Accuracy and Precision of Computer-Assisted Surgery Compared with Conventional Instrumentation and Patient Specific Instrumentation for Total Ankle Arthroplasty

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INTRODUCTION: Computer-Assisted Surgical (CAS) systems have demonstrated their efficacy in enhancing the accuracy of joint arthroplasty resections. The utilization of CAS has resulted in a reduction of outliers and improvement in the targeted alignment of orthopedic implants across many orthopedic applications [1]. Total ankle arthroplasty (TAA) constitutes a suitable surgical intervention for end-stage ankle osteoarthritis, and contemporary TAA techniques have yielded favorable clinical outcomes, establishing them as a viable alternative to ankle arthrodesis [2,3]. The alignment of implants during TAA remains a complex challenge due to limited surgical exposure and reliance on fluoroscopic guidance. To address these limitations, a TAA application for a CAS system and Patient Specific Instrumentation (PSI) were developed by incorporating CT-based alignment to facilitate the procedure for enhancing the accuracy of bone resections. The accuracy and precision of the newly developed TAA CAS system and conventional procedure were previously assessed [4] (Figure 1). The objective of this study was to compare the accuracy of a PSI technique alongside the CAS and conventional system using the same method.

METHODS: TAA was performed by a board-certified, fellowship-trained orthopedic surgeon on twelve artificial ankle joint specimens (PN1132-3, Pacific Research) using conventional instrumentation (Vantage, Exactech). 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 (Metrascan, Black Elite) used for assessing surface profiles with an accuracy better than 25µm. Bone resections were performed using conventional cutting guides and positioning jigs in conjunction with fluoroscopy (Figure 1B). Resections on the talus included a flat cut with three degrees of freedom (e.g. varus, slope, and cut height), whereas tibial resections included distal and medial cuts with five degrees of freedom (e.g. varus, slope, axial rotation, medial offset and cut height). Consistent with established protocols employed in prior peer-reviewed knee arthroplasty studies [5-7], the resected bones were scanned and subsequently overlaid with the initial model using an open source cloud fitting software (CloudCompare) to evaluate the discrepancy between the actual and planned resections. Finally, the PSI results were compared to the CAS and conventional results from the previously executed study.

RESULTS: Tibial deviations from plan and 95% confidence intervals were assessed for the PSI procedure: varus error was 0.69°±0.59°, closed slope error was -3.01°±0.26°, internal rotation error was 0.51°±1.12°, cut height error was -0.97mm±0.40mm, and mediolateral position error was 0.37mm±0.38mm. For the talus: varus error was -1.34°±0.94°, slope error was -0.06°±0.58°, and cut height error was 0.38mm±0.26mm. Finally, the results were compared to the conventional and CAS data from the previous study in a bar chart (Figure 2).

DISCUSSION: The accuracy and precision of the conventional instrumentation was lower than the same resections performed with CAS and PSI when combining all parameters with an average absolute accuracy of 1.63°±1.21° and 0.76mm±0.73mm for the conventional instrumentation, 0.84°±0.19° and 0.27mm±0.06mm for PSI, and 0.48°±0.62° and 0.31mm±0.47mm with CAS. The CAS system helped to reduce outliers of the tibial slope/rotation and talar slope parameters relative to the conventional instrumentation. The PSI system helped to reduce outliers of the talar slope and talar cut height parameters relative to the conventional instrumentation. Regarding limitations, the surrounding soft tissues were not present, and variability across multiple users was not considered. Future work should consider additional surgeon users, cadaver specimens with ankle arthritis and/or deformity. In conclusion, the conventional instrumentation provided acceptable levels of accuracy and precision while the CAS system was able to improve accuracy and precision while reducing outliers without the need of fluoroscopy for positioning of the instrumentation. The PSI instrumentation was able to improve accuracy and precision for talar slope and talar cut height relative to conventional and CAS instrumentation.

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SIGNIFICANCE/CLINICAL RELEVANCE: CAS and PSI may help improve surgical accuracy by facilitating the positioning of instrumentation for resection of bone during TAA surgery.

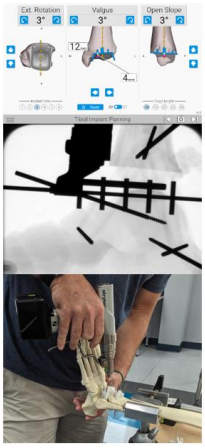

Figure 1A: CAS planning of the tibial resections (top)
Figure 1B: Conventional alignment of the talus using fluoroscopy (middle).
Figure 1C: PSI execution talus using PSI (bottom).