Published in final edited form as:

AJR Am J Roentgenol. 2018 April ; 210(4): W164–W171. doi:10.2214/AJR.17.18664.

The Clinical Significance of Osteophytes in Compartments of the Knee Joint With Normal Articular Cartilage

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Abstract

OBJECTIVE.—The purpose of this study is to determine whether marginal osteophytes in compartments with normal cartilage would be more frequently observed in knees with cartilage lesions and osteophytes in other compartments.

MATERIALS AND METHODS.—This retrospective study reviewed 500 consecutive knee MRI examinations performed within 6 months of arthroscopic knee surgery conducted for 497 patients with symptoms (289 male patients and 208 female patients; age range, 17–74 years; median age, 43 years). The highest grade of cartilage lesion detected at MRI and arthroscopy was recorded. Marginal osteophytes were graded on MRI with use of a standard-ized scoring system, with grade 0 denoting no osteophyte; grade 1, small osteophyte; grade 2, medium-size osteophyte; and grade 3, large osteophyte). The frequency of false-positive osteophytes, defined as osteophytes present in compartments (the patellofemoral, medial tibio-femoral, and lateral tibiofemoral compartments) with normal cartilage observed on MRI and arthroscopy, was calculated. The Goodman and Kruskal gamma statistic was used to test the association of osteophyte size between compartments. Logistic regression was used to test the association between osteophyte size and the severity of the cartilage lesions.

RESULTS.—Marginal osteophytes were seen in compartments with normal cartilage on MRI and arthroscopy in 60.5% of knees (75 of 124) with cartilage lesions and osteophytes in other compartments and accounted for all false-positive grade 2 and grade 3 osteophytes. Marginal osteophytes were seen in 12.7% of knees (13 of 102) that had no cartilage lesions in any compartment on MRI or arthroscopy, and all of these were grade 1 osteophytes. The presence of larger sized osteophytes in the compartments with cartilage lesions was associated with the presence of larger sized osteophytes in the compartments with normal cartilage. More severe cartilage lesions were associated with larger osteophyte size.

CONCLUSION.—Compartments with marginal osteophytes and normal cartilage are commonly seen in knees that have other compartments with osteophytes and cartilage lesions.

Keywords

cartilage; cytokine; MRI; osteoarthritis; osteophyte

Marginal osteophytes are a common feature of osteoarthritis in the knee joint and other diarthrodial joints. These osseous outgrowths are formed in the periosteum at the junction between cartilage and bone, which is covered by synovium in diarthrodial joints [1, 2]. Marginal osteophyte formation begins with dysregulated chondrogenesis involving the differentiation of chondrogenic cells that reside in the periosteum, which results in a cartilage-like structure called a chondrophyte. The chondro-phyte then undergoes ossification to form a chondroosteophyte, and the entire structure eventually turns into bone to form an osteophyte [3, 4]. Studies have shown some adaptive advantage to marginal osteophytes, such as improved joint stability and possible aid in the redistribution of forces to provide articular cartilage protection, but larger osteophyte volumes have been found to decrease knee joint function [5, 6].

Although marginal osteophytes have been identified as a sensitive and early finding of the presence of cartilage lesions in patients with osteoarthritis, the exact pathogenesis of osteophytes is only beginning to be understood. The cytomorphologic findings and gene expression patterns in osteophyte formation resemble those of the healing fracture callus and endochondral ossification of the growth plate [7]. Osteophyte formation and the presence of cartilage lesions have recently been shown to be physically independent phenomena [1, 3, 8]. Previously published studies have shown that osteophyte growth is driven by cytokine release from damaged cartilage and not mechanical forces on the joint capsule, that synovial tissue plays an important role in regulating osteophyte formation, and that exogenously administered cytokines can induce or inhibit osteophyte formation [1, 3, 4, 8–19].

Multiple clinical studies have shown that marginal osteophytes detected on radiography are the most sensitive but least specific finding for predicting the presence of cartilage lesions within the same compartment of the knee joint [20–24]. Without an explanation for false-positive findings, the clinical significance of marginal osteophytes remains confusing. The relatively low specificity of osteophytes for detecting cartilage lesions within the same compartment may be explained by osteophyte growth driven by cytokine mediators in the synovial fluid from cartilage lesions occurring in other compartments of the knee joint. To test this hypothesis, this study assessed for marginal osteophytes in compartments with normal appearing cartilage on both arthroscopy and MRI in knees where there are other compartments with cartilage lesions and marginal osteophytes. It is our hypothesis that marginal osteophytes in compartments with normal cartilage would be more frequently observed in knees with cartilage lesions and osteophytes in other compartments.

Materials and Methods

Study Groups

This retrospective study was performed in compliance with HIPAA regulations and was approved by the institutional review board at our institution. The need for informed consent was waived.

The study group consisted of 497 consecutive patients (289 male patients and 208 female patients; age, 17–74 years; median age, 43 years) who were evaluated at our institution between January 1, 2010, and December 16, 2013 and underwent an MRI examination of the knee performed on the same 3-T scanner within the 6 months before arthroscopic knee surgery was performed. The patients underwent a total of 500 MRI examinations and arthroscopic surgeries, with bilateral imaging studies and procedures performed on the knees of six patients. No patient was excluded on the basis of any factor, including age, sex, severity of cartilage lesions, or history of prior knee surgery other than a cartilage repair procedure. Of the 500 knees evaluated with MRI and arthroscopy, 241 were on the right leg (48.2% of knees), 259 were on the left leg (51.8%), 315 (63.0%) had a medial meniscus tear, 10 (2.0%) had undergone prior medial partial meniscectomy, 148 (29.6%) had a lateral meniscus tear, four (0.8%) had undergone prior lateral partial meniscectomy, 131 (26.2%) had an acute anterior cruciate ligament (ACL) tear, eight (1.6%) had a chronic ACL tear, eight (1.6%) had prior ACL reconstruction surgery, and three (0.6%) had a posterior cruciate ligament tear.

MRI Examination

An MRI examination was performed on 500 knees of 497 patients in the study group, with use of the same 3-T MRI scanner (Signa HDx, version 14.0, GE Healthcare) and an eight-channel phased-array extremity coil. All MRI examinations consisted of an axial frequency-selective fatsuppressed T2-weighted fast spin-echo sequence, a coronal proton density-weighted fast spin-echo sequence, a coronal frequency-selective fat-suppressed proton density-weighted fast spin-echo sequence, a sagittal proton density-weighted fast spin-echo sequence, and a sagittal frequency-selective fat-suppressed T2-weighted fast spin-echo sequence. The imaging parameters of the sequences performed during the MRI examinations are summarized in Table 1.

Review of MRI Examination

All MRI examinations were reviewed by a fellowship-trained musculoskeletal radiologist with 7 years of clinical experience using a PACS workstation (Horizon Medical Imaging, McKesson); the radiologist did not have knowledge of the arthroscopic findings. All sequences were reviewed to determine the presence or absence of cartilage lesions on each articular surface of the knee joint. The most severe cartilage lesion on each surface was scored using the modified Noyes classification system (with grade 0 denoting a normal lesion; grade 1, increased T2 signal intensity of morphologically normal cartilage not oriented at 55° to the external magnetic field; grade 2A, a superficial partial-thickness cartilage defect less than 50% of the total thickness of the articular surface; grade 2B, a deep partial-thickness cartilage defect greater than 50% of the total thickness of the articular

surface; and grade 3, a full-thickness cartilage defect) [25]. Hypointense signal cartilage lesions were also noted [26–28]. The modified Noyes classification system was used to grade each articular surface seen on MRI because it was nearly identical to the classification system used by the orthopedic surgeons at our institution to evaluate the articular cartilage of the knee joint on arthroscopy. The MRI Osteoarthritis Knee Score system was used to grade the size of marginal osteophytes (with grade 0 denoting no osteophytes; grade 1, small osteophytes; grade 2, medium-size osteophytes; and grade 3, large osteophytes) on MRI (Fig. 1). Previous studies have shown high reliability of the MRI Osteoarthritis Knee Score system for assessing the presence and size of osteophytes in patients with knee pain [29].

Arthroscopic Surgery

Arthroscopic surgery was performed on 500 knees of 497 patients in the study group within the 6-month period (after MRI examination) range, 1–181 days; median, 55 days) by one of four experienced orthopedic surgeons at our institution who specialized in sports medicine and had between 11 and 31 years of clinical experience. The surgeons at our institution routinely inspect all articular surfaces both visually and with a surgical probe at arthroscopy, and they then describe the grade of cartilage on each articular surface in the surgical report with use of a modified Noyes classification system (with grade 0 denoting normal cartilage; grade 1, near normal cartilage with softening (grade 1A) or superficial (grade 1B) cartilage fibrillation; grade 2A, a superficial partial-thickness cartilage defect less than 50% of the total thickness of the articular surface; grade 2B, a deep partial-thickness cartilage defect greater than 50% of the total thickness of the articular surface; and grade 3, a full-thickness cartilage defect) [30]. The surgical reports of all patients were retrospectively reviewed by a fellowship-trained musculoskeletal radiologist who was blinded to the MRI findings. The grade of cartilage lesion on each articular surface and the presence or absence of associated soft-tissue findings (including a medial or lateral meniscus tear, prior medial or lateral partial meniscectomy, an acute ACL or posterior cruciate ligament tear, a chronic ACL tear, or prior ACL reconstruction surgery) was recorded.

Statistical Analysis

All statistical analysis was performed using the R programming environment (version 3.2.4, R Foundation). For all statistical tests, differences were considered to be statistically significant if $p < 0.05$.

The knee joint was divided into three compartments: the patellofemoral compartment, including the articulating surfaces of the patella and femoral trochlea; the medial tibiofemoral compartment, including the articulating surfaces of the medial femoral condyle and medial tibial plateau; and the lateral tibiofemoral compartment, including the articulating surfaces of the lateral femoral condyle and lateral tibial plateau. The frequencies of marginal osteophytes and the false-positive rates of marginal osteophytes in the detection of cartilage lesions within the same compartment of the knee joint were calculated for each grade of osteophyte and for all grades of osteophytes for each compartment of the knee joint. The false-positive rate was defined as the frequency of false-positive osteophytes (i.e., osteophytes present in compartments with normal cartilage). The presence of a cartilage lesion within a compartment was defined as a cartilage lesion identified on MRI,

arthroscopy, or both MRI and arthroscopy, whereas the presence of normal cartilage within a compartment was defined as normal cartilage identified on both MRI and arthroscopy. A combined reference standard using both arthroscopy and MRI was used to determine the presence of a cartilage lesion caused by the limitations of each individual method. For example, arthroscopy has been shown to be more sensitive than MRI for the detection of superficial cartilage lesions [31, 32]. However, there are substantial areas at the posterior aspects of the femoral condyles that are hidden from arthroscopy and are therefore better evaluated using MRI [33].

Single-compartment and multiple-compartment logistic regression models were used to test the predictive value of the severity of cartilage lesions for the presence of marginal osteophytes. The severity of cartilage lesions in a compartment was defined as the sum of the highest MRI and arthroscopy grades for each opposing articular surface in the compartment. The single -compartment model used the severity of cartilage lesions to predict the osteophyte grade in the same compartment. The multiple-compartment model used the severity of cartilage lesions within all three compartments to predict the osteophyte grade in each compartment. For the multiple-compartment models, each soft-tissue finding was added to the models to determine whether its inclusion increased the predictive value for the presence of marginal osteophytes. The size of the osteophytes was separated into three distinct categories (grade 0 vs grades 1–3, grades 0–1 vs grades 2–3, and grades 0–2 vs grade 3), to investigate the predictive value of the severity of cartilage lesions with regard to osteophyte size. ROC analysis was used to evaluate the performance of the binary prediction model and to determine the best discrimination threshold with the highest combined sensitivity and specificity.

The negative predictive value of MRI for detecting arthroscopically confirmed normal cartilage was calculated for compartments with marginal osteophytes of grades 0, 1, 2, and 3. Logistic regression models were used to test the predictive value of marginal osteophytes in compartments with normal cartilage on MRI for the presence of cartilage lesions in the same compartment on arthroscopy (i.e., MRI-occult cartilage lesions).

Logistic regression models were used to test the association between the frequency of false-positive marginal osteophytes and age for patients with marginal osteophytes and cartilage lesions in one or two compartments and normal cartilage in one or two other compartments, as well as for patients with no cartilage lesions within any compartment of the knee joint. Chi-square tests were used to test the association between the frequency of false-positive marginal osteophytes and sex, the involved knee, and soft-tissue findings for these groups of patients. If a significant association was found using chi-square tests, logistic regression models were used to estimate the effect of the variable on the false- positive cases.

Goodman and Kruskal gamma statistics were used to test the correlation between the highest grade of marginal osteophytes in the compartments with cartilage lesions and the highest grade of marginal osteophytes in the compartments with normal cartilage, for patients with marginal osteophytes and cartilage lesions in one or two compartments and normal cartilage in one or two other compartments. Logistic regression models were used to test the predictive value of the summation of the grades of marginal osteophytes in the

compartments with cartilage lesions for the presence of the grades of marginal osteophytes in the compartments with normal cartilage for these patients

Results

As is shown in Table 2, the false-positive rate of marginal osteophytes of all grades was 14.6% for the patellofemoral compartment, 18.1% for the medial compartment, and 21.2% for the lateral compartment. Most false-positive cases occurred with grade 1 osteophytes. For grade 1 osteophytes, 53 falsepositive cases were present in patients with cartilage lesions and osteophytes in one or more other compartments. The remaining 13 false-positive cases were present in patients with no cartilage lesion in any compartment of the knee joint. For grade 2 and grade 3 osteophytes, all 34 positive cases were present in patients with cartilage lesions and osteophytes in one or more other compartments.

The presence and size of marginal osteophytes were associated with the severity of cartilage lesions and the presence of soft-tissue findings within the knee joint. As shown in Table 3, the single-compartment models showed that higher grades of cartilage lesions within each of the three compartments of the knee joint predicted higher osteophyte grades in the same compartment, with AUC values ranging from 0.780 to 0.881. The multiple-compartment models showed that higher grades of cartilage lesions within the entire knee joint predicted higher osteophyte grades in each of the three compartments, with AUC values ranging from 0.847 to 0.955. In the patellofemoral compartment, no soft-tissue findings were associated with a greater likelihood of having a marginal osteophyte. In the medial compartment, the presence of a chronic ACL tear was associated with a greater likelihood of having a grade 2 or grade 3 marginal osteophyte (odds ratio [OR], 1.298 [95% CI, 1.070–1.575]; $p = 0.008$). In the lateral compartment, the presence of a lateral meniscal tear was associated with a greater likelihood of having any marginal osteophyte (OR, 1.152 [95% CI, 1.069–1.241]; $p < 0.001$).

The negative predictive value of MRI for detecting arthroscopically confirmed normal cartilage was 90.2% when there were no marginal osteophytes, 81.5% when there were grade 1 marginal osteophytes, 78.8% when there were grade 2 marginal osteophytes, and 76.0% when there were grade 3 marginal osteophytes in the same compartment. The presence of a marginal osteophyte in a compartment with normal cartilage on MRI was associated with a greater likelihood that MRI-occult cartilage degeneration would be detected at arthroscopy (OR, 1.633 [95% CI, 1.353–1.960]; $p < 0.001$).

There were 124 knees in 124 patients (69 men and 55 women; age range, 20–68 years; median age, 46 years) with marginal osteophytes and cartilage lesions in one or two other compartments and normal cartilage in at least one compartment. A total of 60.5% of knees (75 of 124) had marginal osteophytes in the compartment with normal cartilage (false-positive cases), whereas 39.5% of knees (49 of 124) did not have marginal osteophytes in the compartment with normal cartilage (true-negative cases). No significantly greater likelihood of osteophytes in the compartment with normal cartilage was noted on the basis of age ($p = 0.174$), sex ($p = 0.232$), leg ($p = 0.878$), or associated soft-tissue findings ($p = 0.260$) as a discriminator. Figure 2 shows an example of a marginal osteophyte in two

compartments with normal cartilage in a knee with marginal osteophytes and cartilage lesions in the third compartment.

Table 4 shows the numbers and highest grades of marginal osteophytes in each compartment with normal cartilage in knees with cartilage lesions and osteophytes in other compartments. False-positive marginal osteophytes of all sizes were seen in all compartments of the knee joint. However, most false-positive grade 2 and grade 3 marginal osteophytes were present in the lateral compartment. Table 5 compares the highest grades of marginal osteophytes in the compartments with cartilage lesions with the highest grades of marginal osteophytes in the compartments with normal cartilage. A high correlation existed between osteophyte size in the compartments with cartilage lesions and osteophyte size in the compartments with normal cartilage (gamma statistic, 0.818 [95% CI, 0.62–1.00]; $p < 0.001$). In addition, the size of marginal osteophytes in the compartments with cartilage lesions was a significant positive predictor of the presence of marginal osteophytes in the compartments with normal cartilage (OR, 2.282 [95% CI, 1.488–3.761]; $p < 0.001$).

There were 102 knees in 102 patients (62 male patients and 40 female patients; age range, 17–62 years; median age, 24 years) with no cartilage lesion in any compartment of the knee joint. A total of 12.7% of these knees (13 of 102) had marginal osteophytes in compartments with normal cartilage (false-positive cases), whereas 87.3% of knees (89 of 102) did not have marginal osteophytes in the compartment with normal cartilage (true-negative cases). No significantly greater likelihood of osteophytes in the compartment with normal cartilage was noted when age ($p = 0.274$), sex ($p = 0.716$), leg ($p = 0.503$), or accompanying soft-tissue findings ($p = 0.087$) were used as a discriminator. Figure 3 shows an example of a marginal osteophyte in two compartments with normal cartilage in a knee with normal cartilage in all compartments.

Discussion

The present study shows that marginal osteophytes may be seen in compartments of the knee joint with normal cartilage detected on MRI and arthroscopy. Combining all grades of marginal osteophytes, we found false-positive rates of 14.9% for the patellofemoral compartment, 18.3% for the medial compartment, and 19.5% for the lateral compartment. Previous studies have reported false-positive rates for marginal osteophytes detected on radiographs to be as high as 53% for the patellofemoral compartment, 44% for the medial compartment, and 33% for the lateral compartment, with arthroscopy used as the reference standard [23, 24], and as high as 41% for the patellofemoral compartment and 17% in the tibiofemoral compartment, with MRI used as the reference standard [21, 22].

Our study identified a probable explanation for the presence of false-positive marginal osteophytes in compartments of the knee joint with normal cartilage. As in prior studies, we assessed the diagnostic performance of marginal osteophytes by comparing the presence of osteophytes and cartilage lesions in each compartment of the knee joint separately [20–24, 34, 35]. In addition, we controlled for osteophytes and cartilage lesions occurring in other compartments and found that marginal osteophytes in compartments with normal cartilage were primarily observed in knees with osteophytes and cartilage lesions present within other

compartments. Moreover, compartments with larger marginal osteophytes and more severe cartilage lesions were more likely to have osteophytes in other compartments with normal cartilage, and these false-positive osteophytes were more likely to be of larger size. This relationship was seen for each compartment of the knee joint and was not dependent on patient age or sex or associated soft-tissue findings.

Because there is a shared joint space between the compartments of the knee joint, osteophytes at the margins of normal cartilage are likely stimulated to grow by cartilage lesions occurring in other compartments by way of cytokines in the synovial fluid. Marginal osteophyte formation has been shown to be driven by cytokine mediators secreted by cells in the cartilage and synovium [4, 8, 11, 36, 37]. Of importance, osteophyte growth has recently been found to require mediation by cells in the synovial lining, and therefore growth occurs only indirectly by way of the synovial fluid and is not related to direct mechanical stimulation or direct response from adjacent cartilage lesions [1, 3, 4, 8–19]. Two cytokines central to initiating chondrogenesis, the first step in osteophyte formation, are transforming growth factorbeta (TGF- β) and bone morphogenetic protein-2 (BMP-2). TGF- β and BMP-2 are present in high concentrations in osteophytes obtained from patients with knee and hip osteoarthritis [13–15] and in the synovial fluid of animals after acute cartilage injury [38]. TGF- β and BMP-2 have also been shown to induce chondrogenesis in vivo, by direct injection into the knee joint of animals, and in vitro, by exogenous administration to mesenchymal cells in culture, whereas inhibitors of these cytokines have been found to prevent chondrogenesis [3, 12, 17–19].

Roemer et al. [35] compared the severity of cartilage lesions and the size of marginal osteophytes in patients with knee pain with the use of MRI, and they found that the risk of severe cartilage lesions increased with increasing maximum osteophyte grade. Our findings agree with these findings because we also showed that more severe cartilage lesions were associated with higher osteophyte grades. In addition, we found that the summation of cartilage lesions within the knee joint was a greater predictor for the size of marginal osteophytes within a single compartment than when only the severity of cartilage lesions within the same compartment was taken into account. The association between osteophyte size and the severity of cartilage lesions on MRI may be mediated by BMP-2. Serum and synovial fluid levels of BMP-2 have been shown to directly correlate with the severity of cartilage lesions in patients with knee osteoarthritis [39]. Furthermore, animal models of experimental osteoarthritis have found that BMP-2 is expressed in high concentrations in both severely damaged cartilage and large osteophytes during the advanced stages of joint degeneration [37]. The study performed by Roemer and colleagues evaluated only the tibiofemoral joint and found a small subset of knees where there was no substantial cartilage lesions and large osteophytes, which they referred to as a hypertrophic phenotype of osteoarthritis [35]. Our findings raise the possibility that this subset might have been accounted for if the patellofemoral compartment had been evaluated, because large osteophytes and severe cartilage lesions in the patellofemoral joint may have stimulated the growth of osteophytes in the tibiofemoral joint.

The present study showed that the presence of marginal osteophytes in compartments with normal cartilage on MRI was associated with a greater likelihood that MRI-occult cartilage

lesions would be detected at arthroscopy. However, of more importance, the negative predictive value of MRI for detecting arthroscopically confirmed normal cartilage was high for all grades of marginal osteophytes. Therefore, when knee MRI examinations were interpreted, our observations suggested that when marginal osteophytes are seen in a compartment with normal-appearing cartilage, especially in the setting of other compartments with marginal osteophytes and obvious cartilage lesions, the cartilage is more often normal and should not necessarily be interpreted as having an MRI-occult cartilage lesion.

Our study found that false-positive marginal osteophytes were present in only 12.7% of knees in which there was normal cartilage in all compartments, and all of these osteophytes were small grade 1 osteophytes. We used MRI for evaluating marginal osteophytes because the multiplanar, cross-sectional imaging modality is more sensitive than radiography for detecting small osteophytes and because the MRI Osteoarthritis Knee Score system has been shown to have high reliability for assessing the presence and size of osteophytes on MRI [29]. It is highly likely that the frequency of false-positive marginal osteophytes in our patient population without cartilage lesions would have been even lower if radiography had been used to detect osteophyte formation. Our findings suggest that the specificity values of marginal osteophytes identified in a single compartment of the knee joint for detecting cartilage lesions in the same compartment are much higher than the specificity values reported in previous studies, which did not control for osteophytes and cartilage lesions occurring in other compartments [20–24, 34, 35].

Our study has several limitations. One limitation was that the study did not investigate the relationship between false-positive marginal osteophytes and the severity of knee pain because imaging findings were not correlated with clinical findings. Additional limitations of our study include its retrospective design and the presence of selection bias because our patient population did not include all individuals with knee pain evaluated at our institution. Furthermore, for the reasons previously discussed, our study used MRI for detecting marginal osteophytes and it thus is difficult to directly compare our findings with the findings of previous studies that have used radiography to detect marginal osteophyte formation. Our study group also consisted of a heterogeneous cohort of patients with symptoms with a wide age range who likely had a combination of traumatic and degenerative cartilage lesions. However, the presence of acute cartilage injury has been shown to release cytokines that stimulate osteophyte formation [38] and lead to progression of cartilage degeneration within the injured joint [40]. Thus, the significance of osteophyte formation in younger individuals without a clinical diagnosis of osteoarthritis warrants investigation. A final limitation was that our study evaluated marginal osteophytes only. A recent study has shown that knees with intercondylar osteophytes at baseline were at increased risk for radiographic osteoarthritis developing at 48-month follow-up [41]. Future studies are needed to investigate the predictive value of intercondylar osteophytes, by themselves or in association with marginal osteophytes, for detecting the presence of cartilage lesions within the knee joint.

Conclusion

The present study showed that compartments with marginal osteophytes and normal cartilage are commonly seen in knees that have other compartments with osteophytes and cartilage lesions. This finding appears to explain the low specificity of marginal osteophytes for detecting cartilage lesions reported in previous studies, which did not control for osteophytes and cartilage lesions occurring in other compartments [20–24, 37, 39]. We also found that the greatest predictor of the size of marginal osteophytes within a single compartment is the summation of cartilage lesions within the knee joint, rather than the severity of cartilage lesions within the same compartment. Finally, we found that MR imaging can accurately identify arthroscopically confirmed normal cartilage regardless of the presence or the size of a marginal osteophyte. The results of our study have two important clinical implications. First, when marginal osteophytes are seen on MRI in a compartment with normal appearing cartilage, especially in the setting of other compartments with marginal osteophytes and obvious cartilage lesions, the cartilage is more often normal and should not be interpreted as having an MRI-occult cartilage lesion. Second, the identification of a marginal osteophyte in a single compartment of the knee joint on MRI and especially on radiographs, which have a lower sensitivity for osteophyte detection, should be considered a relatively specific indicator of a cartilage lesion within the same compartment.

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Fig. 1—
Illustrations of grades of marginal osteophytes, according to use of MRI Osteoarthritis Knee Score system. Grade 0 denotes no osteophytes; grade 1, small osteophytes; grade 2, medium-size osteophytes; and grade 3, large osteophytes. (Drawing by Markhardt BK, used with permission)

Fig. 2—

25-year-old woman with cartilage lesions in medial compartment and normal cartilage in lateral and patellofemoral compartments at MRI and arthroscopy. **A–E**, Coronal proton density–weighted fast spinecho MR images without (**A**) and with (**B**) fat suppression, sagittal proton density–weighted fast spin-echo MR image (**C**), sagittal fat-suppressed T2-weighted MR image (**D**), and axial T2-weighted fast spin-echo image (**E**) show full-thickness cartilage lesions in medial compartment (*arrowheads*, **A** and **B**) up to grade 3 (*large solid arrows*, **A**, and **B**) marginal osteophytes in medial and lateral compartments (**A** and **B**), and up to grade 2 (open arrows, **A**, **B**, and **E**) marginal osteophytes in patellofemoral compartment (**D** and **E**). Grade 1 osteophytes (*small arrows*, **A**, **B**, **C**, and **E**) and intact anterior cruciate ligament reconstruction (*asterisk*, **A–E**) are also noted.

Fig. 3—
19-year-old woman with normal cartilage noted within all compartments of knee joint at MRI and arthroscopy. **A** and **B**, Coronal proton density–weighted fast spin-echo MR images without (**A**) and with (**B**) fat suppression show grade 1 marginal osteophytes in medial and lateral compartments (*arrows*). Intact ACL reconstruction (*asterisk*) and subtle changes after successful medial meniscal repair are also noted.

TABLE 1:

Imaging Parameters of the Sequences Performed in the MRI Examination

Imaging Parameter	Axial T2-Weighted Fat-Suppressed Sequence	Coronal Proton Density-Weighted Fast Spin-Echo Sequence		Sagittal Sequence	
		Without Fat Suppression	With Fat Suppression	Proton Density-Weighted Fast Spin-Echo	T2-Weighted Fast Spin-Echo
TR	4300	1800	2000	2000	5300
TE	77	20	20	20	80
Matrix size	448 × 224	384 × 224	384 × 224	384 × 224	384 × 224
FOV (cm ²)	18	14	14	14	14
Slice thickness (mm)	3	2	2	2	3
Bandwidth (kHz)	41.7	31.2	31.2	31.2	41.7
Echo-train length	21	4	4	4	20
No. of signal averages	4	2	2	2	3
Scan time	3 min, 30 s	3 min, 25 s	3 min, 26 s	3 min, 26 s	3 min, 16 s

TABLE 2:

Frequency and False-Positive Rates of Marginal Osteophytes in Detecting Cartilage Lesions Within the Same Compartment of the Knee Joint

Grade of Osteophyte and Compartment	Frequency of Osteophytes (%)	No. of Positive Findings/Total Findings ^a	False-Positive Rate (%)
Grade 1			
Patellofemoral	30.6	132/153	13.5
Medial	25.4	88/127	17.3
Lateral	19.6	60/98	14.3
Grade 2			
Patellofemoral	6.8	33/34	0.7
Medial	9.6	47/48	0.5
Lateral	9.4	40/47	3.0
Grade 3			
Patellofemoral	5.6	27/28	0.7
Medial	5.4	26/27	0.5
Lateral	7.4	32/37	2.2
All grades			
Patellofemoral	43.0	192/215	14.6
Medial	40.4	161/202	18.1
Lateral	36.4	132/182	21.2

Note—False-positive osteophytes were defined as osteophytes present in compartments with normal cartilage.

^aNumber of compartments with cartilage lesions and osteophytes/total number of compartments with osteophytes.

TABLE 3:

AUC Analysis of the Predictive Value of the Severity of Cartilage Lesions for the Presence and Size of Marginal Osteophytes

Compartment and Osteophyte Grade	Single-Compartment Model		Multiple-Compartment Model	
	Threshold Value ^a	AUC Value	Threshold Value ^a	AUC Value
Patellofemoral				
Grade 0 vs grades 1–3	3.5	0.819	4.5	0.857
Grades 0 and 1 vs grades 2–3	3.5	0.872	11.5	0.906
Grades 0–2 vs grade 3	4.5	0.880	13.5	0.955
Medial				
Grade 0 vs grades 1–3	2.5	0.795	7.5	0.838
Grades 0 and 1 vs grades 2–3	3.5	0.881	10.5	0.910
Grades 0–2 vs grade 3	4.5	0.875	12.5	0.912
Lateral				
Grade 0 vs grades 1–3	2.5	0.780	7.5	0.847
Grades 0 and 1 vs grades 2–3	3.5	0.842	10.5	0.897
Grades 0–2 vs grade 3	4.5	0.853	10.5	0.949

^a Cutoff for degree of cartilage degeneration that predicts the presence of marginal osteophytes with highest sensitivity and specificity

TABLE 4:

Numbers and Highest Grades of Marginal Osteophytes in Each Compartment With Normal Cartilage in Knees With Osteophytes and Cartilage Lesions in Other Compartments

Compartment	<u>No. of Marginal Osteophytes in Compartment with Normal Cartilage, by Grade</u>		
	Grade 1	Grade 2	Grade 3
Patellofemoral	12	1	1
Medial	25	1	1
Lateral	30	7	5

TABLE 5:

Comparison Between the Highest Grades of Marginal Osteophytes in the Compartments With Cartilage Lesions and the Highest Grades of Marginal Osteophytes in the Compartments With Normal Cartilage

Osteophyte Grade in Compartment With Degenerative Cartilage	No. of Marginal Osteophytes in Compartment With Normal Cartilage, By Grade		
	Grade 1	Grade 2	Grade 3
Grade 1	43	3	0
Grade 2	17	3	2
Grade 3	1	1	5