

Dear World Journal of Orthopedics Reviewers and Editors,

Thank you for taking the time and effort to review our manuscript “Reliability of a Simple Fluoroscopic Image to Assess Leg Length Discrepancy during Direct Anterior Approach Total Hip Arthroplasty”. We believe that we have been able to adequately address your questions and concerns. Our paper is likely to be beneficial to many surgeons who currently employ similar versions of this technique around the world and have wondered about the reliability of fluoroscopy in this clinical setting. We hope you find our explanations and edits listed below on a point-by-point basis satisfactory.

Sincerely,

Sandi Caus, Hailee Reist, Christopher Bernard, Michael Blankstein, Nathaniel J. Nelms

Reviewer: I have several concerns with the manuscript since the pelvic x-ray is not reliable for the clinical findings. Therefore, you have to examine patients and compare your findings with the clinical ones.

We understand your concern in referencing the pelvic x-ray as a measure of leg length alone. Certainly, a full-length x-ray with clinical examination is the best way to assess overall leg length. However, this idea strays away from the primary purpose of our study. The overall purpose of our paper is not to declare certainty in achieving perfect overall leg lengths, but instead to understand how accurate the intra-operative measurement of leg length is by this fluoroscopic technique compared to the standard post-operative x-ray obtained by most surgeons. In essence, we want to know if what we see intra-operatively on a fluoroscopic image is what we will see on the post-op pelvis x-ray. If it looks like the right leg is 0.5 cm longer on intra-operative fluoroscopy, will a similar apparent leg length discrepancy be present on the post-op

pelvis x-ray? Obtaining full length x-rays or using clinical exam to make this comparison would not allow us to answer this question directly since these measurements would be dependent on the lengths of other portions of the lower extremities. Nor are these other techniques more declarative gold standards in this setting. Most surgeons clinically use pelvis x-rays for pre-op planning and post-op assessment of leg lengths along with clinical examination instead of full-length x-rays. Additionally, it is well documented in several of our attached references, that LLD can be estimated with a post-operative pelvis x-ray.

Reviewer: Furthermore, you compare trial components intraoperatively with the real THA postoperatively. How big is the difference between trial components and final THA?

To address your concern here, I would direct attention to our methods as we have provided a comparison of LLD between intra-operative fluoroscopy and post-operative x-ray only after final components have been placed. We are not computing our measurements based on trial components, rather are using a saved image with final components. This is consistent with the study performed by Bingham et al (referenced) in which the authors compared two fluoroscopy dependent techniques only after final components were placed. Therefore, the components represented in the intra-operative fluoroscopic image and post-operative x-ray are identical. To assure that our methods are clear we added to the manuscript: "Fluoroscopic and AP radiographs each with the final components in position were imported to TraumaCad for analysis by two independent observers".

Reviewer: Have you observed any difference between preoperative plannings and intra/postoperative findings?

No significant differences to this effect were observed and such differences would not be relevant to this study.

Reviewer: What about Intraoperative clinical comparison.

Intra-operatively we are limited by virtue of the operative approach in our DAA THA, specifically limited by use of a traction table. As stated in the paper, we can perform the “shuck test” for assessment of THA tension but are unable to conduct a clinical assessment of leg length given our use of a specialized traction table. Furthermore, we have admittedly reported that use of specialized traction tables for DAA THA may increase reliance on fluoroscopically based assessments of LLD since it is not feasible to perform clinical assessment of LLD on the specialized table. This is because the patient’s feet are in non-sterile traction boots with padding. Despite the common reliance on fluoroscopy when using a specialized table, the table provides improved surgical exposure for the surgeon.

Reviewer: Why external rotation? Don’t you typically perform x-rays in internal rotation? Figure one cannot be used to identify the leg length. It seems that you have increased the offset massively.

You are correct that internal rotation is helpful for assessing the full extent of femoral offset on pre-op x-rays for surgical planning and that is also our standard practice. Intra-operatively, with this imaging technique, external rotation of both limbs is very helpful to see the lesser trochanters. We use external rotation specifically with fluoroscopy to view the lesser trochanters for LLD assessment and this is very common among surgeons using a traction table for anterior approach total hip.

Reviewer: Which components were used? According to my personal experience the trial components are typically smaller than the real ones. Even if the leg length fit with the trial components the real ones may not suite.

We are happy to address which components were used, but we believe this is not relevant because our measurements on fluoroscopy and x-ray are only of the final components. Nothing was measured with trial components. The images for which we

performed LLD measurements were again final components in final position.

Reviewer: How about the contralateral arthritis stage?

This is not relevant because we are not trying to assess an ideal leg length or pre-arthritis. Instead, we are comparing two modalities (fluoroscopy and x-ray) in this setting to compare the measurements. Because these fluoroscopic and x-ray images were obtained within minutes of each other with the patient in a supine position for each, there should be no effect of contralateral hip arthritis.

Reviewer: Do you want to even it or lengthen it slightly?

The decision for our goal in leg length was based on a pre-operative and intra-operative assessment. We are not specifically trying to always lengthen slightly but rather this is a patient specific determination. None of this is relevant to this study which assesses a fluoroscopic measure to an x-ray measure as a pure comparison separate from our surgical goal. We present the final leg lengths measured by x-ray only for comparison to other studies and to give a sense of general post-op x-ray symmetry, but this is a very secondary point.

Reviewer: Does the trauma cad measurements always match and represent the real leg lengths? Shouldn't be whole leg x-rays been performed?

Any measurement of leg-length on an AP Pelvis image does not consider other factors that contribute to overall leg length like prior fracture or knee flexion contracture. We are not trying to compare the overall clinical leg lengths. We take those factors into account in our pre-operative planning. In a case where we might have planned to make one leg appear longer on the pelvis x-ray, this does not affect our primary comparison of fluoroscopic to x-ray relative leg lengths. In most cases the relative lengths measured on a pelvis x-ray are consistent with overall leg lengths. We added and edited our conclusions to clarify this concern as follows: "We acknowledge that any measurement of LLD based on imaging of the pelvis alone may not represent

discrepancy in overall leg lengths. True leg length comparison requires clinical evaluation or long leg x-rays, each of which also have their own intrinsic inaccuracies. Even so we demonstrate that combining this fluoroscopic technique with careful pre-operative templating and assessment of joint laxity resulted in minimal average post-operative LLD apparent on x-ray. And this demonstrates that the effects of intra-operative fluoroscopic image distortion do not preclude the clinical usefulness of this simple technique.”

Reviewer: Figure 2 shows still a mismatch in offset. Additionally the x-ray is not centered. These x-rays are not helpful to predict the CCD, offset and leg length. In addition, you can see a slight discrepancy in the greater trochanter which should be about the same.

In this particular case there is some difference in offset but this is not clinically significant nor is it related to our study. The x-ray is well enough centered and of high enough quality to make the necessary measurements. A slight discrepancy in the greater trochanter related to a difference in leg rotation does not alter the leg length measurement.

Reviewer: I am not really sure, why 11 cases had to be removed, since this is an objective measurements. You do not need to use the middle of the lesser trochanter but can also the proximal or distal one. There is no surprise that you observed a significant difference between teardrop and ischium.

Cases with persistent discrepancy between observers after a second independent assessment were removed because they were representative of poor image quality or difficult to assess landmarks. Poor image quality or difficult to assess landmarks did not allow for an accurate assessment of our intra-operative fluoroscopic technique. We do not think it would have been a good idea to change our measurement technique for these cases with poor image quality or poorly/partially visible lesser trochanters.

Reviewer: Discussion: In the results you mentioned that a significant difference was observed. So it is not reliable. You should compare the radiographic with the clinical outcome.

We need to remember that statistical significance is different from clinical significance. Our results show that there is an inherent inaccuracy in the fluoroscopic measurement of leg length compared to the x-ray measurement. The next important questions are: by how much do the intra-op and post op measurements differ and is the technique still generally clinically useful? The realistic surgical goal in THA is to minimize LLD to a clinically insignificant range. We have cited this in our manuscript and alluded to the importance of focusing attention on clinical significance. We showed that by using the teardrops there is a difference between the imaging techniques averaging about 2.2 mm. This is statistically significantly different but clinically the technique is shown to still have significant value. It helps the surgeon to know intra-operatively that the apparent leg length difference seen on fluoroscopy is going to be within 5 mm of the same on the post-op x-ray about 95% of the time.

Reviewer: How does the approach impact the measurements of LLD? I cannot imagine any differences between individual approaches and their impact on fluoroscopy not LLD. **The surgical approach is special in that it makes the use of fluoroscopy very easy since the patient is supine on a radiolucent traction table. The traction boots make the use of fluoroscopy an important adjunct for assuring appropriate leg length. When a patient is by contrast in a lateral decubitus position it has significant influences on imaging accuracy. The advent of the direct anterior approach has created a renewed focus on intra-operative imaging during total hip arthroplasty.**

Reviewer: You mentioned that Bingham et al performed a similar study. So what is the difference to your study?

The premise of the Bingham et al study was to determine if intra-operative fluoroscopy improved LLD when compared to the standard DAA THA without fluoroscopy. This comparison was based on post-operative anterior-posterior pelvic x-ray to determine LLD. In contrast, our study focused on the accuracy of a single intra-operative fluoroscopic image parallel-line technique by means of comparing intra-operative fluoroscopy estimated LLD to the post-operative gold-standard anterior-posterior pelvic x-ray LLD. Thereby, our assessment was limited to a specialized traction table, which contrasts with Bingham et al who utilized both a specialized traction table and conventional table. The use of a conventional table in the non-fluoroscopy group allowed for clinical assessment of LLD by more conventional techniques and was not limited to views of the pelvis. Not to mention Bingham et al really had a completely different study design and question. Given the use of a conventional table in the non-fluoroscopy group, it must be considered that the data is representative of combined clinical and radiographic assessments of LLD rather than mostly radiographic as in the fluoroscopy group. These are major differences between our study and the Bingham et al study, though their study is worth mentioning, and combined with our study sheds light on the importance of continuing our investigation into the use of fluoroscopy in THA.

Reviewer: Do not present new findings in the discussion section.

Thank you for this suggestion, this was addressed by re-structuring this portion of the manuscript and relocating the newly presented results to the closing sentences of our results section.