

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

Edward Haupt, Cole Herbel, Ramiro Lopez, Matthew Rueff, ZACHARY F Tupper, Matthew Hamilton, Prudhvi Tej Chinimilli, Scott Gulbransen, Phong Diep, Laurent Angibaud, Laureline Prouvost

INTRODUCTION:

Total ankle arthroplasty (TAA) has become a viable alternative to ankle arthrodesis (AA) in recent years. However, implant longevity is a concern, as malalignment of either the tibial or talar components has been shown to predispose to premature wear and necessary revision surgery. Thus, customized surgical tools such as computer navigation and patient-specific instrumentation have been utilized to theoretically improve intraoperative alignment of components. The primary outcome of this study is to compare alignment between a computer-assisted surgical (CAS) TAA system, a preexisting patient-specific instrumentation (PSI) system, and conventional fluoroscopic techniques.

METHODS:

TAA was performed on thirty-six artificial ankle joint specimens by a single surgeon; twelve using CAS, twelve with PSI, and twelve with conventional instrumentation. All specimens were scanned both preoperatively and postoperatively using a high-precision 3D scanning tool. Resections and implant placements were then analyzed in 3D processing software and compared between operative modalities. Statistical analysis included one-way ANOVA with associated Tukey tests to assess for differences between groups.

RESULTS:

We found that tibial resections were overall most accurate using CAS, with tibial slope measurements demonstrating significant improvements over PSI ($P < 0.001$) and conventional instrumentation ($P < 0.001$). PSI was more accurate than conventional when considering the axial cut height of the tibial resection ($P < 0.001$). In terms of the talar resections, CAS was statistically superior to conventional methods in two of three measured categories (slope: $P < 0.001$, axial cut height: $P < 0.001$). However, PSI fared better than CAS in those same categories (slope: $P = 0.002$, axial cut height: $P < 0.001$) (Table 1). Employment of the CAS system also decreased implant placement variability (CAS: ± 0.47 mm, ± 0.62 deg; PSI: ± 0.63 mm, ± 1.03 deg; conventional: ± 0.73 mm, ± 1.21 deg) (Table 2).

DISCUSSION AND CONCLUSION:

In this laboratory-based TAA study, we found that both CAS and PSI demonstrated advantages over conventional instrumentation with regards to implant placement accuracy. Tibial resections were found to be overall most accurate under CAS guidance and talar resections were found to be overall most accurate under PSI guidance. Additionally, the observed reduction in implant placement variability has potential positive implications for surgeons. However, as this study was conducted on artificial specimens, effects of soft tissue and preoperative deformities or pathologies were not considered. Future studies should include cadaveric specimens with various pathologies to better simulate conditions encountered in an operating room.

Table 1: P values between study groups

Two-tailed T-test (p-values)	PSI vs. Conventional	CAS vs. Conventional	CAS vs. PSI
Tibial Varus	0.17	0.01*	0.22
Tibial Closed Slope	0.25	< 0.001*	< 0.001*
Tibial Internal Rotation	0.51	0.86	0.32
Tibial Cut Height	< 0.001[‡]	0.17	< 0.001*
Tibial Mediolateral position	0.94	0.82	0.50
Talar Varus	0.10	0.52	0.21
Talar Slope	< 0.001[†]	0.001*	0.002[†]
Talar Cut Height	< 0.001[†]	< 0.001*	< 0.001[†]

Boldface indicates statistical significance

*CAS performed better

[†]PSI performed better

[‡]Conventional performed better

Table 2: Overall Deviations for All Operative Modalities

	CAS	PSI	Conventional	Sign Convention (+)
	Mean (95% CI)			
Tibial Varus (degrees)	0.22 (-0.34 to 0.79)	0.69 (0.10 to 1.27)	1.18 (0.68 to 1.68)	Varus
Tibial Closed Slope (degrees)	-0.50 (-1.03 to 0.02)	-3.01 (-3.90 to -2.11)	-2.38 (-3.16 to -1.60)	Dorsiflexion
Tibial Internal Rotation	-0.10 (-0.79 to 0.58)	0.51 (-0.61 to 1.64)	-0.31 (-2.75 to 2.14)	Internal Rotation
Tibial Cut Height (mm)	0.14 (-0.33 to 0.62)	-0.97 (-1.37 to -0.57)	0.58 (0.08 to 1.07)	Proximal
Tibial Mediolateral position (mm)	0.15 (-0.44 to 0.74)	0.37 (-0.01 to 0.75)	0.32 (-1.13 to 1.76)	Lateral
Talar Varus (degrees)	-0.24 (-1.03 to 0.55)	-1.34 (-2.28 to -0.40)	0.15 (-0.89 to 1.20)	Varus
Talar Slope (degrees)	-1.32 (-1.87 to -0.76)	0.06 (-0.64 to 0.52)	-4.12 (-5.39 to -2.84)	Plantarflexion
Talar PD (mm)	-0.63 (-0.99 to -0.28)	0.38 (0.11 to 0.64)	-1.37 (-1.63 to -1.11)	Distal
Parameters within ± 2 mm / degrees	8 / 8	7 / 8	6 / 8	

Boldface indicates values with mean outside the study's ± 2 degree (mm) accuracy stipulation