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Correlation of meniscus tears on MRI and arthroscopy using the ISAKOS classification provides satisfactory intermethod and inter-rater reliability

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ABSTRACT

Objective To evaluate the inter-rater and intermethod correlation (reliability between MRI and arthroscopy) of knee for findings of meniscus tears using International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) classification on both 1.5 and 3.0 T images.

Methods 81 knees were evaluated in 69 patients aged 30.0±12.6 years (mean±SD). Consecutive arthroscopy-proven meniscal tears were evaluated by two board-certified radiologists on MRI and two sports surgeons on arthroscopies. The surgically validated ISAKOS classification of meniscal tears was used to describe medial meniscus (MM) and lateral meniscus (LM) tears on MRI and re-evaluation of images from completed arthroscopies. Prevalence-adjusted bias-adjusted kappa (PABAK), t-tests and intraclass correlation coefficient (ICC) were calculated.

Results For LM on 1.5 T, the agreements for location, depth, tear length and pattern were good to excellent in all categories except fair for tissue quality (PABAK=0.35–0.41) and zone 2 (PABAK=0.35) identification. For MM, the agreements were good to excellent in all except moderate for tissue quality (PABAK=0.6) and zone 1 and 3 (PABAK=0.40–0.47), and fair for zone 2 identification (PABAK=0.27). Similar results were seen on 3 T with improved LM zonal identification (PABAK=0.52–0.90) and better correlation of tear lengths, which were different on 1.5 T vs 3.0 T (p=0.01–0.03). For 1.5 T cases, both MM and LM tear lengths were larger on MRI versus arthroscopy (MM, p=0.004; LM, p=0.095). For 3 T, the MM tear lengths were larger on MRI versus arthroscopy (p=0.001).

Conclusion ISAKOS classification of meniscal tears on both 1.5 and 3.0 T MRI provides satisfactory inter-rater and intermethod reliability for use in clinical practice. Level of evidence: IV.

INTRODUCTION

The medial and lateral menisci are important structures that provide many essential functions in their intact state. These include axial weight bearing (~70%) and distribution during dynamic loading, joint lubrication, cartilage protection, proprioception and stability.^{1–4} Meniscus tears are linked to extrusion from the joint margins, chondrolysis and development of osteoarthritis.^{5–7} While conservative management is often adequate for degenerative horizontal tears, many tear patterns, such as unstable tear, displaced flaps, bucket handle tears, high-grade radial or root tears and complex tears

What are the new findings?

- ▶ International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) classification provides satisfactory inter-rater reliability for use in clinical practice on 1.5 and 3.0 T scanners.
- ▶ ISAKOS classification provides satisfactory intermethod reliability for use in clinical practice on 1.5 and 3.0 T scanners.
- ▶ There were no major differences in the agreements between 1.5 and 3.0 T imaging with the exception of meniscus tear lengths.

often require surgical management.^{8–10} Meniscus preservation is advised in most cases to mitigate the future possibility of bony overload and to delay further cartilage loss. For repairable meniscal tears, the timing of surgery is important because outcomes are improved if the surgery is performed within 8 weeks of injury.¹¹

Meniscus tears are typically diagnosed on MRI based on the hyperintense signal disrupting the articular surface and/or morphological alteration of the meniscus.^{12–14} MRI has been consistently shown to provide high accuracy in meniscus tear diagnosis.^{13 15–19} Various patterns of meniscus tears exist, and the descriptions of the tears vary across different practices and disciplines,^{20–23} depending on the preferences of the MRI readers and knee surgeons.^{24 25} Due to the lack of consistent terminology and heterogeneity, it becomes difficult to pool the data across different surgical practices and institutions for the evaluation of patient outcomes with respect to various types and degrees of meniscus tears.

The International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) committee recommended and validated a classification system for the meniscus tear evaluation on arthroscopy with an objective of developing a reliable meniscal evaluation and documentation system to ultimately improve the outcomes assessment.²⁶ To facilitate consistent meniscus tear description and interdisciplinary communication, presurgical planning, longitudinal tracking of the meniscus tears and evaluation of patient outcomes, it is important that the knee MRI readers adopt this or a similar classification system on imaging. Both 1.5 and 3.0 T scanners are currently widely available in many practices.^{27–33} A previous study has



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explored this topic on 3 T scanners, which found fair to good intermethod agreement among categories.³⁴ It is essential to validate this classification on both types of field strengths.

In this multireader analysis, we evaluated the correlation of knee MRI and arthroscopy findings of meniscus tears using both 1.5 and 3.0 T scanner images. Our hypothesis was that the ISAKOS classification of meniscal tears provides satisfactory intermodality and inter-rater reliability for use in routine clinical practice of radiologists. A subgoal was to evaluate 1.5 T vs 3.0 T correlation with the arthroscopy findings.

METHODS

This was a cross-sectional retrospective analysis with institutional review board approval. The informed consent was waived.

Patient population

A consecutive series of patients were included who underwent arthroscopy of the knee for a variety of reasons, such as cruciate ligament injury, meniscus tear and cartilage restoration procedures from March 2017 to December 2017. The inclusion criteria were age >14 years, both genders, arthroscopy-proven discrete meniscus tear, and medial meniscus (MM) and/or lateral meniscus (LM) tears, both of which could be present in the same knee, scans from either 1.5 or 3.0 T MRI. The exclusion criteria were metal or susceptibility artefacts, prior meniscus surgery, or missing arthroscopy pictures and results in the electronic health records.

Data collection

A detailed electronic chart review was then performed by two medical students under the direction of a fellowship-trained musculoskeletal radiologist. Demographic data (age and gender), laterality and mean time of MRI to arthroscopy date (in days), and severity were recorded for each patient. All information was recorded on an Excel spreadsheet. The arthroscopy pictures were retrieved from the electronic health records for re-review

by two sports surgeons. All arthroscopies were performed by an experienced board-certified and fellowship-trained sports orthopaedic surgeon, and the different compartments of the knees had been recorded in a standardised sequential manner, displaying all surfaces of both medial and lateral menisci with arthroscopy probes in the field of view.

MRI protocol

The MRI was obtained on 1.5 and 3.0 T scanners (Aera, Skyra, Siemens, Erlangen, Germany; Achieva, Ingenia, Philips, Best, Netherlands) using multichannel phased-array knee coils. The protocol included two-dimensional (2D) intermediate weighted (echo time 35–40 ms) non-fat-suppressed and fat-suppressed imaging sequences in all three planes. The slice thickness was 4 mm on 1.5 T scanners and 3.5 mm on 3 T scanners. In addition, a three-dimensional (3D) fat-suppressed intermediate weighted fast spin echo sequence was also obtained on all 3 T scanners as a standard of care (repetition time=1100–1200 ms, echo time=40–42 ms, fat suppression=frequency selective, voxel=0.65×0.65×0.65 mm³ acquired, plane=coronal acquisition and gradient time=7 min).

MRI data evaluation

The MRI evaluation was performed independently by two musculoskeletal fellowship-trained, board-certified radiologists after a consensus reading on five different meniscus tears. An ISAKOS classification template^{26 35} guide was available for recording the findings (table 1 and figure 1).

The medical students recorded the findings and prompted the radiologists to find and evaluate the tear of medial, lateral or both menisci in the same knee. The readers were blinded to each other's findings and the actual arthroscopy findings, as well as to the surgically recorded types and extent of the meniscus tears. The imaging evaluation was performed on picture archiving and communication system. For 1.5 T scans, the combination of routine multiplanar 2D imaging was used

Table 1 Guide for MRI evaluation of meniscus tear based on International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine classification (modified original arthroscopy-based classification)

| Criteria for meniscus tear identification | Signal hyperintensity disrupting the articular surface of the meniscus and/or abnormal morphology |
|---|---|
| Tear types | |
| Horizontal tear | Runs parallel to the tibial plateau, involves either one of the articular surfaces or the central free edge, dividing the meniscus into superior and inferior portions |
| Longitudinal tear | Runs perpendicular to the tibial plateau and parallel to the long axis of the meniscus, dividing the meniscus into central and peripheral portions |
| Radial tear | Runs perpendicular to both the tibial plateau and the long axis of the meniscus and extends from the free edge towards the periphery along the radial plane of the meniscus (helpful signs- truncated triangle, cleft, ghost, marching cleft) |
| Bucket-handle tear | A longitudinal tear with central migration of the inner 'handle' fragment |
| Horizontal-flap tear | Has a displaced flap component of a predominantly horizontal tear |
| Complex tear | Encompasses two or more tear directions (patterns). |
| Categories | |
| Tear depth | Partial or complete, depending on the tear extending through one or both surfaces of the meniscus. |
| Rim width | Zone 1: <3 mm, zone 2: 3–5 mm, zone 3: >5 mm |
| Radial location | Posterior, midbody or anterior in location |
| Central to popliteus hiatus | Yes/no. A tear of the lateral meniscus that extends partially or completely in front of the popliteal hiatus should be graded as central to the popliteal hiatus. |
| Tear pattern | Tears should be graded as per the predominant tear pattern, described previously. Complex tears include two or more tear patterns. |
| Quality of the tissue | Degenerative characteristics include multiple tear patterns, diffusely increased signal and globular enlargement or irregular meniscal tissue with fibrillation/ fraying changes |
| Length of tear | The distance the tear extends into the meniscus |

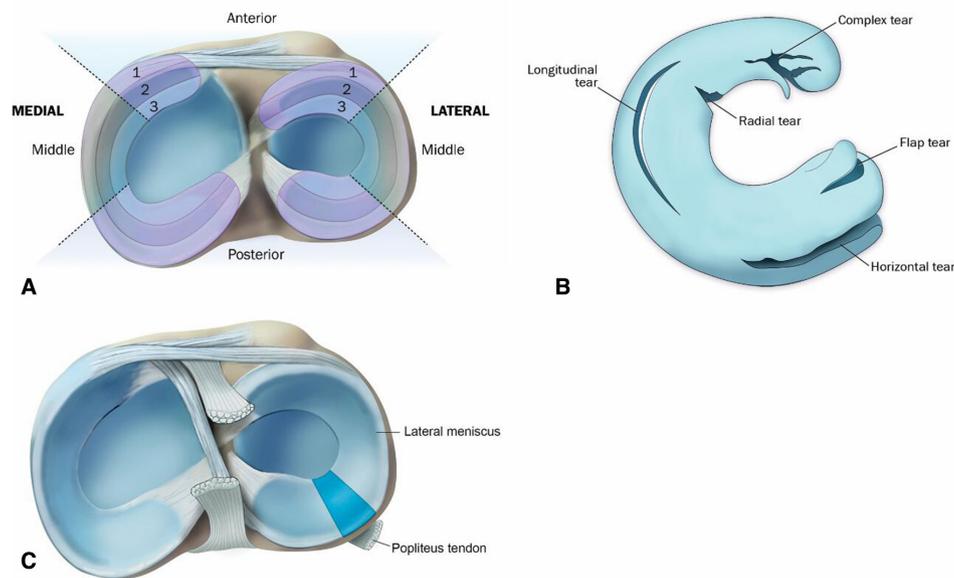


Figure 1 International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine criteria: rim width, tear type and centrality to popliteus hiatus. (A) Zones 1, 2 and 3, which describe the rim width of a meniscal tear. (B) Tear type used to categorise a meniscal tear. (C) Area (dark blue) that is partially or completely central to the popliteus hiatus.

to classify the meniscus tears and to estimate the rim width, zonal location and the size of the meniscus tear (figures 2 and 3). For 3 T scans, additional 2–3 min were spent while performing inline processing of the 3D isotropic images in coronal, sagittal and user-defined axial planes of the menisci to evaluate the aforementioned findings (figures 4–6). No images were degraded by motion or precluded the reading assessment.

Arthroscopy data evaluation

Two fellowship-trained, board-certified sports surgeons evaluated the arthroscopies. They completed a consensus training on five cases followed by independent reads in separate settings blinded to each other's reads. The same two medical students recorded their data using the ISAKOS classification system as

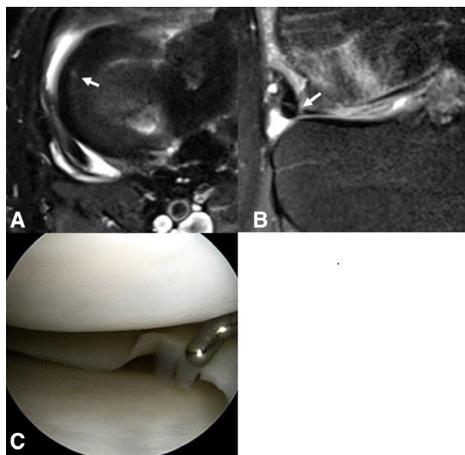


Figure 2 Patient with a radial tear. 1.5 T MRI axial and coronal planes (A,B) show a radial tear of the middle body of the lateral meniscus (arrows). Reader 1 MRI ISAKOS classification: depth: partial; rim width: zone 3; radial location: middle body; central to popliteus hiatus: no; quality: non-degenerative; tear length: 4 mm. Reader 2 MRI ISAKOS classification: depth: partial; rim width: zone 3; radial location: middle body; central to popliteus hiatus: no; quality: degenerative; tear length: 6 mm. Surgeon 1 arthroscopy ISAKOS classification: depth: partial; rim width: zones 2 and 3; radial location: middle body; central to popliteus hiatus: no; quality: non-degenerative; tear length: 6 mm. Surgeon 2 arthroscopy ISAKOS classification: depth: partial; rim width: zone 3; radial location: middle body; central to popliteus hiatus: no; quality: non-degenerative; tear length: 4 mm. ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

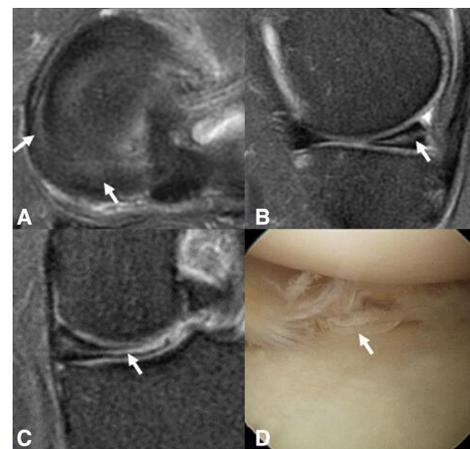


Figure 3 Patient with a horizontal tear. 1.5 T MRI axial, sagittal and coronal planes (A–C) show a horizontal tear of the middle body and posterior horn of the medial meniscus (arrows). Reader 1 MRI ISAKOS classification: depth: partial; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: non-degenerative; tear length: 36 mm. Reader 2 MRI ISAKOS classification: depth: complete; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: non-degenerative; tear length: 35 mm. Surgeon 1 arthroscopy ISAKOS classification: depth: partial; rim width: zones 2 and 3; radial location: middle body; quality: degenerative; tear length: 15 mm. Surgeon 2 arthroscopy ISAKOS classification: depth: partial; rim width: zones 2 and 3; radial location: middle body, posterior; quality: degenerative; tear length: 24 mm. ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

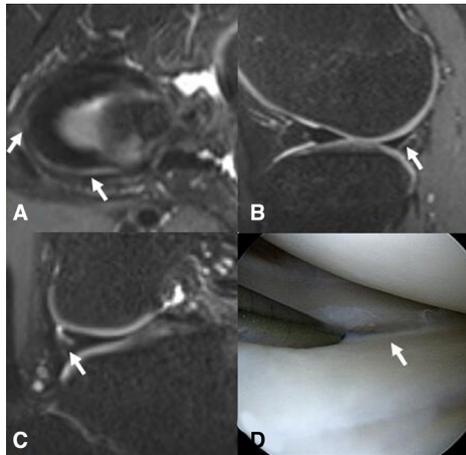


Figure 4 Patient with a longitudinal tear. 3 T MRI axial, sagittal and coronal planes (A–C) show a longitudinal tear of the middle body and posterior horn of the lateral meniscus (arrows). Reader 1 MRI ISAKOS classification: depth: complete; rim width: zones 1 and 2; radial location: middle body, posterior; central to popliteus hiatus: yes; quality: non-degenerative; tear length: 22 mm. Reader 2 MRI ISAKOS classification: depth: complete; rim width: zone 1; radial location: middle body, posterior; central to popliteus hiatus: yes; quality: non-degenerative; tear length: 32 mm. Surgeon 1 arthroscopy ISAKOS classification: depth: complete; rim width: zone 1; radial location: posterior; central to popliteus hiatus: no; quality: non-degenerative; tear length: 10 mm. Surgeon 2 arthroscopy ISAKOS classification: depth: complete; rim width: zone 1; radial location: posterior; central to popliteus hiatus: no; quality: non-degenerative; tear length: 12 mm. ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

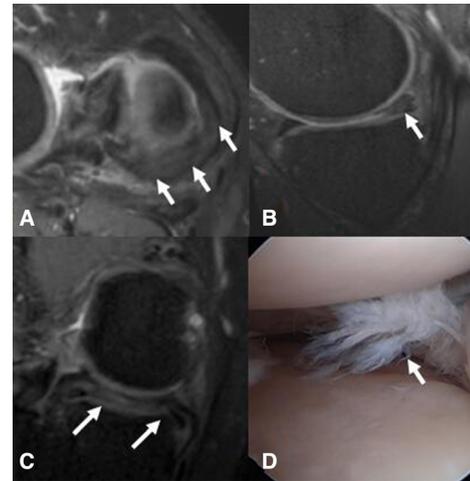


Figure 6 Patient with a complex tear. 3 T MRI axial, sagittal and coronal planes (A–C) show a complex tear of the middle body and posterior horn of the medial meniscus (arrows). Reader 1 MRI ISAKOS classification: depth: complete; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: degenerative; tear length: 45 mm. Reader 2 MRI ISAKOS classification: depth: complete; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: degenerative; tear length: 42 mm. Surgeon 1 arthroscopy ISAKOS classification: depth: complete; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: degenerative; tear length: 30 mm. Surgeon 2 arthroscopy ISAKOS classification: depth: complete; rim width: zones 1, 2 and 3; radial location: middle body, posterior; quality: degenerative; tear length: 28 mm. ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

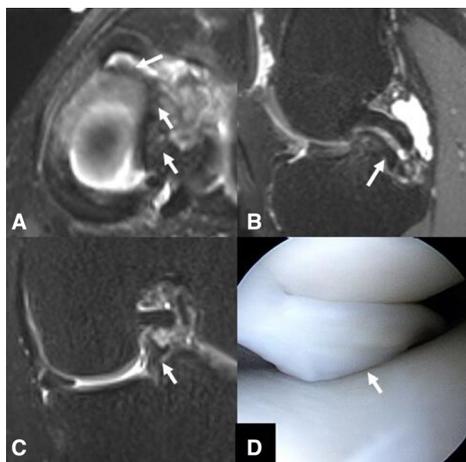


Figure 5 Patient with a bucket-handle tear. 3 T MRI axial, sagittal and coronal planes (A–C) show a bucket-handle tear of the anterior, middle body and posterior horn of the medial meniscus (arrows). Reader 1 MRI ISAKOS classification: depth: complete; rim width: zone 2; radial location: anterior, middle body, posterior; quality: non-degenerative; tear length: 52 mm. Reader 2 MRI ISAKOS classification: depth: complete; rim width: zones 1 and 2; radial location: anterior, middle body, posterior; quality: non-degenerative; tear length: 52 mm. Surgeon 1 arthroscopy ISAKOS classification: depth: complete; rim width: zone 2; radial location: anterior, middle body, posterior; quality: non-degenerative; tear length: 42 mm. Surgeon 2 arthroscopy ISAKOS classification: depth: complete; rim width: zone 1; radial location: middle body, posterior; quality: non-degenerative; tear length: 30 mm. ISAKOS, International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

described earlier. The meniscus tear length was estimated based on the probe diameter.

Statistical analysis

The data were recorded on a Microsoft Excel V.2010 and tabulated as means \pm SD, and percentages. Prevalence-adjusted bias-adjusted kappa (PABAK) and intraclass correlation (ICC) were used to assess the agreements for the categorical and numerical variables, respectively. Agreement between surgeon 1 and surgeon 2, between radiologist 1 and radiologist 2, and all pairwise agreements between all surgeons and radiologists (surgeon 1 vs radiologist 1, surgeon 1 vs radiologist 2, surgeon 2 vs radiologist 1, surgeon 2 vs radiologist 2) were calculated. Estimated agreements and 95% CIs were reported for surgeon 1 versus surgeon 2 and radiologist 1 versus radiologist 2. For surgeon versus radiologist, averaged agreements with 95% CI using pooled SE was used. To compare the agreement between 1.5 and 3.0 T, asymptotic z-tests were used to compare PABAKs and asymptotic z-tests with Fisher's z transformation were used to compare the ICCs. Bonferroni adjustment was applied to the p values to control family-wise error rate. P values of less than 0.05 were considered as statistically significant. All calculations were stratified by MRI strength (tesla) and measurements. A value less than or equal to 0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80 and 0.81–1.00 indicated poor, fair, moderate, good and excellent agreements, respectively.³⁶ The Cicchetti scale (less than 0.40=poor, 0.40–0.59=fair, 0.60–0.74=good and 0.75–1.00=excellent) was used for categorisation of ICC.³⁷ Paired t-tests were used to analyse differences in numerical variables. All analyses were done in SAS V.9.4 and R.

Table 2 Demographics and meniscus tear distribution

| Sex | Age (years) | Mean time from MRI to arthroscopy (days) | R knees (n) | L knees (n) | MM tears (n) | LM tears (n) | |
|-------|-------------|--|-------------|-------------|--------------|--------------|----|
| M | 49* | 27.9±11.3 | 84.5±59.3 | 27 | 24 | 30 | 27 |
| F | 20 | 35.3±14.2 | 78.4±76.5 | 10 | 8 | 11 | 13 |
| Total | 69 | 30.0±12.6 | 83.4±68.4 | 37 | 32 | 41 | 40 |

*Includes one female to male transgender.

F, female; L, left; LM, lateral meniscus; M, male; MM, medial meniscus; R, right.

RESULTS

Patient demographics and meniscal tear distribution

There were 81 knees in 69 patients aged 30.0±12.6 years (mean±SD). Forty-two patients were scanned with a 3.0 T MRI and 27 with a 1.5 T MRI. There were 37 right knees, 32 left knees, and 41 MM and 40 LM tears. The mean time from MRI to arthroscopy was 83.4±68.4 days (table 2).

Types and lengths of the meniscus tears

The most common meniscus tear was the complex type on both arthroscopy (26/81, 32.0%) and MRI (29/81, 35.8%). The least common was the degenerative horizontal type (2/81, 0.02%). The bucket-handle tears were the largest (36.6±6.1 and 49.3±8.4), and as expected, the radial tears were the smallest (4.3±1.9 and 5.6±3.8 mm) on arthroscopy and MRI, respectively (table 3).

Intermethod correlation (reliability between MRI and arthroscopy methods)

For MM on 1.5 T, the PABAK scores are highlighted in table 4. For MM, the agreements were good to excellent in all categories except moderate for zone 1 and 2 (PABAK=0.40, 0.27) and fair for zone 2 identification (PABAK=0.27), as well as tear length (PABAK=0.51). For LM, the agreements were excellent for all categories, except good for tear length (PABAK=0.71), fair for tissue quality, zone 2 (PABAK=0.35), and moderate for zone 1 (PABAK=0.53). The tear lengths were significantly larger on MRI versus arthroscopy in the MM by 11.01 mm (p=0.004, 95% CI 3.64 to 18.39). The tear lengths in the LM were larger on MRI versus arthroscopy by 5.12 mm but not statistically significant (p=0.095, 95% CI -0.917 to 11.152).

For 3 T, similar results were seen. For MM, the agreements were good to excellent for all categories, except moderate for tear length (PABAK=0.57) and fair for zone 1 (PABAK=0.39). For the LM, the agreements were good to excellent for all categories, except moderate for circumferential location, zone 1, and tear depth (PABAK=0.48–0.57), and fair for tissue quality (PABAK=0.38) (table 5). The MM tear lengths were significantly larger on MRI versus arthroscopy in the MM by 9.74 mm (p=0.001, 95% CI 4.22 to 15.25). The LM tear lengths were larger on MRI versus arthroscopy by 4.04 mm but not statistically significant (p=0.26, 95% CI -3.052 to 11.12). Similar

results were seen on 3.0 T with improved LM zonal identification (PABAK=0.52–0.90) and better correlation of tear lengths, which were different on 1.5 T vs 3.0 T (p=0.01–0.03).

Inter-rater correlation (radiologists)

For the MM on 1.5 T cases, the agreements were good to excellent in all categories, except for zonal differentiation (PABAK=0.47). For the LM, the agreements were good to excellent in all categories except moderate for tissue quality (PABAK=0.43) (table 4). For the MM on 3.0 T, the agreements were good to excellent in all categories but moderate for location (PABAK=0.57) and zone 1 differentiation (PABAK=0.22). For the LM, the agreements were good to excellent in all categories but moderate for tissue quality (PABAK=0.43).

Inter-rater correlation (surgeons)

For the MM and LM on 1.5 T, the agreements were good to excellent in all categories. For the MM on 3.0 T, agreements were good to excellent in all categories but moderate for zonal differentiation (PABAK=0.48). For the LM, agreements were good to excellent in all categories but moderate for tear depth (PABAK=0.52) (table 5).

DISCUSSION

This study used the ISAKOS classification system with good to excellent intermethod correlation in most categories using both 1.5 and 3.0 T MRI, with a few instances of fair to moderate correlation. This is a modest improvement from the prior 3 T ISAKOS classification study that showed fair to good intermethod correlation in most categories of ISAKOS meniscus tear classification.³⁴ The results of this study validate that ISAKOS classification can be used in both 1.5 and 3.0 T clinical practices during routine MRI readings. Using such a uniform method, which has been previously validated surgically, would ensure a consistent multidisciplinary communication and may improve patient management and longitudinal evaluation for outcomes.

The intermethod agreement was not so good for meniscus tissue quality and rim width on both 1.5 and 3.0 T imaging. However, the result was similar to the prior studies by Anderson *et al* and Dunn *et al*, where rim width agreement was reported as fair to moderate.^{26,38} The ISAKOS classification system defines

Table 3 Meniscus tear types and lengths on arthroscopy and MRI

| | Tears on arthroscopy (n) | Mean (mm) | SD | Tears on MRI (n) | Mean (mm) | SD |
|-----------------|--------------------------|-----------|-----|------------------|-----------|------|
| Radial | 15 | 4.3 | 2.0 | 16 | 5.6 | 3.8 |
| Horizontal | 2 | 26.0 | 2.8 | 2 | 30.0 | 8.5 |
| Longitudinal | 20 | 14.2 | 6.1 | 13 | 21.6 | 8.7 |
| Bucket handle | 14 | 36.6 | 6.1 | 16 | 49.3 | 8.4 |
| Horizontal flap | 4 | 11.3 | 9.2 | 5 | 12.6 | 11.2 |
| Complex | 26 | 23.3 | 7.9 | 29 | 32.1 | 11.7 |
| Total | 81 | | | 81 | | |

Table 4 Intermethod and interobserver agreement* 1.5 T

| Variable | Surgeons (95% CI) | Radiologists (95% CI) | Surgeons versus radiologists (95% CI) |
|--------------------------------|---------------------|-----------------------|---------------------------------------|
| 1.5 T | | | |
| LM anterior | 0.88 (0.42 to 1.00) | 0.88 (0.42 to 1.00) | 0.76 (0.29 to 1.00) |
| LM central to popliteus hiatus | 1.00 (0.57 to 1.00) | 0.76 (0.29 to 1.00) | 0.76 (0.29 to 1.00) |
| LM middle | 1.00 (0.57 to 1.00) | 0.88 (0.42 to 1.00) | 0.82 (0.35 to 1.00) |
| LM posterior | 1.00 (0.57 to 1.00) | 1.00 (0.57 to 1.00) | 1.00 (0.57 to 1.00) |
| LM tear depth | 0.88 (0.42 to 1.00) | 0.76 (0.29 to 1.00) | 0.71 (0.23 to 1.00) |
| LM tear length | 0.96 (0.91 to 0.99) | 0.76 (0.47 to 0.91) | 0.76 (0.33 to 0.93) |
| LM tear pattern | 0.82 (0.54 to 1.00) | 0.82 (0.54 to 1.00) | 0.91 (0.65 to 1.00) |
| LM tissue quality | 0.76 (0.29 to 1.00) | 0.41 (−0.07 to 0.89) | 0.35 (−0.12 to 0.82) |
| LM zone 1 | 0.76 (0.29 to 1.00) | 0.76 (0.29 to 1.00) | 0.53 (0.05 to 1.00) |
| LM zone 2 | 1.00 (0.57 to 1.00) | 0.65 (0.16 to 1.00) | 0.35 (−0.12 to 0.83) |
| LM zone 3 | 1.00 (0.57 to 1.00) | 0.88 (0.42 to 1.00) | 0.94 (0.49 to 1.00) |
| MM anterior | 0.73 (0.22 to 1.00) | 0.87 (0.36 to 1.00) | 0.87 (0.37 to 1.00) |
| MM middle | 0.73 (0.22 to 1.00) | 0.73 (0.22 to 1.00) | 0.60 (0.08 to 1.00) |
| MM posterior | 0.87 (0.36 to 1.00) | 0.73 (0.22 to 1.00) | 0.87 (0.37 to 1.00) |
| MM tear depth | 0.87 (0.36 to 1.00) | 0.87 (0.36 to 1.00) | 0.60 (0.08 to 1.00) |
| MM tear length | 0.81 (0.53 to 0.93) | 0.78 (0.47 to 0.92) | 0.51 (−0.05 to 0.83) |
| MM tear pattern | 0.73 (0.44 to 1.00) | 0.86 (0.57 to 1.00) | 0.73 (0.44 to 1.00) |
| MM tissue quality | 0.73 (0.22 to 1.00) | 0.73 (0.22 to 1.00) | 0.60 (0.08 to 1.00) |
| MM zone 1 | 0.87 (0.36 to 1.00) | 0.47 (−0.05 to 0.98) | 0.40 (−0.10 to 0.90) |
| MM zone 2 | 0.87 (0.36 to 1.00) | 0.73 (0.22 to 1.00) | 0.27 (−0.23 to 0.76) |
| MM zone 3 | 0.87 (0.36 to 1.00) | 0.47 (−0.05 to 0.98) | 0.67 (0.15 to 1.00) |

*Prevalence-adjusted bias-adjusted kappa and intraclass correlation was used to assess the agreement for categorical and numeral variables, respectively.
LM, lateral meniscus; MM, medial meniscus.

that a tear's rim width should be graded based on the zone that it extends into, farthest from the free edge. Tear zone grading in this study deviates from the prior convention in that each involved zone was recorded; this allowed for a more comprehensive representation of tears. Meniscal tissue quality agreement was fair. Myxoid signal that is unlikely to be identified on arthroscopy was disregarded on MRI interpretation. Free-edge fibrillations may be sometimes missed on MRI and are better detected on arthroscopy. Tissue quality and rim width are very important for planning meniscal repair. Our results suggest that tear reparability may not be adequately assessed on MRI findings alone. Direct inspection and probing during arthroscopy seem to be more valuable than MRI findings alone.

Intermethod agreement for tear pattern was good to excellent on both 1.5 and 3.0 T imaging, better for LM than MM. Tear pattern agreement may be degraded by incomplete tear visualisation on arthroscopy; for example, if the principal direction of a tear is longitudinal with extension towards the notch, a horizontal component extending to the peripheral capsular attachment may not be within the field of view. MRI holds an advantage in this situation as the field of view is not obscured by the torn displaced meniscal tissue nor another knee pathology, such as the commonly associated perimeniscal cyst.

MM tears were significantly larger on 1.5 and 3.0 T than on arthroscopy. LM tears were larger on 1.5 and 3.0 T than on arthroscopy, but not to a statistically significant degree. There are several factors that may have contributed to this difference. MRI allows a more complete visualisation of the extent of a tear than arthroscopy, where the field of view may be obscured. Furthermore, in cases where there was significant lag time from MRI to arthroscopy, lesions may have partially healed.¹⁰ Finally, measuring tear length by approximation with the surgical probe likely introduced some amount of measurement error.

Table 5 Intermethod and interobserver agreement* 3.0 T

| Variable | Surgeons (95% CI) | Radiologists (95% CI) | Surgeons versus radiologists (95% CI) |
|--------------------------------|---------------------|-----------------------|---------------------------------------|
| 3.0 T | | | |
| LM anterior | 0.81 (0.40 to 1.00) | 0.62 (0.19 to 1.00) | 0.76 (0.35 to 1.00) |
| LM central to popliteus hiatus | 0.81 (0.40 to 1.00) | 0.90 (0.51 to 1.00) | 0.48 (0.04 to 0.91) |
| LM middle | 0.81 (0.40 to 1.00) | 0.90 (0.51 to 1.00) | 0.57 (0.14 to 1.00) |
| LM posterior | 0.90 (0.51 to 1.00) | 1.00 (0.64 to 1.00) | 0.95 (0.57 to 1.00) |
| LM tear depth | 0.52 (0.09 to 0.96) | 0.71 (0.29 to 1.00) | 0.57 (0.14 to 1.00) |
| LM tear length | 0.90 (0.77 to 0.96) | 0.87 (0.72 to 0.95) | 0.74 (0.45 to 0.89) |
| LM tear pattern | 0.85 (0.61 to 1.00) | 0.85 (0.61 to 1.00) | 0.93 (0.70 to 1.00) |
| LM tissue quality | 0.90 (0.51 to 1.00) | 0.43 (0.00 to 0.86) | 0.38 (−0.05 to 0.81) |
| LM zone 1 | 0.71 (0.29 to 1.00) | 0.71 (0.29 to 1.00) | 0.52 (0.10 to 0.95) |
| LM zone 2 | 0.71 (0.29 to 1.00) | 0.81 (0.40 to 1.00) | 0.67 (0.25 to 1.00) |
| LM zone 3 | 0.71 (0.29 to 1.00) | 0.90 (0.51 to 1.00) | 0.62 (0.19 to 1.00) |
| MM anterior | 0.65 (0.25 to 1.00) | 0.57 (0.15 to 0.98) | 0.70 (0.30 to 1.00) |
| MM middle | 0.91 (0.55 to 1.00) | 0.91 (0.55 to 1.00) | 0.91 (0.55 to 1.00) |
| MM posterior | 1.00 (0.66 to 1.00) | 1.00 (0.66 to 1.00) | 1.00 (0.66 to 1.00) |
| MM tear depth | 0.65 (0.25 to 1.00) | 0.91 (0.55 to 1.00) | 0.65 (0.25 to 1.00) |
| MM tear length | 0.94 (0.87 to 0.97) | 0.74 (0.49 to 0.88) | 0.57 (0.03 to 0.85) |
| MM tear pattern | 0.82 (0.59 to 1.00) | 0.87 (0.64 to 1.00) | 0.67 (0.44 to 0.90) |
| MM tissue quality | 0.91 (0.55 to 1.00) | 1.00 (0.66 to 1.00) | 0.78 (0.39 to 1.00) |
| MM zone 1 | 0.83 (0.44 to 1.00) | 0.22 (−0.19 to 0.62) | 0.39 (−0.01 to 0.79) |
| MM zone 2 | 0.83 (0.44 to 1.00) | 0.74 (0.34 to 1.00) | 0.70 (0.29 to 1.00) |
| MM zone 3 | 0.48 (0.06 to 0.89) | 0.74 (0.34 to 1.00) | 0.61 (0.20 to 1.00) |

*Prevalence-adjusted bias-adjusted kappa and intraclass correlation was used to assess the agreement for categorical and numeral variables, respectively.
LM, lateral meniscus; MM, medial meniscus.

Inter-reader agreement was good to excellent in most cases, with a few instances of poor to fair agreement. Results were similar to the prior 3 T ISAKOS classification study where inter-reader agreement on 3D MRI was moderate to excellent, except for LM tears.³⁴ Cases of poor to fair agreement were seen predominantly in the LM or in measurements of the rim width. There has been mention in the literature of difficulty diagnosing lateral meniscus tears.¹⁰

The 3 T scanners also include 3D imaging, which leads to better identification of the extent of the meniscus tear, along the rim width and longitudinally. We believe the isotropic voxels on 3D scan lead to more accurate measurements and improved identification of the lesions. Newer 1.5 T scanners can do 3D imaging, but those are not universally available yet. Surprisingly, there were no major differences in the agreements between 1.5 and 3.0 T imaging except for meniscus tear lengths. With meniscus plane reconstructions, the tear length is easily evaluated on 3D imaging as compared with partial voluming artefacts that are frequent on 1.5 T and obscure the meniscus partially in the axial plane. The readers were experienced and used both axial and long-axis images to estimate the extent and length of the tears, which precluded major statistical differences. However, this is an important result validating that both 1.5 and 3.0 T can be used for ISAKOS grading.

There are limitations to this study, including its retrospective nature. The cross-sectional nature of this study limited the ability to prevent lag time between MRI and arthroscopy. In the time between MRI and arthroscopy, it is possible that some meniscus tears may have healed, reducing the tear length as measured by arthroscopy. The surgeons did not have the advantage of real-time physical sensation to evaluate the meniscal quality. Said limitations may have negatively affected intermethod agreement. An additional limitation was that our study, by design, did not evaluate the utility of ISAKOS classification in menisci without tears.

Future studies should consider a prospective study design without much MRI to arthroscopy lag time and real-time measurements of meniscus tears, which may further improve the correlations.

CONCLUSION

ISAKOS classification of meniscal tears on both 1.5 and 3.0 T MRI provides satisfactory inter-rater and intermethod reliability for use in clinical practice, which may improve multidisciplinary communication and aid in patient management and longitudinal tracking of outcomes.

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