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Relationship between crossover sign and anterior center-edge angle

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ABSTRACT

Purpose: The aim of this study was to evaluate the relationship between the anterior center-edge angle (ACEA) and lateral center-edge angle (LCEA) and crossover ratio.
Methods: Consecutive patients presenting for evaluation of hip pain were reviewed. The following measurements were recorded and analyzed: Crossover ratio, LCEA, ACEA, and alpha-angle.
Results: 68 patients met inclusion criteria. The only statistically significant radiographic measurement when stratified by gender was alpha angle ($P < 0.001$). There was moderate correlation between crossover ratio and ACEA and LCEA with coefficients of -0.48 and -0.48, respectively.
Conclusion: A correlation exists between crossover ratio and ACEA and LCEA.

1. Introduction

Femoroacetabular impingement (FAI) remains a common etiology of hip pain in young adults treated by orthopaedic surgeons. The complex interplay between both femoral- and acetabular-sided pathology makes FAI a challenging diagnosis for even the most experienced sports medicine and hip preservation surgeons. Additionally, numerous studies have identified radiographic changes of FAI in asymptomatic patients making the evaluation and treatment of FAI more controversial.[1–4]

Many studies have investigated radiographic characteristics of FAI including the alpha-angle for cam lesions as well as anterior center-edge angle (ACEA) and lateral center-edge angle (LCEA) for both acetabular under- or over-coverage.[5,6] Other studies have investigated signs of acetabular retroversion on the anteroposterior pelvic radiograph including the crossover, ischial spine, and posterior wall signs.[7–9] Several studies have investigated and attempted to clarify the role of the crossover sign with regard to global acetabular retroversion and superior acetabular retroversion.[10] For instance, Zaltz et al. found that the crossover sign may overestimate the presence of acetabular retroversion.[11] Further clouding the picture, several studies have demonstrated variable and limited inter- and intra-observer reliability of many of the radiographic markers of femoroacetabular impingement including crossover sign, lateral and anterior center-edge angles, and alpha angle.[12–15] There has not been a study investigating the relationship between the ACEA or LCEA and the crossover sign.

The aim of this study was to evaluate the relationship between radiographic parameters of acetabular coverage, ACEA and LCEA, and global acetabular retroversion or over-coverage as defined by the crossover sign.

2. Materials and Methods

Consecutive patients presenting for clinical evaluation of hip pain with the senior authors from March 2017–July 2017 were retrospectively identified and reviewed. Clinically obtained radiographs were reviewed for a complete series of anteroposterior (AP) pelvis, 45-degree Dunn, Frog-leg lateral, and False Profile views. All radiographs were obtained and carefully reviewed for acceptability as described by Clohisy et al.[16] AP pelvis radiographs were evaluated for distance from coccyx-symphyseal distance between 1 and 3 cm with symmetric obturator foramen. The following measurements were recorded by the authors (M.H.M, B.A.B., and R.A.C.) on the effected hip: crossover ratio, LCEA, ACEA, and alpha-angle. The crossover ratio was calculated by dividing the distance from the inferior sourcil to the crossover point by the distance from the inferior sourcil to the lateral sourcil (Fig. 1). Quantifying the crossover sign has previously been described in one prior study.[17] Images were reviewed and measured using General Electric® Centricity PACS Radiology RA1000 Workstation (Barrington, IL). Patients were excluded if they had a LCEA or ACEA of less than 20°.

Abbreviations: femoroacetabular impingement, FAI; anterior center-edge angle, ACEA; lateral center-edge angle, LCEA

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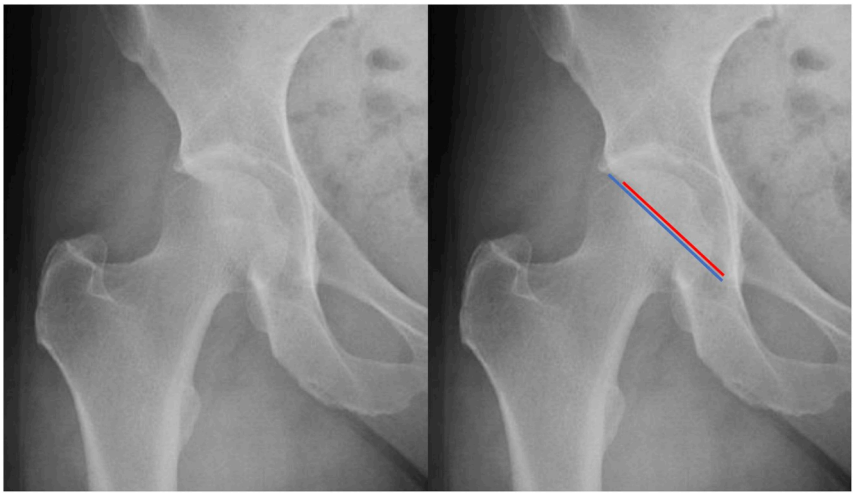

Fig. 1. Two identical images of AP right hip radiograph cross-over ratio measurements drawn on right image. Crossover ratio = A (red)/B (blue) = 56.2/64.9 = 0.87.

Statistical analysis was performed using a two-tailed Student t-test for normally distributed data was used to compare continuous variables. Pearson's correlation was used to evaluate for relationship between radiographic parameters. Statistical significance was accepted at $P < 0.05$. Institutional Review Board approval was waived for this investigation as all data was reviewed retrospectively and radiographs were collected through routine clinical evaluation.

3. Results

Sixty-eight patients (50 female, 18 male) met inclusion criteria for a total of 68 hips that underwent analysis. Of the 68 hips, there was an equal distribution of 34 left and 34 right hips. The average age was 39.9 years (range 18–72), and 67 of the hips had a crossover sign on the AP pelvis radiograph (Table 1).

In this cohort, the mean crossover ratio, LCEA, ACEA, and alpha-angle was 0.80, 34.0°, 37.7°, and 53.4°, respectively. The only radiographic measurement that was statistically significant with gender analysis was the difference in alpha angle ($P < 0.001$) (Table 2).

Pearson correlations revealed a moderate correlation between crossover ratio and both ACEA and LCEA. There was no correlation observed between crossover ratio and alpha-angle (Table 3). The R^2 values for LCEA and ACEA were 0.23 and 0.23, respectively.

4. Discussion

The radiographic and clinical evaluation of FAI remains controversial given the challenges of describing the complex anatomy of the three-dimensional hip joint through two-dimensional radiographs. Hanson et al. reported that there is little consensus on technique to measure LCEA and ACEA from the sourcil or the bone edge but that these variations may affect how a given patient's hip morphology may be categorized.[18] Furthermore, several studies have investigated the variable and limited inter- and intra-observer reliability of radiographic markers of hip anatomy and femoroacetabular impingement. The prevalence of the radiographic findings of FAI in asymptomatic volunteers only further clouds its diagnostic and clinical evaluation.

In this study, we set out to determine if there is a relationship between the crossover ratio and markers of acetabular coverage—namely the ACEA and LCEA. Our cohort of 68 patients had mean crossover ratio, LCEA, ACEA, and alpha-angles of 0.80, 34.0°, 37.7°, and 53.4°, respectively. This cohort had a female predominance (74%), however when stratified by gender, the only statistically significant difference between these groups was a higher mean alpha-angle measurement of 65° in the male cohort compared to 49° in the female cohort. While this could be a result of relative sampling differences of gender in our cohort, the increased alpha angle in the male cohort suggests an increased prevalence of a cam deformity, which has been previously recognized in the literature.[19] Further analysis revealed correlations between crossover ratio and both ACEA and LCEA of −0.48 and −0.48 respectively. This means that as the crossover ratio increases (i.e. moves farther inferiorly towards the inferior sourcil) the ACEA and LCEA increase, which may represent global acetabular retroversion or isolated anterolateral acetabular over-coverage. While we are not aware of another study investigating these specific relationships, several studies have investigated the crossover sign and found that it may overestimate acetabular retroversion and is not specific for acetabular retroversion.[10,11]

The R^2 values of 0.23 for the ACEA and LCEA suggest that their relationship to the crossover ratio is another step toward a more complete understanding of the interplay between acetabular retroversion

Table 1
Demographic data.

Gender	n	Mean Age (years)	Right	Left
Female	50 (73.5%)	40.2	23	28
Male	18 (26.5%)	39.1	11	7
Total	**68**	**39.9**	**34**	**34**

Table 2
Cohort Radiographic data.

Measurement	Mean (n = 68)	Standard Deviation	Female Mean (n = 50)	Male Mean (n = 18)	P-value
Crossover Ratio	0.80	0.12	0.80	0.77	0.37
LCEA (degrees)	34.0	7.8	33.9	39.9	0.15
ACEA (degrees)	37.7	7.0	36.8	34.3	0.84
Alpha-Angle (degrees)	17.8	17.8	49.2	64.9	< **0.001**

Table 3
Correlation of crossover ratio to radiographic measurements.

		ACEA	LCEA	Alpha-Angle
Crossover Ratio	Correlation	−0.48	−0.48	0.10
	P-value	< **0.0001**	< **0.0001**	0.43

and anterior and lateral acetabular over-coverage.

There are several limitations inherent in the design of this study. First, this study was retrospective in nature and evaluated patients presenting with a chief complaint of hip pain introducing the possibility of selection bias. Additionally, while each radiograph was carefully evaluated for quality as described above in the Methods section, it is possible that subtle differences in pelvic tilt and rotation may have influenced the results of this study. Several prior studies have established variable and limited inter-and intra-observer reliability of the radiographic parameters of FAI utilized in this study, which may have had an effect on the recorded measurements. Finally, our methodology excluded patients with hip dysplasia, an etiology representing a significant component of patients presenting for hip pain. Therefore, our results should not be considered generalizable to that population. Further studies are needed to continue to investigate these complex radiographic relationships and allow surgeons to better model and understand femoroacetabular impingement.

5. Conclusions

A correlation exists between crossover ratio and both anterior and lateral center-edge angles. This may represent another step toward a more complete understanding of the complex radiographic relationship of acetabular version and over-coverage leading to femoroacetabular impingement.

Conflicts of interest

The authors of this manuscript, and their immediate family members, have no known conflicts of interest relevant to the content or publication of this manuscript.

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