

# Tunnel Positions in Transportal Versus Transtibial Anterior Cruciate Ligament Reconstruction: A Case-Control Magnetic Resonance Imaging Study

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**Purpose:** The purpose of this study was to examine the difference in the position of bone tunnels prepared by the transportal technique versus the transtibial technique in anterior cruciate ligament (ACL) reconstruction. **Methods:** A consecutive series of 42 patients receiving single-bundle ACL reconstructions were recruited between July 1, 2007, and December 31, 2008. The preparations of the femoral tunnel were performed by the transtibial technique in the first 21 cases and by the transportal technique in the subsequent 21 cases. Magnetic resonance imaging examination was performed in 39 patients (93%) 1 year after the index operation (20 transtibial and 19 transportal). Optimal tunnel position was defined as a lateralized femoral tunnel at a position of less than 11 o'clock for a right knee or more than 1 o'clock for a left knee, an adequate posteriorized femoral tunnel in the fourth quadrant of the modified Bernard line, and a tibial tunnel located in the second quadrant of the modified Amis line. **Results:** The average clock position was 10:18 in the transportal group and 10:54 in the transtibial group ( $P < .001$ ). Five outliers were found in the transtibial group but none in the transportal group. Concerning the femoral tunnel position on the sagittal-cut magnetic resonance imaging scan, the average position along the modified Bernard line was 74% in the transportal group and 69% in the transtibial group ( $P = .029$ ). Concerning the tibial tunnel position, the average tibial tunnel positions along the modified Amis line were 47% and 52%, respectively ( $P = .019$ ). **Conclusions:** The adoption of the transportal technique in single-bundle ACL reconstruction produced improved positions in both the femoral and tibial tunnels when compared with the transtibial technique. **Level of Evidence:** Level III, case-control study.

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**A**rthroscopic-assisted anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed operations in the field of sports medicine. The preparation of the femoral tunnel has traditionally been performed through a predrilled tibial tunnel (the transtibial technique). However, one criticism has been that there is a higher chance of a postoperative vertically orientated graft resulting in reduced rotatory stability with increased pivot shift.<sup>1-8</sup>

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There have recently been attempts to prepare the femoral tunnel through the anterior-medial portal (often referred to as the transportal technique or anterior-medial portal technique). This technique may allow the femoral tunnel to be positioned in a lower "clock" position using a standard clock face as a reference.<sup>9-13</sup> This would be expected to lead to better rotatory stability of the knee. The early reports have been promising,<sup>14-17</sup> and findings in cadaveric simulated surgery supported the hypothesis that a lower-positioned femoral tunnel was more likely when it was prepared through an anterior-medial portal.<sup>6,12,18-22</sup> However, there is still relatively little clinical evidence actually showing that the femoral position is improved in patients receiving transportal ACL reconstruction as compared with a transtibial procedure.<sup>10,13</sup>

The purpose of this study was to compare the femoral tunnel position by use of the transportal technique versus the transtibial technique in primary ACL reconstruction. To test the hypothesis that the transportal technique could afford a better femoral tunnel

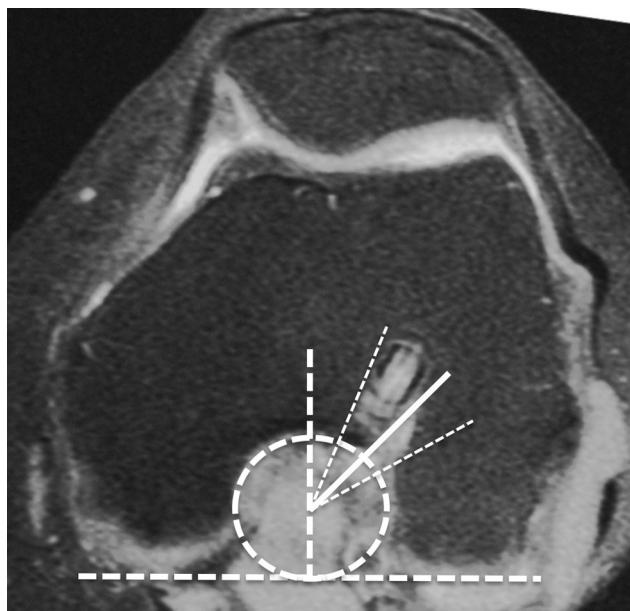
position, we measured the femoral tunnel position with reference to the clock face using magnetic resonance imaging (MRI) performed 1 year after the index operation.

## Methods

A total of 42 patients were recruited from July 1, 2007, to December 31, 2008. The inclusion criteria were as follows: (1) patients had ACL injury with no other concomitant ligament injury of the involved knee, (2) patients were scheduled to undergo primary single-bundle ACL reconstruction, and (3) the ipsilateral hamstring was selected for use as the graft for ACL reconstruction. All of the patients received single-bundle ACL reconstruction with ipsilateral hamstring autograft. The preparation of the femoral tunnel for the first 21 cases was performed through a predrilled tibial tunnel (transtibial technique). The preparation of the femoral tunnel in the subsequent 21 cases was performed through the anterior-medial portal (transportal technique). All the surgeries were performed by the same surgeon. The graft used was hamstring autograft harvested from the ipsilateral knee at the beginning of the operation. It was woven into a 4-stranded graft by the technique of Charlick and Caborn.<sup>23</sup> The preparation of the femoral tunnel was performed in an inside-out manner in all cases, either through the predrilled tibial tunnel (transtibial group) or through the anterior-medial portal (transportal group). In the transtibial group, the preparation of the femoral tunnel was aided by the use of a 7-mm offset guide with the knee at 90° of flexion. In the transportal group, the preparation of the femoral tunnel was performed by a freehand technique with the knee at 120° of flexion. The aiming point at the femoral side was the 10:30 clock-face position for a right knee and 1:30 clock-face position for a left knee.

Reassessment MRI was performed 1 year after the index operation. All of the MRI films were digitized. Measurement was performed with commercially available software (OsiriX; Pixmeo, Geneva, Switzerland). Three observers were involved. Repeated measurement of all the films with at least a 1-week interval was performed by 1 of the authors for the purpose of assessing the intraobserver error. No significant interobserver and intraobserver errors were found in measuring the femoral tunnel clock position (paired *t* test).

The primary outcome assessed was the femoral tunnel clock position measured on the axial-cut MRI scan by use of a modified method described by Rue et al.<sup>24</sup> (Fig 1). The 10:30 clock value for a right knee (or 1:30 for a left knee) was assumed to be the targeted femoral tunnel clock position. This was equivalent to 315° in a circle for a right knee (or 45° for a left knee) (Fig 2). Outliers were considered present if the femoral tunnel clock position was more than 11 o'clock for



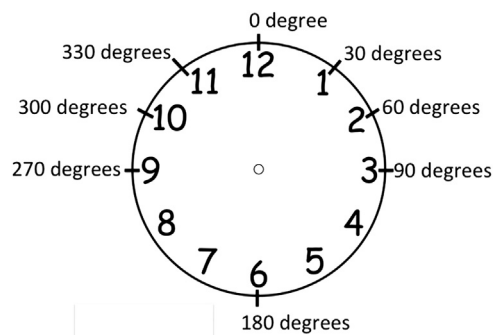
**Fig 1.** Method of measuring femoral tunnel clock position on axial-cut MRI scan.

a right knee (or <1 o'clock for a left knee), which was equivalent to more than 330° for a right knee (or <30° for a left knee).

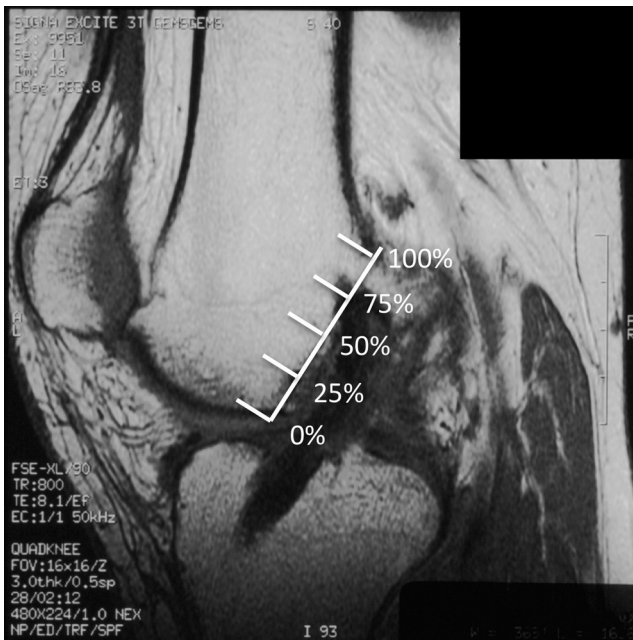
The secondary outcome measures assessed were the anterior-posterior (AP) position of the femoral tunnel and tibial tunnel on the sagittal-cut MRI scan measured by the modified Bernard method<sup>25</sup> (Fig 3) and modified Amis method (Fig 4),<sup>26</sup> respectively. Concerning the tibial tunnel, separate measurements were made with respect to the center of the tibial tunnel and the anterior margin of the tibial tunnel.

## Statistical Analysis

The hypothesis of improved femoral tunnel position with reference to the clock face in patients receiving transportal ACL reconstruction as compared with a transtibial procedure was examined by use of the Student *t* test. Statistical significance was assumed at  $P < .05$ .

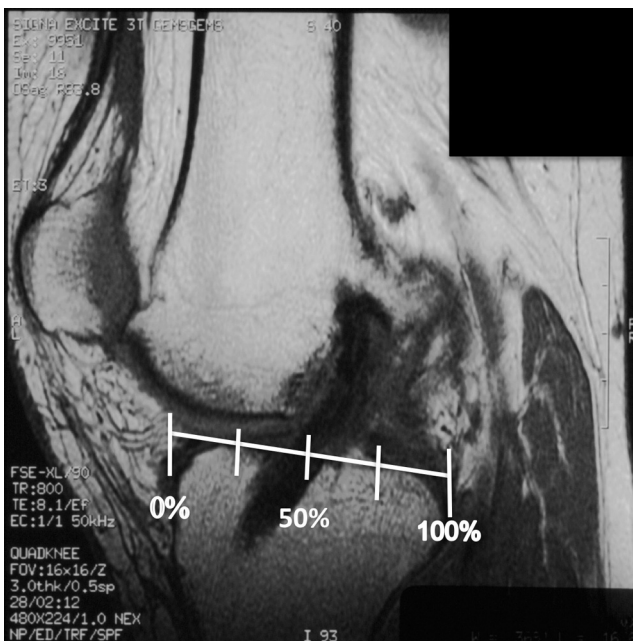


**Fig 2.** Relation between clock position and angle in degrees.



**Fig 3.** Method of measuring femoral tunnel AP position on sagittal-cut MRI scan.

A power analysis was conducted before the start of this prospective case-control study. It was assumed that the adoption of the transportal technique in preparing the femoral tunnel in ACL reconstruction could lead to a lateralization of the femoral tunnel from a clock position of 11 o'clock to 10:30 in a right knee (or 1 o'clock to 1:30 in a left knee). The clinical significance was that a more lateralized femoral tunnel would result in better control in the rotational laxity of the



**Fig 4.** Method of measuring tibial tunnel AP position on sagittal-cut MRI scan.

**Table 1.** Comparison of Preoperative Data and Intraoperative Findings Between Transtibial and Transportal ACL Reconstruction

	Transtibial	Transportal	Statistics
Age (yr)	25.4 ± 6.1	25.6 ± 9.4	NS (Student <i>t</i> test)
Gender (male/female)	18/3	21/0	NS ( $\chi^2$ test)
Side of knee	11 R/10 L	15 R/6 L	NS ( $\chi^2$ test)
Body height (cm)	170 ± 8	173 ± 6	NS (Student <i>t</i> test)
Body weight (kg)	69 ± 11	71 ± 11	NS (Student <i>t</i> test)

L, left; NS, not significant; R, right.

reconstructed knee and hence a reduction in the pivot-shift phenomenon. Assuming a type I error of 0.05 and a type II error of 0.2, we required a minimum of 16 patients in each arm.

## Results

A total of 42 patients with a mean age of 26 years (range, 16 to 45 years) were recruited. There were 39 male patients (93%) and 3 female patients (7%). The right knee was involved in 26 cases (62%) and the left knee in 16 (38%). The mean height and weight of the patients were 172 cm (range, 157 to 190 cm) and 70 kg (range, 44 to 92 kg), respectively. We found that the transportal group and transtibial group were comparable in age, gender, side of the involved limb, body height, and body weight (Table 1).

All of the patients returned for follow-up 1 year after the operation. The follow-up rate for both the transtibial and transportal groups was 100%.

Reassessment MRI was performed in 39 patients (93%) at the first year of follow-up. Three patients did not receive the reassessment MRI scan, and all subsequently did not undergo follow-up at 2 years (2 in the transportal group and 1 in the transtibial group). The rate of compliance with reassessment MRI was 90% in the transportal group and 95% in the transtibial group.

The clock position of the femoral tunnel was significantly better in the transportal group (on average, 10:18 clock-face position [i.e.,  $310^\circ \pm 9^\circ$ ] in right knee or 1:42 clock-face position [i.e.,  $50^\circ \pm 9^\circ$ ] in left knee) than in the transtibial group (on average, 11 o'clock [i.e.,  $326^\circ \pm 7^\circ$ ] in right knee or 1 o'clock [i.e.,  $34^\circ \pm 7^\circ$ ] in left knee) ( $P < .001$ , Student *t* test). If an outlier was defined to be a clock position of more than 11 o'clock in a right knee or less than 1 o'clock in a left knee, significantly more outliers were found in the transtibial group (5 patients) when compared with the transportal group (0 patients) ( $P = .047$ , Fisher exact test).

The AP position of the femoral tunnel was again significantly better in the transportal group (mean of  $74\% \pm 8\%$  along modified Bernard line) than in the transtibial group ( $69\% \pm 1\%$ ) ( $P = .029$ , Student *t* test). When an outlier in the femoral tunnel AP position in the sagittal plane was defined as less than 75% along

the modified Bernard line, it was noted that there were 17 outliers (85%) in the transtibial group but also 8 outliers (42%) in the transportal group ( $P = .017$ , Fisher exact test).

The AP position of the center of the tibial tunnel on the sagittal-cut MRI scan was also significantly better in the transportal group (mean of  $47\% \pm 4\%$  along the modified Amis line) than in the transtibial group ( $51\% \pm 5\%$ ) ( $P = .019$ , Student *t* test). If an outlier in the AP position of the center of the tibial tunnel was defined as a position outside the second quadrant (i.e., 25% to 50%) along the Amis line, only 9 patients in the transtibial group (45%) and 15 patients in the transportal group (79%) were considered to have a satisfactory tibial tunnel AP position. The mistake in the outliers was because of a posteriorly placed tibial tunnel ( $P = .055$ , Fisher exact test).

However, when comparing the anterior margin of the tibial tunnel on the sagittal-cut MRI scan, we found no difference between the transportal and transtibial groups (mean,  $35\% \pm 12\%$  and  $35\% \pm 13\%$ , respectively).

## Discussion

The results of this study support the hypothesis that the use of a transportal approach in preparing the femoral tunnel in single-bundle ACL reconstruction will result in a superior femoral tunnel position on the clock face when compared with the transtibial technique. No vertical tunnel with a position at more than 11 o'clock in a right knee (or <1 o'clock in a left knee) was found in the femoral tunnel prepared by the transportal technique. The average femoral tunnel clock position in the transportal group was the 10:18 clock-face position for a right knee or 1:42 for a left knee.

It was also shown in this study that the practice of the transportal technique in preparing the femoral tunnel in ACL reconstruction led to a better AP tunnel position in the sagittal plane for both the femoral and tibial tunnels ( $P = .029$  and  $P = .019$ , respectively; Student *t* test) when compared with those prepared by the transtibial technique. The average femoral tunnel AP position along the modified Bernard line was 74% and the average tibial tunnel AP position along the modified Amis line was 47% in the transportal group.

There was a recent proposal that a 3-portal technique may be useful in performing ACL reconstruction.<sup>27,28</sup> The viewing portal in this technique is not limited to the anterior-lateral portal but is extended to the anterior-medial portal. The use of an anterior-medial portal approach (or central portal) allowed a more accurate assessment of the anatomic footprint of the ruptured ACL in the femur and hence a more precise femoral tunnel positioning. We support this observation. Five of the measurements of the femoral tunnel clock position in the transportal group still failed to reach the targeted position of the 10:30 clock-face position for a right knee

(or 1:30 clock-face position for a left knee). Because of the lack of binocular vision in the setting of arthroscopy, it is more difficult to judge the distance on the ACL footprint in the "shallow-deep" manner when the viewing portal is limited to the anterior-lateral portal only. Despite the practice of hyperflexing the knee during preparation of the femoral tunnel in the transportal group, the lack of a precise assessment of the femoral tunnel footprint in the transportal group in this study might also be the reason for the 1 case of posterior femoral cortex blowout and relatively suboptimal femoral tunnel AP position along the modified Bernard line (42% of the measurements in the transportal group were not found in the fourth quadrant along the modified Bernard line).

The precision achieved in placing the femoral tunnel by the transtibial technique was highly influenced by the position of the predrilled tibial tunnel.<sup>2,6,12,14,18-22</sup> On the other hand, in the transportal technique, the position of the femoral tunnel is independent of the tibial tunnel. Thus there should not be any difference in the tibial tunnel between the transportal technique and the transtibial technique. However, in a number of studies reporting radiographic results of transtibial ACL reconstruction, it was observed that there was a tendency to place the tibial tunnel more posteriorly.<sup>4,8,13,29</sup> In one computed tomography (CT) study comparing the tibial tunnel position in transtibial single-bundle ACL reconstruction with the cadaveric native ACL tibial footprint, it was noted that the AP position of the tibial tunnel in the sagittal plane (48%) was significantly more posterior than the native anterior-medial bundle footprint (25%).<sup>4</sup> In an MRI study comparing AP tibial tunnel position in single-bundle transtibial ACL reconstruction with the intact ACL tibial footprint in the contralateral knee of the same patient, the tibial tunnel was noted to be  $13\% \pm 3.69\%$  more posterior than the native ACL footprint.<sup>8</sup> In one CT study comparing the transtibial and transportal techniques in single-bundle ACL reconstruction, the tibial tunnel in the sagittal plane was found to be 55.4% along the modified Amis line in the transtibial group and 44.4% along the modified Amis line in the transportal group.<sup>13</sup> A similar observation was found in our study when the center of the tibial tunnel was measured (47% along the modified Amis line in transportal group and 51% along the modified Amis line in transtibial group). However, when the anterior margin of the tibial tunnel was measured by the modified Amis method, no difference was found between the 2 groups (35% in transportal group and 35% in transtibial group). This suggested the possibility of overdrilling of the tibial tunnel in a posterior direction in the transtibial group during the preparation of the femoral tunnel. When one is performing

transtibial ACL reconstruction, the tibial tunnel is prepared first. Through the predrilled tibial tunnel, a guidewire is placed for preparation of the femoral tunnel. The drill will then be introduced along the guidewire through the tibial tunnel for preparation of the femoral tunnel. It is not uncommon to have the guidewire of the femoral tunnel placed in a more posterior position within the tibial tunnel. Even though the guidewire has some flexibility, the tibial tunnel may be reamed more posteriorly when the reamer is introduced through it for preparation of the femoral tunnel. This may be the reason for the more posterior placement of the tibial tunnel in the sagittal plane observed in the transtibial group when compared with the transportal technique.

Despite the use of an offset guide in the transtibial group, we observed that the average femoral tunnel AP position in the sagittal plane in the transtibial group was more anterior than that in the transportal group. A similar finding was observed in an MRI study comparing the transtibial technique and transportal technique.<sup>29</sup> The centroid in the transtibial group in that study was, on average, 3.02 mm anterior (2.60 mm posterior to 9.91 mm anterior) to the matched-pair, native ACL femoral centroid, whereas that in the transportal group was 1.97 mm anterior (1.6 mm to 4.52 mm anterior). However, the remote possibility of technical error in the correct positioning of the femoral offset guide in our study could not be ruled out. The benefit of using the transportal technique in preparing the femoral tunnel in ACL reconstruction was the greater freedom in controlling the femoral tunnel position, because the drilling procedures for the femoral tunnels and tibial tunnels were then independent of one another.

### Limitations

The most significant limitation of this study was the use of reassessment MRI as a tool to measure the postoperative tunnel position. The relative lack of precision of MRI in detecting bone pathology might introduce significant biases. It has been reported that some authors recently attempted to use a CT scan with 3-dimensional (3D) reconstruction for assessing tunnel positions in ACL reconstructions.<sup>11,12,22,30-32</sup> Three-dimensional CT of the operated knee would definitely serve as a much more accurate assessment tool. However, the associated radiation exposure with 3D-CT might not be considered acceptable for some young healthy patients. Because of the consideration of the possible effect of this on the compliance rate, we performed reassessment MRI instead of 3D-CT. The second major limitation of this study was that it was not a randomized study. Potential bias was unavoidable. Experimental study in terms of a randomized controlled trial of surgical treatment was not yet well accepted by the society in our

country. To increase the rate of participation in this study, a prospective case-control study was conducted instead of a randomized controlled trial. The method used in measuring the tibial tunnel AP position was a method modified from that reported by Amis and Jakob.<sup>26</sup> Instead of performing the measurement on plain radiography, we performed the measurement in this study on a single sagittal magnetic resonance image, which best showed the intra-articular exit site of the tibial tunnel and ACL graft. The line of reference was drawn along the tibial plateau. However, it might not be the medial tibial plateau as originally described. Besides, the tibial shelf might not be included on that single sagittal magnetic resonance image. The reader should be aware of this limitation when comparing the results in this study with other research using the original Amis method.

### Conclusions

The adoption of the transportal technique in single-bundle ACL reconstruction produced improved positions in both the femoral and tibial tunnels when compared with the transtibial technique.

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