Original Article

Preoperative Magnetic Resonance Imaging Predicts Intraoperative Labral Width at the 9-O'clock and 12-O'clock Positions in Primary Hip Arthroscopy

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Purpose: To determine whether preoperative magnetic resonance imaging (MRI) can reliably predict labral width in primary hip arthroscopy. **Methods:** Patients who underwent primary hip arthroscopy with labral repair performed by a single surgeon from January 2008 to December 2015 were identified retrospectively from a prospectively collected database. The width of the labrum was measured intraoperatively at the time of surgery. Two orthopaedic surgeons performed labral width measurements on MRI at 3 standardized locations using the clock-face method at 2 time points, 4 weeks apart. Interobserver and intraobserver reliabilities were calculated, and comparisons were performed between intraoperatively measured labral widths and MRI measurements at the 3 positions. **Results:** Fifty-eight patients who underwent primary hip arthroscopy were enrolled in the study. The average labral width measurements at the 3-, 12-, and 9-o'clock positions were 6.8 mm (standard deviation [SD], 1.1), 6.9 mm (SD, 1.3 mm), and 6.2 mm (SD, 0.9 mm), respectively, on MRI compared with 7.2 mm (SD, 1.5 mm), 7.8 mm (SD, 2.3 mm), and 7.3 mm (SD, 1.6 mm), respectively, when measured intraoperatively. The intraoperative measurements were larger than the MRI measurements at all 3 locations, with significant differences at the 12-o'clock ($P = .008$) and 9-o'clock ($P < .001$) positions. The positive predictive value of the MRI measurements was 92% at the 3-o'clock position, 89% at the 12-o'clock position, and 94% at the 9-o'clock position for identifying a labral width of 6 mm or greater. **Conclusions:** Measuring labral width on MRI yielded, on average, a value that is smaller than the intraoperatively measured width in primary hip arthroscopy procedures. MRI can predict a labral width of 6 mm or greater in at least 89% of cases, which will assist in operative planning. **Clinical Relevance:** The clinical implications of this research include identifying the rare patients in whom more advanced hip arthroscopy procedures may be indicated, such as labral augmentation, in instances of inadequate labral volume that will adequately restore the biomechanics of the suction seal.

The width of the hip labrum has been biomechanically implicated in hip distractive stability.[1,2] A smaller "labral height" (<6 mm)—which despite the difference in semantics is the same dimension as the "labral width"—is significantly associated with both a decreased distance to suction-seal rupture and

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decreased peak negative pressure.[2] More recently, the acetabular labral width has been clinically connected to patient-reported outcomes after arthroscopic labral repair for femoroacetabular impingement.[3,4] Kaplan et al.,[3] in 2021, reported inferior outcomes after labral repair in patients with smaller labral widths as measured on preoperative magnetic resonance imaging (MRI). Given the biomechanical and potential clinical inferiority of decreasing labral volume on hip stability, some surgeons have suggested new strategies to improve hip mechanics and thus patient outcomes. These strategies include the labral augmentation procedure, which increases the labrum's functional volume.[1,2,5]

Labral augmentation requires additional time to obtain and prepare a suitable autograft or additional resources to obtain and prepare an adequate allograft.[5] Additionally, it is a technically more complex procedure, often requiring more operative time than traditional arthroscopic labral repair.[5,6] The ability to preoperatively identify patients with hypotrophic or small labra could be valuable for patient counseling and surgeon preparation or could even warrant consultation with a more skilled hip arthroscopist who has experience with labral augmentation. Previous studies have compared MRI measurements with intraoperative measurements of the labrum; however, none have developed a method of predicting labral size intraoperatively from MRI to plan treatment based on size.[7,8] The purpose of this study was to determine whether preoperative MRI can reliably predict labral width in primary hip arthroscopy. It was hypothesized that labral width as determined by MRI would be reliably correlative with arthroscopic measurements in primary hip labral repairs.

Methods

Patient Selection

This study received institutional review board approval (No. 2020-054). Patients who underwent primary hip arthroscopy performed by the senior author (M.J.P.) from January 2008 to December 2015 were identified retrospectively from a prospectively collected database. The inclusion criteria consisted of patients who underwent primary hip arthroscopic surgery with available MRI of the hip and recorded intraoperative measurements of the labral width. The exclusion criteria included missing or insufficient MRI scans of the hip or intraoperative labral width measurements or previous hip arthroscopy on the index hip. Basic demographic information (age, sex, and body mass index) and surgical findings and procedures were obtained from patient charts.

Imaging Evaluation

MRI studies were performed at the host institution and uploaded into the picture archiving and communication system. One board-certified orthopaedic surgeon in a sports medicine fellowship (J.J.E.) and one board-eligible orthopaedic surgeon who has completed a sports medicine fellowship (J.J.R.) independently reviewed and made the labral width measurements on MRI, blinded to the clinical information and intraoperative arthroscopic measurements. Each surgeon made the measurements twice, 4 weeks apart. All measurements were performed using the PACS (picture archiving and communication system) measurement tool (Merge; IBM, Armonk, NY).

Labral width measurements were made at 3 standardized locations using the clock-face method.[9] The anatomic landmarks and imaging plane were agreed on between the surgeons for consistency in the measurement technique, with the imaging plane being focused on the center of the femoral head in the axial, sagittal, and coronal sequences. Measurements were made at the 3- and 9-o'clock positions on axial sequences and at the 12-o'clock position on sagittal sequences (Fig 1). Proton density sequences were used for all measurements. A noncontrast 3-T MRI scan was used in all circumstances.

Intraoperative Measurements

Patients underwent primary hip arthroscopy with labral repair performed by a single surgeon (M.J.P.) using a previously described surgical technique.[6] Labral width measurements were made at the same 3 standardized locations—the 3-, 12-, and 9-o'clock positions—and prospectively recorded intraoperatively. A standardized measuring probe (Smith & Nephew, Andover, MA) with millimeter marks was used in all cases to obtain the labral widths (Fig 2). A single surgeon (M.J.P.) performed all measurements to the nearest millimeter.

Statistical Analysis

An a priori power analysis was performed to determine how many patients would be necessary to detect a mean difference of 1 ± 2.65 mm in labral width.[2] With the α value set to .05 and power set to 0.80, it was determined that 58 patients would be required.

The intrarater reliability was calculated using the 2 measurements made by each surgeon at each standardized location. The measurements were then averaged for each observer, and one of the averaged measurements was randomly assigned at the 3 locations for all patients. The inter-rater reliability was calculated using the intraclass correlation coefficient (ICC) with an absolute-agreement, 2-way random-effects model for a single measurement [ICC(2,1)].[10] The strength of agreement was classified as poor

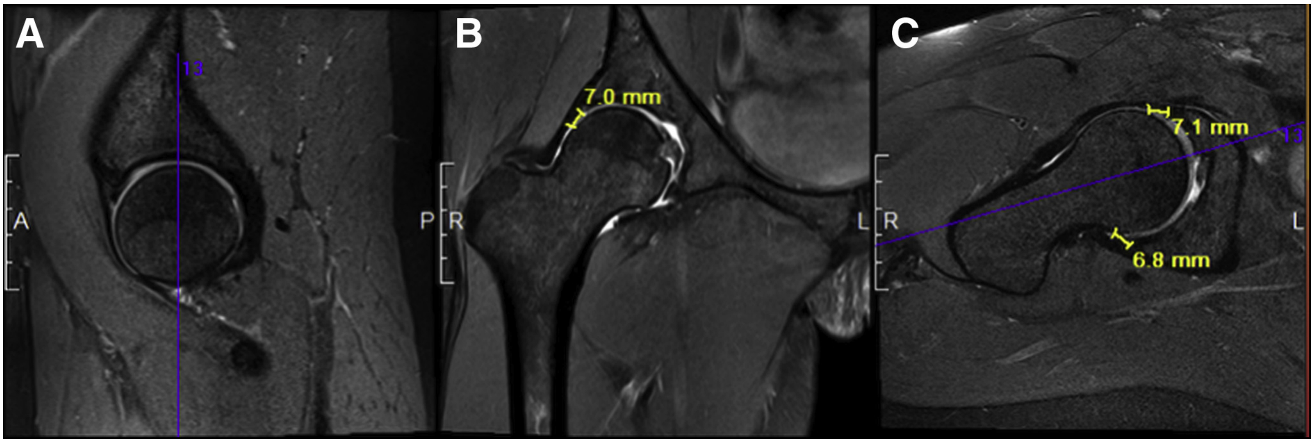

Fig 1. Preoperative magnetic resonance imaging with measurement of labral width in primary surgical case. (A) The sagittal plane was used for centering the femoral head. Measurements were made in the coronal plane for the 12-o'clock position (B) and in the axial plane (C) for the 3- and 9-o'clock positions. (A, anterior; L, left; P, posterior; purple lines, centering of femoral head; R, right; yellow lines, labral width measurements).

when the value was less than 0.40; fair, 0.40 to 0.59; good, 0.60 to 0.74; or excellent, 0.75 or greater. Positive predictive values (PPVs) were calculated to determine the ability of MRI to predict labral widths of 6 mm or greater intraoperatively. A cutoff value of 6 mm was used based on the senior author's previous biomechanical study[2] and has been incorporated into his labral treatment algorithm when deciding between repair and augmentation or reconstruction.

To compare differences between the MRI and intraoperative labral width measurements, a paired-sample *t* test was performed. $P < .05$ indicated a significant difference between measurements ($\alpha = .05$). Bland-Altman plots were created to analyze the presence of proportional bias at each measurement location. Multiple logistic regression was used to determine the effect of other potentially influential or confounding variables associated with intraoperative labral width measurements. All statistical analyses were performed using SPSS software (version 27; IBM).

Results

Fifty-eight patients were included. There were 26 male and 32 female patients, and the mean age was 32.0 ± 12.2 years (range, 15.2-56.9 years). All studies were performed on a 3-T MRI machine using the same imaging protocol.

Intrarater and Inter-rater Reliability

The intrarater and inter-rater reliability expressed by intraclass correlations (ICCs) are reported in Table 1. Surgeon 1 had excellent ICCs (0.828-0.892) and surgeon 2 had fair to excellent ICCs (0.412-0.791) for the MRI measurements. The inter-rater ICCs between the 2 surgeons were good to excellent (0.714-0.820) for the MRI measurements.

MRI Versus Intraoperative Measurements

The average labral width measurements at the 3-, 12-, and 9-o'clock positions are shown in Table 2. The frequency of larger intraoperative measurements was 64% (37 of 58 patients) at the 3-o'clock position, 72% (42 of 58 patients) at the 12-o'clock position, and 78% (45 of 58 patients) at the 9-o'clock position. The differences were statistically significant at the 12-o'clock ($P = .008$) and 9-o'clock ($P < .001$) positions.

When the MRI measurements were rounded to whole numbers, there was no significant difference in the mean differences between MRI and intraoperative measurements. Additionally, a sensitivity analysis was performed using the first measurements of the fellow with the highest intrarater ICCs. Similar mean differences were found at each location.

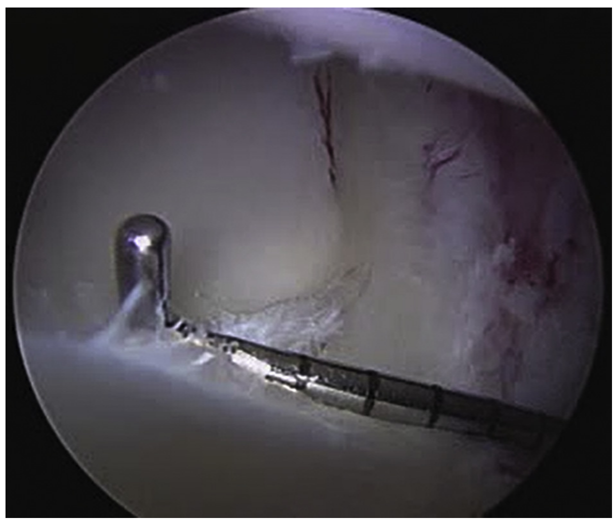

Fig 2. Intraoperative arthroscopic measurement of labral width in left hip when viewing from midanterior portal through 70° arthroscope.

Table 1. Intrarater and Inter-rater Reliability of Labral Width Measurements Using MRI in Primary Hip Arthroscopy Cases

	Intrarater ICC (95% CI)		
	Surgeon 1	Surgeon 2	Inter-rater ICC (95% CI)
3-O'clock position	0.892 (0.772-0.943)	0.769 (0.610-0.863)	0.714 (0.515-0.832)
12-O'clock position	0.873 (0.697-0.938)	0.791 (0.647-0.876)	0.820 (0.682-0.896)
9-O'clock position	0.828 (0.705-0.900)	0.412 (0.009-0.651)	0.759 (0.591-0.858)

CI, confidence interval; ICC, intraclass correlation coefficient; MRI, magnetic resonance imaging.

Bland-Altman plots were made to show the differences in measurement modalities and the magnitude of the differences (Fig 3). A level of agreement within 1 mm of the mean difference was distributed similarly between the measurement locations. Differences greater than 1 mm from the mean difference at the 12-o'clock location had the greatest variability.

Sex Stratification

When data were stratified by sex, the mean labral width measurements determined intraoperatively were larger than the MRI measurements at all 3 locations for both male patients and female patients (Table 2). A statistically significant difference between the MRI and intraoperative measurements was observed for male patients at the 12-o'clock ($P = .026$) and 9-o'clock ($P = .001$) positions. Only at the 9-o'clock position ($P = .001$) was a statistically significant difference between the MRI and intraoperative measurements seen for female patients.

Predictive Model

A multiple regression was run to predict intraoperative labral width from MRI labral width measurements, age, and sex at each of the 3 locations. The β coefficients for the independent variables are shown in Table 3. All co-variables were nonsignificant predictors of intraoperative labral width at each location. Table 4 shows the sensitivities and PPVs for the probability of MRI labral widths identifying intraoperative labral widths of 6 mm or greater.

Discussion

The most important finding of this study was that MRI measurements of labral width showed good to excellent levels of agreement between surgeons in primary hip arthroscopy. The MRI measurements tended to be smaller than the intraoperatively measured labral widths at all 3 positions assessed. Differences in the imaging versus intraoperative measurements occurred at the 12- and 9-o'clock positions. In primary hip arthroscopy, the PPVs of the MRI measurements were 89% or greater at all positions for a labral width of 6 mm or greater, showing that these measurements may provide a clinical tool for preoperative planning.

With a better understanding of labral anatomy and advancements in arthroscopic procedures to address labral pathology, there is clinical value in predicting labral size on preoperative imaging to aid in patient counseling and surgical planning. In a cadaveric study, Storaci et al.[2] found that hips with a smaller labral height (<6 mm) were significantly associated with a decreased distance to suction-seal rupture and decreased peak negative pressure. On the basis of the biomechanical evidence, the senior author has incorporated a 6-mm cutoff into his labral treatment algorithm when deciding to proceed with repair or

Table 2. Comparison of Labral Width Using MRI and Intraoperative Measurement Modalities in Primary Hip Arthroscopy Cases

	MRI Measurement, mm	Intraoperative Measurement, mm	Difference, mm	*P* Value (Paired-Sample *t* Test)
All patients				
3-O'clock position	6.8 ± 1.1	7.2 ± 1.5	−0.40 ± 1.8	.101
12-O'clock position	6.9 ± 1.3	7.8 ± 2.3	−0.90 ± 2.5	.008*
9-O'clock position	6.2 ± 0.9	7.3 ± 1.6	−1.1 ± 1.6	<.001*
Male subgroup				
3-O'clock position	7.0 ± 1.2	7.3 ± 1.4	−0.26 ± 2.0	.512
12-O'clock position	7.1 ± 1.4	8.0 ± 1.4	−0.85 ± 1.8	.026*
9-O'clock position	6.5 ± 0.9	7.6 ± 1.4	−1.0 ± 1.5	.001*
Female subgroup				
3-O'clock position	6.6 ± 0.9	7.1 ± 1.6	−0.51 ± 1.7	.099
12-O'clock position	6.7 ± 1.2	7.6 ± 2.8	−0.94 ± 3.0	.083
9-O'clock position	5.9 ± 0.8	7.0 ± 1.7	−1.1 ± 1.7	.001*

NOTE. Data are presented as mean ± standard deviation.
MRI, magnetic resonance imaging.
*Statistically significant ($P < .05$).

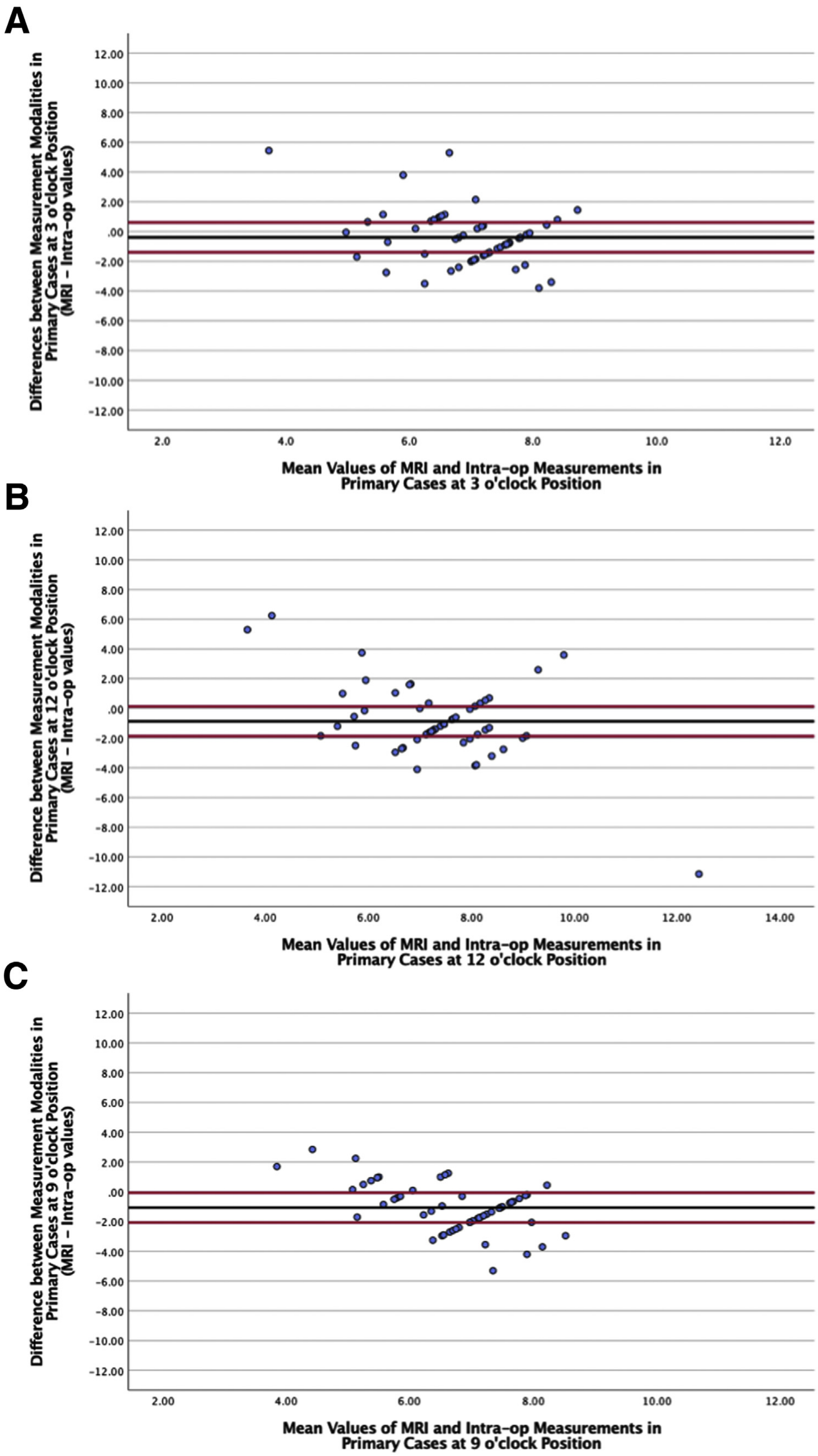

Fig 3. (A-C) Bland-Altman plots at each measurement location depicting level of agreement between measurement modalities. Differences in measurements (magnetic resonance imaging [MRI] values minus intraoperative [Intra-op] values) were plotted against mean measurements. The mean difference (black line) and range of 1 mm from the mean difference (red lines) are marked to show how many measurements were within 1 mm of the mean difference.

Table 3. Regression Coefficients for Predicting Intraoperative Labral Width

Variable	B	95% CI for B	β	*t*	Significance
3-O'clock position					
MRI labral width	0.036	−0.365 to 0.437	0.026	0.180	.858
Sex	−0.174	−1.03 to 0.679	−0.058	−0.409	.684
Age	0.004	−0.031 to 0.039	0.030	0.217	.829
12-O'clock position					
MRI labral width	0.159	−0.318 to 0.636	0.092	0.669	.507
Sex	−0.203	−1.45 to 1.04	−0.045	−0.326	.746
Age	−0.018	−0.069 to 0.032	−0.099	−0.727	.470
9-O'clock position					
MRI labral width	0.334	−0.182 to 0.849	0.189	1.30	.200
Sex	−0.360	−1.26 to 0.539	−0.115	−0.803	.426
Age	0.014	−0.022 to 0.049	0.105	0.757	.452

CI, confidence interval; MRI, magnetic resonance imaging.

augmentation, among other factors (e.g., labral tissue quality and tear morphology).[5] The ability to predict labral width can assist in preoperative planning for augmentation (availability of allograft or increased instrumentation for autograft harvest) or labral repair (use of circumferential vs labral base fixation). Although our study showed significant differences in MRI and intraoperative labral width measurements at all locations except the 3-o'clock position, most of the mean differences were less than 1 mm. The clinical relevance of this finding is important to consider because the probe used for intraoperative measurement only had 1-mm marks. Furthermore, there was high sensitivity in detecting a labral width of 6 mm or greater and high predictive value of accurately predicting labral widths of 6 mm or greater. These findings show the potential utility of a labral width predictive model as developed in this study with further validation and fine-tuning of the measurement methodology.

Other investigators have previously aimed to measure the dimensions of the acetabular labrum on imaging; however, there is a lack of consensus regarding nomenclature and measurement methodology when reporting labral size and distinguishing between normal and hypotrophic labra.[11] In a systematic review, Walker et al.[11] reported on 21 studies describing measurements of the labral dimensions and found the length of the labrum from the chondrolabral junction to be measured from the capsular facet, articular facet, or midsubstance using various anatomic landmarks such as the acetabular rim or labral free edge and the clock-face method on MRI, magnetic resonance arthrography (MRA), computed tomographic arthrography, ultrasound, or arthroscopic assessment.[11] The terms "labral height" and "labral width" were used interchangeably among the studies. Average widths on imaging and arthroscopy were pooled, and the data suggested that the labral width is largest in the superior aspect and smallest in the posterosuperior aspect, which was similar to the differences in labral size by location observed in this study and previously described by the senior author.[9,11]

The accuracy of preoperative prediction of labral size has been assessed previously, with mixed results. Hartwell et al.[8] compared MRA versus intraoperative labral width measurements in 117 patients and found strong inter-rater reliability between readers in MRA-based hip labrum measurements but poor correlation between MRA and intraoperative measurements at the 3-, 12-, and 9-o'clock positions. The average intraoperative measurements were larger than the average MRA measurements at the 12- and 9-o'clock positions, but the level of significance was not reported. Contrarily, Kaplan et al.[7] measured labral widths at the 11:30 clock-face, 3-o'clock, and 1:30 clock-face positions with 1.5- or 3-T MRI or 3-T MRA and compared them with intraoperative measurements, finding good to excellent levels of agreement between all 3 radiographic modalities and surgical assessment. Our study is unique in that only 1 type of imaging modality was included and imaging was performed using the same magnet type and size and the same protocol. The variability in results demonstrates the need for a validation study with a larger patient population, standardized magnetic resonance and intraoperative measurement protocols, and more surgeons at multiple locations.

Finally, a possible explanation for the discrepancies observed between measured labral widths is labral tissue quality. Native labral tissue tends to be flexible, and compression with the probe during measurement could lead to overestimation of the labral width in the

Table 4. Sensitivity and Positive Predictive Value of MRI Labral Width Predicting Intraoperative Labral Width of 6 mm or Greater

Location	Sensitivity, %	Positive Predictive Value, %
3-O'clock position	87	92
12-O'clock position	79	89
9-O'clock position	60	94

primary setting as the tissue conforms to the measuring device. Another variable to consider is sex. Several studies have evaluated labral size in male versus female patients, with mixed findings showing that men or women have larger labra, and there is no significant difference in labral size between sexes.[12-15] In this study, the mean differences in MRI versus intraoperative labral width measurements remained similar when data were stratified by sex.

Limitations

This study is not without limitations. Perhaps the most critical limitation is the differences in measurements. Intraoperatively, measurements were made at time 0 during surgery and collected in a prospective fashion, whereas MRI measurements were retrospective in nature using computer software. There is no validated or standardized way to perform either intraoperative or radiographic measurements. Although there is variation in the clock-face positions reported, with some previous studies reporting measurements at the 1:30 clock-face position, the senior surgeon consistently collected measurements at the 3-, 12-, and 9-o'clock positions to represent the anterosuperior and posterosuperior sections of the labrum, which most commonly show pathologic findings. Additionally, only single measurements were made intraoperatively, preventing inter-rater or intrarater reliability analyses. Although frank differences exist between the 2 forms of measurement, this limitation can be overcome. A second limitation of this study pertains to the results regarding sex stratification. Given that sex was a secondary outcome measure, an a priori power analysis accounting for sex was not performed. Therefore, statistical significance cannot be determined as the data may be underpowered. A third limitation pertains to MRI measurements because MRI strength, slice thickness, and contrast varied. These heterogeneities could have possibly contributed to some variations in measurements both among patients and between observers.

Conclusions

Measuring labral width on MRI yielded, on average, a value that is smaller than the intraoperatively measured width in primary hip arthroscopy procedures. MRI can predict a labral width of 6 mm or greater in at least 89% of cases, which will assist in operative planning.

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