Original Article

Three-Dimensional Computed Tomography Reconstructions May Detect Pincer Lesions With Higher Sensitivity Than Radiographs in Patients With Femoroacetabular Impingement Syndrome

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Purpose: To assess the diagnostic capability of radiographs (XRs) to detect pincer lesions compared with 3-dimensional (3D) computed tomography scans in patients undergoing hip arthroscopy for femoroacetabular impingement syndrome (FAIS). **Methods:** We performed a retrospective review of all patients who underwent hip arthroscopy for FAIS between September 1, 2020, and October 2, 2022. Preoperative imaging was reviewed. Pincer lesions were defined as a lateral center-edge angle greater than 40°; a Tönnis angle greater than 0°; the presence of the ischial spine, crossover, or posterior wall sign; and the presence of overcoverage greater than 80%. Under "select criteria," patients were classified as having a pincer lesion on XRs and 3D computed tomography reconstructions (CTRs) based on the lateral center-edge angle or Tönnis angle alone, whereas "all criteria" added the presence of the crossover sign and coverage percentage. Statistical analysis was performed to determine the diagnostic accuracy of XRs compared with 3D CTRs. **Results:** A total of 69 patients met the inclusion criteria. There were 21 male patients (30.4%) and 48 female patients (69.6%). The mean age was 33 ± 13.5 years. χ^2 Analysis for select criteria found that 3D CTR was more likely than XRs to detect a pincer lesion. χ^2 Analysis for all criteria found that 3D CTR was more likely than XRs to detect a pincer lesion. χ^2 Analysis further showed that when using XRs, a pincer lesion was more likely to be detected under all criteria than under select criteria. Likewise, when using 3D CTR, a pincer lesion was more likely to be detected under all criteria than under select criteria. **Conclusions:** In this study, we found that 3D CTR detected pincer lesions in patients undergoing hip arthroscopy for FAIS with significantly higher sensitivity than XRs alone. **Level of Evidence:** Level III, retrospective cohort study.

Femoroacetabular impingement syndrome (FAIS) comprises a spectrum of hip pathology including the presence of abnormal morphology of the femur and/or acetabulum. Abnormal morphology of the femoral head and neck is commonly referred to as a "cam deformity," whereas abnormal anatomy of the acetabular rim is referred to as "pincer deformity." Identification and measurement of these differing but often coexistent pathologies are important because surgical treatment of each of these requires different strategies.[1-4] Typically, the diagnosis of FAIS has been made with radiographs (XRs) for both cam and pincer deformities. Acetabular shape and orientation are evaluated with weight-bearing anteroposterior (AP) and false-profile views. These views are used to determine the relevant XR parameters associated with pincer-type femoroacetabular impingement (FAI), including the lateral center-edge angle (LCEA), anterior center-edge angle (ACEA), Tönnis angle, crossover sign (COS), posterior wall sign, and ischial spine sign. Pincer-type lesions are typically defined by an LCEA greater than 40°, Tönnis angle less than 0°, ACEA greater than 40°, and positive XR signs including the COS, ischial spine sign, and posterior wall sign.[5-8]

However, because of positioning variability, pincer deformities and acetabular version in particular have been shown to be difficult to identify and classify with XRs.[6,9-14] This is of particular importance in the case of acetabular deformities given that focal or global overcoverage is treated with arthroscopic bone removal but patients with insufficient coverage due to dysplasia or abnormal version may require acetabular

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reorientation.[6-8] Missed or underappreciated pincer deformities may also lead to insufficient resection of acetabular deformity at the time of surgery.[11,15,16] As a result, 3-dimensional (3D) computed tomography (CT) has been used to better understand the extent and nature of acetabular pathology in FAIS. Three-dimensional CT has shown promise in previously published work as a potential tool to help surgeons better understand acetabular version and femoral head coverage.[17,18]

The purpose of this study was to assess the diagnostic capability of XRs to detect pincer lesions compared with 3D CT scans in patients undergoing hip arthroscopy for FAIS. Our hypothesis was that 3D CT scans would have greater diagnostic accuracy than XRs in the detection of pincer lesions in patients with FAIS.

Methods

We performed a retrospective review of all patients who underwent hip arthroscopy for FAIS between September 1, 2020, and October 2, 2022. Institutional review board approval was provided by WCG institutional review board (protocol No. 20225835). Patients were indicated for hip arthroscopy if they received a diagnosis of FAIS as previously defined by the Warwick Agreement[19] and did not respond to a minimum of 12 weeks of physician-directed nonoperative management including activity modification, anti-inflammatory medications, physical therapy, and/or injections. Patients were included in this study if they had adequate preoperative imaging consisting of a standard AP pelvis XR, a false-profile hip XR, and a preoperative CT scan performed with the Stryker HipMap protocol[20-23] (Stryker, Kalamazoo, MI). Patients were excluded if they had inadequate-quality XRs or were missing preoperative XRs.

XR measurements were performed by a board-certified fellowship-trained orthopaedic sports medicine surgeon (K.C.P.). AP pelvic XR measurements included the following: LCEA; Tönnis angle; and presence or absence of the COS, ischial spine sign, or posterior wall sign (Fig 1). False-profile XRs were used to measure the ACEA. The surgeon performing the assessments was blinded to patient demographic characteristics including age prior to measurements. Two sets of measurements were performed a minimum of 2 weeks apart to allow blinding. The average of the 2 measurements was then calculated for comparison to CT measurements.

CT scans were obtained according to the 3D CT protocol. Three-dimensional CT reconstruction (CTR) was then performed by a dedicated measurement analyst trained in pelvic measurements according to the protocol and based on parameters from the published literature (Fig 2).[21-23] It is important to note that each pelvis was placed into identical orientation with respect to alignment on the coronal sagittal and axial views to remove any measurement discrepancy after 3D reconstruction.

Pincer lesions were defined on XRs according to prior literature as an LCEA greater than 40°, negative Tönnis angle, and presence of the ischial spine sign, COS, or posterior wall sign. A pincer lesion on 3D CTR was defined as an LCEA greater than 40°, presence of overcoverage greater than 80%, and presence of the COS.[24]

Patients were classified as having a pincer lesion under 2 sets of criteria. Under "select criteria," patients were classified as having a pincer lesion on XRs and 3D CTR based on the LCEA or Tönnis angle. Under "all criteria," patients were classified as having a pincer lesion on XRs and 3D CTR based on one of the following: LCEA, Tönnis angle, presence of the COS, and coverage percentage.

Statistical Analysis

Statistical analysis was performed using the Pearson χ^2 test to determine whether there was a difference in the detection of pincer lesions between XRs and 3D

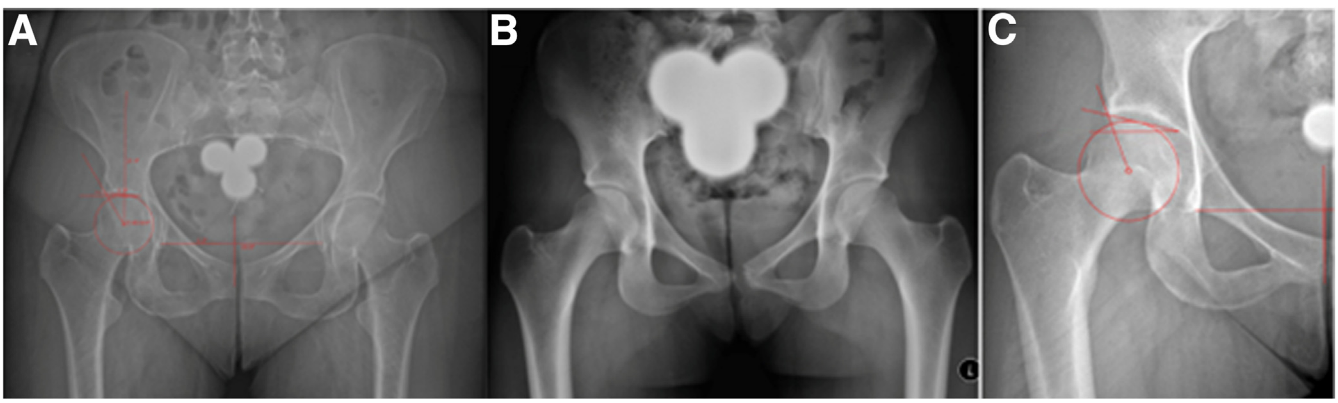

Fig 1. Radiographic measures obtained: lateral center-edge angle and Tönnis angle with positive posterior wall sign (A), positive crossover sign (B), and Tönnis angle with positive ischial spine sign (C).

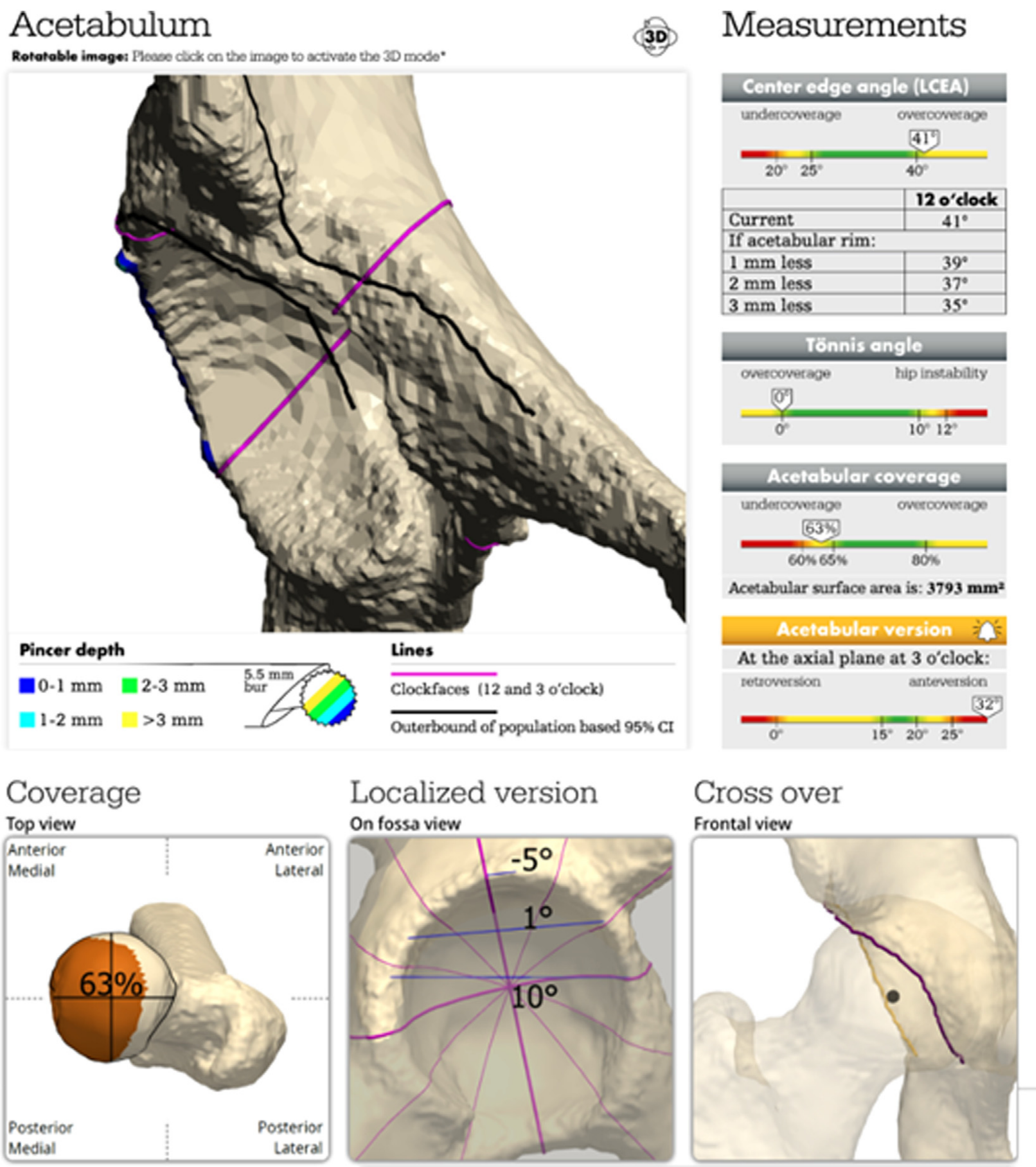

Fig 2. Screenshot of HipMap results from 3-dimensional (3D) computed tomography reconstruction measures for lateral center-edge angle (LCEA), Tönnis angle, positive crossover sign, and acetabular overcoverage. (CI, confidence interval.)

CTR for select criteria and all criteria. The significance level was set at $P \leq .05$. The diagnostic accuracy of pincer lesion detection on XRs versus 3D CTR was determined via sensitivity and specificity analyses, as well as the positive predictive value (PPV), negative predictive value (NPV), false-positive rate (FPR), false-negative rate (FNR), positive likelihood ratio (PLR), and negative likelihood ratio (NLR).

Results

A total of 69 patients met the inclusion criteria. There were 21 male patients (30.4%) and 48 female patients (69.6%). The mean age was 33 ± 13.5 years. There were 15 isolated left hips (25%), 36 isolated right hips (60%), and 9 bilateral hips (15%).

The number of patients with positive findings for a pincer lesion in each scenario is shown in Table 1. Under select criteria, 2 patients had a pincer lesion on XRs and 13 patients had a pincer lesion on 3D CTR. Under all criteria, 14 patients had a pincer lesion on XRs whereas 23 did so on 3D CTR.

χ^2 Analysis showed that there was a significant difference in pincer lesion detection between XR and 3D CTR for select criteria, and 3D CTR was more likely than XRs to detect a pincer lesion (χ^2 [1, N = 69] = 8.87, P = .003). χ^2 Analysis showed that there was a significant difference in pincer lesion detection between XRs and 3D CTR for all criteria, and 3D CTR was more likely than XRs to detect a pincer lesion (χ^2 [1, N = 69] = 11.47, P = .001) (Table 2). χ^2 Analysis further

Table 1. Total Identification of Pincer Lesions Under Both Criteria Classifications

	Evaluation Criteria	
Diagnostic Tool	Select, n	All, n
XR		
Positive	2	14
Negative	67	55
3D CT		
Positive	13	19
Negative	56	50

CT, computed tomography; 3D, 3-dimensional; XR, radiograph.

Table 2. Pearson χ^2 Test Results and Significance

Test Description	χ^2 Value	*df*	*P* Value
XR vs 3D CT			
Select	8.873	1	.003
All	11.47	1	.001
XR using select criteria vs XR using all criteria	8.092	1	.004
3D CT using select criteria vs 3D CT using all criteria	32.036	1	<.001

CT, computed tomography; 3D, 3-dimensional; XR, radiograph.

showed significant differences between the select-criteria and all-criteria classifications for XRs, and a pincer lesion was more likely to be detected under all criteria than under select criteria (χ^2 [1, N = 69] = 8.09, P = .004). Likewise, χ^2 analysis showed significant differences between the select-criteria and all-criteria classifications for 3D CTR, and a pincer lesion was more likely to be detected under all criteria than under select criteria (χ^2 [1, N = 69] = 32.04, P < .001) (Table 2).

Statistical analysis for diagnostic accuracy showed that XRs had a sensitivity of 15.38% and specificity of 100% for pincer lesions with select criteria compared with 3D CTR (Table 3). For pincer lesions meeting all criteria, XRs had a sensitivity of 52.63% and specificity of 92%. Further assessment showed a 100% PPV and 83.58% NPV for XRs when using select criteria compared with 3D CTR. XRs with all criteria showed a 71.43% PPV and 83.64% NPV. When using select criteria, XRs had an FPR of 0% and an FNR of 84.62% compared with 3D CTR. When using all criteria, XRs had an FPR of 8% and an FNR of 47.37%. For select criteria, XRs were found to have a null PLR and a 0.8462 NLR compared with 3D CTR. When all criteria were considered, XRs had a 6.58 PLR and a 0.51 NLR.

Discussion

In this study, XRs showed low diagnostic sensitivity in detecting pincer lesions when using the LCEA and Tönnis angle. This sensitivity was still low but slightly improved when the COS, ischial spine sign, and posterior wall sign were also used to identify pincer lesions. Overall, we observed that nearly half of the pincer deformities detected by 3D CTR went undetected with XRs. χ^2 Analysis revealed that with both select criteria and all criteria used in analysis, 3D CTR had significantly higher ability to detect a pincer lesion compared with XRs alone. This was reflected in the sensitivity calculation for XRs, which was found to be only 15.38%.

Current management strategies primarily use XRs in both the preoperative identification and characterization of pincer-type FAIS. However, our study found that 2-dimensional (2D) XRs have low sensitivity detecting pincer lesions compared with 3D CTR. Many pincer lesions may, therefore, be undetected or underappreciated in patients with FAIS. This is of particular significance because previous studies have found that undiagnosed or unresected pincer-type FAIS is correlated with poor postoperative outcomes. Ross et al.[15] found that in a cohort of 50 patients undergoing revision hip arthroscopy, 13 patients (26%) had residual lateral overcoverage with an LCEA greater than 40°. Zhuo et al.[16] similarly reviewed a cohort of 40 patients undergoing hip arthroscopy and found that a residual pincer lesion of 20% or greater was associated with poorer postoperative outcomes. Therefore, preoperative identification as well as proper intraoperative management of pincer lesions is imperative for improving outcomes in patients undergoing hip arthroscopy for FAIS.

Our study used an LCEA of over 40° and a negative Tönnis angle on CT scans and XRs to identify a pincer lesion. Rhee et al.[25] observed that most authors use an LCEA greater than 35° to 40°. These measurements on XRs were compared with LCEA and Tönnis angle measurements on CT. Measurement of the LCEA on 2D CT has previously been validated.[26] In a separate analysis, we used the LCEA and Tönnis angle in addition to a positive ischial spine sign, positive COS, and positive posterior wall sign, which should increase sensitivity by accounting for pincer lesions attributed to relative retroversion or coxa profunda. Despite these additional XR signs, we still found only a 52% sensitivity of detected pincer lesions compared with 3D CTR.

Previous studies have compared the diagnostic accuracy of XRs in identifying pincer lesions versus multiple modalities including CT. Chadayammuri et al.[27] compared XRs with 2D CT in 410 hips in 205

Table 3. Diagnostic Accuracy: Sensitivity and Specificity

	Sensitivity, %	Specificity, %
XR with select criteria	15.38	100
XR with all criteria	52.63	92

XR, radiograph.

patients undergoing hip arthroscopy for FAI. Their study found that the 2D CT scans estimated the LCEA to be 2.1° higher than the XRs, which was statistically significant. Although their conclusion was that CT measurements may need to be validated compared with XR findings, it is similar to our finding that CT trends toward a larger LCEA, which may indicate underestimation of lateral coverage by routine XRs and missed pincer pathology. Kutty et al.[28] found that use of the LCEA on XRs had a sensitivity of 84% and specificity of 100% in detecting pincer lesions, but this was compared with a single coronal slice on magnetic resonance arthrography, which is not routinely used for the assessment of bony lesions in FAIS. Our study found much poorer sensitivity of 2D XRs in detecting pincer lesions when compared with 3D CT, which is more extensively validated and much more routinely used in the assessment of hip impingement as a result of bony lesions.

Röling et al.[29] reviewed 127 patients undergoing hip arthroscopy for FAIS who all underwent XR and 3D CT evaluation preoperatively. Positive pincer lesions identified on XRs or CT were confirmed with intraoperative impingement assessment. The authors found that XRs were 84% sensitive and 72% specific and 3D CT was 90% sensitive and 43% specific for the evaluation of impingement due to pincer pathology. This was compared with the gold standard of intraoperative assessment of impingement. Their conclusion was that diagnostic accuracy between XRs and 3D CT was similar. This study again differs from ours in both methods and results because we found a much lower sensitivity for XRs when compared with 3D CT as the gold standard rather than intraoperative impingement assessment.

The previously mentioned studies have used the accepted gold standard of intraoperative assessment of impingement as a positive pincer lesion to identify the presence of a pincer lesion on CT compared with XRs, and although intraoperative observation of impingement is undoubtedly concrete, it also introduces variables. The degree of impingement that is called positive on intraoperative assessment is more subjective. Moreover, it introduces surgeon bias because the operating physician has access to the patient's preoperative examination results and imaging.

On the basis of our findings, it may be reasonable to begin to consider 3D CT as the standard of care for preoperative assessment of FAI in patients who may be candidates for hip arthroscopy. We found that compared with the ability of 3D CTR to detect a potentially clinically significant pincer lesion, XRs had very poor sensitivity. Routine use of 3D CTR has the potential to allow preoperative planning for addressing subtle pincer lesions that may be clinically significant that XRs are not sensitive enough to detect. XRs may reliably continue to serve a purpose as a screening tool for the presence or absence of a pincer lesion, but given our findings of an FPR of 47% compared with 3D CTR even when using all diagnostic criteria, this may be reconsidered as well. However, despite our findings on the sensitivity of the diagnostic tools available, we have not shown the clinical utility of detecting pincer lesions with higher sensitivity with 3D CTR, and further research will need to be performed to elucidate potential improvements in clinical outcomes with improved identification of pincer lesions.

Limitations

This study is not without limitations. Our sample size was small, creating the possibility of a type II error. This study was also retrospective in nature, limiting our control in removing confounding variables and the ability to recruit a more comprehensive patient cohort. Another limitation is that although 3D CT scans do seem to improve diagnostic accuracy in detecting impingement lesions, a CT scan involves extra cost compared with XRs and increased risk associated with increased radiation exposure. It is important to note that the results of this study are predicated on the Stryker HipMap 3D CT scan as the gold standard; however, there is no control for the accuracy of these measurements. An additional critique of our study based on these findings would be that CT overestimates lateral coverage, so clearly, we would find more pincer lesions with CT scans than XRs. Further investigation of our data revealed that 10 of the 23 pincer lesions identified by 3D CTR were identified solely by the COS and relative retroversion and not the LCEA or percentage of superior coverage. Only 2 of these positive pincer lesions were identified on XRs using all XR criteria (LCEA, Tönnis angle, ischial spine sign, posterior wall sign, and COS). In our opinion, this indicates that 3D CT is more likely not to miss a pincer lesion given the ability of CT to take version, patient position, and acetabular orientation into account—all of which tend to skew the reliability of XRs.

Conclusions

In this study, we found that 3D CTR detected pincer lesions in patients undergoing hip arthroscopy for FAIS with significantly higher sensitivity than XRs alone.

Disclosures

All authors (C.D.S., E.S., B.J., E.Q., R.G., K.C.P.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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