



Diagnostic efficacy of standard knee magnetic resonance imaging and radiography in evaluating integrity of anterior cruciate ligament before unicompartmental knee arthroplasty

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Objective: The purpose of this study was to investigate the diagnostic efficacy of standard magnetic resonance imaging (MRI) and plain radiographs in determining the status of anterior cruciate ligament (ACL) for surgical decision-making processes in cases of medial unicompartmental knee arthroplasty (UKA).

Methods: A total of 59 knees of 36 consecutive patients who underwent knee replacement surgery were analyzed retrospectively. MRI scans were assessed independently by 3 observers (radiologists), while the plain radiographs were evaluated by an independent radiologist. Results were compared with the intraoperative ACL status. Cross tabulation was used for descriptive statistics to analyze sensitivity, specificity, and accuracy of MRI and plain radiographs.

Results: When the same observer assessed and classified the MRI twice, the reproducibility of the classification system varied from moderate to excellent. However, the interobserver concordance was moderate. The sensitivity of MRI was 73% and the specificity was 81%, while the sensitivity and specificity of plain radiographs was 36% and 79%, respectively. The accuracy of MRI was 80%, while that of the radiographs was 71%.

Conclusion: Detection of intact ACL may be possible on available plain radiographs without necessity for additional means such as MRI, which may cause increase costs and loss of time. In cases where there is uncertainty regarding ACL integrity in degenerative knees, although standard MRI provides additional information on ACL status, it is not of sufficient diagnostic value.

Keywords: Anterior cruciate ligament; arthroplasty; knee; magnetic resonance imaging; osteoarthritis; replacement.

In view of its usage requirement and load characteristics, the knee is the most common joint to be replaced due to development of arthrosis. Arthroplasty has presented

functional and successful solutions for painful and motion-limited joints. However, together with the general health problems in these patients, many new problems

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such as bleeding, pain, infection, implant failure, and immune reaction to the implant have emerged following arthroplasty.^[1] Therefore, the concept of minimally invasive surgery was developed. Minimally invasive surgery has since developed to protect the intact portion of the joint with an intact anterior cruciate ligament (ACL) and to intervene only in the damaged part. Thus, if the joint meets the minimum requirements, instead of total joint arthroplasty, we prefer unicompartmental knee arthroplasty (UKA), which is a safe procedure associated with a lower rate of mortality and lower numbers of serious postoperative complications.^[2]

Recognition of the stability of the ACL is critical in making the decision for mobile bearing UKA.^[3,4] Generally, status of the ACL can be ascertained with certainty intraoperatively only. Consequently, consent must be obtained from the patient for both the unicompartmental and total knee replacement, and the necessary equipment and staff for both procedures must be present.

Although adequate information on joint space can be obtained with radiographs, the ACL can be evaluated indirectly only. Grading the status of the ACL on magnetic resonance imaging (MRI) can also be useful during the surgical decision-making process in cases of UKA.

This study was conducted to investigate the diagnostic accuracy of standard knee MRI and plain radiographs in determining the status of the ACL in osteoarthritic knees in comparison with intraoperative status.

Patients and methods

Patients with medial compartment osteoarthritis were evaluated at the outpatient clinic, where routine physical examination including assessment of range of motion (ROM), gait, and knee instability tests (Lachman's and anterior drawer) were performed. Since they were not performed under general anesthesia, results of preoperative physical examination tests were not included in the study. Standard MRIs of 59 knees of 36 consecutive patients who underwent knee replacement surgery (total or medial unicompartmental) (Table 1) between

October 2010 and November 2011 were reviewed. All operations were performed by the same surgeon (L.A.), who relied upon standard clinical parameters, MRIs, and preoperative routine X-rays (anteroposterior and lateral views obtained while weight bearing). The decision to proceed with either UKA or total knee arthroplasty (TKA) was made according to intraoperative visualization of the medial, lateral, and patellofemoral compartments, and state of the ACL. The ACL was inspected, manually stressed, and probed following standard techniques to assess its structure and function.^[5] The state of the ACL was recorded under 4 categories according to these examinations. Grade 1 implied an intact ligament; Grade 2, an intact but fibrillated ligament (frayed); Grade 3, a nearly completely (more than 50%) torn ligament (disrupted); and Grade 4, a complete tear (absent).^[6] Grades 1 and 2 were accepted as functionally intact, while Grades 3 and 4 were functionally absent. The test was performed by only a single surgeon, so it was not possible to evaluate interobserver variability. Fibrillation of the cartilage of the lateral compartment and even focal erosions if limited to the medial margin of the lateral femoral condyle were not considered to be contraindications for UKA. The state of the patellofemoral compartment was not used as a criterion for final decision. The knees with ACLs in Grades 1 and 2 were accepted as functionally intact and underwent unicompartmental knee replacement surgery. The knees not complying with these criteria underwent total knee replacement surgery.

Imaging in 59 knees with surgical correlation was performed with an Intera imager (Philips Medical Systems, Best, The Netherlands) operating at 1.5 T. Each scanner had a dedicated knee coil. The MRI protocol consisted of sagittal spin-echo T2-weighted images (repetition time [TR]: 3600; echo time [TE]: 100), sagittal proton density images (TR: 2200; TE: 17), and coronal proton density images (TR: 2200; TE: 17). All images were acquired with matrix of 256×192, field of view of 14 cm, and section thickness of 3 mm. No contrast media were given.

Table 1. Types of arthroplasties performed.

Operation	Number of patients and knees
Bilateral unicondylar knee arthroplasty	19 patients (38 knees)
Bilateral total knee arthroplasty	3 patients (6 knees)
Unilateral total knee arthroplasty	2 patients (2 knees)
Unilateral unicondylar knee arthroplasty	11 patients (11 knees)
Unicondylar knee arthroplasty for left knee+total knee arthroplasty for right knee	1 patient (2 knees)
Total	36 patients (59 knees)

MRI scans were assessed independently by 3 observers (radiologists) at 2 discrete times, and the ACL was classified into 4 grades. These assessments were performed with a minimum interval of 10 days. On MRI, Grade 1 implied an intact ligament; Grade 2, partial tear with less than half of the ligament substance disrupted; Grade 3, partial tear with more than half of the ligament substance disrupted; and Grade 4, complete tear.^[7]

All radiographs were evaluated by an independent radiologist. Plain radiographs were classified according to Ahlbäck's grading system modified by Keyes et al. by adding lateral projections to Ahlbäck's anteroposterior views.^[3] All radiographs fulfilling Grades 1 and 2 osteoarthritis were grouped in 'anteromedial arthritis,' while radiographs in Grades 3 and 4 were included in the 'posteromedial arthritis' group. Patients with Grade 5 arthritis were excluded from the study. The ACL was accepted to be intact in the anteromedial arthritis group, while it was accepted as ruptured in the posteromedial arthritis group.^[8]

Statistical Package for the Social Sciences v 20.0 software (SPSS Inc. Chicago, IL, USA) was used to perform the statistical analyses. The concordance between different observations and observers regarding the MRI grading system was evaluated using kappa (κ) statistics. The sensitivity and specificity per each observer were determined using the intraoperative grading of the ACL as reference. Knees with MRI grading 1–2 were matched with the intraoperative grading 1–2, and those with MRI grading 3–4 were matched with intraoperative grading 3–4. In addition, cross tabulation was used for descriptive statistics to analyze sensitivity, specificity, and

accuracy of MRI and plain radiographs. For descriptive tables, the values mostly agreed upon by the radiologists were accepted for analysis. Knees with Grades 1 and 2 were accepted as intact, while those with Grades 3 and 4 were accepted as ruptured for both MRI and intraoperative results.

Results

Mean age of patients at time of operation was 61.9 years (range: 47–81 years). TKA was performed in 9 of 59 knees (15%) because the ACL was assessed intraoperatively to be functionally insufficient.

When the same observer classified the MRIs twice, the intraobserver reproducibility varied from moderate to excellent (kappa: 0.515–0.826). The intraobserver sensitivity of MRI per radiologists was acceptable (57–83%). For most comparisons, the intraobserver specificity was also acceptable (64–87%) (Table 2). However, the interobserver variability was moderate (κ : 0.561) (Table 3). The cross tabulation results comparing MRI and radiographic findings with intraoperative ACL status are presented in Table 4. Furthermore, the sensitivity of MRI was 73%, and the specificity was 81%, while the sensitivity and specificity of plain radiographs were 36% and 79%, respectively. The accuracy of MRI was 80%, while that of the radiographs was 71%.

Discussion

In this study, we graded the ACL according to the intraoperative findings, preoperative radiographs, and MRI examinations. Subsequently, we tried to determine whether standard MRI and radiographs are useful in

Table 2. Intraobserver variation (Cohen's kappa κ values) and specificity&sensitivity results.

Observers	Kappa score	95% Confidence interval	Strength of agreement	Sensitivity (%)	Specificity (%)
#1	0.515	(0.322–0.707)	Moderate	57	78
#2	0.553	(0.308–0.798)	Moderate	83	64
#3	0.826	(0.681–0.971)	Excellent	69	87

The weighted κ guideline Weighted κ (κ_w) Strength: $0.0 \leq \kappa \leq 0.2$ Poor; $0.2 < \kappa \leq 0.4$ Fair; $0.4 < \kappa \leq 0.6$ Moderate; $0.6 < \kappa \leq 0.8$ Good; $0.8 < \kappa \leq 1.0$ Excellent.

Table 3. Interobserver variations for each grade of MRI classification and interobserver agreement (Fleiss' kappa values).

Observers	Classification	Kappa score	95% Confidence interval	Strength of agreement
	Grade 1	0.567	(0.158–0.886)	Moderate
	Grade 2	0.106	(0.000–0.475)	Poor
	Grade 3	0.190	(0.000–0.554)	Poor
	Grade 4	0.330	(0.000–0.696)	Fair
		0.561	(0.053–0.989)	Moderate

Table 4. Cross tabulation results comparing preoperative ACL and plain radiographs with intraoperative ACL status.

	Intraop ACL		Preop MRI		Plain Radiographs	
	Intact (n=48)	Complete tear (n=11)	Intact (n=42)	Complete tear (n=17)	Anteromedial arthritis (n=45)	Posteromedial arthritis (n=14)
Intraop ACL						
Intact			39	9	38	10
Complete tear			3	8	7	4
Preop MRI						
Intact	39	3			32	10
Complete tear	9	8			13	4
Plain radiographs						
Anteromedial arthritis	38	7	32	13		
Posteromedial arthritis	10	4	10	4		

ACL: Anterior cruciate ligament; MRI: Magnetic resonance imaging.

evaluating the ACL in degenerative knees prior to surgery. We found the interobserver agreement of MRI to be moderate for Grade 1, poor for Grades 2 and 3, and fair for Grade 4. Thus, we recognize some problems with the MRI classification our study, in which the interobserver reproducibility showed low agreement, especially when Grade 1 was excluded.

In our study, we also found that the sensitivity and specificity of MRI in degenerative knees were lower (sensitivity: 73%; specificity: 81%) than those reported in traumatic knees previously.^[9–11]

Our results showed lower interobserver agreement on MRI grading. It is likely that these results may be related with 2 main factors. Firstly, our study design was retrospective. We evaluated the status of ACL on standard orthogonal sagittal and coronal planes, and the MRI scans did not include additional oblique sagittal and coronal planes. Owing to its oblique course, standard orthogonal MRI cannot visualize the ACL completely.^[12] Furthermore, popliteal artery and partial volume effects may be handicaps for evaluating of the status of ACL completely. Poor visualization was reported in 5–10% of normal ACLs using standard orthogonal MRI scans.^[13] Improved diagnostic efficacy of oblique MRI scans has been reported in previous studies.^[7,12,14] Hong et al.^[7] reported that oblique coronal MRI improved diagnostic accuracy in the grading of ACL injuries. Similarly, Kwon et al.^[12] reported that additional oblique imaging reduced false-positive diagnoses and increased the specificity of MRI for the diagnosis of ACL tears. Therefore, in patients who are candidates for UKA, further comprehensive studies with additional oblique MRI scans to evaluate the status of ACL preoperatively should be completed. Secondly, in addition to the MRI planes used, chronicity of the ACL tear might have affected our

results. In chronic ACL tears, the presence of a fibrous scar may resemble an intact ligament and result in inadvertently missing the ACL tear.^[15,16]

The current recommendation of most joint arthroplasty surgeons is that a functional ACL is necessary to achieve successful mobile bearing UKA.^[17–22] The critical point in ACL-deficient knees is that the increased anterior tibial translation will lead to accelerated wear and premature failure of the tibial polyethylene (PE).^[14–19]

Deschamps and Lapeyre^[18] were the first to report a high failure rate of UKA associated with absence of the ACL, and Goodfellow et al.^[20] also reported in their study that knees without a functioning ACL failed 10 times more frequently than the rest, usually due to loosening of the tibial component.

Considering this data, surgeons must determine the status of the ACL preoperatively. Yet unfortunately, no preoperative methods have been shown to be reliable in assessing the ACL. To determine the laxity of the ACL, both Lachman's and anterior drawer tests were administered upon physical examination in the outpatient clinic. We did not use the pivot shift test, as it is difficult to achieve a positive result even in a traumatic ACL-deficient knee of a patient who is not under anesthesia. Regarding the stiffness of periarticular structures in osteoarthritic knees, the pivot shift test would be of little diagnostic value. All tests were performed preoperatively, but 1—which was found to have an intact ACL intraoperatively—returned a negative result. We believe this resulted from spasm of the quadriceps muscle caused by pain and the general stiffness of all periarticular tissues in arthritic knees. Johnson et al.^[6] stated in their study that the Lachman's test and MRI together provide a sensitivity of 93.3% and specificity of 99%, which indicate a useful diagnostic ability when these two are combined;

however, they had performed this test under general anesthesia. Nonetheless, it appears more reasonable and clinically relevant to perform this test at the outpatient clinic before surgery so that the surgeon can choose the appropriate implants and instruments in advance.^[23] As a result, clinical assessment of arthritic knees by Lachman's, pivot shift, and anterior drawer tests are not exact predictors of the status of the ACL before surgery.^[24,25]

Only during the operation itself can the final decision be made regarding the status of the ligament by direct visualization and manual examination by probe. Radiographs, MRI, and arthroscopic examination can provide clues about the ACL preoperatively. In the literature, there are several publications addressing the practicality of these methods.^[3,5]

MRI can also be used for assessment of ACL status prior to UKA. Previous studies have shown that MRI has sensitivity values of 93–97% and specificity values of 89–100% in traumatic knees when compared with arthroscopic findings.^[5,9–11,26] To our knowledge, to date, few studies have focused on assessing the potential usefulness of standard MRI for grading the status or appearance of the ACL in either the preoperative workup for UKA or in anteromedial osteoarthritis. However, it is likely that the diagnostic performance of standard MRI for ACL status in degenerative knees may be lower due to their differing appearance from acute ACL tears. In osteoarthritis, not only the cartilage but also the ACL and all other intra-articular structures undergo degenerative changes. Sharpe et al. stated that MRI tends to be more accurate than surgical inspection in detecting deterioration of the ACL, and it plays only a very limited role in evaluation of arthritic knees in patients specifically selected by a surgeon when considering UKA.^[5] This high sensitivity of MRI was attributed to its capacity to view the interior of the degenerated ligament, whereas only the surface of the ligament can be seen intraoperatively. Although MRI is more reliable in detecting the intact ACL, it is less useful in detection of severely ruptured ACLs (high rate of false positivity) (Table 4).

According to Weidow et al.,^[22] the Ahlbäck classification has variable reproducibility and validity. As would be expected, the same observer could reproduce the Ahlbäck classification more precisely on different occasions than could 2 different observers (the intraobserver reproducibility higher than that of the interobserver). When evaluating the radiographs, there are 2 primary problems. The 1st is to determine whether a visible joint space represents the remaining cartilage. The 2nd is to determine whether there is bone attrition.^[22] Additionally, it is not clear how to distinguish Grades 2 and 3 with

respect to amount of posterior tibial attrition. This situation caused lower rates for the accuracy of preoperative plain radiographs when compared with that of MRIs.

The drawback of the present study is that the intraoperative examination of the ACL with probe was subjective, and no quantitative measure was used to stretch the ligament during surgery. Moreover, position of the knee during lateral projection may affect the results of radiographic evaluations. This may explain why plain radiographs had lower rates of sensitivity when compared with MRI in detecting ruptured ACL.

In conclusion, the current study showed that detection of an intact ACL may be possible through available plain radiographs without the need for additional studies such as MRI which may increase costs and loss of time. In cases where there is uncertainty regarding ACL integrity in degenerative knees, although standard MRI provides additional information on ACL status, it is not of sufficient diagnostic value.

Conflicts of Interest: No conflicts declared.

References

1. Atik OS. Unicompartmental or total knee arthroplasty?. [Article in Turkish] *Eklemler Hastalıkları* 2011;22:118–9.
2. Morris MJ, Molli RG, Berend KR, Lombardi AV Jr. Mortality and perioperative complications after unicompartmental knee arthroplasty. *Knee* 2013;20:218–20. [CrossRef](#)
3. Keyes GW, Carr AJ, Miller RK, Goodfellow JW. The radiographic classification of medial gonarthrosis. Correlation with operation methods in 200 knees. *Acta Orthop Scand* 1992;63:497–501. [CrossRef](#)
4. White SH, Ludkowski PF, Goodfellow JW. Anteromedial osteoarthritis of the knee. *J Bone Joint Surg Br* 1991;73:582–6.
5. Sharpe I, Tyrrell PN, White SH. Magnetic resonance imaging assessment for unicompartmental knee replacement: a limited role. *Knee* 2001;8:213–8. [CrossRef](#)
6. Johnson AJ, Howell SM, Costa CR, Mont MA. The ACL in the arthritic knee: how often is it present and can preoperative tests predict its presence? *Clin Orthop Relat Res* 2013;471:181–8. [CrossRef](#)
7. Hong SH, Choi JY, Lee GK, Choi JA, Chung HW, Kang HS. Grading of anterior cruciate ligament injury. Diagnostic efficacy of oblique coronal magnetic resonance imaging of the knee. *J Comput Assist Tomogr* 2003;27:814–9. [CrossRef](#)
8. Mukherjee K, Pandit H, Dodd CA, Ostlere S, Murray DW. The Oxford unicompartmental knee arthroplasty: a radiological perspective. *Clin Radiol* 2008;63:1169–76.
9. Ha TP, Li KC, Beaulieu CF, Bergman G, Chen IY, Eller DJ, Cheung LP, et al. Anterior cruciate ligament injury: fast

- spin-echo MR imaging with arthroscopic correlation in 217 examinations. *AJR Am J Roentgenol* 1998;170:1215–9. [CrossRef](#)
10. Fischer SP, Fox JM, Del Pizzo W, Friedman MJ, Snyder SJ, Ferkel RD. Accuracy of diagnoses from magnetic resonance imaging of the knee. A multi-center analysis of one thousand and fourteen patients. *J Bone Joint Surg Am* 1991;73:2–10.
 11. Boeree NR, Watkinson AF, Ackroyd CE, Johnson C. Magnetic resonance imaging of meniscal and cruciate injuries of the knee. *J Bone Joint Surg Br* 1991;73:452–7.
 12. Kwon JW, Yoon YC, Kim YN, Ahn JH, Choe BK. Which oblique plane is more helpful in diagnosing an anterior cruciate ligament tear? *Clin Radiol* 2009;64:291–7. [CrossRef](#)
 13. Buckwalter KA, Pennes DR. Anterior cruciate ligament: oblique sagittal MR imaging. *Radiology* 1990;175:276–7.
 14. Kosaka M, Nakase J, Toratani T, Ohashi Y, Kitaoka K, Yamada H, et al. Oblique coronal and oblique sagittal MRI for diagnosis of anterior cruciate ligament tears and evaluation of anterior cruciate ligament remnant tissue. *Knee* 2014;21:54–7. [CrossRef](#)
 15. Vahey TN, Broome DR, Kayes KJ, Shelbourne KD. Acute and chronic tears of the anterior cruciate ligament: differential features at MR imaging. *Radiology* 1991;181:251–3. [CrossRef](#)
 16. Link TM, Steinbach LS, Ghosh S, Ries M, Lu Y, Lane N, et al. Osteoarthritis: MR imaging findings in different stages of disease and correlation with clinical findings. *Radiology* 2003;226:373–81. [CrossRef](#)
 17. Goodfellow J, O'Connor J. The anterior cruciate ligament in knee arthroplasty. A risk-factor with unconstrained meniscal prostheses. *Clin Orthop Relat Res* 1992;276:245–52.
 18. Deschamps G, Lapeyre B. Rupture of the anterior cruciate ligament: a frequently unrecognized cause of failure of unicompartmental knee prostheses. Apropos of a series of 79 Lotus prostheses with a follow-up of more than 5 years. [Article in French] *Rev Chir Orthop Reparatrice Appar Mot* 1987;73:544–51. [Abstract]
 19. Feng EL, Stulberg SD, Wixson RL. Progressive subluxation and polyethylene wear in total knee replacements with flat articular surfaces. *Clin Orthop Relat Res* 1994;299:60–71. [CrossRef](#)
 20. Goodfellow JW, Kershaw CJ, Benson MK, O'Connor JJ. The Oxford Knee for unicompartmental osteoarthritis. The first 103 cases. *J Bone Joint Surg Br* 1988;70:692–701.
 21. Newman JH, Ackroyd CE, Shah NA. Unicompartmental or total knee replacement? Five-year results of a prospective, randomised trial of 102 osteoarthritic knees with unicompartmental arthritis. *J Bone Joint Surg Br* 1998;80:862–5.
 22. Weidow J, Cederlund CG, Ranstam J, Kärrholm J, Ahlbäck grading of osteoarthritis of the knee: poor reproducibility and validity based on visual inspection of the joint. *Acta Orthop* 2006;77:262–6. [CrossRef](#)
 23. van den Dorpel A, Swart NM. Letter to the editor: the ACL in the arthritic knee: how often is it present and can preoperative tests predict its presence? *Clin Orthop Relat Res* 2013;471:1054.
 24. Douglas MJ, Hutchison JD, Sutherland AG. Anterior cruciate ligament integrity in osteoarthritis of the knee in patients undergoing total knee replacement. *J Orthop Traumatol* 2010;11:149–54. [CrossRef](#)
 25. Dodd M, Trompeter A, Harrison T, Palmer S. The pivot shift test is of limited clinical relevance in the arthritic anterior cruciate ligament-deficient knee. *J Knee Surg* 2010;23:131–5. [CrossRef](#)
 26. Feller JA, Webster KE. Clinical value of magnetic resonance imaging of the knee. *ANZ J Surg* 2001;71:534–7.