unresolved up to 2 years after ACL reconstruction.[32] However, there were no concerning reports among the young female population so far. The results of our study, which were different from the general consensus, proved that the BTB graft did not affect extensor muscle deficit. Knee flexion muscle deficit was rather statistically significant in the HM group at 60°/s isokinetic muscle strength up to 12 months after surgery and 180°/s at 12 months. Originally, hamstring grafts sacrificed one motor origin by harvesting semitendinosus muscle-tendon unit; however, the BTB graft harvested one-third patella tendon with no harm to the substantial quadriceps muscle motor. Due to fundamental differences, knee extension potential deficit by the BTB-harvested knee is not apparent in young and active patients; however, knee flexion strength deficit in hamstring harvested reconstruction was maintained. There results will widen the indication for BTB autograft for young female population when surgeons perform the anatomic rectangular BTB reconstruction.

Graft-site morbidity associated with the BTB grafts has been reported.[31,33] We unfortunately did not investigate kneeling or knee pain score in the series. Salem et al.[25] reported a significant worse kneeling pain in the BTB reconstruction group compared with the hamstring group even in young female athletes, whereas Shakked et al.[24] reported there was no differences in the incidence of knee pain that prevent activities, a mean visual analog scale score, or rate of kneeling pain in young female patients. Clinical outcomes in our study, which may relate to graft-site morbidity, indicated that there was no significant range of motion deficit, quadriceps muscle deficit, or lower rate and delay of return-to-play.

Limitations

As for limitations of this study, the study compared not only autograft materials but technical methods between rectangular BTB reconstruction to double-bundle hamstring reconstruction. Our investigation is nonrandomized and a retrospective study, and patient surgical procedure selection may not be fully unbiased, even though preoperative demographic data were not significantly different between the 2 groups. The sample size of patients was relatively small; thus, it was statistically underpowered. The small sample size especially affects our results of secondary ACL injuries. Moreover, our study measured instrumental laxity up to 1 year after surgery, and chronologically instrumental laxity can develop even 2 years after surgery.[19,34]

Conclusions

For young female athletes aged 20 years or younger, the BTB group had better knee instrumental stability than the HM group without range of motion loss or knee extensor muscle strength deficit. Although there was no statistical significance in terms of second ACL injury, we observed fewer graft reruptures and an increasing rate of contralateral ACL injuries in the BTB group.

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