Original article

A new aiming guide can create the tibial tunnel at favorable position in transtibial pullout repair for the medial meniscus posterior root tear


Department of Orthopaedic Surgery, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, 2-5-1 Shikatacho, Kitaku, Okayama 700-8558, Japan

A R T I C L E   I N F O

Article history:
Received 5 November 2016
Accepted 25 January 2017

Keywords:
Medial meniscus
Posterior root tear
Pullout repair
PRT guide
Tibial tunnel
Arthroscopic treatment

A B S T R A C T

Introduction: Injuries to the medial meniscus (MM) posterior root lead to accelerated cartilage degeneration of the knee. An anatomic placement of the MM posterior root attachment is considered to be critical in transtibial pullout repair of the medial meniscus posterior root tear (MMPRT). However, tibial tunnel creation at the anatomic attachment of the MM posterior root is technically difficult using a conventional aiming device. The aim of this study was to compare two aiming guides. We hypothesized that a newly-developed guide, specifically designed, creates the tibial tunnel at an adequate position rather than a conventional device.

Materials and methods: Twenty-six patients underwent transtibial pullout repairs. Tibial tunnel creation was performed using the Multi-use guide (8 cases) or the PRT guide that had a narrow twisting/curving shape (18 cases). Three-dimensional computed tomography images of the tibial surface were evaluated using the Tsukada’s measurement method postoperatively. Expected anatomic center of the MM posterior root attachment and tibial tunnel center were evaluated using the percentage-based postero-lateral location on the tibial surface. Percentage distance between anatomic center and tunnel center was calculated.

Results: Anatomic center of the MM posterior root footprint located at a position of 78.5% posterior and 39.4% lateral. Both tunnels were anteromedial but tibial tunnel center located at a more favorable position in the PRT group: percentage distance was significantly smaller in the PRT guide group (8.7%) than in the Multi-use guide group (13.1%).

Discussion: The PRT guide may have great advantage to achieve a more anatomic location of the tibial tunnel in MMPRT pullout repair.

Level of evidence: III.

© 2017 Elsevier Masson SAS. All rights reserved.

1. Introduction

The posterior root of the medial meniscus (MM) serves as an anchor to regulate the meniscal shift during the knee motion and load bearing. Injuries of the MM posterior root, including complete radial and/or oblique tears adjacent to the root ligament and posterior horn, lead to accelerated degeneration of the knee joint articular cartilage by extrusion and disrupting meniscal functions [1]. Medial meniscus posterior root tears (MMPRTs) lead to abnormal biomechanics of the tibiofemoral joint and inability to convert axial loads into hoop stresses [2,3]. Repair of the MMPRT has been shown to reduce the mean tibiofemoral contact pressure by increasing the tibiofemoral contact area in a human cadaveric knee study [4]. Several repair techniques such as transtibial pull-out repair, suture anchor-dependent repair, direct all-inside repair, and posterior reattachment of the MM posterior root have been developed [1,5–11]. MMPRT repairs have more favorable clinical outcomes compared with conservative treatments [9,12] providing patients with Outerbridge grade III or IV cartilage lesions are excluded [13].

An accurate positioning of the anchoring sites of the root seems to be as important as surgical techniques in transtibial pull-out repair as well as meniscal allograft transplantation [10,13]. However, tibial tunnel creation at the anatomic center is technically difficult. A biomechanical study demonstrates that a 3-mm displacement of the meniscal attachment can induce cartilage

* Corresponding author.
E-mail address: matino@md.okayama-u.ac.jp (T. Furumatsu).

http://dx.doi.org/10.1016/j.otsr.2017.01.005
1877-0568/© 2017 Elsevier Masson SAS. All rights reserved.
deformation by decreasing the meniscal hoop tension in a porcine meniscus root tear model [14]. A nonanatomic repair 5-mm posteromedial to the native MM posterior root attachment does not restore the tibiofemoral contact area and pressure in human cadaveric knees [4]. Therefore, an anatomic placement of the MM posterior root attachment is considered to be critical for healing and restoration of meniscal function [15]. Attachment of the MM posterior root is located between the medial tibial eminence (MTE) and posterior cruciate ligament (PCL) [16,17]. Several studies report that the attachment center of the MM posterior root is 9.6 mm posterior and 0.7 mm lateral from the apex of the reproducible bony landmark MTE [4,15,16]. However, an average attachment area of the MM posterior root is 30.4–47.3 mm² and the MM posterior root attachment forms oval or triangular shape [16,18–20]. In addition, patients have their own tibial plateau sizes and their specific MTE locations. Based on these findings, we investigated the anatomic center of the MM posterior root on three-dimensional computed tomography (CT) images using Tsukada’s method that expresses the location on the tibial surface as a percentage of anteroposterior and mediolateral distance [21]. The aim of the study was to compare two different aiming guides in accurately creating the tibial tunnel in comparison with anatomic location. We hypothesized that a specifically designed guide allow to create the tibial tunnel at a more adequate position than a conventional one.

2. Methods

2.1. Patients

This study received the approval of our Institutional Review Board, and written informed consent was obtained from all patients. Twenty-six patients (21 women and 5 men, mean age 57.7 years), who underwent transtibial pullout repairs for MMPRT [22] between April 2015 and December 2016, were included (Table 1).

2.2. Surgical procedure

A standard anterolateral portal was used for arthroscopic visualization using a 30° arthroscope (Smith & Nephew, Andover, MA, USA). A standard anteromedial portal was used for the instruments. Tibial tunnel creation was performed using the Multi-use marking hook guide (Arthrex, Naples, FL, USA) or the PRT guide (Smith & Nephew). The PRT guide was a newly-developed aiming device that had a narrow twisting/curving shape adjusted to the medial intercondylar space (right and left, Fig. 1A–C) [11]. Moreover the PRT guide had sizing scales, hooking spines, and guide pin catching structure. The Multi-use guide did not. After abrasion, the aiming guide was inserted from the anteromedial portal to create a tunnel aperture at the most anatomic location of the MM posterior root by referring the posterior peak of the MTE and the PCL anterior border (Fig. 2A–F). Tibial tunnel creation was performed by a single surgeon (T.F.). The Multi-use guide was used in 8 cases and the PRT guide in 18 cases (Table 1). A 2.4-mm guide pin was inserted in each group at a 55° angle and the tibial tunnel was created with a 4.5-mm cannulated drill. According to our published technique, the tibial end of the MM posterior root/horn was grasped and repaired using the Fast-Fix 360 meniscal repair system (Smith & Nephew) [11]. Tibial fixation was performed using the double spike plate and screw (Meira, Aichi, Japan), with the knee flexed at 40° and with an initial tension of 20 N.

2.3. Three-dimensional CT-based measurements

All patients underwent CT examination at 1 week postoperatively. CT images were obtained with an Asteon 4 Multislice CT System (Toshiba Medical Systems, Tochigi, Japan) using 120 kVp and 150 mA, and 1-mm slice thickness. CT reconstruction of the tibial condyles in the axial plane [23] was completed using a three-dimensional volume-rendering technique (AZE Virtual Place software; AZE Ltd., Tokyo, Japan). Three-dimensional CT images of the tibial surface were evaluated using a rectangular measurement grid as described by Tsukada et al. [21]. The image was rotated to visualize the superior aspect of the proximal tibia, with the internal/external rotation adjusted until the most posterior articular margins of both the medial and lateral tibial plateaus were placed on the horizontal level (Fig. 2A–C). The sizes of the tibial plateaus were quite different. In addition, the distance between the MTE and expected anatomic center of the MM posterior root was affected by the skeletal size. Thus, the location on the tibial surface was assessed using a percentage-dependent method (Tsukada’s method [21]): the location of a critical point was determined by two coordinates (one on an AP axis and the other one on a ML axis). Expected anatomic center of the MM posterior root attachment was determined as the center of a virtual circle that contacted three sides (antero-lateral border of the PCL tibial attachment, lateral margin of the medial tibial plateau, and retro-eminence ridge [24]) of triangular footprint of the MM posterior root (Fig. 3B). Tibial tunnel centers were determined as the central point of circular or oval tunnel aperture. Percentage distance between anatomic center and tunnel center was calculated using the Pythagorean theorem: (percentage distance)² = (difference between the anteroposterior percentage of

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographics and clinical characteristics.</th>
<th>Multi-use guide</th>
<th>PRT guide</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>8</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender, men/women</td>
<td>1/7</td>
<td>4/14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Root tear classification</td>
<td>Type 1/2/3/4/5</td>
<td>0/7/1/0/0</td>
<td>1/15/0/2/0</td>
<td></td>
</tr>
<tr>
<td>Kellogren-Lawrence grade</td>
<td>Grade 0/1/I/II/III/IV</td>
<td>0/4/4/0/0</td>
<td>0/10/8/0/0</td>
<td></td>
</tr>
<tr>
<td>Age, years</td>
<td>59.6±9.1</td>
<td>57.0±12.3</td>
<td>0.288</td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.56±0.04</td>
<td>1.57±0.09</td>
<td>0.342</td>
<td></td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>66.9±18.0</td>
<td>68.4±14.4</td>
<td>0.424</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>27.3±6.3</td>
<td>27.5±4.3</td>
<td>0.469</td>
<td></td>
</tr>
<tr>
<td>Femorotibial angle (°)</td>
<td>179.0±0.8</td>
<td>177.4±1.5</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

Data of age, height, body weight, body mass index, and femorotibial angle are displayed as a mean±standard deviation.

Fig. 1. Aiming guides for pullout repair of the MMPRT. (A) The Multi-use guide and PRT guide for the right and left knees. (B) A guide pin catching structure (dotted circle). A hooking spine (arrow). (C) Curving shapes of each aiming guide.
each center)² + (difference between the mediolateral percentage of each center)².

2.4. Statistical analysis

Data were presented as means ± standard deviations. Differences between groups were compared using the Mann-Whitney U test. Significance was set to P < 0.05. Two orthopedic surgeons (M.F. and T.T.) independently measured the location of expected anatomic center and tibial tunnel center. Each observer performed each measurement twice, at least two weeks apart. The interobserver and intra-observer reliabilities were assessed with the intra-class correlation coefficient (ICC). An ICC > 0.80 was considered to represent a reliable measurement.

3. Results

Anatomic center of the MM posterior root footprint located at a position of 78.5% ± 1.7% posterior and 39.4% ± 2.3% lateral (Fig. 4). The inter-observer and intra-observer reliabilities were considered high, with mean ICC values of 0.94 and 0.96, respectively.

Tibial tunnel center of the Multi-use guide group located at a position of 67.3% ± 5.7% posterior and 33.1% ± 1.6% lateral (Table 2). Tibial tunnel center in the PRT guide group was 70.9% ± 4.1 posterior and 37.6% ± 2.0% lateral. Tibial tunnel centers were thus located more anterior and more medial than the anatomic center in both groups (Fig. 5).

Significant difference in positioning of tibial tunnel center was detected between the Multi-use and PRT guide groups (Table 2). Tibial tunnel center located at more posterior (P = 0.042) and more lateral (P < 0.001) position in the PRT guide group compared with the Multi-use guide group (Fig. 5). Percentage distance between the MM posterior root anatomic center and tunnel center was thus significantly smaller in the PRT guide group (8.7% ± 4.3%) than in the Multi-use guide group (13.1% ± 3.6%, Table 2).

4. Discussion

This study demonstrated that expected anatomic center of the MM posterior root attachment locates at a position of 78.5% and 39.4% in the anteroposterior and mediolateral axes, respectively. The position of tibial tunnel center is located at the anteromedial region compared to the anatomic center. However, the MMPRT narrow curving-shaped device (PRT guide) achieves at a more favorable position rather than the conventional Multi-use guide. Our hypothesis is confirmed.

Sizing scales of the PRT guide may reduce technical errors and help surgeons to create an ideal tunnel aperture nearby the native attachment of the MM posterior root. In addition, the twisting/curving shape of the PRT guide that was specifically adjusted to the medial intercondylar space of the right or left knee may have great advantage to create the tibial tunnel nearby the anatomic center of the MM posterior root attachment. On the opposite, the upturned end of the Multi-use guide does not fit the downslope around the MM posterior root footprint. Scar tissue ablation around the MM posterior root may help an accurate positioning of the tibial tunnel by obtaining a clear arthroscopic view. The femorotibial angle in the Multi-use guide group was slightly larger than that of the PRT guide group (Table 1). This might favor an anteromedial positioning of the tibial tunnel by the Multi-use guide because of unavailability of sufficient medial joint space widening. The outside-in pie-crusting technique that releases the deep medial collateral ligament may be useful to increase the medial compartment opening for the MMPRT repair [25].

Several authors have reported that an anatomic repair of the MMPRT may be critical for restoring the biomechanical function of the MM [4,14,15]. However, there has been no clinical evaluation of the tibial tunnel location in the MMPRT pullout repair.

There are several limitations in this study. First, the sample size was small. Further study with a larger sample size will be required.

Table 2

<table>
<thead>
<tr>
<th>Location of tibial tunnel center for transtibial pullout repair.</th>
<th>Multi-use guide</th>
<th>PRT guide</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibial tunnel center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior (%)</td>
<td>67.3 ± 5.7</td>
<td>70.9 ± 4.1</td>
<td>0.042</td>
</tr>
<tr>
<td>Lateral (%)</td>
<td>33.1 ± 1.6</td>
<td>37.6 ± 2.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Percentage distance (%)</td>
<td>13.1 ± 3.6</td>
<td>8.7 ± 4.3</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Data are displayed as a mean ± standard deviation.
Fig. 3. Measurements of expected anatomic center and tibial tunnel center. (A) The location on the three-dimensional CT-based tibial surface was expressed as a posterolateral percentage using Tsukada's method [21]. Red dot, expected anatomic center of the MM posterior root attachment (in this example: 81% posterior and 40% lateral). Dotted line, the medial intercondylar ridge. (B) A red dashed circle that contacted three sides (anterior border of the PCL tibial attachment, lateral margin of the medial tibial plateau (MTP), and retro-eminenace ridge) is shown. Blue dot, tibial tunnel center (71% posterior and 37% lateral). A yellow dotted line indicates a percentage distance between the anatomic center and tunnel center (10.4%): \[ \frac{(71 - 37)^2 + (40 - 37)^2}{100} \]. Arrowhead, the MTE. (C) The optimal tunnel aperture was observed in the PRT guide group.

Fig. 4. Location of expected anatomic center of the MM posterior root footprint (open dots). A mean of the MM posterior root anatomic center was 78.5% posterior and 39.4% lateral position (red square) on a three-dimensional CT image of the tibial surface.

Fig. 5. Respective locations of anatomic center and tibial tunnel centers. Red square: mean anatomic center location. Blue triangle: mean Multi-use guide tibial center location (white triangles indicate location of each case). Blue dot: mean PRT guide tibial center location (black dots indicate location of each case).

Second, the relationship between the tibial tunnel position and clinical outcome was not evaluated postoperatively. Third, the optimum position of the tibial tunnel center remains unclear. Fourth, there was a possibility that the strongest attachment point of the MM posterior root might be different from the expected anatomic center on three-dimensional CT images. Clinical evaluation of these patients, biomechanical study using several tunnel locations, and detailed anatomic/histological assessments of the native MM posterior root will be required to understand the above limitations.

5. Conclusions

Tibial tunnel center for pullout repair of the MMPRT located at a more favorable position in the specifically designed PRT guide group compared with the Multi-use guide group. Percentage
distance between the MM posterior root anatomic center and tunnel center was significantly smaller in the PRT guide group. The PRT guide may have great advantage in creating the tibial tunnel aperture at a more anatomic location.

Funding

No funding sources were provided for this study.

Disclosure of interest

The authors declare that they have no competing interest.

References