Evaluation of error sources for an Image-based Computer Assisted Surgical System for Total Ankle Arthroplasty

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INTRODUCTION: Computer Assisted Surgical (CAS) systems have been used successfully in joint arthroplasty to improve the accuracy of bony resections. CAS usage leads to reduced outliers and improved targeted alignment of orthopedic implants [1]. The whole procedure is a suite of numerous surgical steps, and even using CAS systems, each of these steps may be associated with error such as mispositioning of the cutting block, play between the sawblade and the cutting slot due to the length and width of slot, or saw bending and skiving of the blade during the resection. However, the incidence of these errors may not be all equal. For this reason, the error sources of the individual surgical steps were evaluated for a novel image-based CAS system for total ankle arthroplasty (TAA).

METHODS: TAA was performed by a board-certified, fellowship-trained orthopedic surgeon on twelve artificial ankle joint specimens (PN1132-3, Pacific Research) using a CAS system (ExactechGPS, Blue-Ortho) featuring a dedicated ankle application. Video tracking was performed to confirm surgical technique was standardized for all specimens. Scans of each of the twelve specimens were performed before TAA using a structured light industrial scanner (Comet L3D, Steinbichler) used for assessing surface profiles with an accuracy better than 50µm [3]. From the initial scan, a DICOM series representative of the CAS system recommended CT scan protocol was created from each model for segmentation, and a model coordinate system was created corresponding to the bony anatomy and mechanical axis of the specimen's tibia and talus. During the simulated surgery, active trackers were fixed to each specimen's tibia and talus to allow registration of the anatomical landmarks. Bone resections were individually virtually planned and performed by the surgeon using template software to choose appropriate implant position and size relative to the bony anatomy. Finally, in a similar way to previously executed peer reviewed knee arthroplasty studies [3, 4], the resected bones were scanned and overlaid with the initial model for assessment of the error relative to the original plan. Figure 1 shows the flow of the procedure from plan to final cut as well as the outlay of the error measurements during slot positioning cut execution and cut verification.

RESULTS: Opportunities for error were identified during positioning, execution, and verification. Error from each step was also summated for an overall error value. Mean and 95 % confidence intervals for positioning, execution and verification errors were less than 2mm and 2° (Figure 2). Average absolute errors for the tibia were: 0.30°/.26mm for positioning, 0.87°/.53mm for execution, 0.89°/.56mm for verification, and 0.74°/.59mm overall. Average absolute errors for the talus were: 0.82°/.52mm for positioning, 0.41°/.51mm for execution, 0.64°/.62mm for verification, and 1.13°/.67mm overall. One deviation to surgical technique was identified with video tracking: The talar fixator was not tightened on specimen five per the operative technique, therefore, the data from specimen five was removed from the analysis.

DISCUSSION: TAA performed with a CAS system resulted in overall error less than 2mm and less than 2° on all specimens. Design elements of the CAS system likely contribute to the low observed error. The surgeon receives visual confirmation of the plan and resection confirmation throughout the procedure which allows for real-time adjustments. The plan and the resection are confirmed during the procedure, and the cut itself can be refined. The positioning error on the tibia was lower in comparison to the talus because the tibial instrumentation allows adjustment of each degree of freedom individually, whereas the talar instrumentation required positioning of the foot in all degrees of freedom concomitantly. The highest error value was from verification of the tibial rotation because the smaller surface in comparison with other resections makes acquisition of the true plane less accurate. Future work should consider additional surgeon users, cadaver specimens with ankle arthritis and/or deformity, and comparison to patient-specific instrumentation (PSI) and traditional conventional techniques. In addition to the demonstrated ability to review the slot and cut positions during the procedure, there is future potential to remove the need for other checks for positioning guides which could reduce the burden on the user and reduce radiation exposure of the patient.

SIGNIFICANCE/CLINICAL RELEVANCE: A navigation system may help improve surgical accuracy by facilitating the positioning of instrumentation for resection of bone during TAA surgery.

REFERENCES: [1] Shatrov; J. of Exp. Orth. 7, 70 (2020), [2] Angibaud; Special Lecture 1; CAOS Korea 2014, [3] Angibaud, Clin Orthop Surg. 2015 Jun; 7(2): 225–233, [4] Angibaud; BJJ, Orthopedic Proceedings; 95-B,2013

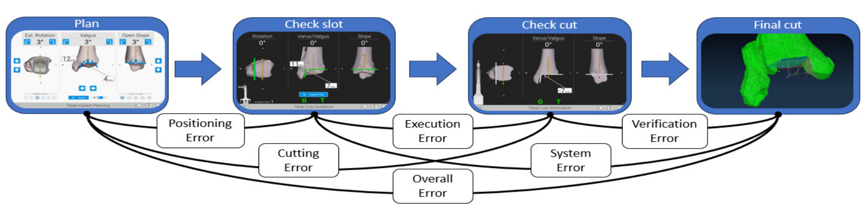

Figure 1: Flow of procedure and six investigated error sources in navigated TAA

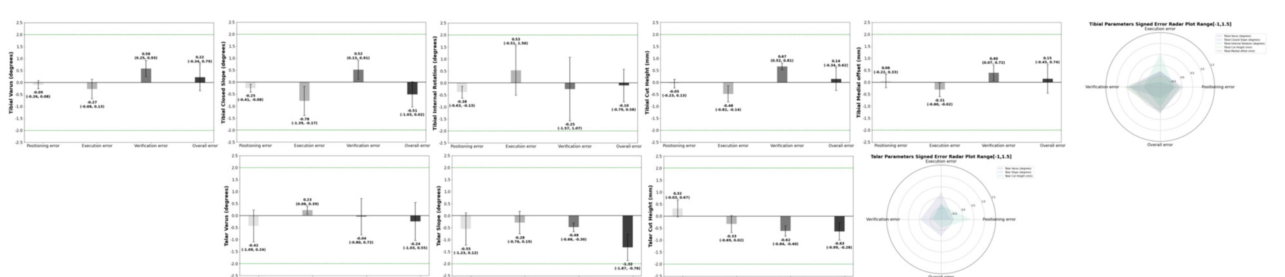

Figure 2: Mean error and 95% confidence intervals with radar plots of error types; Top – Tibial error, Bottom – Talar error; Green lines at 2mm and 2°