Original article

Opening the medial tibiofemoral compartment by pie-crusting the superficial medial collateral ligament at its tibial insertion:
A cadaver study

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ABSTRACT

Background: Arthroscopic treatment of tears in the middle and posterior parts of the meniscus can be difficult when the medial tibiofemoral compartment is tight. Passage of the instruments may damage the cartilage. The primary objective of this cadaver study was to perform an arthroscopic evaluation of medial tibiofemoral compartment opening after pie-crusting release (PCR) of the superficial medial collateral ligament (sMCL) at its distal insertion on the tibia. The secondary objective was to describe the anatomic relationships at the site of PCR (saphenous nerve, medial saphenous vein).

Material and method: We studied 10 cadaver knees with no history of invasive procedures. The femur was held in a vise with the knee flexed at 45°, and the medial aspect of the knee was dissected. PCR of the sMCL was performed under arthroscopic vision, in the anteroposterior direction, at the distal tibial insertion of the sMCL, along the lower edge of the tibial insertion of the semi-tendinous tendon. Continuous 300-N valgus stress was applied to the ankle. Opening of the medial tibiofemoral compartment was measured arthroscopically using graduated palpation hooks after sequential PCR of the sMCL.

Results: The compartment opened by 1 mm after release of the anterior third, 2.3 mm after release of the anterior two-thirds, and 3.9 mm after subtotal release. A femoral fracture occurred in 1 case, after completion of all measurements. Both the saphenous nerve and the medial saphenous vein were located at a distance from the PCR site in all 10 knees.

Discussion: PCR of the sMCL is chiefly described as a ligament-balancing method during total knee arthroplasty. This procedure is usually performed at the joint line, where it opens the compartment by 4–6 mm at the most, with some degree of unpredictability. PCR of the sMCL at its distal tibial insertion provides gradual opening of the compartment, to a maximum value similar to that obtained with PCR at the joint space. The lower edge of the semi-tendinosus tendon is a valuable landmark for PCR of the distal sMCL.

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1. Introduction

Arthroscopic treatment of tears in the middle and posterior segments of the meniscus can be difficult in knees with a tight medial tibiofemoral compartment. Passage of the instruments can damage the medial femoral and tibial cartilage [1,2]. Fakiroglu et al., Atoun et al., and Park et al. [3–5] suggested pie-crusting release (PCR) of the superficial (Fig. 1) or deep medial collateral ligament (MCL) to open the medial tibiofemoral compartment. In PCR, multiple stab incisions are performed in a ligament or tendon to achieve its gradual elongation.

PCR of the MCL is usually described as a procedure performed at the joint line to elongate the superficial and/or deep portions of the ligament. The superficial MCL (sMCL) has two tibial attachment sites: one is proximal, anterior to the anterior tibial expansion of the semi-membranosus tendon; and the other is distal, below the gracilis and semi-tendinosus tendons, about 6 cm distal to the joint line [6,7].

The MCL is the main primary knee stabiliser when valgus stress is applied to the joint. Grood et al. [8] reported that the sMCL supplied 50% to 80% of the resistance to valgus stress. Resistance of the sMCL increases with the degree of knee flexion (57.4% at 5° vs. 78.2% at 25°).

http://dx.doi.org/10.1016/j.otsr.2015.04.002
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The primary objective of this anatomic study was to evaluate the efficacy of sequential anterior-to-posterior PCR of the sMCL at its distal tibial insertion. We measured the opening of the medial tibiofemoral compartment under arthroscopic vision. Our secondary objective was to describe the anatomic relationships of the PCR site to evaluate the risk of injury to vessels and nerves.

We hypothesised that PCR of the sMCL at its distal tibial insertion allowed customised opening of the medial tibiofemoral compartment.

2. Material and method

We studied 10 cadaver knees that had been embalmed (in a mixture of chloral hydrate, glycerol, potassium nitrate, phenol, alcohol, and formaldehyde) then stored at 4 °C. We used the entire lower limb cut at mid-thigh. There were 6 right knees and 4 left knees. Mean age at death was 77 years (range, 71–85 years) and mean height was 168 cm (range, 155–179 cm). Eligibility criteria were absence of invasive procedures on the knee, full knee extension, and knee flexion greater than 120°.

The medial aspect of each knee was dissected to identify the branches of the saphenous nerve, the great saphenous vein, the MCL with its superficial and deep portions, and the tendons of the gracilis and semi-tendinosus muscles (Fig. 2).

After positioning the femur in a vise (Fig. 3), arthroscopy was performed using the standard anteromedial and anterolateral portals.

The cartilage was assessed according to the ICRS classification [9]. Knees with stage 4 osteoarthritis were excluded to avoid measurement bias related to laxity due to bone wear or ligament distension. Maximal opening of the medial tibiofemoral compartment was measured in millimeters with the knee flexed at 45° and application to the ankle of a 300-N valgus stress via a dynamometer, 300 N being the maximal force used to assess knee laxity by stress radiography.

Sequential PCR of the sMCL was then performed at the distal tibial insertion, under arthroscopic vision, after removal of the
superficial fascia. The stabs were performed just below and along the tibial attachment of the semi-tendinosus tendon, using the bevel of a hollow 18G needle, in the anterior-to-posterior direction, after separating the sMCL into thirds. An 18G needle was chosen to replicate the conditions of percutaneous PCR of the sMCL.

Throughout PCR of the sMCL, a 300-N valgus stress was applied continuously. First, horizontal stabs were made in the anterior third of the sMCL. Stabs were then made in the middle third of the sMCL. Finally, subtotal release of the posterior third of the sMCL was performed, leaving a 4-mm-wide band of the most posterior fibres. After each of the three PCR steps, opening of the medial tibiofemoral compartment was measured under arthroscopic vision, with the knee flexed at 45°. We used increasingly large palpation hooks (from 4 to 10 mm) fashioned from 18/10 Kirschner wires to measure the opening in millimetres. To ensure reproducibility of the measurements, a landmark was created by marking the middle of the medial tibial plateau with the tip of a Kirschner wire at the beginning of the procedure (Fig. 4).

3. Results

Mean opening of the medial tibiofemoral compartment before PCR was 4 mm (range, 3–5). Mean increase in opening after PCR of each of the thirds of the sMCL was 1 mm (range, 0–2 mm), 2.3 mm (range, 2–3 mm), and 3.9 mm (range, 3–5 mm), respectively (Table 1). In 1 case, the femur fractured after completion of the measurements. Routine evaluation of the cartilage at the beginning of the procedure showed that, of the 10 knees, 3 had grade 1 lesions, 5 had grade 2 lesions, and 2 had grade 3 lesions.

The PCR site at the distal insertion of the sMCL was located at a mean of 6.06 cm (range, 5.50–6.50 cm) from the joint space, below the lower edge of the semi-tendinosus tendon, and over 2.7 cm (range, 2.1–3.2 cm) to 4 cm (range, 3.4–4.4 cm) of the anterior tibial crest.

The following anatomic structures were located near the distal sMCL insertion (Table 2):

- the tendons of the gracilis and semi-tendinosus muscles, with a mean distance from the distal sMCL insertion to the semi-tendinosus tendon of 6 mm (range, 5–7);
- the great saphenous vein, located at a mean of 1.7 cm (range, 1.4–2.0 cm) behind the posterior edge of the sMCL; in 1 case, a large anterior branch of the great saphenous vein coursed over the distal tibial insertion of the sMCL;
- the saphenous nerve and its branches, which were at a distance from the distal tibial insertion of the sMCL; in contrast, a branch of the saphenous nerve was consistently present at the level of the medial tibiofemoral joint space.

4. Discussion

Several techniques have been developed to avoid injuring the cartilage during arthroscopic medial meniscectomy or repair of the middle and posterior parts of the medial meniscus in tight knees. Banks and Reuben [1] advocated putting pressure on the medial popliteal fossa to push the posterior horn of the medial meniscus anteriorly. However, this technique requires an assistant and moves the posterior vessels and nerves closer to the site of the procedure, where they risk injury if all-inside meniscal repair is performed. Although the under-meniscal portal described by Jo et al. [10] decreases obstruction by the bulge of the medial femoral condyle, it does not increase the joint space to facilitate passage of the instruments. Use of a third portal has been suggested by several authors. Cho [11] described a posteromedial portal to be used with a 70° arthroscope. This technique increases the risk of neurovascular injury (saphenous nerve, popliteal pedicle).

PCR of the MCL has been chiefly described as a ligament-balancing method during total knee arthroplasty (TKA). Bellemans et al. [12] reported a computer navigation-controlled technique in which PCR is performed at the level of the joint space, using a 19G needle to create multiple punctures in the superficial and deep layers of the MCL. The medial tibiofemoral joint space opened by 2.4 mm (range, 2.0–3.5 mm) in extension and 3.4 mm (range, 2.5–6.0 mm) in flexion. Kwak et al. [13] obtained similar results.

![Fig. 4. Measurement of the medial tibiofemoral joint space before and after pie-crusting release (PCR). Arthroscopic view of a right knee. A. Before PCR. B. After PCR of the anterior two-thirds of the superficial medial collateral ligament (sMCL).](image-url)
where

during a cadaver study involving PCR of the sMCL at the joint line: opening of the medial tibiofemoral space was 0.8 to 5.0 mm in extension and 0.8 to 3.0 mm in flexion.

Mihalko et al. [14] evaluated PCR of the sMCL between the medial epicondyle and the joint line. Greater opening was obtained when PCR was performed on the posterior fibres: mean opening was 1.0° in extension and 1.4° in flexion with PCR of the anterior fibres compared to 3.1° in extension and 3.0° in flexion with PCR of the posterior fibres. In contrast, Woodard et al. [15] reported that medial joint space opening was 0.2° in extension and 3.9° in flexion with PCR of the anterior fibres compared to 1.8° in both flexion and extension with PCR of the posterior fibres. PCR of the sMCL at the joint line modifies the joint space opening in both flexion and extension [12–14], usually with greater opening in flexion.

No difference in joint space opening was found between flexion and extension in a study by Yagishita et al. [16] involving PCR at the distal tibial insertion of the sMCL, as performed in our study. Joint space opening was 2.8 mm in extension and 4.1 mm in flexion with PCR at the joint line compared to 2.0 mm in extension and 2.4 mm in flexion with PCR 8–10 cm distal to the joint line. Joint space opening in our study was similar to that reported by Yagishita et al. [16]. However, the two studies are not directly comparable, since all our measurements were obtained with the knee flexed at 45°; we did not obtain measurements at different degrees of knee flexion.

In most studies of arthroscopic PCR, the procedure was performed at the joint line. Fakioglu et al. [3] reported that PCR of the posterior portion of the sMCL using a percutaneous outside-in technique opened the medial tibiofemoral space by 2 mm. Atoun et al. [4] and Park et al. [5] reported inside-out PCR of the deep MCL at the joint line using an 18G needle introduced through the arthroscopy portal. Joint space opening did not seem to exceed 2 mm. Nedelcu and Courage [17] and Colombet [18] suggested performing PCR of the sMCL at the distal tibial insertion but did not describe the anatomic landmarks used for the procedure.

Anterior-to-posterior PCR of the sMCL at its distal tibial insertion allows customisation of the amount of joint space opening. The mean maximal opening is 6 mm, i.e., similar to that obtained with PCR at the joint line [12–16]. An advantage of our technique is that the proximal tibial insertion site and deep layer of the MCL are left intact.

Our cadaver study cannot provide information on the mid- and long-term consequences of PCR of the sMCL. In a study by Fakioglu et al. [3], residual laxity after PCR of the sMCL at the joint line during arthroscopic treatment of meniscal lesions was 2 mm after 1 week, 0.9 mm after 1 month, and 0.1 mm after 3 months. Similarly, in a clinical study, Nedelcu and Courage [17] found no cases of symptomatic valgus laxity 6 months after PCR of the sMCL at its distal tibial insertion. A reasonable hypothesis is that PCR of the sMCL at its distal tibial insertion produces clinical outcomes similar to those seen after a mild sprain.

We performed our study after exposure of the medial aspect of the knee, which allowed ready visualisation of the semi-tendinosus tendon. In obese patients, this tendon may be difficult to identify, and using its lower edge as the landmark for PCR of the sMCL may therefore result in lack of efficacy (due to excessively distal release) or in direct injury to the gracilis or semi-tendinosus tendons.

### Table 1
Opening (in mm) of the medial tibiofemoral joint space after pie-crusting release of the superficial medial collateral ligament.

<table>
<thead>
<tr>
<th>Side</th>
<th>Maximal opening before PCR</th>
<th>Opening after anterior-third PCR (3 punctures)</th>
<th>Opening after anterior-two-thirds PCR (6 punctures)</th>
<th>Opening after subtotal PCR (8 punctures)</th>
<th>Initial cartilage grade (ICRS)</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee 1</td>
<td>L 4</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>Grade 1</td>
<td></td>
</tr>
<tr>
<td>Knee 2</td>
<td>R 3</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>Grade 2</td>
<td></td>
</tr>
<tr>
<td>Knee 3</td>
<td>L 3</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>Grade 1</td>
<td></td>
</tr>
<tr>
<td>Knee 4</td>
<td>R 4</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>Grade 2</td>
<td></td>
</tr>
<tr>
<td>Knee 5</td>
<td>R 5</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>Grade 3</td>
<td>Femoral fracture at the end of the procedure</td>
</tr>
<tr>
<td>Knee 6</td>
<td>R 4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>Grade 2</td>
<td></td>
</tr>
<tr>
<td>Knee 7</td>
<td>L 4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>Grade 1</td>
<td></td>
</tr>
<tr>
<td>Knee 8</td>
<td>R 4</td>
<td>5</td>
<td>6</td>
<td>9</td>
<td>Grade 2</td>
<td></td>
</tr>
<tr>
<td>Knee 9</td>
<td>L 4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>Grade 2</td>
<td></td>
</tr>
<tr>
<td>Knee 10</td>
<td>R 4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>Grade 3</td>
<td></td>
</tr>
</tbody>
</table>

sMCL: superficial medial collateral ligament; PCR: pie-crusting release; ICRS: International Cartilage Repair Society.

### Table 2
Distance between the pie-crusting release site and various anatomic structures.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Joint line – distal sMCL (cm)</th>
<th>Tibial crest – anterior edge of the distal sMCL (cm)</th>
<th>Tibial crest – posterior edge of the distal sMCL (cm)</th>
<th>Great saphenous vein – posterior edge of the sMCL (cm)</th>
<th>Semi-tendinosus – tip of distal sMCL (mm)</th>
<th>Anatomic variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee 1</td>
<td>6</td>
<td>2.6</td>
<td>3.6</td>
<td>1.6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Knee 2</td>
<td>6</td>
<td>2.1</td>
<td>3.4</td>
<td>1.5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Knee 3</td>
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<td>2.6</td>
<td>3.6</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Knee 4</td>
<td>6</td>
<td>2.5</td>
<td>3.5</td>
<td>1.9</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Knee 5</td>
<td>6.5</td>
<td>3</td>
<td>4</td>
<td>1.7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Knee 6</td>
<td>5.8</td>
<td>2.8</td>
<td>4.2</td>
<td>1.5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Knee 7</td>
<td>5.5</td>
<td>3.2</td>
<td>4.5</td>
<td>1.4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Knee 8</td>
<td>6.5</td>
<td>2.6</td>
<td>4.3</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Knee 9</td>
<td>6.2</td>
<td>2.8</td>
<td>4.4</td>
<td>1.5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Knee 10</td>
<td>6.1</td>
<td>3</td>
<td>4.5</td>
<td>1.6</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

sMCL: superficial medial collateral ligament.
In our study, the site of PCR of the sMCL at its distal tibial insertion was consistently at a distance from the branches of the saphenous nerve and great saphenous vein. In contrast, we routinely identified a branch of the saphenous nerve that coursed across the joint line in the posterior-to-anterior direction. Percutaneous outside-in PCR of the MCL at the joint line carries a risk of injury to this branch of the saphenous nerve.

5. Conclusion

PCR of the sMCL at its distal insertion is an easy-to-perform and reproducible method for opening the medial tibiofemoral compartment. Performing PCR along the lower edge of the semi-tendinosus tendon ensures reproducibility and allows customisation of the degree of joint space opening, as the release is performed gradually in the anterior-to-posterior direction. This PCR site is at a distance from the great saphenous vein and branches of the saphenous nerve.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References