

A Novel Method to Limit Parallax Error in Fluoroscopic Cup Orientation During Total Hip Arthroplasty

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ABSTRACT INTRODUCTION: Accurate positioning of the acetabular component is crucial for successful Total Hip Arthroplasty (THA). Modern practice utilizes intraoperative C-arm fluoroscopy to guide acetabular positioning in the Direct Anterior Approach (DAA). However, the nature of fluoroscopic imaging makes it prone to parallax distortions. Intraoperative fluoroscopy utilizes cone-beam imaging, and as a result, changes in C-arm alignment or off-center placement of the component can alter the projected appearance of the cup. This parallax effect can lead to inaccuracies in orientation measurements of the acetabular component if not properly accounted for. This paper presents our recently published, novel cup orientation measurement technique (Suh et al.¹), which models the acetabular component's rim as an ellipse under a true perspective (cone-beam) projection. Our objective is to compare the accuracy of our approach with the widely used Liaw et al. method², particularly as the position of the cup deviates from the center.

METHODS: We retrospectively analyzed 294 intraoperative C-arm images from DAA THA cases. Cup anteversion was estimated with our perspective projection method and with Liaw's parallel projection technique. Anteversion values from both methods were compared across increasing distances of the acetabular cup from the fluoroscopic center. Cup position was quantified with Euclidean distance (in pixels) from the image origin and stratified into bins based on increasing distance from the center. Within each bin, paired comparisons between methods were performed using two-tailed paired *t*-tests. Agreement between methods was further assessed using Bland-Altman analysis, with mean difference and 95% limits of agreement (± 1.96 SD) calculated for each distance bin. Statistical significance was defined as $p < 0.05$. IRB approval was obtained, and all institutional ethical practices were followed.

RESULTS SECTION: In Bin 1 (Distances 21.87 - 158.59, $n = 74$), mean anteversion was 12.84° for the Suh method, and 15.99° for the Liaw method (mean difference -3.15°, $p < 0.00001$). In Bin 2 (Distances 160.63 - 199.32, $n = 73$), mean anteversion was 21.82° for the Suh method, and 19.82° for the Liaw method (mean difference 2.00°, $p = 0.0012$). In Bin 3 (Distances 199.79 - 219.08, $n = 73$), mean anteversion was 23.30° for the Suh method, and 19.91° for the Liaw method (mean difference 3.39°, $p < 0.00001$). In Bin 4 (Distances 219.16 - 273.84, $n = 73$), mean anteversion was 22.46° for the Suh method, and 18.41° for the Liaw method (mean difference 4.05°, $p < 0.00001$).

DISCUSSION: This study compares two methods that measure cup orientation during a DAA THA. Our analysis demonstrates that the discrepancy between the Suh method and the Liaw method steadily increased with distance from the image center, with statistically significant differences observed in every bin. This finding highlights the inherent limitation of the Liaw method, which assumes parallel projection and becomes increasingly inaccurate under cone-beam fluoroscopy as the cup moves off-center. **Limitations:** this study was retrospective and relied on 2D fluoroscopic images without 3D or CT confirmation. Further studies are warranted to validate this method across different imaging environments.

SIGNIFICANCE/CLINICAL RELEVANCE: Accurate intraoperative assessment of cup orientation is essential for successful THA. By accounting for cone-beam projection, this method improves reliability across the fluoroscopic field and may enhance the precision of cup placement during DAA THA.

REFERENCES:

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²Liaw CK, Hou SM, Yang RS, Wu TY, Fuh CS. A new tool for measuring cup orientation in total hip arthroplasties from plain radiographs. *Clin Orthop Relat Res.* 2006;451:134-139. doi:10.1097/01.blo.0000223988.41776.fa

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IMAGES AND TABLES:

