Purpose: To evaluate the diagnostic accuracy of the various tear configurations in a medial meniscal posterior horn root tear and assess whether any correlation exists with other associated knee abnormalities in MR imaging.

Materials and Methods: A retrospective review of 146 preoperative knee MR images were performed by one experienced musculoskeletal radiologist. The tear configuration and other abnormalities were evaluated. Sensitivity, specificity, and diagnostic accuracy of each configuration in the medial meniscal posterior horn root tear were calculated.

Results: A total of 48 medial meniscal posterior horn root tears including 38 full-thickness radial, 7 partial-thickness radial, and 3 complex tears were confirmed during arthroscopy. Overall, the sensitivity, specificity, and accuracy for the detection of medial meniscal posterior horn root tear were 92% (44/48), 99% (97/98), and 97% (141/146), respectively. For each tear configuration, sensitivity, specificity, and accuracy were 82% (31/38), 97% (105/108), and 93% (136/146) for full-thickness radial tears, respectively, and 43% (3/7), 94% (131/139), and 91% (134/146) for partial-thickness radial tears, respectively. The incidence of degenerative joint disease was 85% (41/48) for the tear group, revealing a strong association. In patients with a root tear and with degenerative joint disease, the incidence of high grade cartilage defects involving the medial femoral condyle was at 80% (33/41), compared to 56% (23/41) for the presence of medial meniscal extrusion. In contrast, a similar comparison of incidence for patients with no root tears but with degenerative joint disease was at 68% (17/25) and 26% (8/31), respectively.

Conclusion: MR imaging is very sensitive for the detection of medial meniscal root tears, but has reduced the accuracy with regard to each tear configuration. Medial meniscal root tears showed a strong association with degenerative joint disease. High grade cartilage defects of the medial femoral condyle and medial meniscal extrusions also reveal a strong association with medial meniscal root tears.

Index words: Knee, Medial Menisci, Arthroscopy
Magnetic Resonance Imaging
The menisci are integral to the complex biomechanics of the knee and help to protect adjacent articular surfaces. The medial meniscus, especially its posterior horn and posterior root attachments are most likely to sustain acute and chronic type injuries [1].

Given that meniscal root tears can now be repaired with arthroscopically, the importance of a preoperative MR imaging is emphasized. Without a thorough examination, medial meniscal root tears can be overlooked during arthroscopy if the torn margins of the posterior horn are close to the tibial insertion site. Therefore, correct preoperative characterization of meniscal tears can allow for better preoperative planning and intraoperative examination.

Previous studies have reported high accuracy for MR imaging in the evaluation of meniscal injuries of the knee, with some studies reporting the ability of MR imaging to reveal the configuration of tears [2–5]. A few studies have reported the high accuracy of MRI in evaluating meniscal knee injuries [2, 6]. Lee et al. [6] reported that MRI of the knee is reliable and highly accurate for the detection of radial tears of the medial meniscal root.

To our knowledge, there has been no radiologic report of the accuracy of MR imaging for the diagnosis of medial meniscal posterior horn root tears with respect to the tear configuration.

The purpose of this study was to evaluate the diagnostic accuracy of the various tear configurations in medial meniscal posterior horn root tears and assess any correlation with associated abnormalities in MR imaging.

### Materials and Methods

#### Study Population

The institutional review board granted approval for the entire study. Institutional databases were reviewed to identify patients who underwent both preoperative MR imaging of the knees and arthroscopic knee surgery from January 2005 to June 2007. Arthroscopies were performed between 0 and 91 days after preoperative MR imaging. A total of 146 knees from 144 patients who underwent preoperative MR imaging of the knee had arthroscopic surgeries were evaluated. Of the 144 patients, 48 were arthroscopically confirmed as having medial meniscal root tears. The patient population included 9 men and 39 women, ranging in age from 22–78 years old (mean, 59-years-old).

#### MR Imaging Technique

MR imaging was performed with a 1.5-T scanner (Intera Achieva; Philips Medical Systems, Best, The Netherlands) and a knee coil. Fast spin echo pulse sequences were used to obtain modified proton density-weighted images (TR/TE, 4,000/36) in sagittal, coronal, and axial planes as well as sagittal fat suppression T2-weighted images (TR/TE, 2,293/60). MR imaging parameters were as follows: field of view, 16 cm; excitations 1; matrix size 512 448; section thickness, 3.5 mm for sagittal and axial images and 3 mm for coronal images; no interslice gap.

#### MR Imaging Analysis

MR images were retrospectively reviewed by one musculoskeletal radiologist without knowledge of preoperative MR imaging results. We evaluated the meniscal root tear configuration of the medial meniscal posterior horn on MR imaging and compared it with arthroscopic findings. We calculated the sensitivity, specificity, and diagnostic accuracy of each configuration in the medial meniscal posterior horn root tear.

MR imaging and arthroscopic criteria used for the diagnosis of a medial meniscal root tear required a tear within 5mm of the tibial attachment site of the anterior or posterior horn of the medial meniscus. Previously described MR imaging and arthroscopic criteria for meniscal tears were utilized and tear configurations were evaluated and classified into 1 of 5 configurations [3]. First, a horizontal tear is parallel to the tibial plateau and separates the root into its upper and lower parts. A longitudinal tear is described as a vertical tear (perpendicular to the tibial plateau) that propagates parallel to the main (circumferential) axis of the root. A radial tear is vertical and propagates perpendicular to the main axis. An oblique tear is vertical and propagates obliquely to the main axis of the root. Lastly, a complex tear comprises 2 or more of the tear configurations previously stated.

For a radial tear, our criteria for the diagnosis of full-thickness radial tear and partial-thickness radial tear of medial meniscal root were the same as described in a previous study [7]. We diagnosed a full-thickness radial tear when the meniscal tear extended from the apex through the periphery of the meniscus. When the tear did not extend to the margin of the meniscus and preserved the apex or peripheral portion of meniscus, the diagnosis was a partial-thickness radial tear.

We also evaluated the relationships between medial meniscal root tear and degenerative joint disease, as

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well as accompanying cartilage defects of the medial femoral condyle and pathologic medial meniscal extrusion.

The criteria used for diagnosing degenerative joint disease were articular cartilage defects of the knee joint without clinical manifestations or MR findings of metabolic bone disease, septic arthritis, inflammatory arthritis, connective tissue disease, insufficiency fracture, spontaneous osteonecrosis, or neoplastic disease (5). The criteria for a pathological medial meniscal extrusion was 3 mm or more extrusion of the medial meniscus body, with measurements made from the superomedial edge of the tibial plateau to the periphery of the medial meniscal body at the level of the medial collateral ligament on coronal images (8).

For any associated degenerative joint disease, the degree of cartilage defect involving the medial femoral condyle seen on MR images and confirmed by arthroscopy was graded according to a modified Outerbridge classification (9, 10). Grade 0 indicated intact cartilage; grade 1, chondral softening or blistering with an intact surface; grade 2, shallow superficial ulcer-

Table 1. Correlation Between MR Imaging and Arthroscopic Findings

<table>
<thead>
<tr>
<th>MRI Findings</th>
<th>Full-thickness radial</th>
<th>Partial-thickness radial</th>
<th>Complex</th>
<th>No tear</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthroscopic findings</td>
<td>Full-thickness radial</td>
<td>31</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Partial-thickness radial</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Complex</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>No tear</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>97</td>
<td>98</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>11</td>
<td>0</td>
<td>101</td>
<td>146</td>
</tr>
</tbody>
</table>

Fig. 1. A 62-year-old woman with a left medial meniscal root tear. Sagittal (arrows, A, B), coronal (arrow, C), and axial (arrow, D) modified turbo spin echo images reveal a full-thickness radial tear, but arthroscopy demonstrated a partial-thickness radial tear.
ation, fibrillation, or fissuring involving less than 50% of the depth of the articular surface; grade 3, deep ulceration, fibrillation, fissuring or a chondral flap involving 50% or more of the depth of the articular cartilage without exposure of subchondral bone; and grade 4, full-thickness chondral wear with exposure of subchondral bone.

Results

Arthroscopies performed on 146 knees revealed 48 medial meniscal posterior horn root tears (Table 1). The 98 remaining knees were confirmed to have no root tear in arthroscopy and among them, only one case was misdiagnosed as a radial tear by MRI. Overall sensitivity, specificity, and accuracy for the detection of medial meniscal posterior horn root tear regardless of tear configuration were 92% (44/48), 99% (97/98), and 97% (141/146), respectively (Table 2). With regard to each configuration of root tear, sensitivity, specificity, and accuracy were 82% (31/38), 97% (105/108), and 93% (136/146) for full-thickness radial tears, respectively and 43% (3/7), 94% (131/139), and 91% (134/146) for partial-thickness radial tears, respectively. Two partial-thickness tears were misdiagnosed as full-thickness tears by MRI (Fig. 1) and two other partial-thickness tears displayed no meniscal defects on MRI.

One of the complex tears was misdiagnosed as a par-

<table>
<thead>
<tr>
<th>Table 2. The Diagnostic Accuracy of MR Imaging for Each Configuration of Medial Meniscal Posterior Root Tears</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Configuration</strong></td>
</tr>
<tr>
<td>Full-thickness radial tear</td>
</tr>
<tr>
<td>Partial-thickness radial tear</td>
</tr>
<tr>
<td>All radial tear</td>
</tr>
</tbody>
</table>

Fig. 2. A 75-year-old man with a right medial meniscal root tear. Sagittal (arrows, A, B), coronal (arrow, C), and axial (arrow, D) modified turbo spin echo images reveal a partial-thickness radial tear, but arthroscopy demonstrated a complex radial tear.
tial-thickness tear (Fig. 2), while the other complex tear was misdiagnosed as a complete tear by MRI. Pull-out repair was performed in 26 of 38 full-thickness radial tears and 1 of 3 complex tears. A menisectomy was performed in 12 of 38 full-thickness, 7 of 7 partial-thickness radial tears, and 2 of 3 complex tears. The incidence of degenerative joint disease in patients with root tears was 85% (41/48), revealing a strong association with root tear. In addition, the incidence of degenerative joint disease was lower in patients with no root tears was 31% (31/98). In association with degenerative joint disease, the incidence of high grade (grade 3 and 4) cartilage defects of the medial femoral condyle was 80% (33/41), and the presence of medial meniscal extrusion (≥3 mm) was 56% (23/41) in patients with root tears (Fig. 3). In patients with no root tears, 68% (17/25) displayed high grade cartilage defects of the medial femoral, and 26% (8/31) had medial meniscal extrusion.

Discussion

MR imaging is well established as the best imaging modality for evaluating a patient with suspected meniscal pathology. Previous studies have reported the high accuracy of MR imaging in evaluating meniscal knee injuries (2). Lee and colleagues reported that a knee MR imaging is a reliable diagnostic study for the detection of radial tears involving the medial meniscal root, with an accuracy of 94% (6).

Our study also reveals a high MR imaging accuracy for the evaluation of radial tears involving the medial meniscal root.

Harper et al. (11) reported that radial tears are founded at the posterior horn of the medial meniscus in 53% of cases identified at arthroscopy. Radial tears, which occur at the inner edge of the medial meniscus, destroy the ability of the meniscus to withstand hoop stress (8). Therefore, the MR imaging has an important role in the diagnosis of radial tears involving the medial meniscal posterior horn root. A radial tear is perpendicular to the long circumferential axis of the meniscus. Thus radial tears can be either a full- or partial-thickness tear. In our study, the sensitivity, specificity, and accuracy decreased in each tear configuration of medial meniscal posterior horn root tear, especially for partial-thickness radial tears.

Generally, radial tears occurring in the posterior horn of the medial meniscus are degenerative (12) and the signal change of the meniscus can be seen due to a degenerative change or slight fraying in patients with root tears. In full-thickness radial tears is most commonly manifested as the complete absence of meniscus on at least one image within a series of images. Partial-thickness tears usually involve the apex, and partial-thickness peripheral radial tears with an intact apex are far less common (12). Clinical significance depends on the functional status of intact portion. In MR imaging, we diagnosed a partial-thickness radial tear when the defect of the meniscus is not extending to the margin of the meniscus and the meniscal margin is preserved either at the apex or peripheral portion. Because it is commonly associated degenerative change of meniscal root, the signal change of root itself can disturb the evaluation of partial defect at the meniscal root, which results in decreasing MR imaging sensitivity for partial-thickness radial tears.

A full-thickness radial tear can result in the loss of the meniscal integrity, resulting in either two separate
pieces of menisci or one large meniscal piece attached to the tibia at one end [13]. It is important to know preoperatively whether the radial tear is full-thickness or partial-thickness given that, operative methods are different. As in our cases, patients who were diagnosed with a partial-thickness radial tear underwent a meniscectomy.

Medial meniscal posterior horn radial tears are more common in elderly patients and have little correlation with traumatic injury. Degeneration of the medial meniscus posterior horn precedes the tear [14]. Lee and his colleagues [5] revealed that the incidence of degenerative joint disease in the medial meniscal posterior horn root tear was 97%. In our study, the incidence of degenerative joint disease was 85% (41/48) in patients with root tear, revealing a strong association.

Unlike the radial tears in the posterior horn of the medial meniscus, radial tears in the lateral meniscus are caused by a more severe form of athletic trauma [12]. Moreover, lateral root tears are more common when there is an ACL tear [15]. In a study by Arthur et al. [15], the sensitivity and specificity for diagnosing posterior root tears of lateral meniscus were 94% and 89%, respectively. In many other studies [5, 8, 14, 16], a strong association between the medial meniscal root pathology and meniscal extrusion was reported. Based on reports from Costa and colleagues, the medial meniscus is considered significantly extruded when it goes beyond the medial tibial margin by 3 mm or greater [16]. When a meniscal extrusion greater than 3 mm is identified, the high likelihood exists that additional lesions are present to include meniscal degeneration and meniscal tears involving the meniscal root, which all result from the disruption of meniscal stability.

Our study also reveals that a medial meniscal extrusion is highly associated with root tears, which is not the case for patients with no root tear. Another study reported that meniscal extrusions are important not only because they are strongly associated with underlying tears but because meniscal extrusions themselves are thought to be related to the development of osteoarthritis [17]. In many studies, a medial meniscal extrusion has been shown to precede cartilage loss and onset of bony degenerative joint disease within the knee [18-20]. In our study, with regard to degenerative joint disease, high-grade cartilage defects of the medial femoral condyle were also highly associated with root tears, which is in contrast to patients with no root tears.

In conclusion, MR imaging is accurate for the detection of medial meniscal root tears, but has a reduced accuracy when attempting to classify tear configurations. Medial meniscal root tears were highly associated with degenerative joint disease. High-grade cartilage defects of the medial femoral condyle and medial meniscal extrusions also reveal a strong association with medial meniscal root tears.

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대체만큼의 자기공명영상: 다양한 열상 형태의 진단 정확도와 열상과 관련된 슬관절의 비정상적인 소견

목적: 슬관절 자기공명영상의 내측 반월판 후각 열상의 형태에 따른 진단 정확도 및 열상과 관련된 슬관절의 비정상적인 소견에 대해 알아보고자 한다.

대상과 방법: 관절경 수술 전 시행한 146개의 슬관절 자기공명영상 중 1명의 숙련된 영상의학과 의사가 후향적으로 분석하였다. 자기공명영상에서 나타낸 반월판 열상의 형태와 열상과 관련된 슬관절의 비정상적인 소견에 대해 분석하였으며 이를 관절경 소견과 비교하였다. 관절경에서 확인된 내측 반월판 후각 열상의 각 형태에 따른 자기공명영상의 민감도, 특이도, 정확도를 계산하였다.

결과: 총 48개의 내측 반월판 후각 열상이 관절경 시술에서 확인되었으며, 이중 38개는 전체 중 횡열상, 7개는 부분 중 횡열상, 3개는 복합열상으로 진단되었다. 열상형태에 관계없이, 내측 반월판 후각 열상 전체에 대한 민감도, 특이도, 정확도는 각각 92% (44/48), 99% (97/98), 97% (141/146)로 나타났다. 그러나 반월판 후각 열상 중에서 전체 중 횡열상의 민감도, 특이도, 정확도는 각각 82% (31/38), 97% (105/108), 93% (136/146)였으며, 부분 중 횡열상의 경우 민감도, 특이도, 정확도는 각각 43% (3/7), 94% (131/139), 91% (134/146)였다. 내측 반월판 후각 열상에 있어 슬관절의 퇴행성 관절 질환의 발생 빈도는 85% (41/48)로 강한 연관성을 보았다. 퇴행성 관절 질환은 외반된 반월판 후각 열상 환자에서 백분 암쪽 관절 운동의 연골 결손의 발생 빈도는 80% (33/41)였으며, 내측반월판 반월FormatException 56% (23/41)로 높았다. 반면 퇴행성 관절 질환이 없었던 환자군에서는 각각 68% (17/25)와 26% (8/31)로 그 빈도가 낮은 것으로 나타났다.

결론: 내측 반월판 후각 열상의 진단에 있어서 자기공명영상의 정확도는 매우 높다. 반면 열상의 형태별 진단 정확도는 감소함을 알 수 있다. 또한, 내측 반월판 후각 열상은 슬관절의 퇴행성 관절 질환과 높은 연관성을 보였다. 대퇴 아쪽 관절 운동의 연골 결손과 내측 반월판 연골 탈출 또한 내측 반월판 후각 열상과 높은 연관성을 보였다.