Accuracy of robotic-arm assisted reverse shoulder arthroplasty

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INTRODUCTION: Robotic-arm assisted technology has demonstrated improved accuracy in knee and hip joint arthroplasty[1,2]. Accurate implant placement is associated with successful restoration of native joint biomechanics and improved post-operative outcomes[3]. This study evaluates the implant position accuracy for reverse shoulder arthroplasty (RSA) using a robotic system, Mako Shoulder 1.0 (Stryker Corp.). Accuracy has been quantified by comparing final implant placement in three-dimensional (3D) post-operative imaging relative to pre-operative plans created on 3D patient-specific bone models.

METHODS: Eighteen cadavers (12 males, 6 females; ages 81 ± 8.9 years; BMI 22.1 ± 7.1 kg/m^2) underwent RSA (primary joint replacement) by eighteen orthopedic surgeons with varied experience of robotic-arm assisted joint replacement (7 with no prior experience, 11 with 8 ± 3.8 years of experience). Pre-operative planning was performed by each surgeon with Blueprint software (Stryker Corp.) on patient-specific bone models derived from CT imaging. The Mako Shoulder 1.0 system was used to prepare the glenoid surface onto which a Tornier Perform Reversed Glenoid baseplate was installed. Post-operative 3D imaging was acquired with the installed implant baseplate component. The prepared bone and installed implant were both independently segmented from the imaging data. Post-operative data was transformed to the pre-operative imaging coordinate system by automated best-fit alignment of the pre-operative and post-operative segmented bone models following manual pre-alignment using corresponding landmarks on each model. All data was then transformed to a consistent glenoid coordinate system (Tx: medial-lateral/depth, Ty: anterior-posterior, Tz: superior-inferior) to measure accuracy for each degree of freedom across all specimens. Implant placement error was determined by automated best-fit alignment of the post-operative segmented implant to the CAD model of the utilized baseplate in its planned position relative to the pre-operative bone model.

RESULTS: Results are displayed in Table 1. For each specimen, a positive Tx (medial-lateral/depth) error indicates the executed implant was proud of plan, positive Ty (anterior-posterior) error is posterior of plan, positive Tz (superior-inferior) error is superior of plan, positive Ry (inclination) error is inferiorly inclined, and positive Rz (version) error is retroverted. Implant placement error of mean ± standard deviation relative to plan for depth (0.512 ± 0.723mm), anterior-posterior (0.232 ± 1.159mm), superior-inferior (-0.260 ± 0.794mm), inclination (0.559 ± 2.679deg), and version (-0.460 ± 2.741deg) was achieved.

DISCUSSION: The results of this study demonstrated that robotic-arm assisted shoulder arthroplasty enabled consistent, accurate implant placement compared to plan, aligning with the growing body of evidence supporting robotic technology in orthopedic procedures. Precise positioning of glenoid and humeral components may play an important role in restoring native joint biomechanics, potentially reducing the risk of implant loosening, and contributing to improved long-term functional outcomes. While these results are promising, limitations of cadaveric data should be considered and further research is needed to evaluate the long-term clinical impact of robotic-assisted shoulder arthroplasty, including implant survivorship and clinical outcomes. Our findings support the continued adoption of robotic technology in shoulder arthroplasty to enhance surgical precision and patient care.

SIGNIFICANCE/CLINICAL RELEVANCE: Accurate implant placement in shoulder arthroplasty may improve long-term patient outcomes. Accurate implant placement with robotic arm-assisted shoulder arthroplasty has been demonstrated.

REFERENCES: [1]Hampp et al. (2019), [2]Smith et al. (2020), [3]Argawal et al. (2020)

IMAGES AND TABLES:

	Side	Depth	A-P	S-I	Inclination	Version
Case	L/R	Tx Err (mm)	Ty Err (mm)	Tz Err (mm)	Ry Err (deg)	Rz Err (deg)
1	R	0.952	-0.002	0.278	2.704	1.182
2	R	1.284	0.555	0.718	-1.753	-0.483
3	R	0.957	-0.730	0.982	-0.620	-0.951
4	R	1.322	-1.056	-1.056	2.199	-3.874
5	R	-0.294	0.325	-0.499	2.508	-1.893
6	R	0.114	1.255	-0.349	-1.441	-1.716
7	R	0.262	-0.133	-0.784	2.002	0.746
8	R	1.771	-1.053	-0.375	-2.204	-4.555
9	L	1.865	-0.511	-0.128	-0.659	0.185
10	L	0.046	3.900	1.053	0.617	-0.719
11	L	-0.084	-0.734	-0.288	3.390	0.916
12	L	0.020	-0.280	-1.328	-3.459	6.204
13	L	-0.630	0.520	0.638	0.659	2.620
14	L	0.416	-0.390	0.158	3.574	2.414
15	L	0.752	0.139	-1.621	-5.256	0.537
16	L	-0.326	0.727	-0.314	4.513	-0.866
17	L	0.531	1.377	-1.350	0.248	-4.457
18	L	0.255	0.257	-0.411	3.035	-3.561

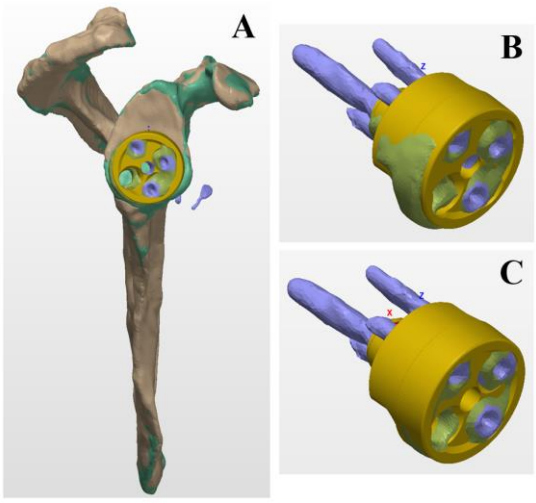

Table 1. Accuracy results for all specimens.

Figure 1. (A) Best-fit alignment of pre- and post-operative data using segmented bone models, (B) error of executed segmented glenoid baseplate (green), relative to pre-operative plan (gold), (C) best-fit alignment of glenoid baseplate component to quantify error, center and peripheral screws (purple) not used in calculation.