

Lateral acetabular labral length is inversely related to acetabular coverage as measured by lateral center edge angle of Wiberg

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ABSTRACT

Patients with developmental dysplasia of the hip often have compensatory labral hypertrophy, which presumably lends stability to an unstable joint. Conversely, patients with acetabular overcoverage may have small or ossified labra. The purpose of this study is to explore the interaction of labral length with the degree of acetabular hip coverage. A retrospective cohort of patients with hip pain presenting to a hip preservation center, who had undergone hip magnetic resonance imaging and AP pelvis radiographs were studied. General linear multivariate models were used to assess the association between three measures of labral length (lateral, anterior and anterior inferior locations along the acetabular rim) and the X-ray derived lateral center edge angle (LCEA) of Wiberg. Of the three acetabular labral locations measured, only the lateral labrum was associated with LCEA Wiberg ($P = 0.0008$). Lateral labral length increases as LCEA of Wiberg decreases. The anterior and anterior inferior labral locations did not show a predictable increase in labral length as LCEA Wiberg decreased.

INTRODUCTION

Developmental hip dysplasia commonly leads to premature coxarthrosis [1–4]. Congenital dislocation of the hip is the most severe form of hip dysplasia, and if untreated, can contribute to dysmorphic and dysfunctional hip joints. Less severe dysplasia can go unrecognized in childhood and become symptomatic in adulthood. In his seminal series of normal and pathologic hip joints [2], Gunnar-Wiberg posited that much of the senile adult osteoarthritis of the hip (malum coxae senile) was, in fact, related to variably deficient acetabular coverage. He found that patients with center edge angles of greater than 25° rarely developed premature coxarthrosis, less than 20° commonly developed premature arthrosis, and that ‘angles between

20° and 25° are borderline angles, smaller ones indicating defective development and larger ones a normal acetabulum’.

The acetabular labrum acts as a soft tissue constraint to the hip joint, increasing acetabular depth, providing joint seal and distributing weight bearing forces, with overall benefit to the joint’s biomechanical properties. With acetabular undercoverage, the labrum has been shown to hypertrophy. This phenomenon was demonstrated on hip arthrogram images as early as 1939, referred to as the limbus thorn by Wiberg [2], and more recently at surgery [5–8] and with magnetic resonance imaging (MRI) evaluation [9–15].

Conversely, the labrum has been shown to completely ossify in cases of global pincer deformity [16]. This phenomenon of labral dynamism may explain why in 2–15% of asymptomatic patients the labrum has been described as ‘absent’ predominantly in the anterosuperior quadrant [17, 18]. The lateral labrum is only rarely reported as absent [19].

We hypothesized that compensatory changes in labral size would be demonstrated across all degrees of lateral acetabular coverage and that labral length would be inversely proportional to the degree of acetabular coverage. The purpose of this study was to correlate labral length on dedicated hip MRI studies at each of three locations along the acetabular rim, to the radiographic lateral center edge angles (LCEA) of Wiberg. Our study serves as preliminary work exploring the potential compensatory changes the labrum undergoes in response to variable degrees of acetabular coverage. Labral size on MRI could potentially represent an important anatomic biomarker of hip joint stability, with labral hypertrophy or labral atrophy potentially contributing valuable information to the treatment plan.

MATERIALS AND METHODS

Study population

This study was approved by the institutional review board at our institute. Retrospective review of all patients presenting to a hip preservation center over a 12-month period was performed in order to obtain a study population with dedicated MRI of the hip, dedicated musculoskeletal CT of the pelvis and AP pelvic radiograph. Data from dedicated pelvic CT scans were used in a separate research project. Dedicated hip MRI studies were a heterogeneous mix of routine non-contrast MRI, MR arthrogram (MRA) and delayed gadolinium enhanced MRI of cartilage (DGEMRIC). Patients were excluded for history of acetabular sided surgery, uninterpretable MRI and age greater than 65 years of age. Only a single MRI per patient was evaluated, but bilateral exams were individually assessed. Of the 87 MRI studies with standardized AP pelvic radiographs [20, 21], six were excluded related to prior hip surgery (two periacetabular osteotomies, two total hip arthroplasties, and two prior hip arthroscopies with acetabular rim trimming), three MRI studies were duplicates with patients having more than one MRI during the retrospective review period, one patient had metallic shrapnel around the hip producing significant susceptibility artifact, and one patient was greater than 65 years of age. This yielded 76 MRI studies on 65 patients (11 patients had bilateral exams).

MRI and radiographic evaluation

MRI images included in the study group were performed on one of three MRI systems (Philips, Siemens, GE), on either 1.5T or 3T field strength. MRI imaging protocols included routine non-contrast MRI of the hip (43), MR arthrograms of the hip (14) and MR hip DGEMRIC studies (19). For MRI hip protocol, patients were placed supine on the MRI exam table, with feet secured in internal rotation. Multichannel torso array coil was employed in all cases for image acquisition. All protocols included small FOV sequences dedicated to the affected hip in straight coronal (FOV 18–22 cm, 4 mm slice thickness), axial (FOV 18–22 cm, 4 mm slice thickness) and sagittal planes (FOV 18–22 cm, 4 mm slice thickness). Pulse sequences included a combination of intermediate weighted fat suppressed and non-fat suppressed sequences (TR 1667–2000, TE 45–51) for all MRI studies, and T1 fat suppressed and non-fat suppressed sequences (TR 491–917, TE 11–17) for MR arthrogram and DGEMRIC studies.

MRI studies were reviewed by the author, an MSK Radiologist with 10 years of experience. The length of the acetabular hip labrum was measured at three separate anatomic sites along the acetabular rim: lateral, anterior and anterior inferior. We defined the lateral labrum as the labrum at the level of the central coronal MRI image cross-referenced to the axial and sagittal planes (Fig. 1), the anterior labrum as the labrum at the level of the central sagittal slice as cross-referenced to the axial and coronal planes (Fig. 2), and the anterior inferior labrum as the labrum at the level of the central axial slice as cross referenced to the coronal and sagittal planes (Fig. 3). The labral length was

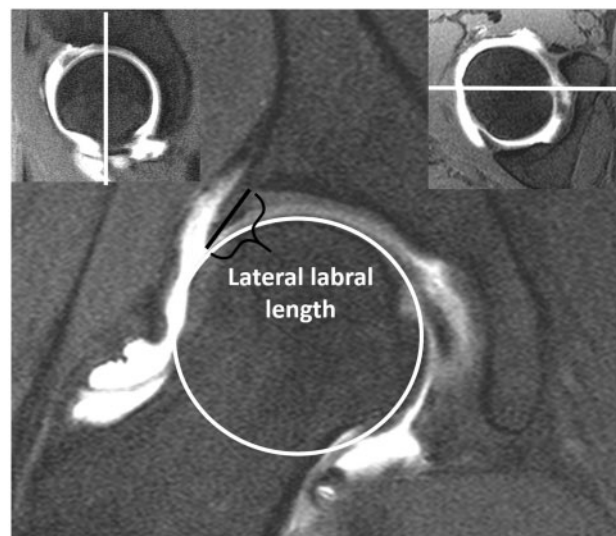


Fig. 1. Lateral labral measurement technique on MRI.

measured from the acetabular rim to the tip of the labrum in millimeters (mm) on the PACS workstation (McKesson Enterprise, Richmond, BC, Canada). If the labrum was macerated or ossified and immeasurable at any location, these subjects were excluded from the initial analysis. Nine MRI studies were excluded from the multivariate model related to unmeasurable labrum. Six of the labra were unmeasurable related to labral maceration (three anterior and three anterior inferior) and three were unmeasurable related to ossification (one lateral and two anterior).

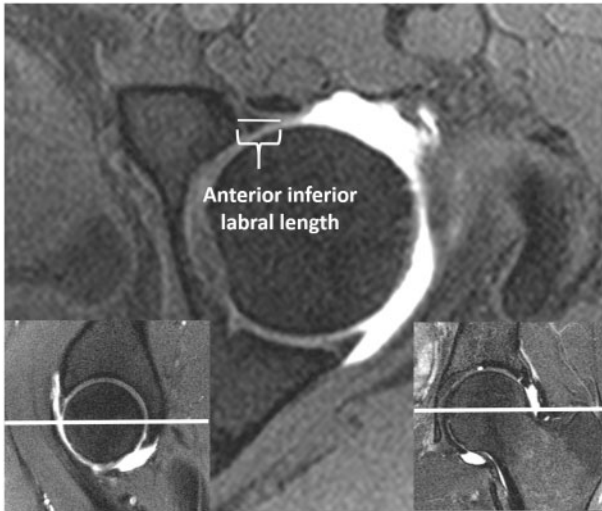


Fig. 2. Anterior inferior labral measurement technique.

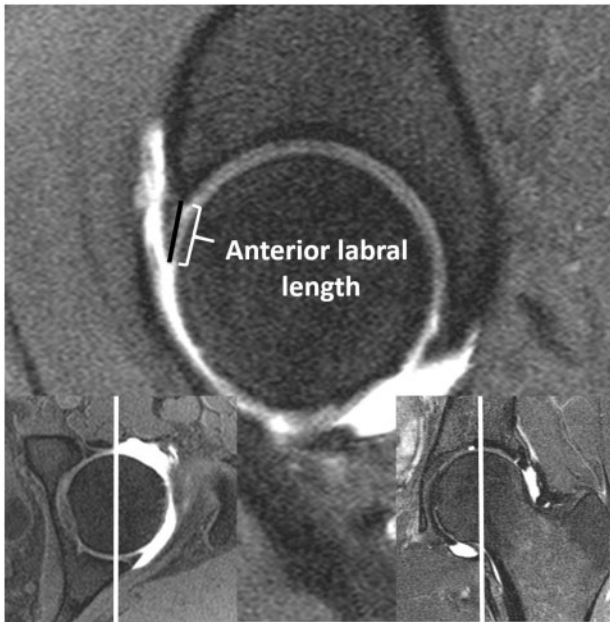


Fig. 3. Anterior labral measurement technique.

The standard AP pelvic view was obtained with the patient positioned supine with the lower extremities internally rotated 15° to maximize femoral neck length. The X-ray beam was directed midway between the anterior superior iliac spine (ASIS) and the pubic symphysis, with a focus film distance of 100 cm. Films were considered adequate given symmetric obturator foramina and a distance of 1.0–3.0 cm between the coccyx and pubic symphysis [20, 21].

Radiographic evaluation

AP pelvis radiographs were evaluated by an MSK radiologist with three years of experience. The lateral center edge angle (LCEA) of Wiberg [2] was measured of the hip being studied according to the published techniques (Fig. 4). The LCEA of Wiberg is the angle between a true vertical (perpendicular to a true horizontal of the pelvis) and the lateral osseous margin of the acetabular rim. True horizontal was defined as a line connecting the undersurface of the ischial tuberosities.

Statistical analysis

All hypotheses were tested at a Type I error rate of 0.05 level.

To test the relationship between lateral central edge angle and MRI measured hip labrum length, we fit a general linear multivariate model to the LCEA Wiberg with the three measurements of labral length, lateral, anterior and anterior inferior, used as outcome variables. As predictors, we used gender, LCEA angle and their interaction. We used a backwards stepwise method to evaluate, in turn, the gender by LCEA angle interaction, and then, if non-

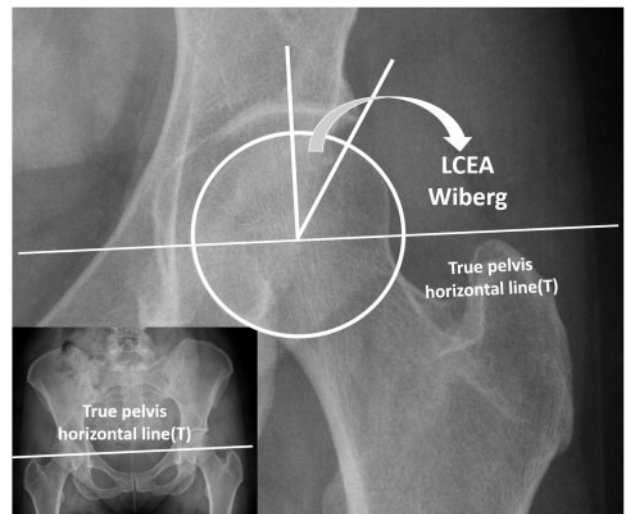


Fig. 4. LCEA Wiberg.

significant, the gender and LCEA main effects. If there were no significant gender differences, we dropped gender from the model. Hypothesis testing was performed using the Hotelling–Lawley trace. The multivariate analysis required that all three labral measures be nonmissing.

Finally, to compare labral lengths at all locations between genders, we fit a general linear multivariate model with indicator variables for male and female gender as the predictors, and the three labral lengths as the outcomes. We used a Hotelling–Lawley test at a Type I error rate of 0.05.

RESULTS

The demographics and summary data of the patient cohort are shown in Table I. Mean labral lengths and standard deviations for each labral location are demonstrated in Table II.

There was no significant difference between genders in labral length at each location overall ($F=2.61$, $ndf=3$,

Table I. Study group demographics

Total MRI studies	76
Hip	
Right	33
Left	19
Bilateral	12
Patients	
Total	65
Female	46
Male	19
Age	
Mean	35.11
Standard deviation	12.81
Range	15–63

Table II. Average labral length data in the overall cohort

	Lateral labral length mm (stdv)	Anterior labral length mm (stdv)	Anterior inferior labral length mm (stdv)
MRI studies ($n = 76$)	7.88 (2.30)	8.01 (2.47)	7.22 (2.36)

$ddf=68$, $P=0.0587$). There was a significant association between labral length and LCEA Wiberg ($F=6.37$, $ndf=3$, $ddf=63$, $P=0.0008$). The length of the lateral hip labrum was significantly associated with the LCEA Wiberg ($\beta=-0.16$, $t=-3.98$, $P=0.0002$, 95% CI = $(-0.24, -0.08)$). The lengths of the anterior hip labrum ($\beta=0.01$, $t=0.25$, $P=0.80$, 95% CI = $(-0.08, 0.11)$) and the anterior inferior hip labrum ($\beta=-0.05$, $t=-1.03$, $P=0.30$, 95% CI = $(-0.14, 0.04)$) were not significantly associated with the LCEA Wiberg. Figure 5 shows the predicted linear regression relationship between lateral labrum length and the LCEA Wiberg based on measured values.

DISCUSSION

Our results demonstrate the labral length to be inversely proportional to the degree of acetabular coverage as measured by the radiographic LCEA Wiberg. The anterior and anterior inferior labral length did not correlate to the degree of lateral acetabular coverage.

Labral enlargement in the setting of developmental dysplasia of the hip has been noted by MRI [9–15] and at surgery [5, 6, 8, 22]. Mild forms of developmental hip dysplasia may not become apparent until adulthood, yet in these patients the labrum confers crucial stability to a borderline unstable joint, with arthroscopic debridement or resection producing negative clinical outcomes [6–8]. This labral enlargement may serve to provide greater joint surface congruity and deepening the acetabular fossa, contributing to hip joint stability [6, 23, 24]. By studying a patient population with wide variability in acetabular coverage, our study suggests that the acetabular labrum undergoes compensatory changes in size in response to variable degrees of acetabular coverage and hip stability.

The dysplastic hip can vary in clinical presentation, from congenital dislocation as a child to mild forms of hip pain as an adult. Mild forms of hip dysplasia may not always produce premature hip disease [2], with the various soft tissue constraints contributing sufficiently to hip stability, allowing normal function of the hip over a lifetime. It is the unstable dysplastic or unstable borderline dysplastic hips that will contribute to premature hip joint disease and early onset of pain, and should be the target of acetabular reorientation surgery to attempt to replicate normal weight bearing forces across the hip joint. In his seminal series following dysplastic hips, Wiberg noted that although a slightly dysplastic hip may remain normal throughout life, a hip with ‘definite subluxation’ will show inevitable osteoarthritic changes by the time the patient reached the 6th decade of life [2]. According to Wedge and Wasylenko, there is at least a 5-year window from the

onset of hip pain in the dysplastic patient and the demonstration of coxarthrosis on radiographs [4]. This is a critical time where a reliable imaging sign of hip instability would support surgical intervention, altering the natural history of the disease.

Although the LCEA of Wiberg has been a valuable and commonly used radiographic tool for assessing hip dysplasia since the original description in 1939 [2], in some cases it may underestimate the severity of dysplasia [25]. MRI signs of dysplasia have been less extensively investigated, with prior studies exploring the MRI center edge angle [26], describing labral and chondral damage [9], elevation of the fovea capitis (fovea alta) [27] and hypertrophy of the iliocapsularis muscle [28]. However, labral length as measured by MRI is rarely discussed.

Our study confirms prior qualitative observations of increasing labral size in patients with developmental dysplasia of the hip [9–15]. However, this is the first study to suggest, in a quantitative manner, that this compensatory labral hypertrophy progresses along a linear model, increasing in size as the degree of hip coverage decreases, and potentially decreasing in size as acetabular coverage increases. In our study the lateral labrum was the only location that was linearly related to the degree of lateral acetabular coverage.

The average length of the lateral, anterior and anterior inferior labra in our study were larger compared to the average length of 52 hip MRI studies in an asymptomatic

population studied by Cotten et al., where anterior and lateral labrum measured an average of 6.5 mm in length [18]. Comparison of our results to prior studies measuring labral volumes in dysplastic [15] and normal volunteers [19, 29] is not directly comparable as our data concentrated on labral length only. Similar to Cotten et al. [18], we also observed that the caliber of the labral base at the acetabular rim rarely varied significantly and it was the length that was dynamic in regard to acetabular coverage. Kubo *et al.* demonstrated statistically significant increases in acetabular labral volume (presumably largely related to the increase in labral length) in patients with dysplasia compared to normal controls at all measured labral positions. Interestingly, in normal control subjects the labrum increases in size more posteriorly [18, 29], but in Kubo's dysplastic patient population the anterosuperior (equivalent to our anterior position) and superior portions (equivalent to our lateral labral position) of the labrum were larger than the posterosuperior portion [15]. We did not show the anterior labrum to have the same association with the LCEA as the lateral labrum. This may be a function of a combined population of patients including patients with dysplasia, normal acetabular coverage and acetabular overcoverage, resulting in a small overall number of patients with significant dysplasia. Additionally, we did not study acetabular version and femoral torsion which might have implications related to compensatory size changes of the anterior labrum.

There was no statistical difference in labral size at any labral position between men and women in our study population. This is counter to the findings of Aydingöz [19], who studied 360 hip MRI studies in 180 asymptomatic volunteers, equally stratified between genders and demonstrated the labrum in males to be statistically larger than in females on the mid-coronal MRI slice (equivalent to our lateral labrum position). The lack of difference in labral size between genders in our study may be explained by our symptomatic patient population, suffering from dysplasia and/or impingement, as well as the relatively small fraction of males in our study (only 30% of the study population).

This study has a number of limitations. The sample size did not allow us to stratify the data into the usual clinical divisions of acetabular coverage. Our study group did not have sufficient numbers of patients with acetabular overcoverage to explore this patient population specifically. The linear relationship of lateral labral length to LCEA suggests that as acetabular coverage increases, the need for soft tissue constraints decreases. The patient population largely consisted of a young patient population with hip pain and may not be generalizable to an older population. This

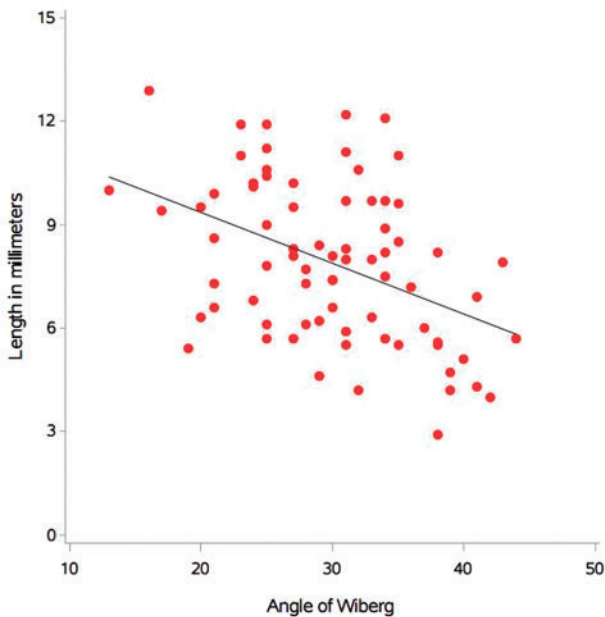


Fig. 5. Linear regression line showing the relationship between the LCEA Wiberg and the length of the lateral hip labrum.

patient population was selected intentionally however, as older patients would tend to have more joint degeneration, and the compensatory labral changes we sought to measure may be confounded by age related labral injury. Labra that were unmeasurable because of maceration or ossification were not able to be included in the analysis, but clearly these are important patients, with either excessive stress on the labrum producing maceration (possibly related to DDH or FAI) or bony replacement of the labrum, conceivably related to the inverse labral compensation of acetabular overcoverage. The size of the acetabular labrum may be affected by overall patient size, and the labral length was not correlated to subject BMI or height. However, the labral size did not differ between male and female. Finally, the LCEA Wiberg was obtained by a single trained observer. The intraobserver variability of LCEA Wiberg has been shown to be excellent, but the interobserver variability is poor [30].

Patients with mild or borderline dysplasia continue to represent a challenging subset of patients to definitively manage. The choice between arthroscopy and acetabular realignment procedures in this patient population is a difficult one, and it is hard to justify the length of rehabilitation and recovery necessary following acetabular realignment to prevent coxarthrosis that may be years or decades in the future. Labral hypertrophy on MRI may represent an important imaging biomarker of hip instability and with future outcomes data, become a data point to guide appropriate management by the hip preservation team. Conversely, further interrogation on the labral morphology related to acetabular overcoverage is warranted given our findings. A small labrum may be an important marker of pincer impingement, indicating the need for a comprehensive surgical approach that includes acetabular rim recession to eliminate bony impingement and labral reconstruction rather than simple labral debridement or repair.

In conclusion, our study seeks to introduce the concept of labral dynamism by demonstrating a linear increase in lateral labral length as measured on the central coronal slice of dedicated hip MRI studies when compared with decreasing LCEA of Wiberg.

CONFLICT OF INTEREST STATEMENT

None declared.

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