# Feasibility and Reliability of a Semi-Automated Workflow for Measuring Neck–Shaft Angle and Tip–Apex Distance on Hip Radiographs

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INTRODUCTION: Geriatric hip fractures are commonly treated with cephalomedullary nails. Accurate measurement of postoperative neck–shaft angle (NSA) and tip–apex distance (TAD) is critical for assessing implant positioning and outcomes after hip fracture fixation. These measurements are therefore commonly performed in orthopaedic trauma surgery and research. Manual measurement methods are subjective and prone to user error, while fully automated, AI-based solutions remain inaccessible to most clinicians due to coding and infrastructure requirements. A semi-automated workflow in the open-source platform ImageJ/FIJI was developed and tested to determine its feasibility and reliability for performing NSA and TAD measurements on standard hip radiographs.

METHODS: After institutional review board approval, 1,292 fractures treated with the InterTAN cephalomedullary nail (Smith & Nephew, Memphis, Tennessee, U.S.A.) for proximal femur fractures between 2011-2024 at two high-volume academic trauma centers were analyzed. To standardize the workflow, a custom macro script was written in an open-source image analysis platform ((Fiji is Just) ImageJ 2.16.0/1.54p) to automate measurement steps and minimize user-dependent variability (Image 1). We selected five deliberately heterogeneous cases (range of implant specifications, sex, NSA/TAD values, image quality, and laterality) from the cohort, including four female and one male patient. Repeated measurements (five per AP and lateral radiograph for each fracture) were used to assess intra-observer reliability. Reliability for postop NSA, AP, and lateral TAD, and total TAD was quantified using intraclass correlation coefficients (ICC), and agreement was further evaluated with Bland-Altman analysis to determine bias and 95% limits of agreement.

RESULTS SECTION: Intra-observer reliability was excellent, with ICCs of 0.985 for postop NSA, 0.964 for AP TAD, 0.918 for lateral TAD, and 0.978 for total TAD. Mean bias across repeats was negligible (<0.1 for all parameters). The 95% limits of agreement were –3.36° to +3.55° for NSA, –2.09 to +2.17 mm for AP TAD, –2.70 to +2.75 mm for lateral TAD, and –2.86 to +2.99 mm for total TAD.

DISCUSSION: This pilot study shows that a semi-automated ImageJ/FIJI workflow yields highly repeatable NSA and TAD measurements, supporting its feasibility. ICCs exceeded 0.9 for all parameters, with narrow Bland–Altman limits of agreement indicating minimal error relative to clinical thresholds. Limitations include the small sample size and single-user design, which restricts assessment of inter-observer variability.

SIGNIFICANCE/CLINICAL RELEVANCE: Reliable measurement of NSA and TAD is essential for evaluating implant placement and predicting fixation failure after hip fracture surgery, yet current measurement methods are prone to error. This study establishes a semi-automated workflow using accessible software as a practical, reproducible tool that enhances measurement precision with a low barrier to clinical adoption.

IMAGES AND TABLES:

Table 1. Intra-observer reliability of NSA and TAD measurements on postoperative radiographs (ICC, bias, 95% LOA)

| Measurement | ICC | Bias | LOA (95%) |
|---|---|---|---|
| **Postop NSA (°)** | 0.985 | 0.1 | –3.36-3.55 |
| **AP TAD (mm)** | 0.964 | 0.04 | –2.09-2.17 |
| **Lateral TAD (mm)** | 0.918 | 0.03 | –2.70-2.75 |
| **Total TAD (mm)** | 0.978 | 0.07 | –2.86-2.99 |

Abbreviations: NSA (Neck Shaft Angle), TAD (Tip-Apex Distance), LOA (Limits of Agreement)

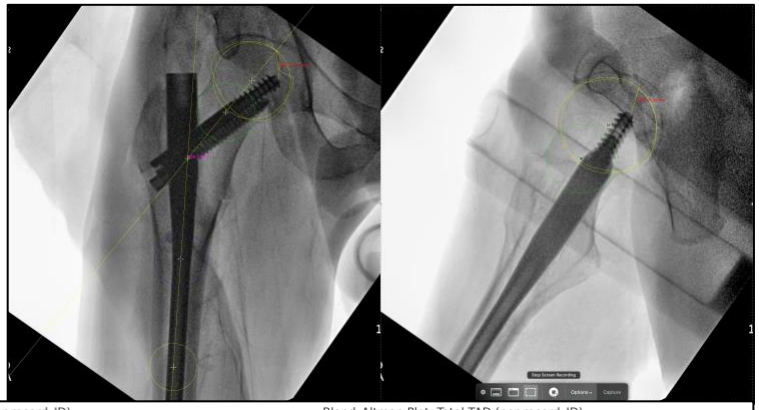

Image 1. Semi-automated workflow for measuring postoperative neck–shaft angle (NSA) and tip–apex distance (TAD) on AP (left) and lateral (right) hip radiographs using a custom macro script. Circles are used to define the femoral shaft anatomic axis (AP only) and the femoral neck axis (AP and lateral), from which angles and distances are calculated.

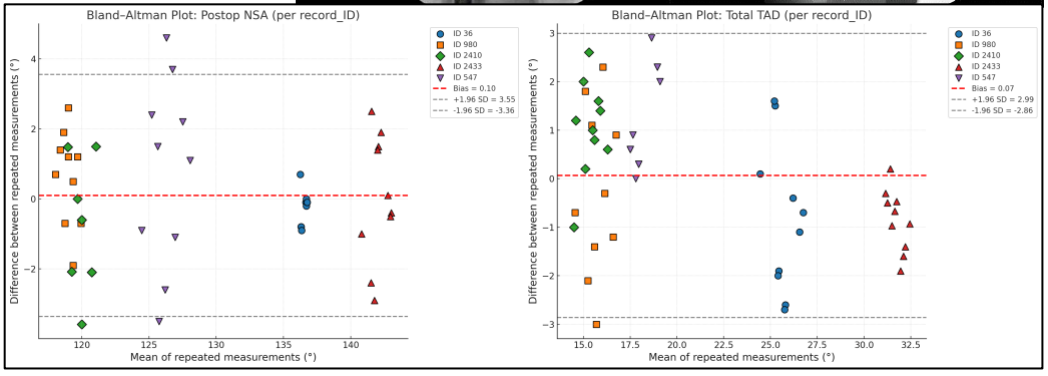


Image 2. Bland–Altman plots for postoperative neck–shaft angle (NSA, left) and total tip–apex distance (TAD, right) across five patients with five repeated measures each. Bias was negligible, and 95% limits of agreement demonstrated narrow variability, confirming excellent intra-observer reliability.