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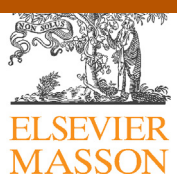

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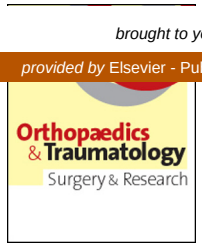

ORIGINAL ARTICLE

A new arthroscopic technique for lateral meniscal allograft transplantation: Cadaver feasibility study

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KEYWORDS
Lateral meniscus;
Meniscectomy;
Meniscal allograft;
Arthroscopy;
Meniscal anchors

Summary
Introduction: The three prerequisites for a successful meniscal allograft are fixation, graft sizing and precise positioning. The goal of this study was to demonstrate that lateral meniscal allografts can be reliably positioned using a fully arthroscopic technique.
Hypothesis: This surgical technique is feasible and results in good positioning of the meniscal graft.
Material and methods: Twelve fresh cadavers were used in the study. The meniscal graft implantation procedure was performed entirely by arthroscopy. The meniscal horns were fixed with screw-in suture anchors and the meniscal border was fixed to the capsule by arthroscopic meniscus-capsule sutures. The main outcome measure of good implant positioning was based on the distance between the implanted location of the posterior horn of the lateral meniscus (PHLM) and its original location. To accomplish this, aerial photographs of the tibial plateau were used to compare the insertion zones and to calculate the distance between them. These measurements were performed by two surgeons and then compared.
Results: Eleven of the 12 procedures (92%) were performed successfully. The posterior horn of the lateral meniscus was positioned an average of 4.3 mm in the medial—lateral axis and 1.7 mm in the anterior—posterior axis away from its original location. Thus the position of the implanted PHLM was on average 4.6 mm away from its original location.
Discussion: This fully arthroscopic technique is feasible. It offers the advantages associated with minimally-invasive surgery and results in good positioning of the posterior horn of the allograft. Two limitations of this study are that the size of the implant was not matched and the chosen fixation method was not subjected to biomechanical evaluation. The lack of a tibial tunnel will make it easier to combine this procedure with ACL reconstruction. In these conditions, the clinical application of this technique seems to be timely.
Level of proof: IV — Controlled experimental study.

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Introduction

The structure and biomechanical properties of the meniscus have been thoroughly studied [1—4]. Meniscal injuries require various treatments aimed at preserving the bulk of the meniscal tissue, either by leaving the injured tissue as is or by repair it. When this is not possible, partial meniscectomy is inevitable. Meniscal allograft transplantation may be a treatment alternative to partial or total meniscectomy, which has a poor prognosis. Meniscal replacement is used for very specific indications: patient below 40 years of age, normal alignment, stable knee, maximum Grade 3 cartilage injury. It provides satisfactory clinical and functional results, but does not ensure the cartilage is protected over the long-term [5,6].

Numerous open and arthroscopic techniques have been described. Many agree on the importance of anatomical position and appropriate sizing of the graft, which are essential criteria for restoring the mechanical properties of the meniscus [7—10]. One controversial but crucial aspect is the fixation of the meniscal horns of the graft to make sure they can withstand loading [11,12]. Bone anchoring of the meniscal horns provides greater biomechanical properties and better stability than fixation to soft tissues [7,11]. The most common methods involve the use of bone plugs or bone bridges into the tibial plateau. Thus the three prerequisites for a meniscal allograft are precise positioning, graft sizing and fixation.

The goal of this study was to demonstrate that lateral meniscal allografts can be reliably positioned using a fully arthroscopic technique where the anterior and posterior horns are fixed to bone using interference anchors, without the need for a tibial tunnel. The purpose of the study was to validate the feasibility of this technique, but not to validate the mechanical quality of the fixation or the sizing of the graft.

Materials and methods

Twelve fresh cadavers were used. Knees had to be injury-free to be included. Knees were excluded if a scar was visible or the knee was too stiff to allow the procedures to be performed. The subjects were paired into Subjects A-B based on comparable morphological criteria (in-seam length and knee width) to obtain appropriate graft sizes from Subject A to Subject B, and vice-versa from Subject B to Subject A for the contralateral knee. Thus for the right knee, if the recipient was subject A (RA), the donor was subject B (DB). The right recipient knee, RA, was prepared arthroscopically to remove all meniscal tissue from the lateral tibiofemoral compartment. The right donor knee, DB, was disarticulated so the lateral meniscus could be collected as a whole (Fig. 1a). Immediately before the collection, an aerial view photograph of the tibial plateau with the menisci intact in DB was performed as a control for the position of the posterior horn of the lateral meniscus (PHLM) of Subject B (Fig. 1a and b). The allograft collected from the right knee of DB was implanted into the right knee of RA (Fig. 1c). This sequence was inverted for the left knee. In all, each subject acted as the donor for one knee and as the recipient for the other.

Surgical technique

The two meniscal horns and the popliteal hiatus were located and marked on the lateral meniscal allograft collected from the donor subject. The two meniscal horns were prepared in an identical manner with two FiberWire sutures (Arthrex, Naples, FL, USA) of different colors. On each horn, a ''hemi-Kessler'' suture pattern was performed with the sutures coming out on the tibial side of the allograft. A horizontal mattress suture was placed at the popliteal hiatus with the suture ends coming out of the meniscus wall (Fig. 2). For the implantation, each subject was placed in dorsal decubitus with the knee flexed and the extremity free of any movement. Two standard anteromedial (AM) and anterolateral (AL) arthroscopy portals were made. The graft was introduced through the AL portal into the previously prepared lateral tibiofemoral compartment. The graft was inserted with grasping forceps and positioned into the lateral tibiofemoral compartment. The sutures facing the popliteal hiatus were retrieved using a relay suture that had been introduced with a highly curved needle (Banana SutureLassoTM, Arthrex, Naples, FL, USA) and went outside-in through the popliteal hiatus of the recipient subject. This traction suture was used to temporarily stabilize the graft while the PHLM was being fixed. The PHLM position was determined by using the residual meniscal tissue and the lateral tibial spine as guides. A third portal located about 2 cm outside and above the AL portal was made to allow the anchor to be inserted while aiming at the PHLM with an attack angle to the tibial surface of at least 30° (Fig. 3). The PHLM sutures were retrieved through this accessory AL portal and armed onto a knotless suture anchor (SwiveLock FT, 4.75 × 19 mm, Arthrex), which was used to anchor the sutures to the tibial plateau (Fig. 4). Once the PHLM had been fixed, ''all-inside'' suturing was performed on the posterior segment using four or five dedicated arthroscopic sutures (Meniscal Cinch, Arthrex). The viewing camera was then introduced by the accessory AL portal. The sutures on the anterior horn of the graft were retrieved by the AM portal and then also armed onto a second knotless suture anchor that was used to attach this horn to the tibial plateau (Fig. 5). In some cases, the anterior segment required outside-in suturing for final stabilization.

Measurements

The innovative aspect of this technique is the PHLM implantation. A successful outcome was defined as the achievement of a relevant PHLM position.

Once the procedure was completed, the recipient knee was disarticulated to take an aerial view photograph of the tibial plateau with the graft in place. Thus for one subject, we had two aerial view photographs of the tibial plateau (Fig. 6):

- one photograph that was flipped horizontally of the Donor knee with the original lateral meniscus (control photograph) (equivalent to the horizontally flipped photograph of DB on Fig. 1d);
- one photograph of the recipient knee with the allograft in place (equivalent to the RB photograph on Fig. 1d).

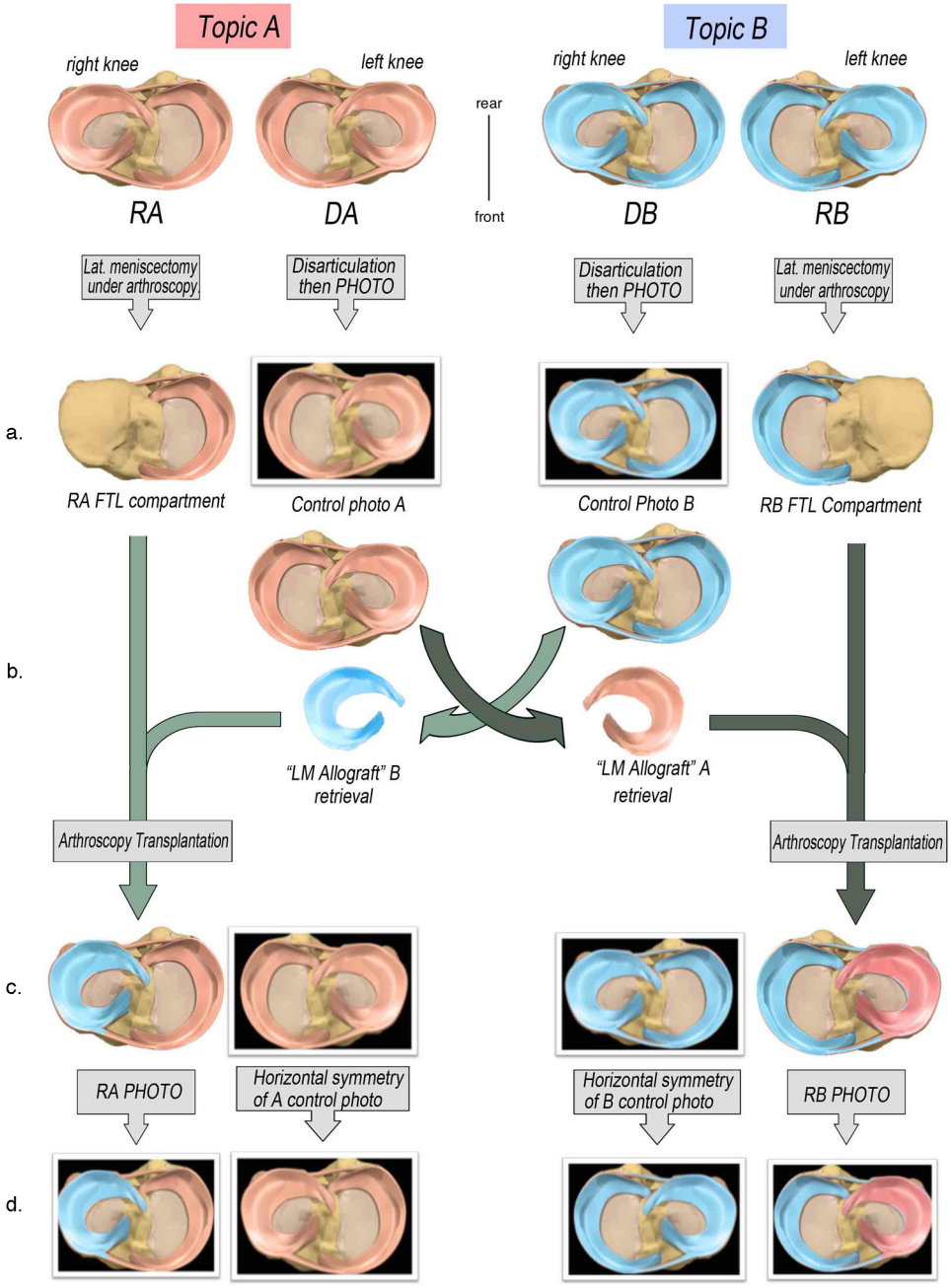

Figure 1 Methodology for implanting and evaluating the positioning of the lateral meniscus allograft: a: the recipient knees (RA and RB) were prepared under arthroscopy so that the lateral tibiofemoral (LFT) compartment is free of meniscal tissue; donor knees (DA and DB) are dislocated to take an aerial photograph of the tibial plateau and obtain a control photograph of the menisci position; b: after taking the photograph, lateral menisci were dissected from donor knees (DA and DB); c: the recipient knees (RA and RB) were grafted with the corresponding lateral meniscal allograft; d: aerial photographs of the recipient knees (RA and RB) were taken after meniscal transplantation and compared with the control photographs of the donor knees (DA and DB)to analyze the positioning of the posterior horn of lateral meniscus (PHLM).

The photographs of a subject's two knees could then be compared with imaging software (Photoshop CS3) on a comparable and standardized scale after being horizontally flipped. Our hypothesis was that a subject's left and right knees were symmetric and comparable. Nevertheless, if a small difference was found, it was corrected using the imaging software. When the two photographs were comparable and ready to be analyzed, a plane Cartesian coordinate system was applied to all the photographs so that the differences in the position of the original and grafted PHLM could be measured in mm. Since the knees had been disarticulated, we considered the meniscus as being free of loading on the tibial plateaus. Thus assuming that the anatomical structures were stable, we established a reference

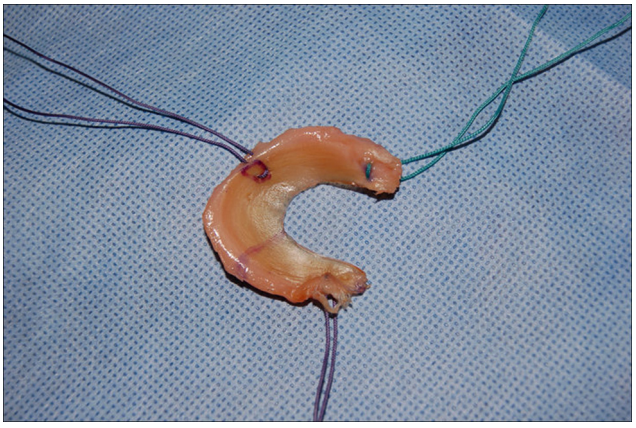

Figure 2 Preparation of the meniscal transplant with three sutures.

coordinate system where the x-axis was tangent to the posterior segment of the medial meniscus and the y-axis was perpendicular to the latter, and tangent to the middle segment of the medial meniscus. From this landmark, the PHLM position could be established to calculate the percent variation in the distance separating the original horn from the implanted horn. These differences were projected onto a standard 75 × 40 mm tibial plateau so that the average gap size (in mm) could be calculated. All the PHLM position measurements were performed by two independent, blinded observers.

Statistics

A non-parametric Wilcoxon test was used to compare the distance gap between the original and implanted PHLM. The significance threshold was set at $P < 0.05$. The analysis was performed using the ''R project for Statistical Computing'' software.

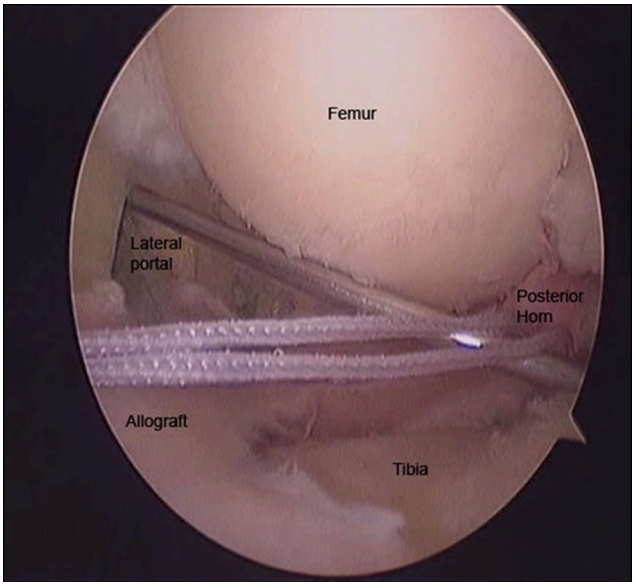

Figure 3 Arthroscopic view showing the placement of the suture anchor through the lateral accessory portal in order to attain an angle > 30° relative to the lateral tibial plateau (right knee).

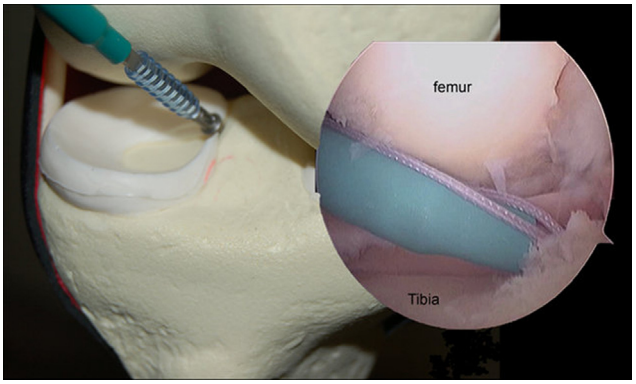

Figure 4 Placement of the posterior horn of lateral meniscus (PHLM). Arthroscopy and Sawbone views (right knee).

Results

Posterior horn of lateral meniscus implantation

The PHLM implantation was successful in 11 of 12 (92%) cadaver subjects. Despite matching, the one failure occurred because the graft was too small, which did not allow the desired position to be obtained. All of the peripheral sutures were completed in nine of 11 cases. For the two menisci that were too small, the anterior segment could not be sutured since it was too short.

Posterior horn of lateral meniscus positioning

The difference in the position of the original and implanted horn was 5.7% ($P = 0.83$) in the medial-lateral direction (x-axis) and 4.2% ($P = 0.96$) in the anterior—posterior direction

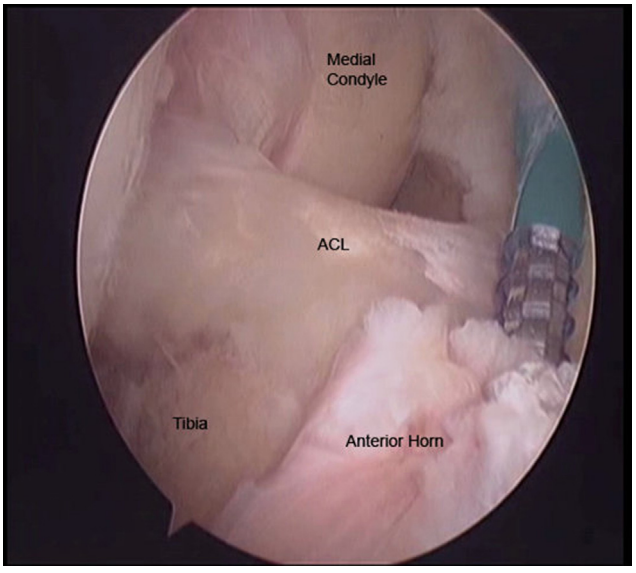

Figure 5 Arthroscopic view showing the placement of the anchor for the anterior horn of lateral meniscus (right knee).

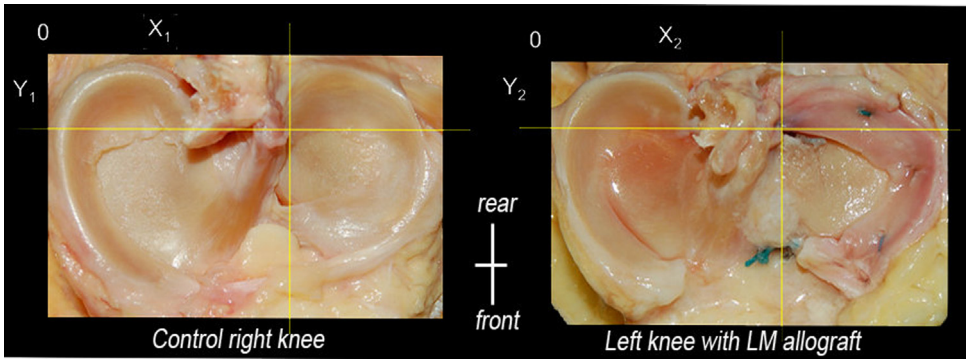

Figure 6 Final view with the control photograph (right knee equivalent to DB on Fig. 1) and the photograph with theplacementof the lateral meniscal transplant of recipient knee (left knee equivalent to RB on Fig. 1). A Cartesian coordinate system was applied on the same photographs to analyze the position of the posterior horn of lateral meniscus (PHLM).

(*y*-axis). If these variations are projected onto a standard (75×40 mm) tibial plateau, the variation in medial-lateral distance would be 4.3 mm and 1.7 mm in the anterior—posterior distance. The average variation in distance between the original and implanted PHLM was calculated based on the Pythagorean Theorem and found to be 4.6 mm.

Discussion

A fully arthroscopic implantation technique with suture anchor fixation of the posterior horn is technically feasible and allows the posterior horn of the meniscal graft to be correctly positioned.

Many allograft techniques have been put forward: first open techniques [13] and then arthroscopic techniques, since these have lower morbidity and better exposure. The fixation of the meniscal allograft is crucial, but was not evaluated in this study. Soft tissue fixation [14,15], bone plugs [16] and bone bridges [17] have been described. Various clinical and biomechanical studies suggest that bone fixation of the meniscal horns is superior to soft tissue fixation [7,9,11,16,18], however Verdonk et al. have reported satisfactory results in a patient series were only soft tissue fixation was used [14]. More recently, fixation with bone plugs was compared to fixation of the horns directly to the tibial plateau (equivalent fixation method to our technique) [19]. No differences in the functional and radiographic results were found at the mid-term follow-up. Furthermore, bone plugs are technically more difficult to use and require anatomical graft placement. Bone bridge fixation requires significant bone resection in the tibia, which leads to a notable risk of complications that can affect the integrity of the tibial intercondylar eminence [20]. The technique proposed in the current study provides the advantage associated with an arthroscopy technique and with direct meniscal horn fixation to bone, which seems to be equivalent to bone plugs [19]. Also, this technique completely spares the tibia, since no bone tunnel or bone trough is made. This is an advantage since an ACL reconstruction could be performed at the same time as the allograft is being implanted.

The distance between the two edges of the anterior and posterior horns of the lateral meniscus has been shown to be between 6 and 10 mm. If the allograft position is off by more than 5 to 6 mm, the biomechanical properties of the implant could be altered, with a loss of function and early failure [21]. Furthermore, viewing the PHLM can be problematic, even when a posterolateral approach is used. In our study, the position of the posterior horn, which is the most challenging aspect of this technique, was satisfactory since the implanted horn was at less than 5 mm from the position of the original horn. By using a superolateral accessory portal on a knee in forced varus-flexion, the anchor could be positioned close to the anatomical insertion point of the posterior horn. Our measurements are relevant since two right and left knees can be legitimately compared, given the good correlation in the morphometric knee joint dimensions between the right and the left knee [22].

One of the limitations of this study was the choice of meniscal allograft. No X-ray, MRI, or CT-scan planning was possible. The choice was based on the assessment of similar morphotypes of the cadaver subjects in order to match them. We believe that a better planning of the allograft size would not improve the PHLM positioning, as it is solely based on technical requirements and this fixation is performed first.

Conclusion

This study demonstrates that our arthroscopic technique for lateral meniscal transplantation is reliable in terms of the PHLM positioning and the peripheral sutures. The mechanical properties of the horn fixation and the consequences of faulty meniscus sizing were not evaluated. The relative simplicity of this technique, especially in cases of ACL reconstruction since no additional bone tunnel is required, has led us to start using this technique in our clinical practice.

Disclosure of interest

P. Hardy: Ad-hoc work: expert reports and consulting activities for Arthrex without royalties. The other authors have not conflict of interest to disclose relative to this article.

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