# Acetabular Rim Reduction for the Treatment of Femoroacetabular Impingement Correlates With Preoperative and Postoperative Center-Edge Angle

Marc J. Philippon, M.D., Andrew B. Wolff, M.D., Karen K. Briggs, M.P.H., Chad T. Zehms, M.D., and David A. Kuppersmith, B.S.

**Purpose:** The purpose of this study was to quantify the change in degrees in the center-edge (CE) angle for each millimeter of acetabular rim resected in hips undergoing arthroscopic acetabular rim trimming. **Methods:** Preoperative and postoperative CE angle and millimeters of rim reduction were prospectively collected in 58 hips that underwent arthroscopic rim reduction. There were 35 women and 23 men. The mean age was 32 years. The inclusion criterion was hip arthroscopy for femoroacetabular impingement in patients without dysplastic hips. Two orthopaedic surgeons made independent measurements of the CE angle on preoperative and postoperative anteroposterior pelvis radiographs. To determine the amount of rim reduction intraoperatively, the lunate surface was measured with an arthroscopic ruler at the 12-o'clock position before and after rim trimming. The rim trimming was performed by a single surgeon using a 5.5-mm motorized bur. **Results:** For the 58 hips included in this study, the mean rim reduction performed was 3.2 mm (range, 1 to 9 mm). The mean change in CE angle was 3.9° (range, 0° to 17°). All numbers were normally distributed. By use of a regression model, the change in the CE angle could be determined by the following formula: Change in CE angle $= 1.8 + (0.64 \times$ rim reduction in millimeters). The interobserver intraclass correlation coefficient for radiographic measurement of the CE angle was 0.92 (95% confidence interval, 0.87 to 0.95), indicating excellent interobserver reliability. **Conclusions:** The amount of change in the CE angle can be estimated by the amount of bony resection performed at the 12-o'clock position on the lunate surface in the arthroscopic treatment of femoroacetabular impingement. We found that 1 mm of bony resection equals 2.4° of change in the CE angle and 5 mm of bony resection equals 5° of change in the CE angle. **Level of Evidence:** Level II, diagnostic study.

Hip arthroscopy has become an increasingly used tool for the treatment of intra-articular hip pathology,[1,2] with increased awareness of the etiology of hip pain and an ever-expanding amount of literature on the results of various treatments performed arthroscopically.[3-8] The rationale for acetabular rim trimming is 3-fold: (1) to directly address the offending pathology causing the impingement as in pincer-type or mixed pincer-cam–type femoroacetabular impingement (FAI), (2) to resect areas of grade IV chondral damage, and (3) to protect repaired damaged labrum from further impingement.[1,2]

In patients with FAI, acetabular overcoverage can be treated with acetabular rim trimming either arthroscopically or through an open procedure in an attempt to restore the normal anatomy of the femoroacetabular articulation.[1,2,8-11] That pincer-type or mixed cam-pincer–type FAI can cause labral tears, chondral damage, and significant disability is well documented.[1-15] Excellent results of arthroscopic acetabular rim trimming in conjunction with other procedures, such

*From the Steadman Philippon Research Institute (M.J.P., K.K.B., D.A.K.), Vail, Colorado; Nirschl Orthopaedic Center (A.B.W.), Arlington, Virginia; and Naval Health Clinic (C.T.Z.), Great Lakes, Illinois, U.S.A.*
*Recipient of the 2009 Arthroscopy Association of North America Fellows Essay Award.*
*Supported by Smith & Nephew, Andover, MA.*
*Received March 31, 2009; accepted November 4, 2009.*
*Address correspondence and reprint requests to Marc J. Philippon, M.D., Steadman Hawkins Research Foundation, Attention: Clinical Research, 181 W Meadow Dr, Ste 1000, Vail, CO 81657, U.S.A. E-mail: karen.briggs@shsmf.org*

*0749-8063/9180/$36.00*
*doi:10.1016/j.arthro.2009.11.003*

as osteochondroplasty of the femoral head-neck junction and labral repair to treat these disorders, have been encouraging.[1-7]

Acetabular rim trimming not only can function to correct the retroversion or coxa profunda causing pincer- or mixed-type FAI, but it can also protect compromised or repaired labral tissue and remove areas of chondral damage.[1,2] Often, chondral defects are seen at the lateral margin of the acetabular rim at the chondral-labral junction. This can be seen as a result of carpet delamination of the articular cartilage from labral detachment and subsequent wear, repetitive and/or irregular abutment from cam-type FAI, or traumatic injury.[1,7-11] It has been our practice to eliminate these areas at the chondral-labral junction through acetabular rim trimming where possible.

However, it is difficult to ascertain the limits of resection of the acetabular rim to avoid what amounts to iatrogenic acetabular dysplasia. In 1939 Wiberg[12] described the center-edge (CE) angle as an assessment of acetabular dysplasia, noting that CE angles greater than 25° were normal, angles between 24° and 20° were borderline normal, and angles less than 20° were pathologic. This range of normal was subsequently verified by Fredensborg[16] in patients aged 15 to 80 years. In Wiberg's study of 44 patients aged 13 to 60 years, all hips in the pathologic range went on to develop osteoarthritis in the 4- to 28-year follow-up period, with the rate of development of osteoarthritis, as well as the likelihood of subluxation, correlating with lower CE angles.[12] A similar study by Cooperman et al.[14] could not replicate the direct correlation of rate of progression of osteoarthritis and CE angle or other radiographic measurements of acetabular dysplasia, but they reported that most of the 32 hips in their study followed for 22 years with CE angles less than 20° went on to develop osteoarthritis.

A 1995 study by Murphy et al.[15] from Bern, Switzerland, followed the contralateral hips of 286 patients who had a total hip arthroplasty for acetabular dysplasia. They found that no patient in whom the hip functioned well until the age of 65 years had a CE angle less than 16°.

More recently, hips with pathologic CE angles have been associated with labral tears.[17] In a 2006 study by Guevara et al.,[17] the hips of 99 patients with unilateral surgically confirmed labral tears were compared with the contralateral hips of 85 of these patients without evidence of labral tears. They reported that the prevalence of CE angles less than 20° was significantly higher in the hips with labral tears than in the contralateral hips without labral tears (42% *v* 16%, $P < .01$).

To minimize the risk of creating an underconstrained hip or a hip likely to have progression of osteoarthritis, it may be important to be able to correlate the amount of resection performed with preoperative and postoperative radiographic imaging. A useful and practical predictor of future hip pathology stemming from acetabular insufficiency is the CE angle.[12] The CE angle has been shown to be a predictor of future hip arthrosis.[12-15]

The purpose of this study was to determine whether the change in CE angle effected by arthroscopic acetabular rim trimming could be estimated by intraoperative measurements. Our hypothesis was that the change in CE angle from preoperative to postoperative radiographic measurements could be determined from the change in the measurement of the lunate surface at the 12-o'clock position at the time of arthroscopic acetabular rim trimming.

## METHODS

Between August 2007 and April 2008, 58 patients were prospectively enrolled in this institutional review board–approved study. Patients presented for the treatment of debilitating hip pain. The mean age at the time of arthroscopy was 32 years (range, 18 to 61 years). There were 23 men and 35 women. There were 22 left hips and 36 right hips. The mean body mass index was 23 (range, 18 to 32).

Inclusion criteria were hip arthroscopy for the treatment of FAI and rim reduction at the time of hip arthroscopy. Exclusion criteria were dysplastic hips, hips that did not undergo arthroscopic acetabular rim trimming, and hips with inadequate preoperative and/or postoperative anteroposterior (AP) pelvis radiographs. Inadequate films were defined by greater than 2 to 3 cm of distance between the sacrococcygeal joint and the pelvic brim and/or increased rotation as evidence by greater than 1 to 2 cm of lateral shift from the midline in the distance from the sacrococcygeal joint and the pelvic brim. Preoperative AP pelvis radiographs were evaluated for the CE angle. The CE angle was measured as the angle subtended between a perpendicular line from the center of the femoral head and the lateral margin of the acetabulum (Fig 1). This was measured both preoperatively and postoperatively.

The acetabular depth was measured intraoperatively. A graduated intraoperative ruler was used (Fig 2). The measurement was taken by a single surgeon from the superior aspect of the cotyloid fossa to approximately the 12-o'clock position of the lunate surface, opposite the transverse acetabular ligament. This

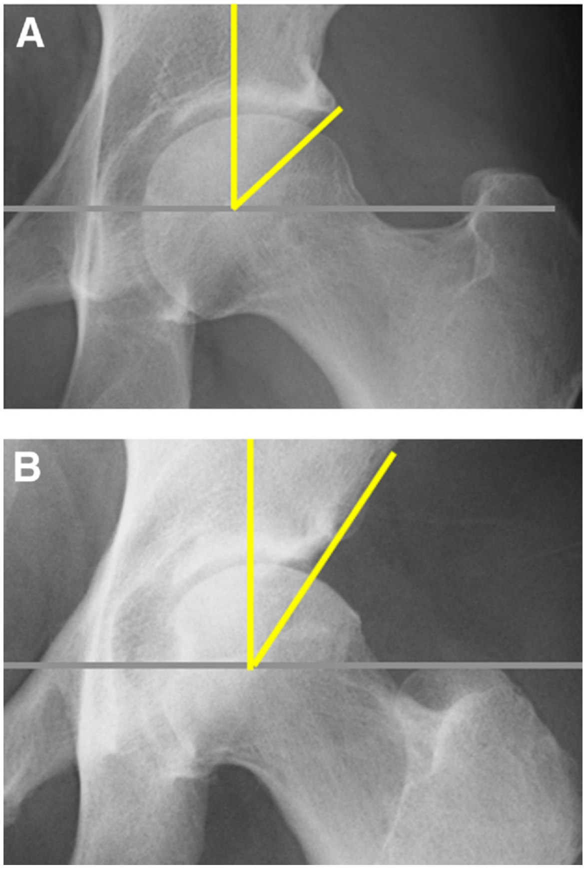


**Figure 1.** AP view of hip from a pelvis radiograph showing CE angle measurement (A) preoperatively and (B) postoperatively. The preoperative CE angle was 40°, and the postoperative angle was 33°.

measurement was recorded in a prospective database both preoperatively and postoperatively.

Two orthopaedic surgeons made independent measurements of the CE angles to determine interobserver reliability of the CE angle. The rim trimming was performed by a single surgeon using a 5.5-mm motorized bur.

### Statistical Analysis

Comparisons between continuous variables were performed by use of the Pearson correlation coefficient. Comparison of continuous variables by binary categorical variables was performed by use of the independent-samples *t* test. A linear regression model with backward stepwise selection was used to determine the equation that expressed the dependent variable in terms of constants and the independent variable. The coefficient of multiple determination (adjusted $r^2$) was used to indicate how much of the variability in the change in CE angle was accounted for by the rim reduction in the final multiple linear regression model. Statistical analysis was performed by use of SPSS software (version 10.0; SPSS, Chicago, IL).

## RESULTS

The mean preoperative CE angle was 36.4° (range, 25° to 51°) for observer 1. For observer 2, the mean preoperative CE angle was 36.7° (range, 22° to 51°). The mean postoperative CE angle was 32.3° (range, 23° to 49°) for observer 1. For observer 2, the mean postoperative CE angle was 33.1° (range, 22° to 44°). The interobserver intraclass correlation coefficient for radiographic measurement of the CE angle was 0.92 (95% confidence interval, 0.87 to 0.95), indicating excellent interobserver reliability.

The mean preoperative 12-o'clock acetabular depth was 25 mm (range, 12 to 41 mm). The mean postoperative 12-o'clock acetabular depth was 21.8 mm (range, 11 to 34 mm). The mean rim reduction performed was 3.2 mm (range, 1 to 9 mm). The mean change in CE angle was 3.9° (range, 0° to 17°) (Table 1). The change in CE angle correlated with the reduction of acetabular rim ($r = 0.4$, $P = .004$) (Fig 3).

On the basis of multivariate linear regression, difference in rim reduction predicted change in CE angle ($r^2 = 0.3$, $P = .003$). From this regression, the following equation was obtained to estimate the relation: Change in CE angle = 1.8 + (0.64 × rim reduction in

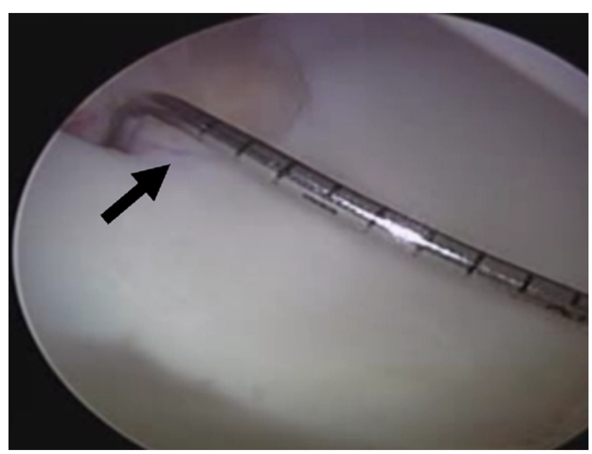

**Figure 2.** Intraoperative view of acetabular depth measurement at superior aspect of cotyloid fossa (arrow) to approximately 12-o'clock position of lunate surface, opposite transverse acetabular ligament.

**TABLE 1.** *Estimated Changes in CE Angle by Millimeter of Rim Reduction*

| Millimeter of Rim Reduction | Change in CE Angle |
|---|---|
| 1 | 2.4° |
| 2 | 3.1° |
| 3 | 3.7° |
| 4 | 4.4° |
| 5 | 5.0° |

millimeters). For 1 mm of rim reduction, 2.4° of reduction in CE angle can be expected (Table 1).

## DISCUSSION

This study showed that the change in CE angle could be estimated from millimeters of acetabular bony resection. Furthermore, this study showed that the CE angle is a reliable measurement with excellent inter-rater reliability as a radiographic diagnostic tool for the measurement of acetabular coverage.

Although CE angle is not a perfect means of assessing acetabular coverage, there is certainly a range below which the hip is at a higher risk of developing osteoarthritis, labral tears, and even instability.[12-17] It is our practice to use the guidelines set forth by Wiberg[12] to identify dysplastic hips as well as a guide for the amount of rim resection possible in any particular hip. Thus rim trimming is not performed in patients with CE angles less than 20° and is performed minimally, if at all, in hips with CE angles approaching 25°. However, these numbers are not considered in isolation. Other measurements should also be taken into consideration, including the weight-bearing surface angle, Sharp's angle, acetabular width-to-depth ratio, and femoral head extrusion index, as well as evidence of lateral or superior subluxation of the femoral head.[17-20] False profile views of the pelvis can also be helpful and have been reported to be more sensitive than AP pelvis views for the diagnosis of dysplasia.[13] In patients in whom acetabular coverage is of particular concern, computed tomography scan with or without 3-dimensional reconstruction can be helpful. However, because of concerns of radiation exposure, this is not part of our routine practice. Thus, although there are perhaps more complete means of assessing the amount of acetabular coverage of a hip, the CE angle on an AP pelvis radiograph is simple and reproducible, with relatively low radiation exposure and a relatively long track record of reports in the literature.

The findings in this study suggest that changes from preoperative to postoperative CE angles on the AP pelvis radiograph can be predicted by the amount of acetabular rim trimming performed at the 12-o'clock position. The regression model performed in this study found that the following: Change in CE angle $= 1.8 + (0.64 \times$ rim reduction in millimeters). Put more simply, the first millimeter of rim trimming will decrease the CE angle by approximately 2.4°, with each additional millimeter resected decreasing the CE angle by 0.6 mm to a change of 5° for a 5-mm rim trimming.

The utility of this finding lies in its simple application for clinical use. With a carefully measured preoperative CE angle on an AP pelvis radiograph, the surgeon can use these numbers as a rough guideline as to how the amount of acetabular rim trimming will affect the postoperative CE angle. This is of paramount importance in the treatment of hips in which a large rim trimming would be desirable. For example, in a patient with a preoperative CE angle of 35°, a chondral defect of 5 mm in width at the chondral-labral junction could be safely eliminated by a 5-mm rim trimming because the CE angle would be predicted to decrease to 30°.

As outlined previously, the CE angle is by no means a flawless predictor of future hip pathology. This formula provides a method to use the CE angle to estimate the amount of rim that can be removed. There are several other limitations to this study. Among these are variations in the quality of the AP pelvis radiographs. Although we excluded patients with AP pelvis radiographs in which the distance from the

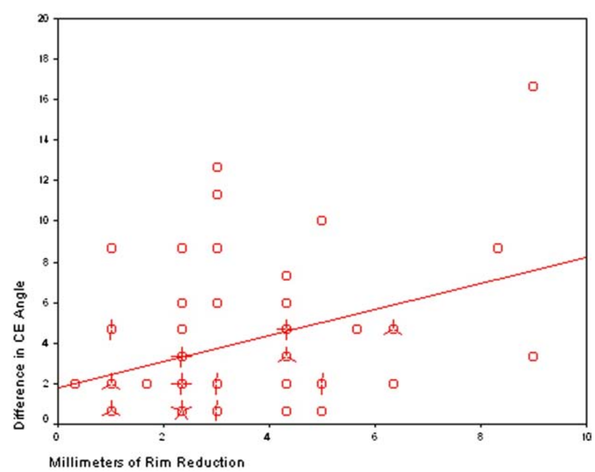


**FIGURE 3.** Statistical graph showing change in CE angle correlated with reduction of acetabular rim. A circle represents 1 patient, with each additional cross bar indicating an additional patient at the data point. The y-intercept is at 1.8 mm, as shown in the formula. The line, which the formula is based on, is an estimation of the relation between the change in CE angle and reduction in acetabular rim.

pelvic brim to the sacrococcygeal junction was not between 2 and 3 cm, this still allows for a fairly wide variation of angles of radiographic projection. Indeed, a recent report suggests that pelvic tilt can cause significant variations in determinations of acetabular angles.[21] Another limitation of this study is that the rim reduction was only measured at the 12-o'clock position on the lunate surface. This only measures 1 aspect of the acetabular rim resection. Although the vast majority of rim reductions performed at our institution include the 12-o'clock position, it is sometimes the case that more resection is performed in areas posterior or, more commonly, anterior to the 12-o'clock position, as in cases of pincer-type FAI caused by acetabular retroversion. Furthermore, a recent study by Zumstein et al.[22] has shown the relative inaccuracy of intraoperative arthroscopic estimation of the positioning of the resection on the clock face of the acetabular rim especially for more posteriorly based rim trimmings. This possible inaccuracy of our position on the clock face at precisely the 12-o'clock position was mitigated by our consistent measurement of the rim trimming directly superior to the superior aspect of the cotyloid fossa. Similarly, the AP radiographs and the CE angle measurements of these radiographs may not reflect more anteriorly based rim trimmings because they do not project as the lateral-most aspect of the acetabulum by which the CE angle is measured. This likely accounts for some of the data points in which a significant rim resection was performed with little change in the CE angle.

## CONCLUSIONS

The findings of this study showed that the amount of change in the CE angle can be estimated by the amount of bony resection performed at the 12-o'clock position on the lunate surface in the arthroscopic treatment of femoroacetabular pincer impingement. We found that 1 mm of bony resection equals 2.4° of change in the CE angle and 5 mm of bony resection equals 5° of change in the CE angle. The following formula can be used: Change in CE angle $= 1.8 + (0.64 \times$ rim reduction in millimeters).

## REFERENCES


1. Philippon MJ, Stubbs AJ, Schenker ML, Maxwell RB, Ganz R, Leunig M. Arthroscopic management of femoroacetabular impingement: Osteoplasty technique and literature review. *Am J Sports Med* 2007;35:1571-1580.
2. Philippon MJ, Schenker ML. A new method for acetabular rim trimming and labral repair. *Clin Sports Med* 2006;25:293-297.
3. Philippon MJ, Briggs KK, Kuppersmith DA, Hines SL, Maxwell RB. Outcomes following hip arthroscopy with microfracture. *Arthroscopy* 2007;23:e11 (Abstr).
4. Philippon MJ, Briggs KK, Hines SL, Kuppersmith DA, Maxwell RB. Early results of labral repair. *Arthroscopy* 2007;23:e9-e10 (Abstr).
5. Larson CM, Giveans MR. Arthroscopic management of femoroacetabular impingement: Early outcomes measures. *Arthroscopy* 2008;24:540-546.
6. Philippon MJ, Schenker ML, Briggs KK, Kuppersmith DA, Maxwell RB, Stubbs AJ. Revision hip arthroscopy. *Am J Sports Med* 2007;35:1918-1921.
7. Philippon MJ, Schenker ML, Briggs KK, Kuppersmith DA. Femoroacetabular impingement in 45 professional athletes: Associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc* 2007;15:908-914.
8. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: A cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2003:112-120.
9. Lavigne M, Parvizi J, Beck M, Siebenrock KA, Ganz R, Leunig M. Anterior femoroacetabular impingement: Part I. Techniques of joint preserving surgery. *Clin Orthop Relat Res* 2004:61-66.
10. Beck M, Leunig M, Parvizi J, Boutier V, Wyss D, Ganz R. Anterior femoroacetabular impingement: Part II. Midterm results of surgical treatment. *Clin Orthop Relat Res* 2004:67-73.
11. 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. *Bone Joint Surg Br* 2005;87:1012-1018.
12. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint. *Acta Chir Scand* 1939;83:58.
13. Harris WH. Etiology of osteoarthritis of the hip. *Clin Orthop Relat Res* 1986:20-33.
14. Cooperman DR, Wallensten R, Stulberg SD. Acetabular dysplasia in the adult. *Clin Orthop Relat Res* 1983:79-85.
15. Murphy SB, Ganz R, Muller 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.
16. Fredensborg N. The CE angle of normal hips. *Acta Orthop Scand* 1976;47:403-405.
17. 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.
18. Sharp IK. Acetabular dysplasia: The acetabular angle. *J Bone Joint Surg Br* 1961;43:268-272.
19. Li PL, Ganz R. Morphologic features of congenital acetabular dysplasia: One in six is retroverted. *Clin Orthop Relat Res* 2003:245-253.
20. Delaunay S, Dussault RG, Kaplan PA, Alford BA. Radiographic measurements of dysplastic adult hips. *Skeletal Radiol* 1997;26:75-81.
21. Richards PJ, Pattison JM, Belcher J, Decann RW, Anderson S, Wynn-Jones C. A new tilt on pelvic radiographs: A pilot study. *Skeletal Radiol* 2009;38:113-122.
22. Zumstein M, Hahn F, Sukthankar A, Sussmann PS, Dora C. How accurately can the acetabular rim be trimmed in hip arthroscopy for pincer-type femoral acetabular impingement: A cadaveric investigation. *Arthroscopy* 2009;25:164-168.