Original article

Serial magnetic resonance imaging study of posterior cruciate ligament reconstruction or augmentation using hamstring tendons


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Abstract

Purpose: The purpose of this study was to analyze serial changes in the magnetic resonance imaging (MRI) signals of autograft hamstrings single bundle posterior cruciate ligament (PCL) reconstruction and the effects of remnant preservation (augmentation).

Material and methods: Twenty-two isolated PCL injuries were arthroscopically reconstructed or augmented with hamstring tendons. MRI scans were obtained at 3, 6, and 12 months, and prior to the second-look arthroscopy (average 20.7 months). The patients were divided into 2 groups by remnant preservation: five PCL reconstructions after PCL remnant resection (Group Rec) (23%), and 17 reconstructions preserving the remnant (Group Aug) (77%). The 22 patients were also divided into two groups depending on the location of the PCL tear. There were 9 knees with proximal tear (Type P) (41%) and 13 knees with distal tear (Type D) (59%). The signal intensity and fiber continuity of 4 zones (proximal, middle, distal intra-articular, and tunnel zones) were evaluated by the Mariani score.

Results: The average MRI evaluation score gradually increased from 6 months through the final MRI. The intra-articular part of the graft exhibited slower maturation (12 months – final scan) as compared with the tunnel zones (6–12 months). The distal zone underwent better maturation than the proximal or middle zones at all points. In the proximal zone, the score for Group Aug was significantly higher than Group Rec. In the proximal zone, the Type D score with a proximally-preserved remnant was significantly higher than Type P without a proximal remnant.

Conclusions: The hamstring tendons require more than 1 year to achieve low-signal intensity. PCL remnant has a beneficial effect on the maturation of the hamstring graft.

Level of evidence: IV: therapeutic case series.

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1. Introduction

Magnetic resonance imaging (MRI) has been widely-used in the past to evaluate graft integrity following hamstring anterior cruciate ligament (ACL) reconstruction, and has provided much information regarding the healing process [1–5]. With respect to the posterior cruciate ligament (PCL), the value of MRI in diagnosing native PCL tears [6–8] and the natural healing process without surgery has also been well-established [9–14]. There have been few studies to date reporting graft integrity following PCL reconstruction, and little is known about the fate of the PCL graft. There is only one serial MRI evaluation of graft integrity up to 12 months after PCL reconstruction [15]. They studied the graft integrity using MRI, and reported that their intensity increased at 6 months and then decreased gradually. They concluded that graft maturation requires more than 12 months after PCL reconstruction.

Over the last decade, there has been increased interest in new and improved techniques for PCL surgery with better results. Recently, several augmentation techniques for PCL injury have been reported [16–23]. Six clinical reports have concluded good results for PCL reconstruction with preservation of the remnant [17,18,20–23]. It is still unclear whether the preserved PCL remnant could support graft maturation after PCL reconstruction.

The purpose of this study was:

- to analyze the serial changes in the MR signals of the hamstring autograft used for PCL reconstruction and augmentation;

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2. Materials and methods

2.1. Patients

From 2002 through 2011, 22 arthroscopic single bundle PCL reconstruction for isolated PCL injury were performed by a single surgeon.

There were 19 men and 3 women (mean age 31.5 years 18–53 years, SD ± 10.2). The average time between injury and surgery was 32 months (1 month–20 years, SD ± 60.3 months).

The indication for surgery was a side to side 5 mm difference and continuity of the PCL on MRI. In the first 5 cases (2002–2003) (23%) PCL remnant was resected (Group Rec); in the next 17 cases (77%) it was preserved (Group Aug). Combined anterior cruciate ligament or posterolateral tears were excluded.

2.2. Surgical technique

The graft tendons (semitendinosus and gracilis) were harvested, and then used as a seven or eight strand graft. The average graft diameter of the femoral side was 8.1 mm (6–10 mm) and the tibial side was 9.1 mm (7.5–11 mm). For proper preparation of the tibial tunnel, a postero-medial portal was carried out [24]. The surgeon introduced the PCL tibial guide system to the back side of the PCL, positioning more than 1.5 cm below the articular surface and just distal to the tibial PCL insertion, to avoid damage to the remnant PCL attachment.

To prepare the femoral tunnel without removing PCL remnant, the surgeon placed the tip of a pin and drilled about 7 mm proximal to the margin of the articular cartilage of the medial femoral condyle at the 1 o’clock position for a right knee (11 for a left knee), from the high antero-lateral arthroscopic portal, mimicking the antero-lateral bundle. The graft tendon was fixed to the femoral tunnel using EndoButtons CL (Smith & Nephew Endoscopy, Andover, MA). It was fixed with 2 staples (Meira, Nagoya, Japan) to the tibia with maximum manual anterior drawer stress and the knee joint flexed at 90°.

2.3. Postoperative rehabilitation

For the first 10 days, a knee brace was used to immobilize the knee in a slightly flexed position. Early ranges of motion exercises were allowed with a soft brace that had a 90°–initial range of motion restriction. Weight-bearing was allowed as tolerated at 3 weeks after the operation. At 6 months, the patients were allowed to take off the brace. By 10 months, sports activities could be resumed.

2.4. Patient Assessment

Serial postoperative evaluations and MRI scans (1.5-Tesla Signa HDxt; GE Healthcare, Copenhagen, Denmark) were performed at 3, 6 and 12 months and at final evaluation (just before the second arthroscopy and extraction of the staples from the tibia) (18–27 months; average 20.7 months, SD ± 2.6 months). To evaluate the stability of the knee, bilateral radiographs were obtained by maximum manual posterior stress. The posterior stability was graded according to the 4 groups of the IKDC evaluation form.

2.5. MRI classification

The preoperative MRI scans were classified with regard to the PCL injury location and the remnant (Fig. 1). Type P was a proximal tear, and the remnant was detected mainly distally (9 knees) (41%). In Type D, the PCL tear was distal, and the remnant was detected mainly proximally (13 knees) (59%), including 3 cases of PCL avulsion fracture.

All MRI interpretations were performed by an orthopaedic surgeon, who was not aware of the results of the clinical evaluation. All examinations used a 320 × 256 matrix, 16 FOV, and 4 mm continuous slice thickness. The standard knee imaging protocol included SE T2-weighted (TR: 3100, TE: 85, Ex: 2) sequences with fat suppression (axial, coronal, and sagittal planes) and SE proton density (TR: 2000, TE: 20, Ex: 2) sequences (coronal and sagittal planes).

The MRI evaluation was performed using the Mariani analysis (Table 1) [15]. This evaluation method consists of two steps. One is the 4-level grading system to analyze the signal intensity at each zone [25] and the other is the morphologic continuity parameters of the graft [26]. The 4-level grading system is as follows [25]. Grade I: homogeneous, low-intensity signal within the entire graft segment. Grade II: at least 50% of a “normal” ligament signal. Grade III: less than 50% of the normally apparent ligament signal. Grade IV: diffuse increase in signal intensity with abnormal appearing

Fig. 1. Preoperative MRI classification of the PCL injury. (A) Proximal injury and the remnant is detected mainly distally (Type P): 9 knees. (B) Distal injury and the remnant is detected mainly proximally (Type D): 13 knees.

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strands of ligament. The intra-articular pathway of the PCL autograft were divided into a proximal zone corresponding to the graft at the femoral tunnel entrance, a middle zone corresponding to the central graft area, a distal zone corresponding to the graft near the tibial tunnel, and the tibial zone corresponding to the graft within the tibial tunnel [25]. The 4 zones examined were rated from 3 points for grade I to 0 point for grade IV.

The continuity of the PCL reconstruction was scored in 3 grades as follows [26]:

- grade A, a well-defined ligament;
- grade B, a wavy but continuous ligament contour;
- grade C, a non-delineated ligament.

The ligament continuity was scored as 1 point for grade A to 0 point for grade C. Therefore, the MRI score ranged from 0 (worse) to 13 (best) points (3 points for each of the 4 zones plus 1 point for ligament continuity).

2.6. Statistical analysis

After expressing each measurement as a mean ± standard error of the mean (SEM) in the figures, a statistical software package (Statview, Abacus Concepts Inc, Berkeley, CA) was utilized. Mann–Whitney U test, Wilcoxon test, and the Kruskal-Wallis test were utilized for comparisons between the groups. P values below 0.05 were considered statistically significant.

3. Results

3.1. Laxity

Posteroir laxity, as determined by bilateral radiographs with maximum manual posterior stress, showed statistically significant differences in a pre- versus postoperative comparison (P < 0.0001, Table 2). All 22 patients achieved a posterior draw from 0 to < 5 mm. No significant differences were detected between the Groups Rec and Aug (pre-operation P = 0.26, last follow-up P = 0.46) nor Types P and D (pre-operation P = 0.29, last follow-up P = 0.62).

Table 1

<table>
<thead>
<tr>
<th>Zonal signal intensity</th>
<th>Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 points: grade I</td>
<td>1 point: grade A</td>
</tr>
<tr>
<td>2 points: grade II</td>
<td>0.5 point: grade B</td>
</tr>
<tr>
<td>1 point: grade III</td>
<td>0 point: grade C</td>
</tr>
<tr>
<td>0 point: grade IV</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Postoperative laxity</th>
<th>Preoperative</th>
<th>Last follow-up</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n = 22)</td>
<td>10.9 ± 4.4</td>
<td>1.0 ± 2.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>&lt; 3 mm</td>
<td>0</td>
<td>15 (88%)</td>
<td></td>
</tr>
<tr>
<td>3–5 mm</td>
<td>0</td>
<td>7 (32%)</td>
<td></td>
</tr>
<tr>
<td>5–10 mm</td>
<td>10 (45%)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>&gt; 10 mm</td>
<td>12 (55%)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Group Rec (n = 5)</td>
<td>12.2 ± 3.5</td>
<td>1.8 ± 2.0</td>
<td>0.0431</td>
</tr>
<tr>
<td>Group Aug (n = 17)</td>
<td>10.5 ± 4.6</td>
<td>0.8 ± 2.4</td>
<td>0.0003</td>
</tr>
<tr>
<td>Type P (n = 10)</td>
<td>12.3 ± 5.2</td>
<td>0.9 ± 2.4</td>
<td>0.0077</td>
</tr>
<tr>
<td>Type D (n = 12)</td>
<td>9.9 ± 3.7</td>
<td>1.1 ± 2.4</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

Note: the stress view (mean ± SD) radiographs were performed using manual posterior stress. All data are presented as the no. of cases (%) unless otherwise indicated. No significant differences were detected between groups or between types.

3.2. Clinical examination

All 22 patients had no knee joint effusion pre- or postoperatively. After PCL reconstruction, 21 patients (91%) demonstrated unrestricted range of motion without extension deficits (< 3°) or flexion deficits (0°–5°). One patient (5%) still had a 10° extension deficit.

3.3. MRI score

The average MRI evaluation (signal intensity and continuity) score was 7.3 ± 2.0 at 3 months, 6.6 ± 1.3 at 6 months, 7.7 ± 1.0 at 12 months and 9.6 ± 1.4 at the final scans (Fig. 2A). Significant differences were detected between 3 and 6 months (P = 0.019), between 6 and 12 months (P = 0.0045), and between 12 months and the final scans (P = 0.0001). The grafted hamstring tendons required more than 1 year to achieve a low-signal intensity over its entire course.

The MRI score progression for each zone is shown in Fig. 2B. A significant difference in the tibial tunnel zone was detected between 6 and 12 months (P = 0.007). In contrast, the scores for the proximal, middle, and distal zones in the joint were still low at 12 months after the operation. Significant differences between 12 months and the final scans were detected in the proximal, middle, and distal zones (proximal: P = 0.0015, middle: P = 0.003, distal: P = 0.025). The portion of the graft in the joint exhibited slow maturation. Regional differences between each MRI scan were also assessed (Table 3). Significant differences were detected at every MRI scan both between the proximal and distal zones, and between the middle and distal zones. Therefore, there were regional differences in hamstring PCL reconstruction. Hamstring grafts had a faster maturation at the tibial tunnel zone (6–12 months), but slower maturation at the proximal, middle and distal zones (12 months – final scan).

Fig. 2. Time course of the MRI scores from all 22 cases at 3, 6 and 12 months, and the final postoperative scan. A: total score. The MRI scores increased from 6 months through to the final scan (18–24 months). Significant differences were detected at every time point. B: regional scores at the proximal, middle, distal, and tibial zones, and their differences. The scores from the tibial zones (in the bone) increased from 6 months to 12 months. In contrast, the scores from the proximal, middle, and distal zones (in the joint) increased from 12 months to the final scan. The scores from the distal zone are significantly higher than those from the proximal and middle zones.

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Table 3
Regional score differences at each MRI scan.

<table>
<thead>
<tr>
<th></th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
<th>Final scan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal score</td>
<td>1.24 ± 0.15</td>
<td>1.00 ± 0.17</td>
<td>1.24 ± 0.17</td>
<td>1.96 ± 0.15</td>
</tr>
<tr>
<td>Middle score</td>
<td>1.24 ± 0.14</td>
<td>0.88 ± 0.08</td>
<td>1.14 ± 0.10</td>
<td>1.82 ± 0.11</td>
</tr>
<tr>
<td>Distal score</td>
<td>2.00 ± 0.14</td>
<td>1.91 ± 0.12</td>
<td>2.05 ± 0.11</td>
<td>2.41 ± 0.11</td>
</tr>
<tr>
<td>Proximal vs Middle</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Proximal vs Distal</td>
<td>0.0024</td>
<td>0.002</td>
<td>0.0032</td>
<td>0.0399</td>
</tr>
<tr>
<td>Middle vs Distal</td>
<td>0.0018</td>
<td>0.0003</td>
<td>0.0004</td>
<td>0.0022</td>
</tr>
</tbody>
</table>

score: mean ± SEM.

The MRI scores of the proximal, middle, distal and tibial zones for the 2 surgical groups are shown in Fig. 3. In the proximal zone, the scores for Group Aug were significantly higher than for Group Rec (6 months P = 0.013, 12 months P = 0.002, final scans P = 0.002). No significant differences were detected for the middle, distal, and tibial zones.

The MRI scores of the proximal, middle, distal, and tibial zones for the 2 preoperative tear types are shown in Fig. 4. In the proximal zone, Type D knees scored significantly higher than Type P (6 months P = 0.030, 12 months P = 0.001, final scans P = 0.049). No significant differences were detected in the middle, distal or tibial zones.

The Fig. 5 summarizes the evolution with time of MRI features (Group Aug, Type P).

3.4. Second-look arthroscopy

Second-look arthroscopy was systematically carried out. The graft tension was nearly normal in all patients. The synovial coverage was good and the graft continuity was well preserved, with no partial disruption except in 1 case. This partial rupture exhibited high signal MRI intensity in the proximal zone. There were no effects from the killer turn that might have caused loosening or tearing of the graft at the tibial attachment site.

4. Discussion

In this study, significant differences in MRI signal intensity were found between the surgical technique groups and the preoperative
Fig. 5. Serial proton density MRI scans of the PCL augmentation. A: preoperative MRI scan. Injury Type P, proximally injured and the remnant was preserved at the distal side. B: MRI scan at 3 months. The distal zone showed low intensity signal. C: MRI scan at 6 months. Every zone showed high intensity signal. D: MRI scan at 12 months. Distal and tibial zones showed low intensity signal. E: MRI scan at 21 months. Every zone showed low intensity signal.

tear types. Moreover, the graft has a variable, time-dependent MR appearance up to 20.7 months, in accordance with the experimental findings of Bosh and Kaspereczky [27,28].

Finally, there are regional differences in the MR signal. After PCL reconstruction with the patellar tendon, Mariani observed slower graft healing at the distal zone, with localized increased signal intensity disappearing by the 12-month evaluation [15]. He speculated that the “killer turn” angle at the tibial tunnel entrance, may produce abnormal graft stresses and explains this finding. On the other hand, he did not detect similar findings at the femoral tunnel, another area of increased stress. He used the interference screw fixation at the articular entrance of the medial femoral condyle. Our data detected an increased signal intensity at the femoral side and its subsequent disappearance at the 18–27 months evaluation. In our opinion, the true killer turn in PCL reconstruction is located at the femoral tunnel entrance, especially when a graft without a bone block is used causing a high signal around the femoral tunnel.

Recently, operative techniques that spare the remnant fibers have been introduced [16–23]. Although the clinical data do not support a significant improvement [17,18,20–23], the remnant fibers should theoretically prevent graft failure from the killer turn effect [12,13,29,30]. In our study, the signal intensity at the femoral tunnel entrance is lower in the Group Aug than in the Group Rec. The evaluation between the tear types also indicates a positive effect in the Group Aug. The scores of the distal tear type are significantly better than the proximal one at 6 and 12 months, and on the final scan of the proximal and middle zones. Although the clinical data do not detect a difference between the operative methods or the tear types, the MRI signal intensity evaluation supports the importance of the remnant preservation.

Our study has some limitations, including a relatively short-term follow-up, and a small sample group. It is a retrospective study.

5. Conclusions

The hamstring tendons for PCL reconstruction require more than 1 year to achieve a low-signal intensity but a high intensity signal remains more prolonged at the proximal zone than at the distal zone. The remnants might have beneficial effects on maturation at the proximal and middle zones, especially with a preoperative proximal remnant.

Disclosure of interest

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

References


