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Original Article

Minimizing the risk of injury to the popliteal artery during pullout repair of medial meniscus posterior root tears: A cadaveric study

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A R T I C L E I N F O

Keywords:
Medial meniscus posterior root tears
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A B S T R A C T

Background: The purpose of this study was to investigate the positional effect of guide pins used in the transtibial pullout repair of medial meniscus posterior root tears on the popliteal artery.
Methods: We used eight cadaveric knees. Two 2.4-mm guide pins were inserted into the posterior root of the medial meniscus at 50° to the articular surface from the medial edge of the tibial tuberosity (anteromedial group) and the anterior edge of the medial collateral ligament (posteromedial group) using an aiming guide placed at the posterior root attachment of the medial meniscus from the anteromedial portal. The posterior capsule was dissected, and the popliteal artery was identified. The positional effect of the guide pins on the popliteal artery was photographed arthroscopically at 0°, 30°, 60°, and 90° knee flexion angles. The popliteal artery diameter and the minimum distance between the popliteal artery center and the guide pin tip were measured.
Results: At 90° knee flexion, most of the guide pins in the anteromedial (6 knees; 75 %) and posteromedial groups (7 knees; 87.5 %) collided with the femoral intercondylar wall. The rate of collision was significantly higher at the 90° knee flexion position than that at other angles ($p = 0.02$). The average shortest distance between the popliteal artery center and the guide pin tip at 0° knee flexion in the posteromedial group (5.4 mm ± 3.4 mm) was significantly greater than that at other knee flexion angles, although the mean distance in the posteromedial group was so negligible that the guide pin could penetrate the popliteal artery.
Conclusions: Knee flexion at 90° causes less damage to the popliteal artery during the transtibial pullout repair of medial meniscus posterior root tears.

The posterior root of the medial meniscus (MM) supports and controls meniscal shift during knee motion and load bearing. MM posterior root tears (MMPRTs), which are complete tears adjacent to the root attachment, lead to the accelerated degradation of the knee joint cartilage by disrupting meniscal functions.[1]

Transtibial pullout repair, an arthroscopic repair technique, has demonstrated favorable midterm outcomes in patients with MMPRTs.[2] Generally, iatrogenic neurovascular injuries are listed as a risk factor for arthroscopic surgery. Especially in transtibial pullout repair of MMPRTs, there is a possibility of popliteal artery (PA) injury during tibial tunnel creation. This may occur because of the critical location of the guide pin or reaming drill inserted from the anteromedial tibia to the anatomical posterior root attachment of the MM where the PA descends at close proximity opposite the posterior capsule. Although reports are available on arthroscopic PA injury,[3,4] to our knowledge, no studies have reported on PA injury in the transtibial pullout repair of MMPRTs. This may be due to the care involved in the technique employed, but there may also be other factors such as the tibial tunnel orientation and the surgical limb position that allow the procedure to be performed safely.

Therefore, this study aimed to investigate the effect of guide pin position on the PA during the transtibial pullout repair of MMPRTs. We hypothesized that leg positioning at 90° of flexion causes decreased proximity of guide pins to the popliteal artery.

1. Methods

1.1. Specimen preparation

Eight cadaveric knees (two right and six left knees) embalmed using Thiel's method[5] in our university were used in this controlled laboratory

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study. Six of the cadavers were of men and two were of women, and the mean age at death was 88.6 years (range, 73–96 years). Knees that exhibited obvious deformation or had previously undergone surgical procedures were excluded. A priori power analysis showed that eight specimens were needed to provide a power of 0.8 and a significance level of 0.05. The specimens were donated to the Department of Anatomy, and the study protocol was approved by the Ethics Committee of our university. The skin and soft tissue were removed from the medial aspect of the proximal tibia to reveal the insertion position of the guide pins.

1.2. Surgical technique

Standard anteromedial and anterolateral arthroscopic portals were used in this study. A 30° arthroscope (Smith & Nephew, Andover, MA) was introduced through the anterolateral portal. The posterior cruciate ligament (PCL) was resected and debrided to widen the posterior intercondylar field of view and to identify the exact posterior root of the MM. Subsequently, the MM posterior root was dissected, and its attachment was identified. After cleaning the posterior root, the aiming guide (Unicorn Meniscal Root [UMR] guide, Arthrex)[6] was placed at the posterior root attachment of the MM from the anteromedial portal, with reference to the point of 10 mm posterolateral to the posterior peak of the medial tibial eminence.[7] A 2.4-mm guide pin was inserted using the UMR guide at a 50° angle to the articular surface.[8] In the anteromedial (AM) group, the guide pin was inserted from the medial edge of the tibial tuberosity (TT), and in the posteromedial (PM) group, the guide pin was inserted from the anterior edge of the medial collateral ligament (MCL; Fig. 1). The posterior capsule was dissected using an arthroscopic shaver, and the PA was identified.

1.3. Technique analysis

The guide pins were advanced to a position closest to the PA at 0°, 30°, 60°, and 90° knee flexion. The positional effect of the guide pins on

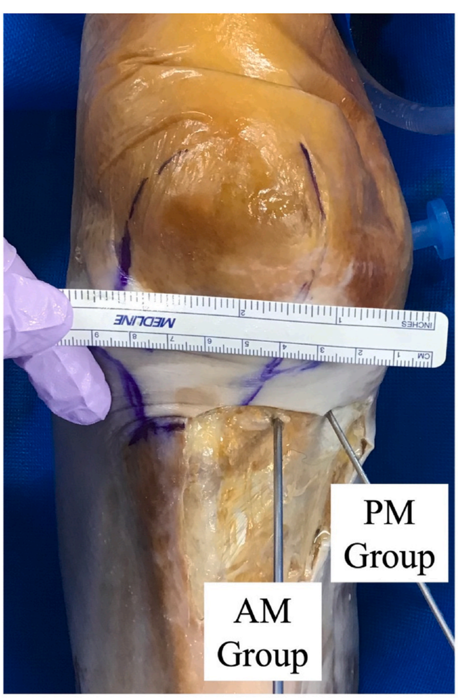

Fig. 1. Direction of guide pins insertion. In the anteromedial (AM) group, the guide pins were inserted from the medial edge of the tibial tuberosity; in the posteromedial (PM) group, they were inserted from the anterior edge of the medial collateral ligament.

the PA was photographed arthroscopically (Fig. 2). When taking pictures, the arthroscope was set on the footprint of the PCL, and the arthroscopic probe was inserted through the posteromedial portal, placed at the vessel location, and photographed to show the actual measurements. Using the obtained images, the diameter of the PA and the minimal distance between the center of the PA and the tip of the guide pin were measured using Image J software version 1.53a (National Institutes of Health, Bethesda, Maryland, USA; available at https://imagej.nih.gov/ij/). If the guide pin struck the intercondylar wall before reaching the posterior fossa, it was excluded from measurement and analysis.

1.4. Statistical analysis

Fisher's exact test was used to test the association between the number of guide pins that struck the femoral intercondylar wall and touched the PA and each angle of knee flexion. Data on the minimal distance between the center of the PA and the tip of the guide pin are presented as mean ± standard deviation. Differences between the AM and PM groups were compared using Student's t-test, and the relationship between the knee flexion angle and the guide pin insertion was analyzed using a one-way analysis of variance with Tukey's post hoc tests. Statistical significance was set at $P < 0.05$. All analyses were conducted using R version 4.1.0 (R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/).

2. Results

In six of the 8 AM group (75 %) and seven of the 8 PM group (87.5 %) knee specimens, the guide pin struck the femoral intercondylar wall and did not reach the popliteal fossa when the guide pin was inserted at 90° knee flexion (Fig. 3). In both groups, the rate of collision of the guide pin with the intercondylar wall was significantly higher at the 90° knee flexion position compared with other angles ($p < 0.01$) (Fig. 4). Meanwhile, when the guide pin was inserted at 0° knee flexion, it came in contact with the PA in all cases (Fig. 5). The percentage of contact with PA was significantly higher at the 0° knee flexion position than at the 90° flexion position. The average diameter of the PA was 5.4 mm ± 0.6 mm. On comparing each flexion angle in the AM and PM groups, the mean minimal distance between the center of the PA and the tip of the guide pin at 0° knee flexion in the AM group (2.0 mm ± 0.8 mm) was significantly shorter than that in the PM group (5.4 mm ± 3.4 mm). However, the mean minimal distance in the PM group was so negligible that the guide pin could strike the PA. There was no significant difference in the relationship between each knee flexion angle in each group

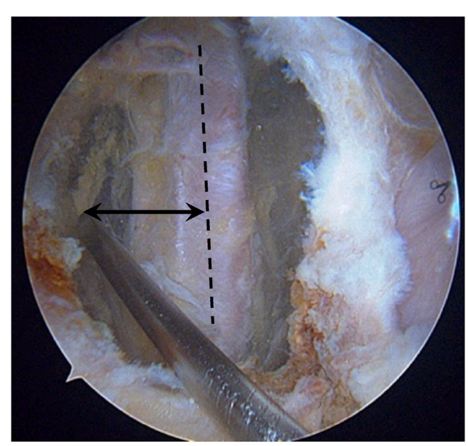

Fig. 2. Minimal distance between the center of the popliteal artery (PA) and the tip of the guide pin (double arrow).

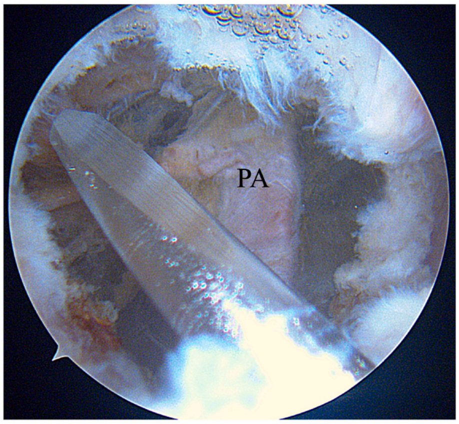

Fig. 3. Arthroscopic view of the left knee with 90° flexion. The guide pin struck the femoral intercondylar wall. PA, popliteal artery.

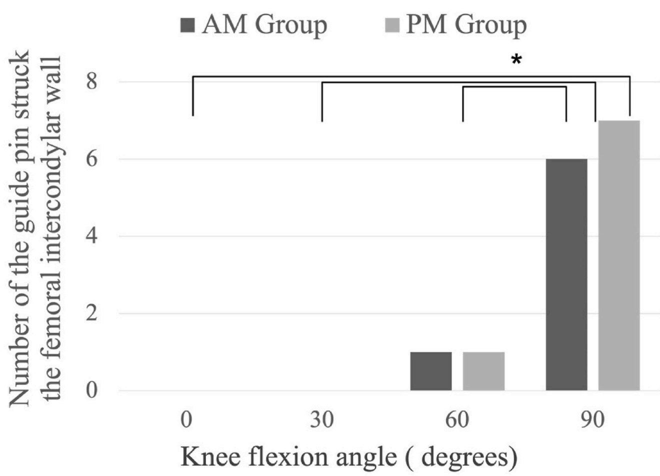

Fig. 4. Number of guide pins that struck the femoral intercondylar wall. In both groups, the rate of collision of the guide pins with the intercondylar wall is significantly higher at the 90° knee flexion position compared with that at other angles (*$p < 0.01$). AM, anteromedial; PM, posteromedial.

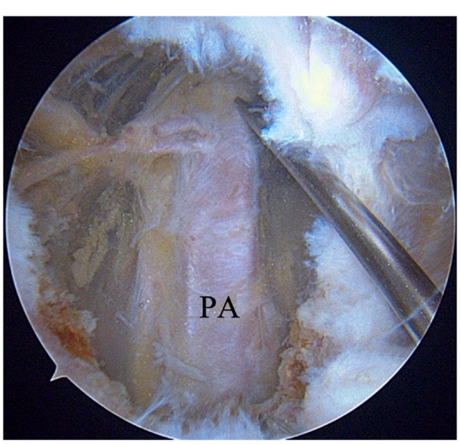

Fig. 5. Arthroscopic view of the left knee with 0° flexion. The guide pin came in contact with the popliteal artery (PA).

Table 1
Relationship between knee flexion angle (°) and distance (mm) between the center of the popliteal artery and the tip of the guide pin.

Knee flexion angle (°)	0°	30°	60°	90°	*P value*
AM group distance (mm)	2.0 ± 0.8	4.2 ± 3.0	4.6 ± 3.0	6.9 ± 0.0	*0.15*
PM group (mm)	5.4 ± 3.4	5.6 ± 3.6	5.7 ± 5.0	3.6 ± 1.2	*0.93*
P value	0.02**	0.45	0.62	N/A	

The mean distance between the center of the popliteal artery and the tip of the guide pin, excluding the pin that struck the intercondylar wall. Double asterisks (**) indicate that the mean distance in the posteromedial (PM) group was significantly higher than that in the anteromedial (AM) group at the 0° knee flexion position.

(Table 1).

3. Discussion

This study investigated the positional effect of the guide pins used in the transtibial pullout repair of MMPRTs on the PA. Our most important finding was that the 90° knee flexion position was safer and less likely to damage the PA during tibial tunnel creation during the transtibial pullout repair of MMPRTs. Most guide pins struck the femoral intercondylar wall and did not reach the posterior fossa at 90° knee flexion. If the guide pin does not reach the posterior fossa, it will not damage the PA posterior to the posterior capsule. Moreover, the mean distance between the center of the PA and the tip of the guide pin in the PM group was significantly greater than that in the AM group at 0° knee flexion ($p < 0.01$). However, there was no significant difference in the mean distance at 30°–90° knee flexion between the two groups. Moreover, the mean distance in the PM group was so negligible that the guide pin could strike the PA. This suggests that the location of tibial tunnel may have little association with the PA injury, and the 90° knee flexion position can reduce the risk of damage to the PA when the tibial tunnel is being created during the transtibial pullout repair of MMPRTs.

Anatomically, the PA runs slightly lateral to the midline of the tibial plateau and lies in close proximity opposite the posterior capsule.[9] Some studies have reported on the relationship between the PA position and limb position. Ninomiya et al. found that knee hyperflexion may cause medial migration of the PA.[9] Farrington et al. found that the PA moves farther away from the tibial cortex at 90° knee flexion.[10] During tibial tunnel creation, guide pin insertion and drilling are directed from the AM surface of the tibia toward the attachment at the posterior root of the MM to ensure that the direction of the tibial tunnel created is from medial to lateral. Accordingly, the 90° knee flexion limb position is better during tibial tunnel creation because the distance between the PA and the guide pin is greater at this angle than at other angles. These previous findings are similar to those obtained in our study, wherein we found that it was safer to operate at 90° knee flexion.

Some studies have reported the neurovascular safety of arthroscopic MM repair. Al-Fayyadh et al. found that the all-inside repair of MM posterior horn tears utilizing the anteromedial portal was very safe, as the artery did not lie within the portal's trajectory.[11] Baena et al. evaluated the margin of safety to avoid injury to the popliteal neurovascular bundle during an inside-out suture procedure performed at a 10-mm distance from the posterior horn of the MM.[12] They reported that the suture site was adequately far from the popliteal neurovascular bundle for the operation to be performed with an appropriate safety margin when the needle was inserted from three points (located medially, centrally, and laterally to the patellar tendon) during the inside-out suture procedure and the distance between each suture site and PA was measured using magnetic resonance imaging and cadaveric specimen. Similar to these studies, the direction of guide pin insertion in our study was from the medial aspects of the tibia to the attachment in the

MM; however, in our study, most of the guide pins hit the femoral intercondylar wall rather than the PA. To the best of our knowledge, the fact that more than 80 % of the guide pins did not reach the posterior fossa has not been reported previously. Based on our findings, we recommend that the guide pins be inserted from the side closest to the MCL.

This study has several limitations. First, it is possible that the shortest distance measurement was not accurate as this measurement was made by two-dimensional evaluation using photographed images obtained in the study; it might have been more accurate if measured in three dimensions using computed tomography images. Using the computed tomography images, we could also have accurately measured the insertion depth of the guide pin, which was not measured in this study, and might have assisted in measuring the distance from the tip of the guide pin to the center of the PA. Furthermore, the PCL was dissected to clearly capture the positional relationship between the guide pin and PA. The complete sectioning of the PCL results in a longer tibial posterior translation distance between the knee flexion angles of 0° and 120°,[13] which may have altered the measured distance as compared to that of a normal knee. Moreover, the posterior capsule may have shifted from the normal PA position due to it being dissected. Second, although several studies have revealed that the anatomical repair of the MMPRTs may be important for restoring the biomechanical functions of the MM,[14–16] there has been no clinical evaluation of the favorable location of tibial tunnel creation during the pullout repair of MMPRTs. The risk of PA injury may change if an appropriate location is identified for tibial tunnel creation. Additionally, we chose only 50° angle of insertion of the guide pin from tibia in the study. Regarding this choice, a lot of papers reported that the insertion angles of guide pin ranged between 45 and 55° during transtibial MMPRTs pull out repairs.[6,7,17] The direction of insertion into the PA would have been influenced by the angle of the knee joint. However, it might also have been affected by the direction in which the bony tunnel was created. Third, ours was a cadaveric study and not a study on a live human body. Since most people who donate their bodies are usually old, displacement of the blood vessels might be unclear. Therefore, it would be necessary to obtain data based on specimens from young donors who were old enough to undergo repair of the MMPRTs. Fourth, the Thiel fixation is superior to formalin fixation in terms of the flexibility of soft tissues.[18] However, the Thiel fixation might change the position of the PA in the living body. Therefore, the differences in the PA location between living and Thiel-fixed bodies need to be considered in future studies.

In conclusion, most guide pins used in the transtibial pullout repair of MMPRTs struck the femoral intercondylar wall and did not reach the posterior fossa when the knees were flexed at 90° in both the AM and PM groups. Although there was no significant difference in the mean distance between the center of the PA and tip of the guide pin at 30°–90° knee flexion, the mean distance in the PM group was significantly greater than that in the AM group at 0° knee flexion. However, the mean distance in the PM group was extremely negligible that the guide pin could strike the PA. Therefore, the location of tibial tunnel may have little association with the PA injury. Consequently, tibial tunnel creation at 90° knee flexion is a safe option and is less likely to cause damage to the PA during the transtibial pullout repair of MMPRTs.

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Ethical statement

This study was approved by the Ethics Committee of our university. The specimens were donated to the Department of Anatomy.

Authors' contributions

YM carried out the data analysis. TK designed the study plan. AT conducted this study. SO, KS, and YO collected the data and assisted the experiment. TY organized this study. All authors read and approved the final statistical analysis.

IRB information

This study was approved by the Ethics Committee of the Sapporo Medical University School of Medicine (authorization number 1-2-68).

Declaration of competing interest

The authors report that they have no conflicts of interest in the authorship and publication of this article.

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