

Assessing TKA Alignment: Accurate and Adjustable Annotation using Artificial Intelligence

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Disclosures: A. Mika: None. Y. Suh: None. D. Moyer: None. J. Wilson: None. S. Engstrom: 3B; Enovis, LinkBio. 9; AAHKS-Advocacy Committee, AAOS-Coding Coverage and Reimbursement Committee. G. Polkowski: 1; Enovis. 3B; Enovis. 9; Board Member AAHKS. R. Martin: None.

INTRODUCTION:

Optimal implant position and alignment remains a controversial, yet critical topic in primary total knee arthroplasty (TKA). Future study of optimal implant position requires the ability to measure component positions at scale. While artificial intelligence possesses potential in this realm, current algorithms have limited accuracy, do not allow for oversight, and require extensive training time. Therefore, the purpose of this study was to develop and validate a machine learning model that can automate, with surgeon directed adjustment, implant position annotation.

METHODS:

A retrospective series of 280 primary TKAs, performed in 160 patients was identified. The femoral-tibial angle (FTA), distal femoral angle (dFA), and proximal tibial angle (pTA) were manually annotated from the immediate post-op radiograph. We then trained a neural network to predict each annotated position. Training employed a novel label augmentation procedure of dilation, reweighting, and scheduled erosion steps (Figure 1) The model was compared against three previously described predication methods (Baseline 0, 1 and 2). Accuracy was then assessed using a validation set of 19 patients.

RESULTS:

The training model significantly improved accuracy over baseline non-augmented training models. The model was significantly improved compared to Baseline 0 and Baseline 1 across all measures (dFA: $p < 1e-15$, pTA: $p < 1e-15$, FTA: $p < 1e-15$), and Baseline 3 for two of three measures (dFA: $p < 1e-9$, pTA: $p < 1e-9$, FTA: $p = 0.443$). In the final model the mean squared prediction error (difference from clinician annotation) was 0.5 degrees for dFA, 0.1 degrees for FTA, and 0.6 for pTA (Figure 4).

DISCUSSION:

Utilizing a novel machine learning algorithm, trained on a limited dataset of 280 TKAs, the accuracy of component position measurement was approximately 0.5 degrees. We believe this accuracy is well within the standard error of manual measurements and has substantial clinical implications for rapidly analyzing large datasets, use for intraoperative implant alignment, as well as identifying implant positions of other joint replacements. Furthermore, the proposed model outputs annotated, adjustable points from which the angles are calculated allowing for clinician oversight (Figure 5).

SIGNIFICANCE: A novel machine learning algorithm achieved high accuracy in measuring component position for TKAs, suggesting its clinical relevance in analyzing large datasets, and intraoperative implant alignment.

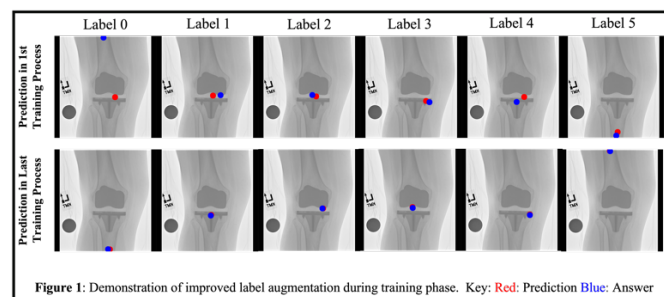


Figure 1: Demonstration of improved label augmentation during training phase. Key: Red: Prediction Blue: Answer

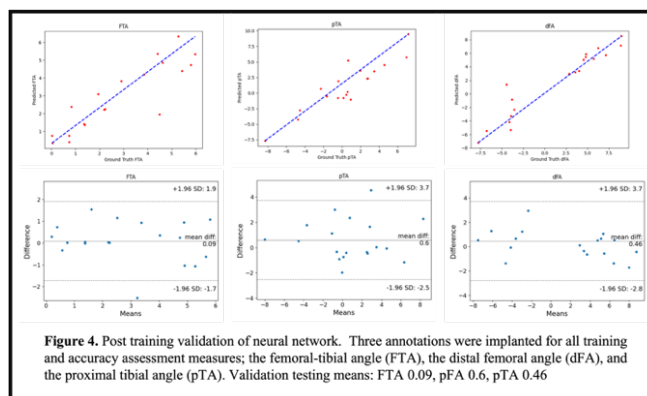


Figure 4: Post training validation of neural network. Three annotations were implanted for all training and accuracy assessment measures; the femoral-tibial angle (FTA), the distal femoral angle (dFA), and the proximal tibial angle (pTA). Validation testing means: FTA 0.09, pFA 0.6, pTA 0.46

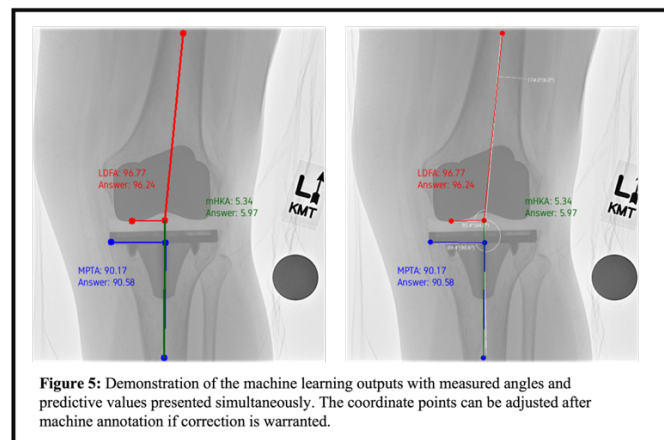


Figure 5: Demonstration of the machine learning outputs with measured angles and predictive values presented simultaneously. The coordinate points can be adjusted after machine annotation if correction is warranted.