Radiographic and Demographic Factors Can Predict the Need for Primary Labral Reconstruction in Hip Arthroscopic Surgery

A Predictive Model Using 1398 Hips

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Background: Labral tears are the most common findings in patients with symptomatic femoroacetabular impingement (FAI). The restoration of labral function is critical, and labral reconstruction has been proposed as an alternative for irreparable tears.

Purpose: To compare preoperative radiographic measurements and demographics of patients who underwent primary arthroscopic labral reconstruction versus primary labral repair and to identify factors that are predictive of the need for reconstruction.

Study Design: Case-control study; Level of evidence, 3.

Methods: Patients who underwent their index hip arthroscopic procedure between October 2010 and November 2018 and underwent either labral reconstruction or repair were included in the study. A total of 18 variables (14 radiographic and 4 demographic) were assessed in a bivariate comparison and analyzed in a multivariate logistic model.

Results: A total of 251 primary reconstruction and 1147 primary repair procedures were included. The logistic model selected age, body mass index (BMI), Tönnis grade, lateral center-edge angle (LCEA), and alpha angle. The odds of reconstruction were 2.52 times higher in patients with Tönnis grade 1 than 0 (odds ratio [OR], 2.52 [95% CI, 1.82-3.49]). Each additional degree in the LCEA was associated with a 6% increase in the odds of reconstruction (OR, 1.06 [95% CI, 1.04-1.09]) and 4% for each additional degree in the alpha angle (OR, 1.04 [95% CI, 1.03-1.05]). Higher age (per log 10 unit) and BMI also increased the likelihood of reconstruction (OR, 11.29 [95% CI, 4.23-30.10] and OR, 1.03 [95% CI, 1.00-1.06], respectively).

Conclusion: In a multivariate analysis, factors identified as preoperative predictors for primary arthroscopic labral reconstruction in the setting of FAI and labral tears were Tönnis grade, LCEA, age, and BMI. These predictive factors may be useful for the clinician in determining the preoperative likelihood of primary labral reconstruction.

Keywords: labral reconstruction; labral tear; hip arthroscopic surgery; predictive factors

The importance of the labrum to the biomechanics of the hip joint has been well-documented by the literature.[4,17,22] A labral tear is one of the most frequent findings in symptomatic femoroacetabular impingement (FAI).[5-7,12] Compared with labral debridement, labral preservation has shown superior long-term outcomes.[31] The decision to select labral reconstruction or labral repair is based predominately on intraoperative findings.[2,15,24] Generally, repair of the labrum is undertaken when the quality of the labral tissue is adequate to restore the "sealing effect" of the joint.[20,33,38] This holds even in revision cases.[36] However, when labral tissue is compromised beyond repair, reconstruction is preferred. Reconstruction has been shown to be a superior alternative to debridement,[14] with favorable outcomes at short-term and midterm follow-up.[8,9,41,46] In primary arthroscopic surgery, calcified labra, hypoplastic labra, and irreparable tears warrant reconstruction.[29,41]

Yet, labral reconstruction is one of the most challenging procedures in hip arthroscopic surgery.[30] The ability to anticipate it before surgery can benefit surgical case planning and preparation.[30]

The purpose of this article was to compare preoperative radiographic measurements and demographics of patients who underwent primary arthroscopic labral reconstruction versus primary labral repair and to identify factors that are predictive of the need for reconstruction. We hypothesized that a significant difference would be found in the preoperative radiographic measurements and demographics of these 2 groups.

The American Journal of Sports Medicine
2020;48(1):173–180
DOI: 10.1177/0363546519887749

METHODS

Participation in the American Hip Institute's Hip Arthroscopy Registry

While the present study represents novel findings, data on some patients in this study may have been reported in other studies.[8,9,29] All data collection received institutional review board approval.

Patient Selection

This retrospective study draws from a prospectively maintained institutional database. Patients were included if they underwent their index hip arthroscopic procedure and underwent either labral reconstruction or simple labral repair by the senior author (B.G.D.) between October 2010 and November 2018. Currently, the overall primary reconstruction rate according to the institutional (American Hip Institute) database is 6%. Patients without complete sets of radiographic measurements, as outlined in the following section on radiographic measurements, were excluded. Additionally, patients with Tönnis grade $\geq$2, previous hip conditions such as Legg-Calve-Perthes disease, slipped capital femoral epiphysis, pigmented villonodular synovitis, ankylosing spondylitis, and avascular necrosis were excluded. Patients who underwent labral treatment other than reconstruction or repair were also excluded (labral debridement, labral augmentation).[10,37]

The definition of a reparable versus irreparable labral tear was based on the senior author's expertise and discretion during the intraoperative diagnostic labral evaluation. Labral tears were considered irreparable if the labrum appeared (1) to be mostly or completely calcified or (2) to be inadequate (nonviable) and not amenable to labral repair.[15,31] Patients were selected for hip arthroscopic surgery if they did not achieve relief of pain symptoms after nonoperative management (rest, nonsteroidal anti-inflammatory drugs, cortisone injections, and physical therapy).

Generally, labra deemed irreparable or calcified were reconstructed. The algorithm used to decide whether to reconstruct or repair the labrum may be found in the 2015 study by White and Herzog.[45] For a period of time, the segmental reconstruction option with either an autograft or allograft was used as the initial workhorse technique, which required precise measurement of the segmental labral defect to avoid graft-defect mismatching.

While segmental reconstruction provided favorable short-term and midterm outcomes,[8,9,13,14] the technique was improved upon to reduce the opportunity for defect-graft measurement errors. Starting in January 2016, the circumferential option with the pull-through maneuver using either a hamstring or tibialis anterior tendon allograft was used. This modification allowed intra-articular graft customization and perfect graft length.[35] Regardless of the technique, knotless suture anchoring was the method of graft fixation.

Radiographic and Demographic Measurements

A total of 14 radiographic measurements of the hip joint were taken from 3 views: the anteroposterior, false-profile, and Dunn 45° views.[11] The anteroposterior view provided 11 measurements: Tönnis grade, lateral center-edge angle (LCEA),[47] acetabular inclination (AI),[42] joint space (lateral, central, and medial), neck shaft angle, ischial spine sign, crossover sign, presence of coxa profunda, and presence of protrusio acetabuli.[11] All measurements were continuous variables except for Tönnis grade,[42] coxa profunda, and acetabular protrusion. The false-profile view provided the measurement for anterior center-edge angle (ACEA),[26] while the Dunn 45° view provided measurements for alpha angle[34] and femoral offset.[19] The institution's radiographic measurements have demonstrated interobserver reliability in previously published studies.[16,23,39,40] Age at surgery, body mass index (BMI), sex, and operative side were also recorded in the database.

Statistical Analysis

Variable Comparison: Bivariate Analysis. The 14 radiographic measurements along with the 4 demographic variables were evaluated in a bivariate analysis. Descriptive statistics for continuous variables were reported as means and standard deviations, and categorical variables were reported as totals and percentages. The *P* values for comparing continuous variables, such as age or BMI, between

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Submitted May 15, 2019; accepted September 20, 2019.

One or more of the authors has declared the following potential conflict of interest or source of funding: B.G.D. has had ownership interests in Hinsdale Orthopaedics, the American Hip Institute, SCD#3, North Shore Surgical Suites, and Munster Specialty Surgery Center; has received research support from Arthrex, ATI, the Kauffman Foundation, Stryker, and Pacira Pharmaceuticals; has received consulting fees from Adventist Hinsdale Hospital, Arthrex, MAKO Surgical, Medacta, Pacira Pharmaceuticals, and Stryker; has received educational support from Arthrex, Breg, and Medwest; has received speaking fees from Arthrex and Pacira Pharmaceuticals; and receives royalties from Arthrex, DJO Global, MAKO Surgical, Stryker, and Orthomerica. B.G.D. is the Medical Director of Hip Preservation at St. Alexius Medical Center, a board member for the American Hip Institute Research Foundation, AANA Learning Center Committee, the *Journal of Hip Preservation Surgery*, and the *Journal of Arthroscopy*. The American Hip Institute Research Foundation fund research and is where this study was performed. R.W.-S. has received educational support from DePuy and Encore Medical; hospitality payments from Acumed and Globus Medical; and food/beverage and travel/lodging support from Arthrex, Stryker, and Smith & Nephew. P.J.R. has received food/beverage and travel/lodging support from Arthrex, Stryker, and Smith & Nephew. J.S. has received food/beverage and travel/lodging support from Arthrex, Stryker, and Smith & Nephew. A.C.L. has received educational support from Medwest and Smith & Nephew; research support from Arthrex, Stryker, and Medacta; food and beverage from Smith & Nephew, Stryker, Zimmer Biomet, Arthrex; travel and lodging from Stryker and Arthrex; and consulting fees from Arthrex and Graymont Medical. A.C.L. is the Medical Director of Hip Preservation at St. Alexius Medical Center. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Patient Demographics and Radiographic Findings[a]

	Repair	Reconstruction	*P* Value
Age at surgery, mean ± SD, y	34.98 ± 13.57	40.99 ± 11.74	<.001
BMI, mean ± SD, kg/m^2	25.69 ± 5.05	27.40 ± 5.42	<.001
Sex			
Male	413 (36)	116 (46)	.0032
Female	734 (64)	135 (54)	
Side			
Right	598 (52)	142 (58)	.2095
Left	549 (48)	109 (43)	
Tönnis grade			
0	976 (85)	158 (63)	<.001
1	171 (15)	93 (37)	
Coxa profunda			
Yes	253 (22)	60 (24)	.52491
No	894 (78)	191 (76)	
Protrusio acetabuli,[b] n			
Yes	0	2	
No	1147	249	

[a]Data are presented as n (%) unless otherwise specified. BMI, body mass index.
[b]The low number of cases was not amenable for a meaningful statistical comparison.

the reconstruction and repair groups were computed using either the *t* test for normally distributed samples or the nonparametric Wilcoxon rank-sum test otherwise. The *P* values for comparing categorical variables were computed using the Fisher exact test. A *P* value <.003 was considered significant.

Logistic Regression Model: Multivariate Analysis. All predictors were evaluated using a logistic regression model. For continuous variables, the linearity between the continuous predictor and the log odds of reconstruction (logit) was assessed via restricted cubic splines, and a linearizing transformation was found where needed. Variables were selected for the multivariate logistic model using the minimum Akaike information criterion. Odds ratios (ORs) with their corresponding 95% CIs and *P* values were reported. Additionally, 2-way interactions among the variables in the final model were evaluated. Model accuracy was reported and defined as the average of the percentage with repair correctly classified and the percentage with reconstruction correctly classified. The receiver operating characteristic (ROC) area under the curve was also reported as a measure of accuracy.

RESULTS

Radiographic Measurements and Demographics

A total of 251 hips (237 patients) that underwent primary labral reconstruction and 1147 hips (1063 patients) that underwent primary labral repair were identified from the institution's database as having met all inclusion criteria. There was a greater prevalence of Tönnis grade 1 in the reconstruction group than in the repair group (37% vs 15%, respectively; $P < .001$). Patients who underwent reconstruction had a greater degree of acetabular coverage by the LCEA (33.25° ± 7.31° vs 30.41° ± 6.22°, respectively; $P < .001$) and AI (3.45° ± 5.26° vs 4.77° ± 4.79°, respectively; $P = .0013$). Additionally, there was a greater disruption of femoral head-neck junction concavity as measured by the alpha angle (65.11° ± 13.21° vs 59.45° ± 12.21°, respectively; $P < .001$) and femoral offset (0.33 ± 0.26 vs 0.44 ± 0.28 cm, respectively; $P < .001$). The remainder of the radiographic measurements and demographics of the patients in the study are presented in Table 1. The mean age of patients who underwent reconstruction was 40.99 ± 11.74 years, while that of those who underwent repair was 34.98 ± 13.57 years. The mean BMI of the reconstruction and repair groups was 27.40 ± 5.42 and 25.69 ± 5.05 kg/m^2, respectively. There was a greater proportion of male patients in the reconstruction group (46% vs 36%, respectively; $P = .0032$).

Bivariate Analysis and Predictor Variable Search Results

The bivariate comparison revealed 9 variables that significantly differed between the repair and reconstruction groups, with $P < .003$: age at surgery, BMI, sex, Tönnis grade, LCEA, AI, ACEA, alpha angle, and femoral offset. Tables 1 and 2 summarize the findings from the analysis of demographic and radiographic variables, respectively.

Predictive Model for Labral Reconstruction Versus Repair

The logistic regression selected age, BMI, and 3 of the 14 radiographic measurements (Tönnis grade, LCEA, alpha angle). The odds of reconstruction were 2.52 times higher

TABLE 2
Continuous Radiographic Measurements[a]

	Repair	Reconstruction	*P* Value
Ischial spine sign, cm	0.35 ± 0.43	0.35 ± 0.48	.3791
Crossover sign, %	12.90 ± 15.74	13.21 ± 17.22	.7027
LCEA, deg	30.41 ± 6.22	33.25 ± 7.31	<.001
AI, deg	4.77 ± 4.79	3.45 ± 5.26	.0013
Medial joint space, cm	0.36 ± 0.10	0.37 ± 0.10	.1037
Central joint space, cm	0.38 ± 0.09	0.38 ± 0.09	.7589
Lateral joint space, cm	0.44 ± 0.11	0.44 ± 0.12	.2275
Neck shaft angle, deg	133.30 ± 5.68	133.00 ± 5.62	.2942
ACEA, deg	31.04 ± 7.02	32.99 ± 8.37	<.001
Alpha angle, deg	59.45 ± 12.21	65.11 ± 13.21	<.001
Femoral offset, cm	0.44 ± 0.28	0.33 ± 0.26	<.001

[a]Data are presented as mean ± SD. ACEA, anterior center-edge angle; AI, acetabular index; LCEA, lateral center-edge angle.

in those with Tönnis grade 1 than 0 (OR, 2.52 [95% CI, 1.82-3.49]). Every additional degree in the LCEA was associated with a 6% increase in the odds of reconstruction (OR, 1.06 [95% CI, 1.04-1.09]) and 4% for each additional degree in the alpha angle (OR, 1.04 [95% CI, 1.03-1.05]) (Figure 1 and Table 3). While AI was significant in the bivariate analysis, AI did not add to the final model when controlling for LCEA. AI and LCEA were found to be negatively correlated ($R = -0.59$) and subsequently removed from consideration (Figure 2). Higher age (per log 10 unit) and BMI were also found to increase the likelihood of reconstruction (OR, 11.29 [95% CI, 4.23-30.10] and OR, 1.03 [95% CI, 1.00-1.06], respectively). While BMI was borderline statistically significant, the choice was made to include the variable because of clinical relevance.[3] The multivariate logistic regression model is included in Table 3. The nominal model accuracy was 70.5% with an ROC area of 0.74. The equation for the model calculator is as follows:

$$\textit{predicted need for primary labral reconstruction} = \frac{e^x}{1+e^x},$$

where e^x is the odds of reconstruction, and $x = -10.59 + 0.925$ Tönnis grade $+ 0.061$ LCEA $+ 0.039$ alpha angle $+ 2.424$ age $+ 0.026$ BMI.

DISCUSSION

This study analyzed 18 variables in a cohort of 1398 hip arthroscopic procedures performed by a single surgeon (B.G.D.) to identify radiographic and demographic factors that are predictive of the need for primary labral reconstruction. The initial bivariate analysis between the reconstruction and repair groups found that 8 preoperative variables were significantly different. Demographically, the reconstruction group was older ($P < .001$), had a higher BMI ($P < .001$), and was proportionally more male ($P = .0032$). Radiographically, the reconstruction group had a greater proportion of hips with Tönnis grade 1 ($P < .001$), greater LCEA ($P < .001$), lower AI ($P = .0013$), higher ACEA ($P < .001$), and higher alpha angle ($P < .001$). The multivariate analysis identified age, BMI, Tönnis grade, LCEA, and alpha angle as predictors for reconstruction.

Nakashima et al[32] identified predictors of an unsalvageable labral tear at the time of initial hip arthroscopic management of FAI. From the results and findings, they concluded that age >45 years, BMI ≥23.1 kg/m^2, and vertical center anterior angle ≥36° were risk factors for an unsalvageable labral tear at initial hip arthroscopic surgery for patients with FAI.[32] In their study methodology, the authors included preoperative and minimum 2-year follow-up patient-reported outcomes (PROs) as part of their inclusion criteria. The repair and reconstruction groups achieved comparable outcomes. As with Utsunomiya et al[43] in their predictive model for severe cartilage damage in the hip based on 2396 hip arthroscopic procedures, we decided not to include PROs because (1) a comparison of outcomes in the short term and midterm between labral reconstruction and labral repair performed at our institution (American Hip Institute) has been published[9,13] and (2) the power of the study would have been decreased by this approach. A major limitation mentioned by Nakashima et al[32] in their study was that the labral reconstruction group was small (25 patients). The reconstruction group of the current study included 251 primary labral reconstruction procedures. The findings and conclusions of the current study validate those presented by Nakashima et al.

In a recent systematic review, Al Mana et al[1] stated that conclusions could be made in regard to age and its association with PROs after labral reconstruction. Poorer outcomes have been associated with older age at the time of hip arthroscopic surgery.[18] Frank et al[21] reported that patients older than 45 years performed worse compared with younger patients. Nevertheless, the authors stated that physiological age instead of chronological age alone may be more representative of the durability of the hip joint, which is a concept that we share. Currently, there is no age cutoff for patients undergoing labral reconstruction.[27] According to Herickhoff and Safran,[24] the

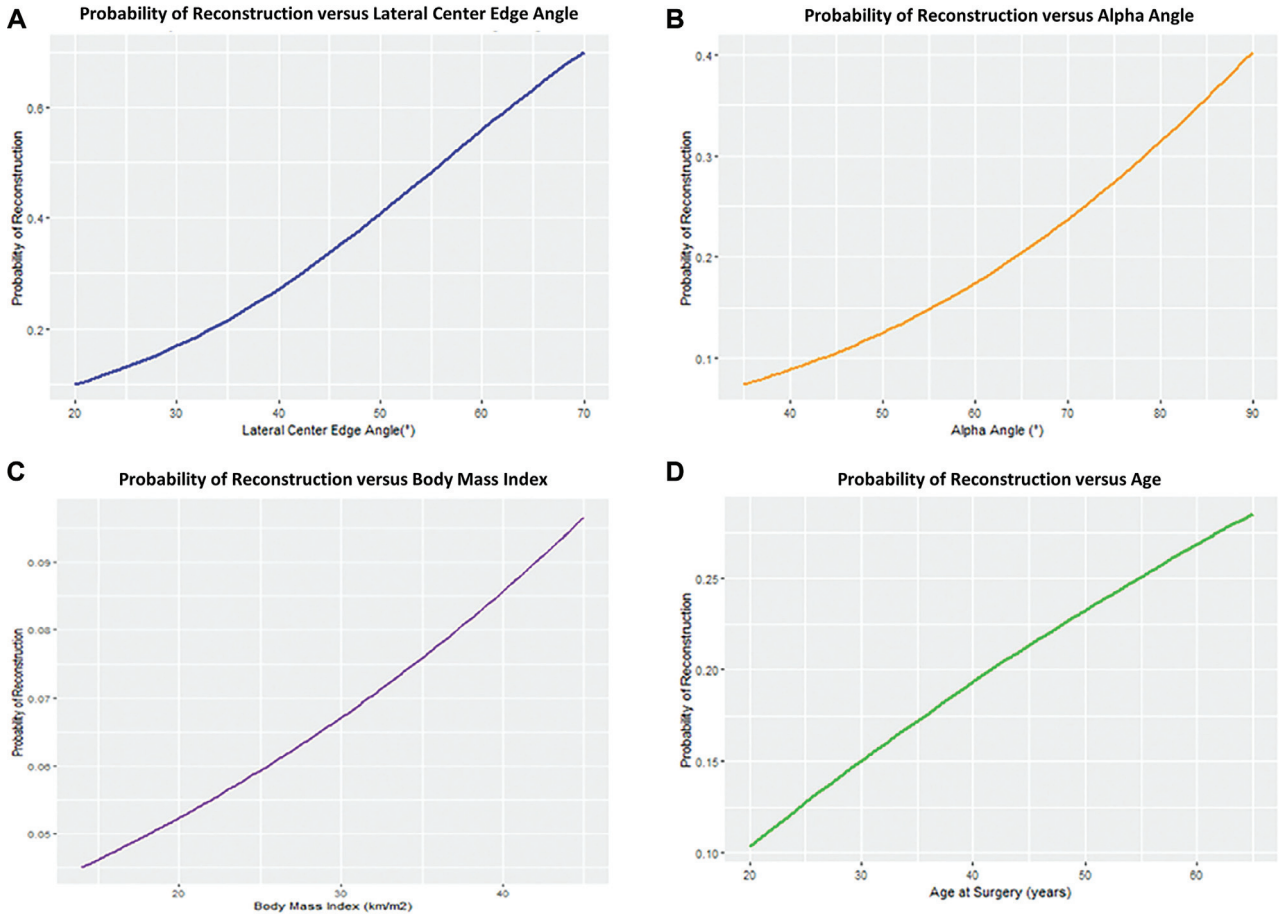

Figure 1. Plots show the probability of reconstruction for an increase in (A) lateral center-edge angle, (B) alpha angle, (C) body mass index, and (D) age.

TABLE 3
Logistic Regression Model Predicting Labral Reconstruction Versus Repair[a]

Predictor	Log OR	SE	OR	95% CI	*P* Value
Tönnis grade 1 vs 0	0.925	0.166	2.52	1.82-3.49	<.001
LCEA per degree	0.061	0.011	1.06	1.04-1.09	<.001
Alpha angle per degree	0.039	0.006	1.04	1.03-1.05	<.001
Age per log 10 unit	2.424	0.500	11.29	4.23-30.10	<.001
BMI per kg/m^2	0.026	0.014	1.03	1.00-1.06	.0664

[a]Accuracy of 70.5% and receiver operating characteristic area of 0.74. BMI, body mass index; LCEA, lateral center-edge angle; OR, odds ratio.

intraoperative appearance of the labrum is the single most important factor for labral treatment decisions. We cannot provide the specific reason behind age being an important variable for the preoperative model of the need for labral reconstruction; however, we suggest that older age may be associated with more severe intra-articular damage, which has been previously reported by others.[21] The association of increased age and increased labral tear severity has also been recently reported.[32,41]

As mentioned before, Tönnis grade was found to be an important preoperative predictor as well. Presently, there is a paucity in the literature on this distinct topic. Maldonado et al[28] published their results on arthroscopic primary labral reconstruction with severe acetabular chondral damage. A total of 38 primary segmental reconstruction procedures were matched 1:1 to 38 primary segmental resection procedures based on Tönnis grade, age, sex, BMI, acetabular microfracture performance, and

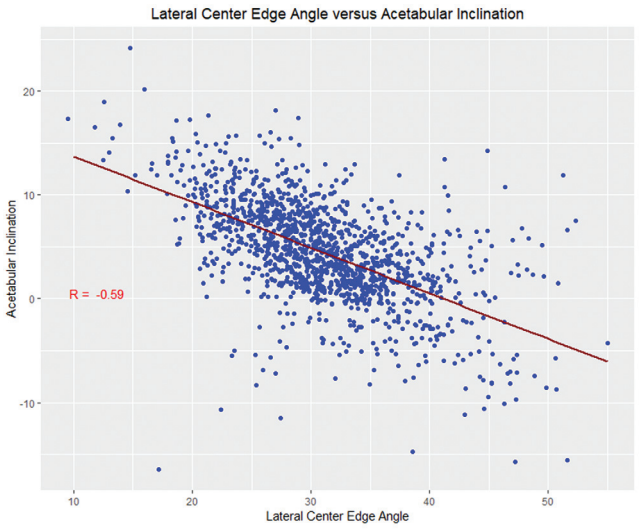

Figure 2. Correlation between lateral center-edge angle and acetabular inclination. Pearson $R = -0.59$.

femoral Outerbridge grade, with both groups having acetabular Outerbridge grade III or IV cartilage lesions. At a minimum 2-year follow-up, comparable outcomes were obtained for both groups. However, the group that underwent segmental labral resection was 4 times more likely to require a conversion to total hip arthroplasty.

Most of the literature surrounding labral reconstruction focuses on specific distinctions between techniques and PROs.[1] Domb et al,[14] in a minimum 2-year follow-up comparison between labral reconstruction and debridement in cases of irreparable labral tears, found that the former group achieved superior scores on the Non-Arthritic Hip Score and Hip Outcome Score–Activities of Daily Living subscale.

In the primary setting, Chandrasekaran et al[9] published a comparison of 34 patients who underwent segmental labral reconstruction with a pair-matched group of 68 patients who underwent labral repair. At a minimum 2-year follow-up, the study revealed comparable improvements in PROs, patient satisfaction, and the incidence of secondary procedures.[9]

Scanaliato et al[41] also reported short-term follow-up (mean, 24 months) outcomes of primary labral reconstruction versus repair. The authors compared PROs of 94 labral repair and 58 circumferential reconstruction procedures and found comparable improvements in both groups. Previously, Lebus et al[25] presented a predictive model for PROs at a minimum 2-year follow-up for 234 patients who underwent labral reconstruction. The authors reported that higher preoperative PROs were the most significant predictors of improvement. Lower PROs, joint space narrowing, and previous surgery were predictive of inferior results and satisfaction.[25]

Domb et al[13] recently published their results with a minimum 5-year follow-up with labral reconstruction for irreparable labral tears using a segmental technique. In a nested pair–matched study, the authors matched 17 primary reconstruction cases to 51 primary repair cases based on age, sex, and BMI. Comparable midterm outcomes were found between groups for several PROs (modified Harris Hip Score, Non-Arthritic Hip Score, Hip Outcome Score–Sports-Specific Subscale). Nonetheless, patient satisfaction was still significantly better for the labral repair group. Furthermore, the authors stated that the findings suggest, at least in cases of reparable tears, that primary repair remains a stronger treatment option. While arthroscopic reconstruction indicates promising short-term and midterm results, it is a technically difficult procedure that requires considerable preparation and surgical training.[30] The findings in this study allow for preoperative anticipation of potential primary labral reconstruction. Specifically, surgeons who plan to perform arthroscopic labral reconstruction and are in the early phase of the learning curve can better anticipate reconstruction.[15,29,35,44,45,48]

To our knowledge, this study is one of the first to discuss radiographic predictor factors for labral management. A total of 18 variables (14 radiographic measurements from 3 views and 4 demographic factors) were considered for the predictive model. The incorporation of multiple measurements along with different radiographic views provides more comprehensive information on the morphology of the hip joint.

Limitations

These findings and the model presented are limited by the number of variables collected by the institution's database; thus, variables that might be predictive but not recorded by the institution could not be considered for the model. This is reflected in the final model accuracy of 70.5% and an ROC area of 0.74, which implies that while the 5 factors reported are important, there may be other factors not among the 18 considered. While magnetic resonance imaging has an important role in preoperative decision making, this variable was not included in the predictive model. Additionally, given that data were used from a single institution's database and that the decision to reconstruct or repair was made by a single surgeon, the generalizability of these findings is limited. As such, this would benefit from external validation.

CONCLUSION

In a multivariate analysis, factors identified as preoperative predictors for primary arthroscopic labral reconstruction in the setting of FAI and labral tears were Tönnis grade, LCEA, alpha angle, age, and BMI. These predictive factors may be useful for the clinician in determining the preoperative likelihood of primary labral reconstruction.

ACKNOWLEDGMENT

The authors thank Dr Jeffrey Gorbein, principal statistician of the Division of General Internal Medicine and Health Services Research at the University of California, Los Angeles, for the support given in statistical work and predictive model creation.

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