Accuracy and Precision Evaluation of 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 resections. CAS usage leads to reduced outliers and improved targeted alignment of orthopedic implants [1]. Total ankle arthroplasty (TAA) is a surgical treatment for end-stage ankle osteoarthritis, and the latest generation of TAA is associated with favorable clinical outcomes as a modern alternative to ankle arthrodesis [2]. Alignment of the implants during TAA is challenging because of limited surgical exposure and reliance on fluoroscopic alignment. Therefore, a TAA application for CAS system was developed using CT-based alignment alongside required fluoroscopy with the intent of facilitating the procedure and improving accuracy of bone resections. The objective of the study was to evaluate the accuracy and precision of the TAA CAS system.

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 was segmented, 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 by the surgeon performing the operation using template software to choose appropriate implant position and size relative to the bony anatomy. Conventional cutting guides were then guided into place according to the template using the CAS system. 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) (Figure 1). Finally, in a similar way to previously executed peer reviewed knee arthroplasty studies [4, 5], the resected bones were scanned and overlaid with the initial model for assessment of the error relative to the original plan.

RESULTS: For all eight angular and positional cut parameters across both the tibia and the talus, the mean signed overall intraobserver error was less than 2mm and 2° relative to the plan, and the 95% confidence interval was less than 2mm and 2° (Table 1). Both angular and positional overall errors on the tibia were less than 1mm and 1° relative to the plan according to the mean and 95% confidence intervals. One deviation to surgical technique was identified with video tracking: The talar fixator was not tightened on specimen five which leading to tracker movement during talus resection. Therefore, the data from specimen five was removed from the analysis since the operative technique for the TAA navigation system was not followed.

DISCUSSION: The results of the study show that the bone resections using the evaluated TAA application for CAS were associated with satisfactory accuracy level compared to conventional mechanical instruments and PSI blocks [6]. For the specimens in this study, the accuracy of the tibial cut was better than the accuracy of the talar cut. This was likely due to the volume of bone available for stabilizing the resection guides with bone pins. The talar bone requires two pins for tracker fixation and then two pins for block stability, but more stabilizing pin options are available on the tibial guide. Regarding limitations, in vivo, more mass and stability is present because of the surrounding soft tissues, so a solid foot with stabilized calcaneus was used for the study instead of an independent talus bone to mitigate vibrations from the saw. 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. The results point to resections with errors of less than 2mm and 2° and therefore the system can offer both accurate and precise intraoperative surgical resection measurements during computer-assisted TAA.

REFERENCES: [1] Shatrov; J. of Exp. Orth. 7, 70 (2020), [2] Burgesson, B; Orthopaedic Proceedings 102-B, 2020, [3] Angibaud; Special Lecture 1; CAOS Korea 2014, **[4**] Angibaud, Clin Orthop Surg. 2015 Jun; 7(2): 225–233, **[**5] Angibaud; BJJ,Orthopedic Proceedings; 95-B,2013, [6] Berlet; Foot Ankle Int. 2014 Jul;35(7):665-76

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

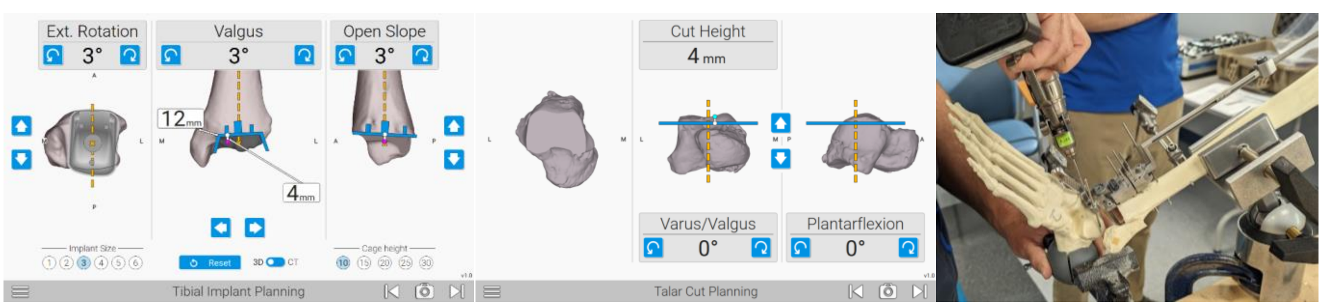

Figure 1: Example tibial and talar plans (left and middle respectively) and subsequent execution (right)

Table 1: Differences between planned resection and final measured resection, described as overall error

Parameter/Specimen	Tibial varus (°)	Tibial closed slope (°)	Tibial IR (°)	Tibial cut height (mm)	Tibial medial offset (mm)	Talar varus (°)	Talar slope (mm)	Talar cut height (mm)
Mean	**-0.22**	**0.51**	**0.10**	**-0.14**	**-0.15**	**0.24**	**1.32**	**0.63**
Lower CI (95%)	**-0.79**	**-0.02**	**-0.58**	**-0.62**	**-0.74**	**-0.55**	**0.76**	**0.28**
Upper CI (95%)	**0.34**	**1.03**	**0.79**	**0.34**	**0.45**	**1.03**	**1.87**	**0.99**
Specimen 1	-0.40	0.70	1.90	-0.07	-1.22	2.10	0.05	0.47
Specimen 2	1.50	1.70	0.01	0.73	0.34	0.95	0.40	0.24
Specimen 3	1	0.70	-0.90	-0.54	-0.13	2.18	2.57	1.28
Specimen 4	0.20	1.40	-0.05	0.11	-0.22	-1.15	1.80	0.64
Specimen 6	-1	1.35	-1.32	0.26	1.48	0.38	1.43	1.01
Specimen 7	-0.60	0.60	-0.01	1.05	0.08	-0.85	2.10	0.47
Specimen 8	-1.1	-0.70	0.21	-0.92	0.29	-1	0.88	0.52
Specimen 9	-0.20	0.20	-0.70	-0.08	0.38	0.38	0.85	0.96
Specimen 10	-1.10	-0.60	-0.60	-1.43	0.18	0.39	1.50	-0.19
Specimen 11	-0.55	0.10	1.50	-0.10	-1.35	0.16	0.60	0.02
Specimen 12	-0.20	0.10	1.1	-0.56	-1.44	-0.93	2.30	1.55