The purpose of this study was to evaluate the ability of 3.0-Tesla magnetic resonance imaging (MRI) to accurately assess knee articular cartilage lesions. Sixteen patients who had knee 3.0-T MRI and underwent knee arthroscopy for partial meniscectomy were included. Three fellowship-trained sports medicine orthopedic surgeons reviewed all images. Articular lesions on MRI were graded from 1 to IV and compared with arthroscopic grading using the Outerbridge and the International Cartilage Repair Society (ICRS) classifications. The articular surface was divided into 6 regions. Based on MRI findings, of the 288 articular surface evaluations, 113 (39%) surface evaluations were classified as disease-positive (grade 2 to 4). Kappa interrater reliability scores for MRI evaluation, Outerbridge classification, and ICRS classification were 0.13, 0.54, and 0.41, respectively. Using the Outerbridge classification as a reference standard, the sensitivity, specificity, and accuracy were 57%, 71%, and 63%, respectively. Using the ICRS classification, sensitivity, specificity, and accuracy were 59%, 71%, and 69%, respectively. When isolating the articular grading to the senior author on MRI evaluation vs Outerbridge classification, the sensitivity, specificity, and accuracy were 54%, 92%, and 75%, respectively. Based on the current findings, 3.0-T MRI is as an invaluable noninvasive tool with good diagnostic value for assessing articular cartilage lesions of the knee, although it may not be as sensitive and accurate as previously reported.

The authors are from the Department of Orthopaedic Surgery (MER, DCV, GFH, SJN, RM, CTV); the Department of Biokinesiology and Physical Therapy (WSB); the Department of Radiology (PMC, RM), Keck School of Medicine, University of Southern California, Los Angeles; and the Department of Orthopaedic Surgery (RM), Kaiser Permanente, Baldwin Park, California.

The authors have no relevant financial relationships to disclose.

Correspondence should be addressed to: Diego C. Villacis, MD. Department of Orthopaedic Surgery, Keck School of Medicine, University of Southern California, 1200 N State St, GNH 3900, Los Angeles, CA 90033 (diego.villacis@gmail.com).

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Figure: Coronal (A) and sagittal (B) 3.0-Tesla magnetic resonance images using a T2-weighted proton density magnetic resonance image with fat suppression sequence showing a full-thickness defect of the cartilage involving the posterior aspect of the medial femoral condyle. This finding was classified as a grade 4 lesion and was confirmed during arthroscopy on the Outerbridge and International Cartilage Repair Society classifications.
Traditionally, radiographs have been used to indirectly evaluate chondral lesions. The development of magnetic resonance imaging (MRI) has revolutionized the ability of physicians to directly assess articular cartilage with a noninvasive modality. Despite this advancement, cartilage lesions, such as thin fissures, cartilage flaps, and shallow defects, remain difficult to accurately evaluate with standard MRI. Numerous authors have attempted to determine the specificity and sensitivity of MRI as a tool for detecting articular cartilage pathology evident on arthroscopy. The current standard for MRI evaluation of cartilage is 1.5-Tesla (T) imaging, and most studies establishing MRI for the assessment of articular cartilage were conducted at this field strength. However, 3.0-T MRI is becoming more widespread in clinical practice. The approximate 9-fold increase in proton energy can produce images of articular cartilage with higher spatial resolution and thinner sections than 1.5-T systems, without sacrificing signal-to-noise ratio or prolonging the time of image acquisition. Animal studies have demonstrated that 3.0-T has a higher detection rate and the potential for more accurate assessment of cartilage lesions when compared with 1.5-T. Recent studies comparing the diagnostic performance of 1.5-T vs 3.0-T MRI for evaluating the articular cartilage of the knee have found the accuracy to be significantly higher for 3.0-T MRI (P<.05). However, limited literature has examined whether 3.0-T MRI can accurately assess articular defects in humans using the gold standard of arthroscopy. The purposes of this study were to evaluate and verify the ability of 3.0-T MRI to identify and to assess knee articular cartilage when compared with arthroscopic evaluation.

**Materials and Methods**

A prospective cohort study of 16 patients (8 men and 8 women) with a mean±SD age of 41.9±10.5 years (range, 20-58 years) was conducted between September 2009 and July 2010. Inclusion criteria were a history of knee pain greater than 3 months and clinical suspicion of internal knee pathology. Patients with a history of ipsilateral knee surgery, evidence of ligamentous injury, or with externally obtained MRI were excluded. Patients received 3.0-T MRI at the institution and underwent knee arthroscopy by a single surgeon (C.T.V.) (Figures 1, 2). Institutional review board approval was obtained for the study. Images were taken with no gap between the individual slices in an effort to obtain full articular imaging. A 3.0-T technique-phased array coil was used to obtain the following sequences of the knee of interest: (1) axial proton density fat saturated: repetition time, 2000; echo time, 35; echo train length, 8; bandwidth, 42; field of view, 16 cm; 384×384; and 2-mm contiguous; (2) coronal proton density fat saturated: repetition time, 2000; echo time, 35; echo train length, 8; bandwidth, 42; field of view, 16 cm; 384×384; and 2-mm contiguous; and (3) sagittal proton density fat saturated: repetition time, 2000; echo time, 35; echo train length, 8; bandwidth, 42; field of view, 16 cm; 384×384; and 2-mm contiguous. Images were blindly reviewed by 3 fellowship-trained sports medicine orthopedic surgeons (M.E.R., G.F.H., C.T.V.). The articular surface of the knee was divided into 6 regions: patella, [Figure 1](#): Coronal (A) and sagittal (B) 3.0-Tesla magnetic resonance images using a T2-weighted proton density magnetic resonance image with fat suppression sequence showing a full-thickness defect of the cartilage involving the posterior aspect of the medial femoral condyle. This finding was classified as a grade 4 lesion and was confirmed during arthroscopy on the Outerbridge and International Cartilage Repair Society classifications.

[Figure 2](#): Arthroscopic image (A) and arthroscopic image with a probe (B) demonstrating the corresponding articular cartilage defect observed in Figure 1.
trocchlea, medial femoral condyle, lateral femoral condyle, medial tibial plateau, and lateral tibial plateau. To score each of the surfaces using MRI, all 3 imaging planes (sagittal, coronal, and axial) were viewed. Scoring of the articular cartilage on MRI evaluation is defined as grade 0 (normal cartilage), grade 1 (focal increased signal in articular cartilage but no defect in the cartilage), grade 2 (fibrillation or erosion comprising less than 50% of the cartilage thickness), grade 3 (defects greater than 50% of the articular cartilage depth, with or without small bone ulcerations), and grade 4 (extended full-thickness articular cartilage defect with denudation of bone). The knee arthroscopy video recordings were reviewed for all study patients, and grades using the Outerbridge and International Cartilage Repair Society (ICRS) classifications were assigned to each articular region (Tables 1, 2). Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the MRI evaluation in detecting cartilage lesions confirmed by arthroscopy were determined in each of the 6 regions of articular cartilage lesions confirmed by arthroscopy were determined in each of the 6 regions of articular cartilage (Table 3). Kappa interrater reliability was calculated among the 3 surgeons for MRI evaluation, ICRS classification, and Outerbridge classification grading. Grading by the senior author (C.T.V.) was isolated for MRI evaluation vs Outerbridge classification with calculation of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy.

**RESULTS**

Ninety-six articular surfaces were evaluated by 3 surgeons, for a total of 288 surface evaluations for each of the 3 grading systems. Based on MRI evaluation, 82 surface evaluations (28.5%) were graded as 0, ninety-three (32.3%) as 1, seventy (24.3%) as 2, twenty-seven (9.5%) as 3, and 16 (5.5%) as 4. All grades of articular cartilage lesions were collapsed into disease-positive (grades 2 to 4) or disease-negative (grades 0 to 1) for each articular surface. This resulted in a total of 175 (60.8%) surface evaluations classified as disease-negative and 113 (39.2%) graded as disease-positive.

Results from the comparison between MRI grade and arthroscopy grade using the Outerbridge classification or the ICRS grading system are shown in Table 3. Magnetic resonance imaging, when compared with the Outerbridge classification across all anatomical regions, had a sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 57%, 71%, 59%, 74%, and 63%, respectively. Similarly, when

### Table 1

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>Normal cartilage</td>
</tr>
<tr>
<td>1</td>
<td>Cartilage with softening and swelling</td>
</tr>
<tr>
<td>2</td>
<td>Fragmentation and fissuring in an area half an inch or smaller in diameter</td>
</tr>
<tr>
<td>3</td>
<td>Fragmentation and fissuring in an area larger than half an inch</td>
</tr>
<tr>
<td>4</td>
<td>Erosion of cartilage down to bone</td>
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</table>

### Table 2

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal cartilage</td>
</tr>
<tr>
<td>1a</td>
<td>Soft indentation</td>
</tr>
<tr>
<td>1b</td>
<td>Superficial fissures and cracks</td>
</tr>
<tr>
<td>2</td>
<td>Lesions extending down to less than 50% of the cartilage depth</td>
</tr>
<tr>
<td>3a</td>
<td>Defects extending down more than 50% of the cartilage layer</td>
</tr>
<tr>
<td>3b</td>
<td>Defects down to the calcified layer</td>
</tr>
<tr>
<td>3c</td>
<td>Defects down to but not through the subchondral bone layer</td>
</tr>
<tr>
<td>3d</td>
<td>Delamination, including bulging of the cartilage around the lesion</td>
</tr>
<tr>
<td>4a</td>
<td>Penetration of the subchondral bone but not across the entire diameter of the defect</td>
</tr>
<tr>
<td>4b</td>
<td>Penetration across the full diameter of the defect</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Classification</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
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<td>59</td>
<td>74</td>
<td>63</td>
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<tr>
<td>ICRS</td>
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<td>71</td>
<td>49</td>
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<tr>
<td>Senior author*</td>
<td>54</td>
<td>92</td>
<td>85</td>
<td>70</td>
<td>75</td>
</tr>
</tbody>
</table>

*Abbreviations: ICRS, International Cartilage Repair Society; MRI, magnetic resonance imaging; NPV, negative predictive value; PPV, positive predictive value.

*Magnetic resonance imaging vs arthroscopy using Outerbridge classification.
compared with the ICRS grading system across all anatomical regions, MRI had a sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 59%, 71%, 49%, 80%, and 69%, respectively.

Interrater reliability kappa score was calculated for MRI evaluation, Outerbridge classification, and ICRS classification scores. The corresponding values were 0.13, 0.54, and 0.41, respectively. A commonly cited scale for interpretation of kappa score interprets MRI evaluation (0.13) as slight agreement (range, 0.01-0.20) and both the Outerbridge (0.54) and ICRS (0.41) classifications as moderate agreement (range, 0.41-0.60).18

Isolation of grading by the senior author for MRI evaluation vs Outerbridge classification produced a sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of 54%, 92%, 85%, 70%, and 75%, respectively. These results are displayed in Table 3.

**Discussion**

Traditionally, 1.5-T MRI has been the standard for evaluating articular cartilage. More recently, multiple studies have reported that 3.0-T allows better visualization of cartilage lesions compared with 1.5-T MRI, with increased sensitivity and specificity in animal and cadaver models.6,14,19-23 Therefore, 3.0-T MRI may be better suited for the overall assessment of knee articular cartilage pathology. However, limited research has been published evaluating 3.0-T MRI for clinical in vivo cartilage imaging.5-7,15

In an unblinded retrospective study, Kijowski et al6 compared the diagnostic performance of 1.5-T vs 3.0-T MRI protocols for evaluating the articular cartilage of the knee in symptomatic patients. Sensitivity, specificity, and accuracy for detecting cartilage lesions were 70.5%, 85.9%, and 80.1%, respectively, for 3.0-T MRI compared with 69.3%, 78.0%, and 74.5%, respectively, for 1.5-T MRI.6 Specificity and accuracy were significantly higher at 3.0-T MRI (P<.05), leading the investigators to conclude that 3.0-T MRI was superior to 1.5-T MRI.6

In a similar unblinded retrospective study, Wong et al7 reported the diagnostic performance of 3.0-T MRI to be superior (P<.5) to 1.5-T MRI in sensitivity (75.7% vs 70.6%, respectively) and accuracy (88.2% vs 86.4%, respectively) of cartilage lesions in the knee. Von Engelhardt et al8 prospectively evaluated patients with persistent knee pain and suspected cartilage lesions using 3.0-T MRI compared with arthroscopy. When collapsing all grades of cartilage into disease-positive and disease-negative, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 91%, 85%, 87%, 90%, and 88%, respectively. A more recent study by Von Engelhart et al9 comparing corresponding articular lesion grading on 3.0-T MRI vs arthroscopy found positive predictive values ranging from 39% to 72% in contrast to specificity and negative predictive values ranging from 85% to 95%.

These previously reported results are numerically superior to the current findings (Table 3). This discrepancy in results may be partially explained by deviation in grade among multiple reviewers. A kappa score calculation for interrater reliability of the Outerbridge (0.54) and ICRS (0.41) classification scores found moderate agreement. Previous studies have reported interrater reliabilities for the Outerbridge and ICRS classification scores of 0.52 and 0.62, respectively.24,25 The kappa score of 0.13 for MRI represented slight agreement among the reviewers. Despite this, the current findings suggest that definitive assessment of the nature and extent of articular cartilage lesions may not be made as accurately and reproducibly with 3.0-T MRI as previously thought.

This study had several weaknesses. The kappa score for MRI found only slight agreement among reviewers. This result may be partly due to differences in experience level between the fellows and the senior author and the likely learning curve for cartilage assessment on 3.0-T MRI. Therefore, the authors isolated the findings of the senior author and calculated MRI vs arthroscopy using the Outerbridge classification. This produced similar values for specificity (92%) and PPV (85%) to those previously reported, yet sensitivity remained lower at 54%. A tendency to underestimate lesions on MRI may be attributed to the difficulty in determining the depth of articular cartilage lesions.27 Another potential weakness is that all MRIs were reviewed and graded by orthopedic surgeons as opposed to a musculoskeletal radiologist.5-7,16 However, this may be more accurate to the daily clinical practice of many orthopedic surgeons, who rely on their own assessments of MRIs.

As new technology emerges, the diagnostic gap between imaging and direct visualization through arthroscopy is sure to narrow. Several imaging modalities have been introduced in recent years for assessing the biochemical integrity of articular cartilage, with the most attention focused on delayed gadolinium-enhanced MRI of cartilage. These modalities have been primarily used for research purposes, but growing evidence has supported their use in clinical settings.27-30 However, with significant barriers, such as cost, accessibility, and familiarity to clinicians, its widespread clinical use in the community is unlikely for the foreseeable future. Therefore, with 3.0-T MRI proven advantageous to 1.5-T MRI and multiple studies demonstrating its good diagnostic value, it should be considered the most advantageous noninvasive tool for evaluating articular cartilage in clinical settings. Further studies to clarify the diagnostic capability of a 3.0-T MRI to detect cartilage lesions should be pursued. Studies with large patient enrollment and study designs to evaluate interrater reliability, between musculoskeletal radiologists and orthopedic surgeons would be of great benefit.
CONCLUSION

Based on the current findings, 3.0-T MRI is as an invaluable noninvasive tool with good diagnostic value for assessing articular cartilage lesions of the knee, although it may not be as sensitive and accurate as previously reported.

REFERENCES