Excellence in Research Award

A Hybrid Transtibial Technique Combines the Advantages of Anteromedial Portal and Transtibial Approaches

A Prospective Randomized Controlled Trial

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Background: The anteromedial (AM) portal and transtibial (TT) approaches are 2 common anterior cruciate ligament (ACL) femoral tunnel drilling techniques, each with unique benefits and disadvantages. A hybrid TT (HTT) technique using medial portal guidance of a flexible TT guide wire has recently been described that may combine the strengths of both the AM portal and the TT approaches.

Hypothesis: The HTT technique will achieve anatomic femoral tunnel apertures similar to the AM portal technique, with improved femoral tunnel length and orientation.

Study Design: Randomized controlled trial; Level of evidence, 2.

Methods: A total of 30 consecutive patients with primary ACL tears were randomized to undergo the TT, AM portal, or HTT technique for femoral tunnel positioning at the time of reconstruction. All patients underwent 3-dimensional computed tomography of the operative knee at 6 weeks postoperatively. Femoral and tibial tunnel aperture positions and tunnel lengths, as well as graft bending angles in the sagittal and coronal planes, were measured.

Results: Tibial tunnel lengths and aperture positions were identical between the 3 groups. The AM portal and HTT techniques achieved identical femoral aperture positions in regard to both height (P = .629) and depth (P = .582). By contrast, compared with the AM portal and HTT techniques, femoral apertures created with the TT technique were significantly higher ($P < .001$ and $P < .001$, respectively) and shallower (P = .014 and P = .022, respectively) in the notch. The mean femoral tunnel length varied significantly between the groups, measuring 35.2, 41.6, and 54.1 mm for the AM portal, HTT, and TT groups, respectively ($P < .001$). Last, there was no difference between the mean coronal (P = .190) and sagittal (P = .358) graft bending angles between the TT and HTT groups. By contrast, compared with the TT and HTT techniques, femoral tunnels created with the AM portal technique were significantly more angulated in the coronal plane (17.7° [$P < .001$] and 12.5° [P = .006], respectively) and sagittal plane (13.5° [$P < .001$] and 10.5° [P = .013], respectively).

Conclusion: This prospective randomized controlled trial found that the HTT technique achieved femoral aperture positions equally as anatomic as the AM portal technique but produced longer, less angulated femoral tunnels, which may help reduce graft strain and mismatch. As such, this hybrid approach may represent a beneficial combination of both the TT and the AM portal techniques.

Registration: NCT02795247 (ClinicalTrials.gov identifier)

Keywords: ACL reconstruction; anatomic; hybrid; transtibial; anteromedial portal

A number of studies have demonstrated the importance of anatomic graft placement during anterior cruciate ligament (ACL) reconstruction, as both biomechanical and clinical outcomes are optimized when grafts are placed in the center of the femoral and tibial ACL insertions.[3,4,8,11,23,25,30,33] While the transtibial (TT) technique remains one of the most common femoral tunnel positioning techniques worldwide, numerous studies have demonstrated that tibial tunnel constraint on the femoral drill guide prevents anatomic femoral tunnel positioning with this approach.[7,15,26,33] It is possible to modify the TT

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technique to achieve anatomic femoral tunnel positioning but only by compromising the tibial tunnel aperture and/or length and this is much more technically challenging.[26]

As a result of these limitations, the anteromedial (AM) portal technique, in which the femoral drill guide is inserted through the medial portal to eliminate tibial tunnel constraint, has become a popular alternative to the TT approach. While allowing anatomic femoral apertures, this approach introduces new technical challenges and provides less-optimal tunnels.[13] This occurs in part because the knee must be hyperflexed with this technique, making it difficult to obtain a familiar and consistent view of the lateral wall of the notch during surgery.[16] Additionally, the transportal path and horizontal trajectory of the guide wire and reamer increase the risk of medial femoral condyle articular cartilage damage and posterior cortical breakthrough.[5] Finally, the more horizontal trajectory of the resulting tunnels creates a shorter tunnel and a more acute graft bending angle. This makes graft passage more tedious, increases graft forces at the tunnel aperture, and may negatively affect graft healing.[5,12,34,35]

The juxtaposition of these 2 opposing techniques has left surgeons with a difficult choice: accept a less anatomic aperture position but with an otherwise ideal and easily prepared tunnel (TT) versus achieving an anatomic aperture position but creating greater technical difficulty and an otherwise suboptimal tunnel (AM portal). Furthermore, there are conflicting clinical data regarding which technique results in superior patient outcomes.[1,9,28,36] A hybrid TT (HTT) approach has been developed to address this dilemma by combining the strengths of these 2 techniques (Figure 1). In the HTT approach, a flexible TT guide wire is directed from the medial portal without the need for knee hyperflexion. Recently, this technique was examined in a cadaveric model and was found to achieve femoral tunnel apertures equally as anatomic as those created with the AM portal technique while maintaining similar tunnel length, integrity, and angulation as the TT approach.[21]

The purpose of this prospective randomized controlled trial was to validate these previous cadaveric findings by evaluating the intra-articular aperture position, tunnel length, and femoral tunnel angulation created by the TT, AM portal, and HTT techniques in vivo. We hypothesized that the HTT technique would achieve anatomic femoral tunnel apertures with improved femoral tunnel length and orientation compared with the AM portal technique.

METHODS

This was a prospective randomized controlled trial conducted at a tertiary referral center including 30 consecutive patients undergoing ACL reconstruction between December 2016 and April 2017. Institutional review board approval was obtained before the initiation of the study. The clinical trial was registered on ClinicalTrials.gov (NCT02795247). Funding for the investigation was provided by our institutional research institute. Inclusion criteria included skeletally mature patients requiring primary ACL reconstruction with or without associated partial meniscectomy or meniscal repair for an acute or subacute (within 6 months of injury) ACL tear. Patients with chronic ACL deficiency (>6 months), multiligamentous injuries (defined as grade >I medial collateral ligament, lateral collateral ligament, or posterior cruciate ligament laxity), revision surgery, or degenerative joint disease (any evidence of Fairbank changes or marginal osteophytes on preoperative imaging) were excluded to minimize the potential effect of secondary notch overgrowth and/or joint subluxation on femoral tunnel features. Surgeons were permitted to abandon the randomized technique at the time of surgery based on necessity if any aspect of the expected femoral tunnel was thought to potentially negatively affect a patient's outcome. All surgical procedures were performed by 2 fellowship-trained sports medicine specialists (J.E.F. and D.P.P.). J.E.F. performed 2 procedures with the AM portal technique and 2 with the TT technique, and D.P.P. performed 8 with the AM portal technique, 10 with the HTT technique, and 8 with the TT technique.

Informed consent was obtained from all patients deemed eligible to participate in the investigation based on the above criteria. A random number generator was used to determine treatment allocation into 1 of 3 groups: TT, AM portal, or HTT. Randomization was carried out at least 5 days before surgery to provide ample time for the surgical team to ensure that the equipment required for the assigned technique was prepared and present in the operating room. Patients were not blinded as to what treatment they were to receive.

Basic patient demographic information and preoperative clinical data were collected and recorded. This included age, sex, body mass index (BMI), and concomitant injuries. Graft choice was based on a discussion between the primary surgeon and patient before surgery and before

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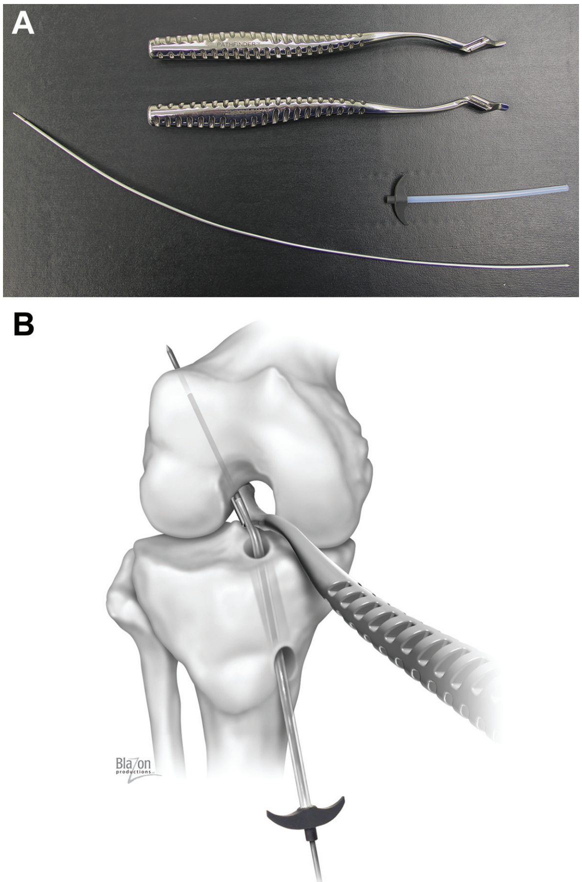

Figure 1. The hybrid transtibial technique is made possible by the use of a novel femoral drill guide (Pathfinder; DanaMed) as well as a flexible transtibial guide wire that obviates the need for hyperflexion. (A) A pair of right and left guides along with the flexible guide wire and plastic sheath. (B) The femoral drill guide is positioned through the medial portal to assist guidance of the flexible transtibial guide wire for femoral tunnel drilling.

randomization. At surgery, a tibial tunnel was created using a starting point 30 mm distal to the joint line and 15 mm medial to the medial margin of the tibial tubercle. A rigid guide wire was drilled from this starting point through the center of the tibial ACL insertion and then overreamed with a cannulated, straight 10-mm rigid reamer. Femoral tunnels were then created with one of the following techniques:

1. TT technique: With the knee at 90° of flexion, a 7-mm over-the-top guide (Arthrex) was passed through the tibial tunnel to position a rigid guide wire on the femur. Once positioned around the posterior wall, the guide was maximally externally rotated to achieve the closest possible guide pin position to the center of the native ACL footprint. After the guide wire was drilled through the distal femur and the drill guide was removed, the wire was overreamed with a 10-mm rigid acorn reamer.
2. HTT technique: With the knee at 90° of flexion, a 7-mm offset Pathfinder ACL femoral drill guide (DanaMed) was inserted through a standard medial portal. A flexible, sheathed nitinol guide wire (DanaMed) was then passed separately through the tibial tunnel and into the open slot of the drill guide (Figure 1B). Once fully seated within the open slot, the drill guide was advanced to the lateral wall of the notch with the tip of the wire positioned as close as possible to the center of the femoral ACL footprint. The guide wire was then drilled through the distal femur using a standard motorized drill from outside the tibial tunnel. Once drilling was complete, the sheath was slid off the wire, enabling the Pathfinder guide to be separated from the wire and withdrawn from the knee via the medial portal. A flexible 10-mm VersiTomic reamer (Stryker) was then passed over the wire to ream the femoral tunnel.
3. AM portal technique: A side-specific 7-mm offset VersiTomic AM portal drill guide (Stryker) was inserted through the medial portal and used to position a flexible guide wire as close as possible to the center of the native femoral footprint with the knee at 110° of flexion. With the knee maintained in this position, a flexible 10-mm VersiTomic reamer was then used to ream the femoral tunnel.

At 6 weeks after surgery, patients underwent 3-dimensional computed tomography (CT). Femoral and tibial tunnel lengths were measured, as were femoral and tibial tunnel intra-articular aperture positions using the quadrant method as described by Bernard et al[6] (Figure 2). Next, tunnel angulation was assessed by measuring the coronal and sagittal graft bending angles. The graft bending angle was calculated as the angle between the line connecting the centers of the intra-articular tibial and femoral tunnel apertures and the line connecting the intra- and extra-articular femoral tunnels, as previously described (Figure 3).[32]

Comparisons between 2 groups were performed with the Student t test and between 3 groups with analysis of variance (ANOVA) for continuous normal distribution data. The Pearson chi-square test was used for nominal categorical data. Statistical significance was set at $P < .05$. Overall, 2 blinded fellowship-trained musculoskeletal radiologists measured femoral and tibial aperture positions, and interobserver reliability was assessed using the kappa statistic. A power analysis was performed based on a previous cadaveric analysis in which the distance between the femoral insertion of the ACL and the femoral guide pin used for the reconstruction technique was measured. The following distances were calculated for the TT, AM portal, and HTT techniques: 3.8 ± 1.3, 0.8 ± 0.9, and 0.5 ± 0.7 mm, respectively. However, we conservatively estimated a smaller effect size by modifying the data input per technique as follows for the TT, AM portal, and HTT techniques: 3.4 ± 1.3, 1.0 ± 0.9, and 0.5 ± 0.7 mm, respectively. With these values, the Satterthwaite (unequal variances) t test, comparing both the AM portal and the HTT techniques with the TT technique, was used with an estimated power of 90% and

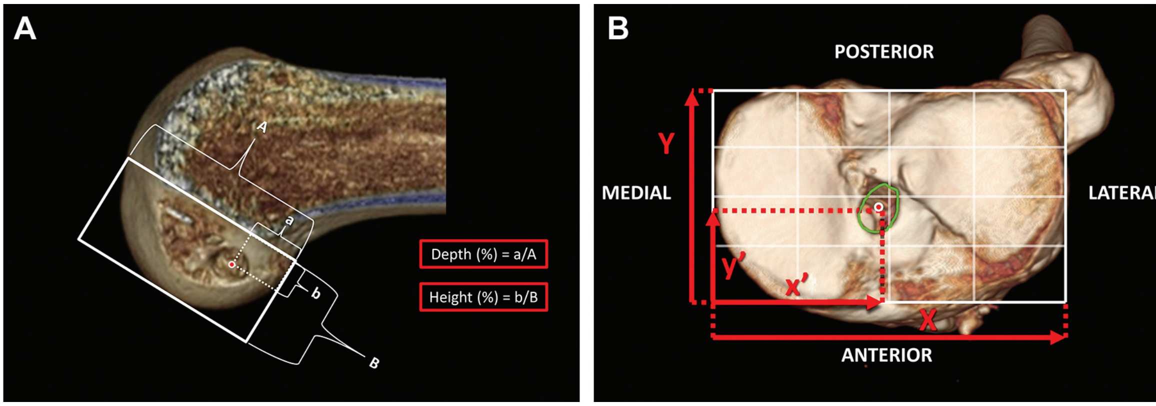

Figure 2. Assessment of intra-articular aperture positions using the quadrant method. (A) The location of the center of the femoral tunnel aperture was measured as a percentage of the depth and height of the lateral condyle. Line *A* represents the total sagittal length of the lateral condyle along the intercondylar fossa, and line *B* represents the maximum intercondylar height. Line *a* is the distance along line *A* from the most posterior aspect of the condyle to the center of the aperture, while line *b* is the distance along line *B* from the most superior aspect of the intercondylar fossa to the center of the aperture. The aperture depth was calculated as a percentage equal to *a/A*, while the aperture height was calculated as a percentage equal to *b/B*. (B) The location of the center of the tibial tunnel aperture (green circle) was measured as a percentage of the total medial-to-lateral (distance *X*) and anterior-to-posterior (distance *Y*) dimensions of the tibial plateau. Line *x'* represents the distance from the most medial aspect of the tibial plateau to the center of the aperture, and line *y'* represents the distance from the most anterior aspect of the plateau to the center of the aperture. The medial-to-lateral and anterior-to-posterior positions of the aperture were calculated as a percentage equal to *x'/X* and *y'/Y*, respectively.

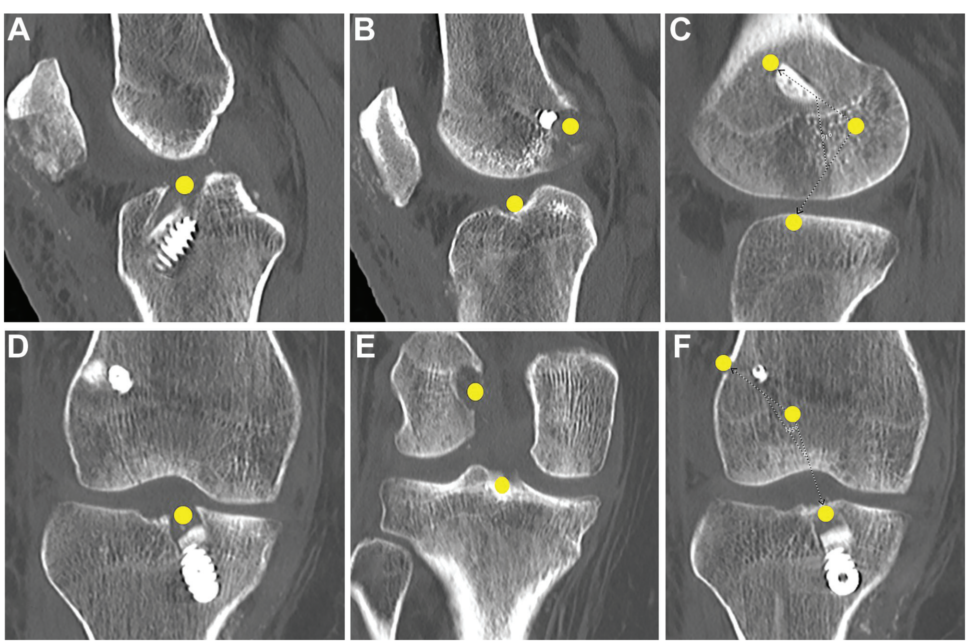

Figure 3. Measurement of the graft bending angle in the (A-C) sagittal and (D-F) coronal planes using yellow circles as measurement points. (A, D) First, the center of the intra-articular tibial aperture was identified. (B, E) Next, the center of the intra-articular femoral aperture was identified. (C, F) Last, the center of the extra-articular femoral tunnel was identified. The graft bending angle was measured as the angle between these points, representing the intra-articular graft and the extra-articular femoral tunnel.

alpha level of .025. These calculations yielded an estimated 8 participants per technique. To ensure adequate power and account for any differences in tunnel positions that may occur when cadaveric values are translated to humans, 10 patients were enrolled per group for a target enrollment of 30 patients.

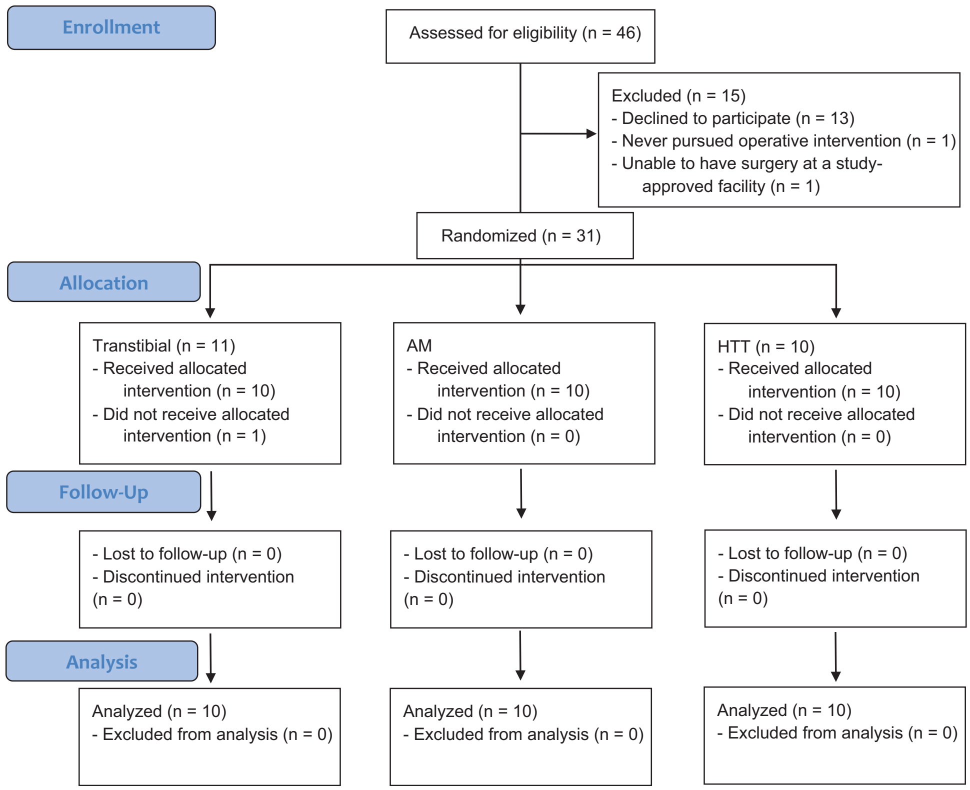

Figure 4. Consolidated Standards of Reporting Trials (CONSORT) flow diagram of the study. AM, anteromedial; HTT, hybrid transtibial.

RESULTS

From December 2016 through April 2017, a total of 46 patients were assessed for eligibility in this investigation, of whom 31 patients were randomized to the TT (n = 11), AM portal (n = 10), or HTT (n = 10) group (Figure 4). One patient in the TT group was excluded from the investigation at the time of surgery, as it was thought that the femoral tunnel could not be placed in an acceptable position because of constraint of the tibial tunnel. All of the remaining 30 patients included in the final analysis completed postoperative follow-up.

The mean age of the patients included in the study was 27.2 ± 8.3 years (range, 17.1-44.8 years), and 19 (63.3%) were male patients (Table 1). The mean BMI was 25.6 ± 4.2 kg/m^2 (range, 17.6-34.4 kg/m^2). There were no significant differences in any preoperative variables between the 3 groups including age, sex, or BMI ($P > .05$). Intraoperatively, all patients received a bone–patellar tendon–bone autograft, except for a single patient in the TT group, who received a quadrupled hamstring autograft. Concomitant injuries were treated in 7 patients, all of which were meniscal tears treated via debridement or repair.

Regarding femoral and tibial tunnel aperture positions, there was excellent interrater reliability for femoral depth (R = 0.93), femoral height (R = 0.97), and tibial anteroposterior position (R = 0.95), with moderate interrater reliability for tibial mediolateral position (R = 0.53). ANOVA found no significant differences in the mediolateral or anteroposterior aperture position of the tibial tunnels between the 3 groups (P = .210 and P = .898, respectively) (Table 2). Furthermore, when each group was individually compared with the other (TT vs AM portal, TT vs HTT, and AM portal vs HTT), there were no significant differences in the mediolateral (P = .183, P = .225, and P = .919, respectively) or anteroposterior (P = .807, P = .279, and P = .474, respectively) position of the apertures.

ANOVA found significant differences between the 3 groups regarding both the depth and the height of the femoral aperture (P = .008 and $P < .001$, respectively) (Table 2). A comparison of individual groups to one another identified no significant differences in the femoral aperture position between the AM portal and HTT techniques in regard to both depth (P = .582) and height (P = .629). By contrast, compared with the AM portal and HTT techniques, femoral apertures created by the TT technique were significantly higher ($P < .001$ and $P < .001$, respectively) and shallower (P = .014 and P = .022, respectively) in the notch.

There were no differences between the mean lengths of the tibial tunnel based on technique (P = .647) (Table 2). However, the mean femoral tunnel length differed significantly between the 3 groups, measuring 35.2, 41.6, and 54.1 mm for the AM portal, HTT, and TT groups, respectively ($P < .001$). Individual comparisons between the groups found that the AM portal technique produced

TABLE 1
Patient Demographic and Preoperative Characteristics[a]

	TT (n = 10)	AM Portal (n = 10)	HTT (n = 10)	All (N = 30)	*P* Value
Age, mean ± SD, y	30.1 ± 9.6	26.2 ± 6.5	25.4 ± 8.4	27.2 ± 8.3	.412
Male sex, %	50.0	70.0	70.0	63.3	.709
BMI, mean ± SD, kg/m^2	24.4 ± 4.3	26.1 ± 4.0	26.4 ± 4.4	25.6 ± 4.2	.564
Concomitant injuries, n (%)	2 (20.0)	3 (30.0)	2 (20.0)	7 (23.3)	.999

[a]AM, anteromedial; BMI, body mass index; HTT, hybrid transtibial; TT, transtibial.

TABLE 2
Tibial and Femoral Tunnel and Aperture Characteristics[a]

	TT	AM Portal	HTT	*P* Value
Tibial aperture, %				
Mediolateral	45.4 ± 2.9	46.9 ± 1.1	46.7 ± 1.4	.210
Anteroposterior	42.2 ± 3.3	41.9 ± 3.6	41.5 ± 2.4	.898
Femoral aperture, %				
Depth	37.6 ± 3.9	33.5 ± 3.9	32.5 ± 2.9	**.008**
Height	13.1 ± 3.3	32.8 ± 7.1	31.9 ± 5.0	**<.001**
Tibial tunnel length, mm	39.5 ± 2.8	40.7 ± 3.4	40.0 ± 2.3	.647
Femoral tunnel length, mm	54.1 ± 9.9	35.2 ± 1.6	41.6 ± 4.1	**<.001**
Mean coronal graft bending angle, deg	164.0	146.3	158.8	**<.001**
Mean sagittal graft bending angle, deg	114.0	100.5	111.0	**.001**

[a]Data are shown as mean ± SD unless otherwise indicated. Bold indicates statistical significance ($P < .05$). AM, anteromedial; HTT, hybrid transtibial; TT, transtibial.

femoral tunnels significantly shorter than with the TT (18.9 mm; $P < .001$) and HTT (6.4 mm; $P < .001$) techniques. The difference between the TT and HTT femoral tunnels was also found to be significant (12.5 mm; $P = .006$).

A comparison of the graft bending angle in all 3 groups found significant differences in both the coronal ($P < .001$) and the sagittal ($P = .001$) planes (Table 2). Individual comparisons between groups found that in the coronal plane, there was no difference in graft bending angles between the TT (164.0°) and HTT (158.8°) techniques ($P = .190$). The AM portal technique, however, resulted in more acutely angulated grafts (146.3°) compared with the TT ($P < .001$) and HTT ($P = .006$) techniques. Similarly, the AM portal technique resulted in a graft bending angle that was significantly more angulated in the sagittal plane (100.5°) compared with the TT (114.0°; $P < .001$) and HTT (111.0°; $P = .013$) techniques. There was no difference between the TT and HTT sagittal graft bending angles ($P = .358$).

DISCUSSION

Our data suggest that the HTT technique produced femoral tunnel apertures with no significant differences compared with the AM portal technique but with improved femoral tunnel length and orientation compared with the AM portal technique. These findings are significant, as it has become increasingly clear how critical many aspects of the femoral tunnel are to attain clinical success. As such, much attention has recently been focused on producing an ideal femoral tunnel, particularly in regard to aperture position, tunnel length, and angulation. Regarding the ideal femoral tunnel aperture position, several studies have demonstrated that a femoral tunnel placed in the upper half of the femoral insertion is rotationally indistinguishable from an ACL-deficient knee.[10,17,23,24] On the other hand, a graft placed in the center of the femoral insertion, only 4 to 5 mm lower on the notch wall, normalizes anterior and rotational stability.[18,23] Prospective clinical data have confirmed that comparable differences in aperture position translate into significantly improved instrumented laxity and standardized outcome scores.[25,30] Additionally, increased femoral insertional overlap by the tunnel aperture is associated with optimized kinematics, greater stability, and decreased failure rates.[19,27] Femoral tunnel length also plays a significant role in regard to graft fixation and graft tunnel mismatch, with tunnels longer than 35 mm optimizing these variables.[26] Finally, increased femoral tunnel angulation, relative to the intra-articular course of the graft, makes graft passage more difficult. Increased graft bending angles also likely increase the forces experienced by the graft at the shallow edge of the tunnel aperture,[12] which may be detrimental to graft maturation.[31]

TT drilling is the most common femoral tunnel positioning technique used for ACL reconstruction, and it affords surgeons with unique advantages. First, it is a familiar and reproducible approach that most surgeons are comfortable performing. Furthermore, inserting instruments through the tibial tunnel allows the knee to remain at 90° of flexion throughout the entire operative procedure, providing a reproducible view of the intercondylar notch while eliminating the need for hyperflexion by an assistant. Drilling and reaming through the tibial tunnel are also safe, preventing damage to the articular cartilage, and graft passage is easy because the femoral tunnel is closely aligned with the tibial tunnel. This also minimizes the graft bending angle at the femoral tunnel aperture, which may assist in graft maturation, as has been shown via postoperative magnetic resonance imaging.[31] The main drawback to the TT technique is the constraint placed on the femoral drill guide by the tibial tunnel, preventing anatomic guide placement on the femur. Unless the tibial tunnel is compromised by either posteriorizing its aperture or using a very proximal starting point, creating a critically short tunnel, it is not likely that the TT approach will achieve more than 50% overlap of the (upper) portion of the native femoral insertion,[5,15,26] an aperture position known to be rotationally inferior.[18,23] While good to excellent results have been reported with the traditional TT technique, recent clinical data support improved outcomes with more anatomic aperture positions.[9,29]

As the aperture limitations of the TT technique have become clearer, the AM portal approach has gained popularity by eliminating tibial tunnel constraint on the femoral drill guide. This approach allows more anatomic femoral aperture positioning but sacrifices many of the benefits of the TT technique.[2,13,22,37] For one, because this approach usually requires hyperflexion to create a safe wire trajectory,[16] visualization of the lateral wall is more difficult and less consistent, potentially explaining why anatomic aperture positioning with this approach is not guaranteed.[14,20] Passage of the reamer in front of the medial femoral condyle can also result in iatrogenic damage to the articular cartilage. Last, the horizontal trajectory of the guide wire as it passes from the medial portal to the lateral femoral condyle results in a shorter and more angulated femoral tunnel,[5] increasing the risk of graft tunnel mismatch, making graft passage more challenging, and potentially increasing graft forces at the aperture. It has been previously shown that the magnitude of the graft bending angle seen with AM portal tunnels results in a 2- to 3-fold increase in graft strain at the femoral tunnel aperture, producing increased graft signaling on postoperative magnetic resonance imaging.[12,21,34,35]

Despite the various differences between the TT and AM portal approaches, there is no consensus regarding which technique is superior. A 2017 meta-analysis of 5 randomized controlled trials found better results associated with ACL reconstruction using an AM portal technique compared with a TT technique in regard to postoperative stability, as determined by Lachman and pivot-shift testing as well as postoperative International Knee Documentation Committee and Lysholm scores.[9] Conversely, a large registry study comparing TT with tibial-independent femoral tunnel creation, including both AM portal and retroreaming techniques, found a decreased revision rate for graft failure in the TT group.[36] In fact, the risk of revision was 1.41 times higher specifically in patients younger than 22 years who underwent ACL reconstruction with a tibial-independent femoral tunnel. Similar results were found in a Danish registry study in which an AM portal technique was found to have significantly higher revision rates compared with a TT technique.[28] It is not currently known whether these results are consistent with one another; namely, whether AM portal femoral tunnels allow for a more normal knee but at the price of exposing the graft to higher forces and a correspondingly higher risk of failure. It is also not yet clear of the relative role that aperture position and tunnel angulation play on graft strain after ACL reconstruction.

Such data, as well as the fact that these techniques have opposing pros and cons, present a difficult problem: accept an imperfect nonanatomic aperture for an otherwise ideal technique or obtain an anatomic aperture with greater technical difficulty at the expense of multiple important femoral tunnel features. The HTT technique evolved as a combination of these 2 approaches in an effort to combine their strengths and simplify this dilemma by producing anatomic apertures without the requirement of knee hyperflexion and with femoral tunnel length and integrity that more closely mirror those of TT tunnels. The data obtained via 3-dimensional CT in this prospective randomized controlled trial confirm the previously obtained cadaveric data.[21] Namely, the HTT technique produces anatomic femoral aperture positioning, maintaining both the technical ease and beneficial tunnel characteristics of the TT technique. Thus, this method appears to provide a favorable balance between the 2 most commonly used ACL reconstruction techniques.

This study does have certain limitations. First, despite being a prospective randomized controlled trial, it could not be fully blinded, as the intervention had to be known by the surgical teams. Potential bias was nonetheless minimized by the randomization of surgical approaches and the blinding of surgical techniques during measurements of our primary outcome variables on CT. Furthermore, because the primary outcome variables of this study were radiographic, our results can only speculate as to the clinical effect of the HTT approach on outcomes and/or revision rates.

CONCLUSION

This 3-dimensional CT investigation provided in vivo data showing that the HTT technique can reliably create anatomic femoral tunnel apertures without the need for knee hyperflexion while maintaining optimal tunnel length, integrity, and angulation. This technique may represent a positive evolution in ACL reconstruction by combining the advantages of the AM portal and TT approaches. Future studies are warranted to determine if stability, outcomes, and/or revision rates are altered with the HTT technique.

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