MRI of the knee in patients who underwent medial unicompartmental arthroplasty (MUA): Normal anatomy and interobserver reproducibility

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<th>Poster No.:</th>
<th>C-2292</th>
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<tr>
<td>Congress:</td>
<td>ECR 2010</td>
</tr>
<tr>
<td>Type:</td>
<td>Scientific Exhibit</td>
</tr>
<tr>
<td>Topic:</td>
<td>Musculoskeletal</td>
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<tr>
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<tr>
<td>Keywords:</td>
<td>knee, medial unicompartmental arthroplasty, magnetic resonance imaging</td>
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<tr>
<td>DOI:</td>
<td>10.1594/ecr2010/C-2292</td>
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Purpose

Medial unicompartmental arthroplasty (MUA) represents a common treatment in patients affected by arthritis of the medial compartment of the knee with a preserved lateral compartment.\(^1\)\(^-\)\(^4\) This approach represents an intermediate and less invasive solution compared to a total knee replacement,\(^5\) with an implant survival rate reaching 98% at 10 years\(^6\) and 92% at 20 years.\(^6\)\(^-\)\(^10\) In addition, MUA is burdened by a lower postoperative morbidity, with a faster recovery and an improved functional response compared with total knee replacement.\(^1\)\(^,\)\(^11\)\(^,\)\(^12\)

In patients who underwent MUA, imaging follow-up is aimed at evaluating residual articular function and monitoring the progression of lateral compartment arthritis.\(^13\)\(^,\)\(^14\) The implant and the surrounding bone are roughly assessed with plain radiographs,\(^13\)\(^\)\(^,\)\(^15\)\(^,\)\(^16\) while superficial soft tissues are effectively evaluated by ultrasound (US).\(^17\)\(^,\)\(^18\) However, none of these imaging techniques is effective in assessing the central pivot, lateral meniscus, and cartilage of the lateral compartment.

To date, articular implants are considered as devices limiting magnetic resonance (MR) imaging due to the induction of susceptibility artefacts.\(^19\) However, a recent feasibility study\(^20\) demonstrated the safety of MR imaging in patients who underwent MUA and the superiority of T1-weighted turbo spin-echo (TSE), proton density (PD)-weighted TSE, T2-weighted TSE, and short tau inversion-recovery (STIR) sequences in the diagnostic evaluation of such patients. That study\(^20\) was conducted only on four patients, without considering specific residual anatomical items, and without providing an estimation of interobserver reproducibility.

The purpose of our preliminary study was to evaluate safety and potential diagnostic value of MR imaging of the knee treated with MUA.

Methods and Materials

Patients and Imaging Protocol

Institutional Review Board approval and patients' informed consent was obtained.

Between December 2005 and January 2006, 8 patients (5 males, 3 females, age range 56-80 years) with a MUA Oxford III (Biomet, London, UK) prospectively underwent MR imaging of the implanted knee. Such prostheses are made of a femoral shield and a
tibial plate made in cobalt-chrome-molybdenum alloy, clearly visible on plain films. An anatomic-like radiolucent polyethylene meniscus is inserted between those metal components (Figure 1A on page 1, B on page 2).

All investigations were performed with a 1.5 T MR equipment (Sonata Maestro Class, Siemens, Erlangen, Germany) and flexible coil wrapped around the knee. Acquisition protocol consisted of axial T1-weighted TSE, sagittal T2-weighted TSE, coronal PD-weighted TSE, and coronal and sagittal STIR sequences (Table 1 on page 3). Examination time was evaluated as composed of acquisition time (the sum of sequences duration) and also time for patient positioning, initial scout sequences, and patient removal from the scanner.

All patients were asked to remain in our department for about 30 minutes after the examination to assess any adverse event.

**Image Analysis**

For each sequence, we evaluated the visibility of femoral-patellar relationship, femoral-patellar cartilage, Hoffa's fat pad, patellar ligament, lateral meniscus, femoral-tibial lateral joint, lateral collateral ligament, anterior cruciate ligament, femoral-tibial lateral cartilage, posterolateral corner, and posterior cruciate ligament. The evaluation was conducted independently by two radiologist with ten and four years of experience in musculoskeletal MR imaging. Each of the two readers provided a semiquantitative visibility index of the above mentioned items for each sequence, taking into account masking artefacts and image (contrast/spatial) resolution, as follows: 0=not visible, 1=insufficient visibility, 2=sufficient visibility; 3=optimal visibility.

**Statistical analysis**

For each sequence, each of the 11 items was considered adding the visibility of all eight patients. This sum was divided by the potential maximum value (3×8=24), obtaining a percentage visibility index (PVI). We calculated the distribution of PVI for each of the two readers, considering the following intervals: <55%, #55% and <70%, #70% and <85%, #85%. Interobserver reproducibility was estimated with the percentage of discordant cases and unweighted Cohen's kappa. The SPSS software package (SPSS Inc., release 17.0 for Windows) was used.

**Images for this section:**
Table 1. Technical parameters of 1.5 T magnetic resonance sequences used in the evaluation of the knee in patients who underwent medial unicompartmental arthroplasty

<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>Flip angle</th>
<th>Slice thickness (mm)</th>
<th>Number of slices</th>
<th>Acquisition time (min:sec)</th>
</tr>
</thead>
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<tr>
<td>T1-weighted TSE</td>
<td>540</td>
<td>9.5</td>
<td>120°</td>
<td>7.0</td>
<td>18</td>
<td>1:00</td>
</tr>
<tr>
<td>PD-weighted TSE</td>
<td>2900</td>
<td>13.0</td>
<td>150°</td>
<td>7.0</td>
<td>18</td>
<td>2:35</td>
</tr>
<tr>
<td>T2-weighted TSE</td>
<td>2900</td>
<td>81.0</td>
<td>150°</td>
<td>7.0</td>
<td>18</td>
<td>2:35</td>
</tr>
<tr>
<td>STIR*</td>
<td>2500</td>
<td>54.0</td>
<td>180°</td>
<td>7.0</td>
<td>18</td>
<td>3:12</td>
</tr>
</tbody>
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Note. TR repetition time; TE = echo time; TSE = turbo spin-echo; PD = proton density; STIR = short tau inversion-recovery. For all sequences: matrix=512×512; field of view=200×200 mm; number of excitations=1.*Interpulse time of STIR sequence=130 msec.

Fig. 1: Table 1
Results

Acquisition time was about 20 minutes, plus 3-5 minutes for patient positioning, initial scout sequences, and patient removal from MR scanner. No patient reported pain, heat or other local or general discomfort either during the examination or during the following 30 minutes.

PCL was unseen in all patients by both observers. For the remaining ten items evaluated in four different sequences (40 items in total), the more experienced radiologist obtained the following PVI: 33 items were reported to have a PVI #85%, five items from 70% to 84%, and two items from 55% to 69%. The less experienced radiologist obtained the following results: 31 items were reported to have a PVI #85%, five items from 70% to 84%, two items from 55% to 69%, and two items <55%. The following PVI ranges were reported for the ten visible anatomical items: femoral-patellar relationship 83-100%; femoral-patellar cartilage 92-100%; Hoffa's fat pad 75-92%; patellar ligament 79-100%; lateral meniscus 100%; femoral-tibial lateral joint 100%; lateral collateral ligament 96-100%; anterior cruciate ligament 54-83%; femoral-tibial lateral cartilages 92-100%; posterolateral corner 100% (Table 2 on page ).

Figures 2 to 5 show the spectrum of findings detected in our series: chondropathy of the lateral femoral trochlea, subchondral edema, joint effusion, chondropathy of the medial articular facet of the patella, subchondral pseudocyst, and overload bone edema of the fibula.

Interobserver reproducibility analysis showed kappa values of 0.78 for T1-weighted TSE, T2-weighted TSE, and PD-weighted TSE sequences and of 0.74 for STIR sequence. On a total of 4 sequences × 8 patients × 11 structures = 352 single evaluations, a direct comparison between each evaluation showed agreement between the two readers for 331/352 (94%) items, disagreement of 1 point in 20/352 (5.7%) items, and disagreement of 2 points in 1/352 (0.3%) items.

Images for this section:
Fig. 1: Figure 1 (A) Anteroposterior radiogram of a knee of a patient who underwent medial unicompartmental knee arthroplasty (F=femur; T=tibia). On the medial side, an unicompartmental implant (S=femoral shield; asterisk=tibial plateau; arrow=polyethylene meniscus) is clearly visible. Arrowheads indicate surgical metallic stitches.
Fig. 2: Figure 1 (B) laterolateral radiogram of a knee of a patient who underwent medial unicompartmental knee arthroplasty (F=femor; T=tibia). On the medial side, an unicompartmental implant (S=femoral shield; asterisk=tibial plateau; arrow=polyethylene meniscus) is clearly visible. Arrowheads indicate surgical metallic stitches.
Fig. 3: Figure 2 Coronal proton density-weighted turbo spin-echo image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment and the distal part of the anterior cruciate ligament (black arrows). On the contrary, the lateral compartment is clearly visible (F=femoral lateral condyle; T=tibia; circles=femoral cartilage; arrowheads=lateral meniscus; white arrows=lateral collateral ligament).
Fig. 4: Figure 3 (A) Sagittal T2-weighted turbo spin-echo image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment. However, chondropathy of the lateral femoral trochlea (black arrows), subchondral edema (white arrows), and joint effusion (black and white circles) are clearly visible on the lateral compartment. Note that the lateral meniscus is correctly displayed (M). F=femoral lateral condyle; T=tibia; P=patella.
**Fig. 5:** Figure 3 (B) axial T1-weighted turbo spin-echo image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment. However, chondropathy of the lateral femoral trochlea (black arrows), subchondral edema (white arrows), and joint effusion (black and white circles) are clearly visible on the lateral compartment. Note that the lateral meniscus is correctly displayed (M). F=femoral lateral condyle; T=tibia; P=patella.
Fig. 6: Figure 3 (C) coronal short tau inversion-recovery image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment. However, chondropathy of the lateral femoral trochlea (black arrows), subchondral edema (white arrows), and joint effusion (black and white circles) are clearly visible on the lateral compartment. Note that the lateral meniscus is correctly displayed (M). F=femoral lateral condyle; T=tibia; P=patella.
Fig. 7: Figure 4 (A) Sagittal T2-weighted turbo spin-echo image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment. Despite that, chondropathy of the medial articular facet of the patella (arrows) is clearly visible (F=femur; T=tibia; P=patella).
**Fig. 8:** Figure 4 (B) axial T1-weighted turbo spin-echo image of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (black and white asterisks) masks the medial compartment. Despite that, chondropathy of the medial articular facet of the patella (arrows) is clearly visible (F=femur; T=tibia; P=patella).
**Fig. 9:** Figure 5 Sagittal short tau inversion-recovery sequence of a knee of a patient who underwent medial unicompartmental knee arthroplasty. The artefact (asterisk) does not relevantly affect the quality of this sectional image taken of the lateral compartment. A faded subchondral edema can be seen on the patella (arrowheads) in conjunction with a chondropathy of the lateral femoral trochlea (white arrows). More distally, a subchondral pseudocyst (black arrow) and overload bone edema of the fibula (circles) are clearly demonstrated (F=femoral lateral condyle; T=tibia; P=patella).
Conclusion

Our study demonstrated that 1.5-T MR imaging is effective and reproducible in the evaluation of the residual structures of the knee in patients who underwent MUA with Biomet Oxford III implant.

None of our patients reported pain, heat or other local or general discomfort either during the examination or during the following 30 minutes. This result was expected and it is consistent with the previous feasibility report.\textsuperscript{20} The need of using not gradient-echo based MR imaging sequences to evaluate the treated knee of patients who underwent MUA with metallic implants has been previously discussed:\textsuperscript{20} spin-echo based sequence have the basic advantage of reducing the size of the susceptibility artefact thanks to the effect of the 180° pulse which reverts the spin position and lowers the impact of local magnetic inhomogeneity.\textsuperscript{19,20}

In our series, the posterior cruciate ligament as well as the entire medial compartment was never visible. This is due to the strong susceptibility artefact produced by the implant and to the anatomical location of the ligament itself, which runs from the lateral side of the medial femoral condyle to the posterior intercondylar eminence.

Our results show an optimal visibility of the anterior compartment (see Figures 3 on page and 4 on page). This is potentially very helpful for the analysis of the relationship between femur and patella, as well as in the diagnosis of patellar chondropathy and patellar ligament tendinopathy. The lateral compartment of the knee resulted also clearly assessable (see Figures 2 on page, 3 on page, and 5 on page). This is even clinically more relevant. In fact, osteoarthritis of the lateral compartment - together with cartilage degeneration - is one of the major issues in the follow-up of patients with MUA, as well as the main source of pain.\textsuperscript{13} In these subjects, plain radiographs can demonstrate the presence of a chondropathy only at late stages,\textsuperscript{21} while US is effective only in the detection of secondary synovitis.\textsuperscript{22} In this setting, MR imaging could be very helpful to demonstrate arthritis and chondropathy of lateral compartment at an earlier stage, as well as the presence of initial ischemia of subchondral bone that cannot be diagnosed with plain films. This is true in the general population but also in patients treated with MUA. Our experience shows that the susceptibility artefact determined by the Biomet Oxford III implant does not affect the detection of subchondral bone edema of lateral compartment in STIR sequences (see Figure 3c on page and 5 on page).

Likewise, the artefact produced by this implant did not affect the assessment of soft tissues of the lateral compartment. The lateral collateral ligament (see Figure 2 on page), the joint capsule, and the components of the posterolateral corner were clearly visible. US is extremely effective in the evaluation of superficial structures of the lateral
compartment but has a limited diagnostic value in the assessment of meniscus and cartilage. In this setting, MR imaging is well known to be effective not only in the detection of cartilage wears, subchondral edema, or meniscal tears, but also to set a specific plan of treatment in symptomatic patients with negative plain films.\textsuperscript{23}

Some considerations are needed for the anterior cruciate ligament, whose visibility was limited compared to other structures included in our evaluation (see Figure 2 on page ). This is mainly due to its distal insertion on the medial side of the intercondylar eminence, partially hindered by the susceptibility artefact. However, the anterior cruciate ligament is not the main structure affected in patients with MUA, and a careful evaluation of patient’s history could orientate towards a correct diagnosis.

In the present study two radiologists with different experience in musculoskeletal MR imaging were the independent readers. On 352 evaluations (4 sequences × 8 patients × 11 anatomical items), readers had a one-degree disagreement in only about 6% of cases and a two-degree disagreement in less than 1% of cases, showing the robustness of MR imaging evaluation of knees treated with MUA, as confirmed by the substantial agreement demonstrated by kappa statistics. This means that the experience of the reader does not affect substantially the visibility of the residual anatomy after MUA.

Some study limitations should be taken into account. Firstly, the small sample size. However, at the best of our knowledge, this is the largest in vivo MR imaging study of the knee after MUA. Secondly, we only assessed the visibility of residual knee anatomy but not the clinical value of MR imaging of patients with MUA. However, we can speculate that, for the items not masked by the susceptibility artefact, the diagnostic value of MR imaging can be similar to that we usually get for knee without implant. At any rate, a dedicated study is needed to address this issue. Thirdly, our results should be referred to the Biomet Oxford III implant and to its particular shape and metal alloy and cannot be extrapolated to other implant types.

To summarize, our study showed that in patients who underwent a MUA, MR imaging allows a safe, valuable, and reproducible evaluation of residual knee anatomy except for cruciate ligaments. In symptomatic patients with negative plain films and US findings, MR imaging can be considered a valuable tool in the assessment of both anterior and lateral compartments of the treated knee, thus possibly affecting the therapeutic approach. Prospective studies with arthroscopy and/or follow-up correlation are warranted to confirm the clinical value of these findings.

References

**Personal Information**

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