Labral Injury: Radiographic Predictors at the Time of Hip Arthroscopy

John M. Redmond, M.D., Asheesh Gupta, M.D., Jon E. Hammarstedt, B.S., Christine E. Stake, M.A., Kevin F. Dunne, B.S., and Benjamin G. Domb, M.D.

Purpose: The purpose of this study was to investigate the influence of multiple demographic and radiographic findings on the size of labral tears identified at the time of hip arthroscopy. **Methods:** Data were prospectively collected for patients treated with arthroscopic labral repair or debridement from February 2008 to August 2011. Preoperative radiographic and demographic data were collected for 392 patients during the study period. Exclusion criteria included revision surgery and previous hip conditions. An anteroposterior pelvic view, 45° Dunn view, and false-profile view were used to measure Tönnis grade, neck-shaft angle, alpha angle, lateral center edge angle (LCEA), anterior center edge angle (ACEA), acetabular inclination, and the extent of crossover sign when present. At the time of surgery, labral tear size and location were documented for all patients, using traditional acetabular clock face nomenclature for sizing. A multiple linear regression analysis was then performed to assess the correlation of radiographic and demographic findings with the size of the labral tear. **Results:** Regression analysis displayed statistical significance for sex ($P < .0001$), age ($P < .0001$), and alpha angle ($P = .005$) with labral tear size. For female patients, Tönnis grade ($P = .0004$) and neck-shaft angle ($P = .004$) correlated with labral tear size. This model accounted for only 26% of variation in labral tear size. **Conclusions:** Preoperative risk factors for the extent of labral tear size are male sex, increasing age, and increasing alpha angle. Labral tears were larger in female patients with higher Tönnis grades and lower neck-shaft angles. Measurements of acetabular coverage and version showed no correlation with labral tear size. The majority of labral tear size variation was not accounted for in this model. **Level of Evidence:** Level IV, therapeutic case series.

Femoroacetabular impingement (FAI) and hip dysplasia are frequently seen in young adults with hip pain.[1-3] FAI results from abnormal bony contact between the femoral head-neck junction against the acetabulum and has been divided into cam and pincer morphologic types.[1,2] Hip dysplasia results in structural instability and acetabular rim overload.[4] Both of these conditions may contribute to an environment that leads to labral and chondral damage.

From American Hip Institute (A.G., J.E.H., C.E.S., K.F.D., B.G.D.), Westmont, Illinois; and the Department of Orthopedic Surgery, Mayo Clinic (J.M.R.), Jacksonville, Florida, U.S.A.

The authors report the following potential conflict of interest or source of funding: B.G.D. receives support from Arthrex, Pacira, Mako Surgical, American Hip Institute, Breg, MedWest, Athletic and Therapeutic Institute, Orthomerica, DJO Global, and Stryker.

Received March 11, 2014; accepted July 2, 2014.

Address correspondence to Benjamin G. Domb, M.D., American Hip Institute, A1010 Executive Ct No. 250, Westmont, IL 60559, U.S.A. E-mail: drdomb@americanhipinstitute.org

0749-8063/14207/$36.00
http://dx.doi.org/10.1016/j.arthro.2014.07.002

Early chondrolabral damage precedes joint space narrowing, and multiple radiographic parameters have been proposed as possible predictors of chondrolabral injury.[5,6] The extent to which radiographic findings correlate with premature joint damage is not fully understood. There are studies in the literature that note a correlation between radiographic findings and chondrolabral pathologic processes as well as studies that are unable to detect a correlation.[7-10] Additionally, radiographic findings of FAI are highly prevalent among an asymptomatic population.[11,12] Murphy et al.[13] have also shown that dysplasia frequently leads to degenerative changes in the hip.

The clinical examination remains imperative when evaluating young patients with hip disease; however, demographic and radiographic risk factors for chondrolabral damage may help guide treatment. Knowledge of radiographic risk factors for chondrolabral damage may help tailor bony correction during FAI and dysplasia treatment. The purpose of this study was to investigate the influence of multiple demographic and radiographic findings on the size of labral tears identified at the time of hip arthroscopy. We hypothesized that increased age, increased Tönnis grade, increased alpha angle, decreased lateral center edge angle (LCEA), decreased anterior center edge angle (ACEA), increased crossover percentage, increased acetabular inclination, and decreased neck-shaft angle would all correlate with labral injury.

Methods

A retrospective cross-sectional study was performed in patients treated with arthroscopic labral repair or debridement from February 2008 to August 2011. Inclusion criteria were patients undergoing arthroscopic labral treatment who had radiographic measurements entered into our database. At the time of this study, patients who completed 2-year follow-up triggered radiographic review and input into our database. This does not represent a consecutive series of patients. Exclusion criteria were revisions and patients with previous hip conditions such as Legg-Calves-Perthes disease and avascular necrosis. Demographic data were recorded for age and sex. Our institutional review board approved this study. Radiographic and demographic data were collected preoperatively on 392 patients. An anteroposterior pelvic view, 45° Dunn view, and false-profile view were used for radiographic measurements.

Indications for Surgery

Clinically, all patients had signs and symptoms of a labral tear for longer than 3 months for which nonoperative treatment failed. Signs and symptoms of a labral tear included groin pain, pain surrounding the hip, and positive impingement test results. Nonoperative treatment included a minimum of 6 weeks of physical therapy. Before surgery, all patients underwent plain radiography, as described earlier.[5] Patients also underwent preoperative magnetic resonance imaging or magnetic resonance imaging arthrography to confirm labral pathologic processes.

Surgical Technique

All surgical procedures were performed by the senior author (B.G.D.) with the patient in the modified supine position using a minimum of 2 portals.[14,15] After establishment of portals and capsulotomy, diagnostic arthroscopy of the hip joint was performed, which included measuring the size of the labral tear.

Data Recording

At our institution, a detailed intraoperative data sheet is recorded for all patients undergoing hip arthroscopy. At the time of surgery, labral tear size was documented for all patients, using traditional acetabular clock face nomenclature to determine size and location of the tear (Fig 1).[10] Labral tears were described using the Seldes classification, with type 1 tears being separation at the chondrolabral junction, and type 2 tears being intrasubstance damage.[16] To describe the position of the labral tear, the acetabulum is divided into 12 sectors corresponding to a clock face.[10] Three o'clock represents the most anterior aspect of the acetabulum and 12 o'clock is the most superior. Labral tear size was documented by recording the number of sectors involved in the tear. For example, a tear from 12 o'clock to 3 o'clock involved 3 sectors. Tears were measured in half-sector increments, and no attempt was made to measure tear size in smaller increments.

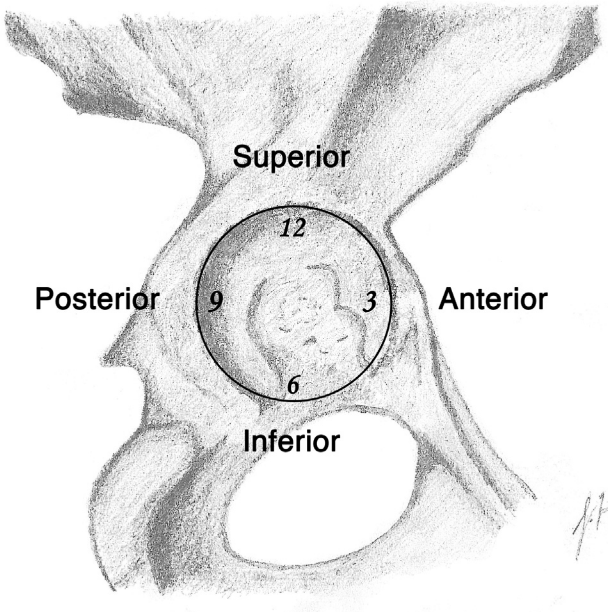

Fig 1. Acetabulum with clock face. The 3 o'clock position is the most anterior and the 9 o'clock is the most posterior.

Radiographic Measurements

At our institution, radiographic data on all patients undergoing hip arthroscopy are recorded after 2-year follow-up by hip preservation fellows. The measurements were taken by multiple readers; however, previous interobserver reliability has been shown for our group.[17] Using the anteroposterior pelvis radiograph, the LCEA, acetabular inclination, acetabular crossover, and femoral neck-shaft angle were measured.[5] When a crossover sign was present, we estimated the percent of crossover by dividing distance from the superior acetabulum to the point of intersection of the anterior and posterior wall by the entire length of the posterior wall. This was done to gauge the amount of acetabular retroversion. A 45° Dunn view was used to measure the alpha angle.[5] A false-profile view was used to measure the ACEA.[5]

Statistics

The simultaneous influence of the 9 potential predictors on size was assessed using backward stepwise linear regression with a liberal $P < .10$ variable

Table 1. Study Group Demographics

Sex			
Male	Female	Age, y (range)	
160	232	37.7	(14.2-76.4)

retention criterion. All possible 2-way interactions among the variables were considered except those with ACEA. Knotted splines were fit for LCEA and ACEA to allow for a nonmonotone association because these variables were expected to have nonmonotone relations with size. Resampling ("bootstrap") estimates of the final regression coefficients and their standard errors were computed and compared with the usual (least square) estimates to determine if the usual estimates were consistent.

Results

Radiographs

The study included 392 patients with hip radiographs. There were 160 male patients (mean age, 40.2 years; range, 15.7 to 74.9 years) and 232 female patients (mean age, 36.0 years; range, 14.2 to 76.4 years). Patient demographic data are detailed in Table 1. The mean labral tear size was 2.9 ± 1.2 clock sectors (Fig 2).

Multiple Linear Regression

Statistical data for each category are detailed in Table 2. Regression analysis displayed statistical significance for sex ($P < .0001$), age ($P < .0001$), and alpha angle ($P = .005$) with labral tear size. For female patients, Tönnis grade ($P = .0004$) and neck-shaft angle ($P = .004$) correlated with labral tear size (Table 3). No correlation between labral tear size and LCEA, ACEA, acetabular inclination, or extent of crossover sign was seen. Adjusting for all variables in the model, male patients exhibited a larger labral tear of 0.51 sectors ($P = .001$) when compared with tears of female patients.

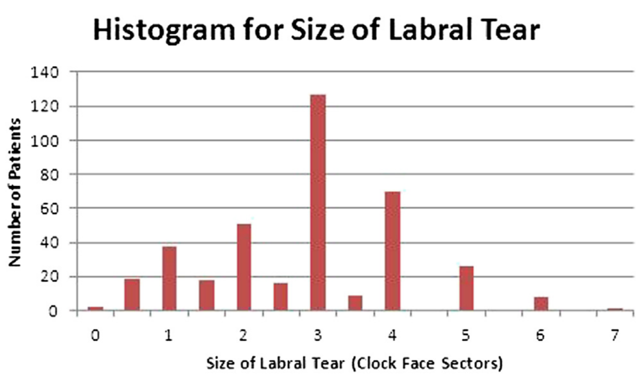

Fig 2. Histogram for labral tear size determined intra-operatively for the study cohort of 392 patients.

Table 2. Statistical Metrics for the Dependent Variable (Labral Tear Size) and 8 of 9 Predictor Variables

	Count	Average	Range	SD
Labral tear size		2.9	0.0-7.0	1.3
Age	392	37.7	14.2-76.4	14.3
Tönnis grade	392	0.4	0.0-3.0	0.6
Neck-shaft angle	367	130.3	122.0-141.0	2.8
Alpha angle	376	59.8	32.0-105.0	12.5
LCEA	392	29.8	11.0-49.0	6.2
Acetabular inclination	392	4.4	−11.0-20.0	4.9
ACEA	206	30.4	3.0-55.0	8.5
Crossover %	389	14.9	0.0-65.0	17.1

ACEA, anterior center edge angle; LCEA, lateral center edge angle; SD, standard deviation.

The mean age of all patients in the study was 37.7 years, with the youngest patient being 14.2 years and the oldest patient being 76.4 years. The multivariate regression statistical model suggests a positive correlation between age and labral tear size. An increase in age by 1 year for male patients and female patients correlates to an increase in labral tear size of 0.02 sectors ($P < .0001$) and for an increase in age of 25 years, the labral tear size increased 0.5 sectors.

Of the 392 patients in the study, the mean alpha angle was 59.8°, with a low of 32° and a high of 105°. The statistical model suggested that as the alpha angle increases by 1°, the size of the labral tear increases by 0.016 sectors ($P = .005$). In other words, for every 10° change in alpha angle, the tear size increases 0.16 sectors. The positive relationship between alpha angle and an increase in labral tear size was not sex dependent.

There were 267, 110, and 14 patients in the study group with Tönnis grades of 0, 1, and 2, respectively. One patient had a Tönnis grade of 3. The statistical model suggests a positive relation between Tönnis grade and size of labral tear. For female patients, an increase in the Tönnis grade by one increases labral tear size by 0.66 sectors ($P = .0004$). Male patients displayed a similar positive trend, with an increase in Tönnis grade increasing the size of the labral tear by 0.22 sectors; however, there was no statistical significance ($P = .165$).

The 232 female patients in the study had a mean neck-shaft angle of 130.4°, with a low of 122° and a high of 141°. For female patients, an inverse relationship was seen, because the size of the labral tear decreased by a mean of 0.09 sectors for an increase in 1° of the neck-shaft angle ($P = .0044$). To the contrary, for male patients, the size of the labral tear displayed no statistical significance with neck-shaft angle. Of the 160 male patients in the study, the mean neck-shaft angle was 130.2°, with a high of 138° and a low of 122°.

Variation

This model using the factors described accounts for only about 26% of the variation in size ($R^2 = 0.264$),

Table 3. Multivariate Linear Regression Model Comparing 9 Variables

Predictor	Effect of Labral Tear Size	Standard Error	*P* Value
Age (per year)	0.0203	0.005	<.0001
Male/female difference	0.510	0.134	<.0001
Alpha angle (per degree)	0.016	0.006	.0050
Tönnis grade, female	0.656	0.182	.0004
Tönnis grade, male	0.216	0.155	.1648
Neck-shaft angle, female	−0.092	0.032	.0044
Neck-shaft angle, male	0.019	0.034	.5711
Acetabular inclination			.2802
LCEA			.3004
ACEA			.7723
Crossover			.3073

ACEA, anterior center edge angle; LCEA, lateral center edge angle.

i.e., most of the variation in labral tear size is not accounted for by these factors.

Discussion

In this study we were able to identify several preoperative variables that correlated with labral tear size: male sex, age, and alpha angle. Labral tears were larger in female individuals with higher Tönnis grades and lower neck-shaft angles. In addition to a thorough clinical examination of young patients with hip disease, radiographic analysis is key to understanding the mechanism of impingement or dysplasia. Most labral tears occur in the setting of radiographic abnormalities, and failure to address abnormal bony morphologic processes during hip preservation surgery has been shown to be a risk factor for revision surgery.[18,19] The current study correlates radiographic findings with the amount of labral damage at the time of arthroscopy. The major findings of this analysis are that femoral morphologic characteristics correlated with labral tear size more than acetabular morphologic characteristics. We found no correlation for labral tear size when evaluating acetabular coverage or version. Cam lesions and, in female patients, femoral neck-shaft angle were independent risk factors for labral tear size. Male individuals tended to have larger labral tears. We also found that most of the variation in labral tear size could not be predicted by the markers we evaluated.

Cam lesions have been associated with hip pathologic processes since the introduction of “pistol grip” and “head tilt” deformities.[20,21] Johnston et al.[8] evaluated the relationship between the size of cam lesions and the presence of cartilage and labral damage. Larger cam lesions were associated with full-thickness chondral defects and labral detachment. In this article, the authors also noted that as a patient’s alpha angle increased, so did the amount of chondral damage. In another recent study by Van Thiel et al.,[22] patients younger than 50 years of age undergoing total hip arthroplasty were more likely to have a larger alpha angle than were patients older than 50 years. Our study essentially confirms these findings, although we used labral tear size as a marker for the degree of injury.

The femoral neck shaft angle has been evaluated as a predictor of hip pathologic conditions. In a study by Guevara et al.,[23] no correlation was seen between patients with labral tears and a control group for neck-shaft angle. However, Ranawat et al.[24] noted hip symptoms in patients with decreased hip neck-shaft angle compared with asymptomatic patients. The current study also identified larger labral tears in female individuals with lower neck-shaft angles, although this was not seen in male individuals. In patients with low-grade hip dysplasia, the femur often shows coxa valga and increased anteversion.[25] The current study found coxa vara to be associated with larger tears in female patients; it therefore seems unlikely that the mechanism of labral tears in this cohort was caused by dysplasia. Patients with coxa vara may be more predisposed to femoral retroversion and therefore impingement.[26] Further study is needed to quantify this relationship.

Kappe et al.[9] compared radiographs to surgical findings in 123 hips undergoing surgery for FAI. All patients in this series underwent femoral osteoplasty through an open surgical hip dislocation or an anterior approach to the hip. Radiographic analysis included LCEA, inclination of the acetabulum, lateral head extrusion index, acetabular retroversion, neck-shaft angle, alpha angle, femoral offset, Tönnis grade, and Kellgren and Lawrence grade. In this study, 55% of patients had a labral tear and only the degree of osteoarthritis and age correlated with labral pathologic conditions. The current study also found a correlation between age and Tönnis grade with labral tear size. However, we also detected a radiographic correlation with labral tear size for alpha angle and, in female individuals, neck-shaft angle. It should be noted that all patients in the current study underwent hip arthroscopy, which, in our opinion, is likely more sensitive than open surgical hip dislocation or an anterior approach for detecting chondrolabral pathologic processes.[27]

In the current study, male patients tended to have larger labral tears than did female patients, controlling for all other radiographic risk factors. Although male individuals have been shown to have a higher degree of cam lesions and less anteversion, the current study controlled for the effect of alpha angle and still noted larger tears in the male patients.[28] It is possible that relative femoral retroversion plays a role in men having larger labral tears; however, further research is necessary.

In the current study, age and Tönnis grade also correlated with labral tear size. Because labral tears have been considered a precursor to hip osteoarthritis, the correlation between labral tear size and Tönnis grade is not surprising.[29] Age likely reflects a longer exposure to conditions such as FAI and dysplasia and again is not a surprising correlation.

This study found a number of risk factors for labral tear size. We used this end point as a surrogate for the amount of intra-articular damage; however, we realize this is debatable and does not include extent of chondral injury. It should be noted that the risk factors in this model accounted for only 26% of variation in labral tear size. That said, the risk factors can be used clinically to counsel patients. For example, male individuals with large alpha angles might be expected to have greater intra-articular damage at the time of hip arthroscopy, and this may alter the postoperative course.

The strengths of the current study include the largest correlation between arthroscopic and radiographic risk factors in the literature. A multivariate regression analysis was performed, which allowed age, Tönnis grade, and sex to be controlled for when evaluating femoral and acetabular morphologic risk factors.

Limitations

This study has several limitations. First, we looked at 9 variables in the multiple linear regression. These variables accounted for only 26% of variation in this model, and obviously other factors, which we did not identify, play a large role in labral injury. Clearly, there are other radiographic variables that play a role in FAI and dysplasia. It is likely that femoral version plays a role in determining labral tear size; however, 3-dimensional imaging of the femoral axis was unavailable for many of the patients in this study. Second, multiple readers measured radiographs over a period of years. This did allow us to include a large number of patients, and other studies have shown reliability between readers.[23,24] Third, this represents a nonuniform group of patients undergoing hip arthroscopy in our database. The labral tears are caused by FAI, borderline dysplasia, traumatic injury, and ligamentous laxity. Finally, to our knowledge, the ability to measure labral tear size arthroscopically has not been validated.

Conclusions

Preoperative risk factors for the extent of labral tear size are male sex, age, and alpha angle. Labral tears were larger in female individuals with higher Tönnis grades and lower neck-shaft angles. Measurements of acetabular coverage and version showed no correlation with labral tear size. Most labral tear size variation was not accounted for in this model.

Acknowledgement

The authors thank Luke Cramer, M.D., Youssef El Bitar, M.D., Timothy Jackson, M.D., Dror Lindner, M.D., and Jeffrey Gornbein, Ph.D, for their assistance with radiographic measurements and statistics.

References

1. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: Femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br* 2005;87:1012-1018.
2. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: A cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2003:112-120.
3. Klaue K, Durnin CW, Ganz R. The acetabular rim syndrome. A clinical presentation of dysplasia of the hip. *J Bone Joint Surg Br* 1991;73:423-429.
4. Leunig M, Ganz R. [The Bernese method of periacetabular osteotomy]. *Orthopade* 1998;27:743-750 [in German].
5. Clohisy JC, Carlisle JC, Beaulé PE, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am* 2008;90:47-66 (suppl 4).
6. Clohisy JC, Dobson MA, Robison JF, et al. Radiographic structural abnormalities associated with premature, natural hip-joint failure. *J Bone Joint Surg Am* 2011;93:3-9 (suppl 2).
7. Ejnisman L, Philippon MJ, Lertwanich P, et al. Relationship between femoral anteversion and findings in hips with femoroacetabular impingement. *Orthopedics* 2013;36:e293-e300.
8. Johnston TL, Schenker ML, Briggs KK, Philippon MJ. Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. *Arthroscopy* 2008;24:669-675.
9. Kappe T, Kocak T, Bieger R, Reichel H, Fraitzl CR. Radiographic risk factors for labral lesions in femoroacetabular impingement. *Clin Orthop Relat Res* 2011;469:3241-3247.
10. Tannast M, Goricki D, Beck M, Murphy SB, Siebenrock KA. Hip damage occurs at the zone of femoroacetabular impingement. *Clin Orthop Relat Res* 2008;466:273-280.
11. Hack K, Di Primio G, Rakhra K, Beaulé PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. *J Bone Joint Surg Am* 2010;92:2436-2444.
12. Jung KA, Restrepo C, Hellman M, AbdelSalam H, Morrison W, Parvizi J. The prevalence of cam-type femoroacetabular deformity in asymptomatic adults. *J Bone Joint Surg Br* 2011;93:1303-1307.
13. Murphy SB, Ganz R, Müller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am* 1995;77:985-989.
14. Byrd JW. Hip arthroscopy: The supine position. *Instr Course Lect* 2003;52:721-730.
15. Kelly BT, Weiland DE, Schenker ML, Philippon MJ. Arthroscopic labral repair in the hip: Surgical technique and review of the literature. *Arthroscopy* 2005;21:1496-1504.
16. Seldes RM, Tan V, Hunt J, Katz M, Winiarsky R, Fitzgerald RH Jr. Anatomy, histologic features, and vascularity of the adult acetabular labrum. *Clin Orthop Relat Res* 2001:232-240.

17. Domb BG, Martin DE, Botser IB. Risk factors for ligamentum teres tears. *Arthroscopy* 2013;29:64-73.
18. Wenger DE, Kendell KR, Miner MR, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. *Clin Orthop Relat Res* 2004:145-150.
19. Philippon MJ, Maxwell RB, Johnston TL, Schenker M, Briggs KK. Clinical presentation of femoroacetabular impingement. *Knee Surg Sports Traumatol Arthrosc* 2007;15:1041-1047.
20. Murray RO. The aetiology of primary osteoarthritis of the hip. *Br J Radiol* 1965;38:810-824.
21. Stulberg SD, Cordell LD, Harris WH, Ramsey PL, MacEwen GD. Unrecognized childhood hip disease: A major cause of idiopathic osteoarthritis of the hip. In: Amstutz HC, ed. *The hip*. Maryland Heights: C. V. Mosby, 1975;212-228.
22. Van Thiel GS, Harris JD, Kang RW, et al. Age-related differences in radiographic parameters for femoroacetabular impingement in hip arthroplasty patients. *Arthroscopy* 2013;29:1182-1187.
23. Guevara CJ, Pietrobon R, Carothers JT, Olson SA, Vail TP. Comprehensive morphologic evaluation of the hip in patients with symptomatic labral tear. *Clin Orthop Relat Res* 2006;453:277-285.
24. Ranawat AS, Schulz B, Baumbach SF, Meftah M, Ganz R, Leunig M. Radiographic predictors of hip pain in femoroacetabular impingement. *HSS J* 2011;7:115-119.
25. Argenson JN, Flecher X, Parratte S, Aubaniac JM. Anatomy of the dysplastic hip and consequences for total hip arthroplasty. *Clin Orthop Relat Res* 2007;465:40-45.
26. Tönnis D, Heinecke A. Acetabular and femoral anteversion: Relationship with osteoarthritis of the hip. *J Bone Joint Surg Am* 1999;81:1747-1770.
27. Redmond JM, Gupta A, Stake CE, Domb BG. The prevalence of hip labral and chondral lesions identified by method of detection during periacetabular osteotomy: Arthroscopy versus arthrotomy. *Arthroscopy* 2014;30:382-388.
28. Hetsroni I, Dela Torre K, Duke G, Lyman S, Kelly BT. Sex differences of hip morphology in young adults with hip pain and labral tears. *Arthroscopy* 2013;29:54-63.
29. McCarthy JC, Noble PC, Schuck MR, Wright J, Lee J. The Otto E. Aufranc Award: The role of labral lesions to development of early degenerative hip disease. *Clin Orthop Relat Res* 2001:25-37.