Preoperative Planning Enhances Humeral Cut Accuracy and COR Restoration in Anatomic Total Shoulder Arthroplasty

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INTRODUCTION: Total shoulder arthroplasty (TSA) has greatly benefited from computed tomography (CT)-based 3-dimensional preoperative planning. However, much of the focus has been on the glenoid. As a result, there has been a scarcity of research focusing on planning and accurate execution of the humeral portion of the procedure. One of the primary aims of anatomic TSA is the restoration of the humeral Center of Rotation (COR) of the joint, as poor COR restoration has been shown to correlate directly with inferior outcomes[1]. While there is evidence in the literature that planning may ensure a more accurate restoration in non-pathological humeral anatomies[2], accurately executing the plan becomes even more important and challenging for pathological anatomies, as osteophytes and other deformities can influence the plane of humeral cut, and hence the COR restoration. This study attempted to analyze the influence of humeral preoperative planning on pathological humeri by comparing COR restoration of planned cases with unplanned cases. The hypothesis is that executing the planned cases improves the COR restoration of the executed cuts.

METHODS: Five de-identified Computed Tomography (CT) scans were chosen from a clinical database of over 100,000 cases presenting for shoulder arthroplasty (Virtual Implant Positioning™). The cases were chosen such that they corresponded to -3, -1, mean (0), 1, and 3 standard deviations from the mean humeral diameter in the database. They were then preoperatively planned by three fellowship-trained surgeons using the Virtual Implant Positioning™ software (Arthrex Inc.). The humerus and scapula models were 3D printed using a novel printing process (3DAnatomy™, Arthrex Inc.). All four rotator cuff muscles were silicone molded and glued in the anatomically correct positions. Each model was then mounted inside a silicone shoulder with skin to simulate a realistic surgical scenario. The humeral cuts were performed in 3 phases: (1) prior to any humeral planning, (2) utilizing a preoperative humeral plan alone, and (3) using standard transfer instrumentation along with the humeral plan. All humeri were postoperatively digitized using a portable 3D scanner (Revopoint Miraco Pro) and converted into a Stereolithography (STL) format. The models were then imported into Materialise 3-Matic (Materialise NV) where the prosthetic head was virtually placed on the cut surface. Using existing literature methods[3], the native humeral head sphere was created. A best-fit "post-op" sphere was also created using the surface of the prosthetic head. The distance between COR of the two spheres was calculated in Medial-Lateral (M-L) and Anterior-Posterior (A-P), and Superior-Inferior (S-I), along with a "3D Deviation". The Neck Shaft Angle (NSA) of the cut and cut thickness was also measured. All measurements were made in SolidWorks (Dassault Systèmes).

RESULTS SECTION: A total of 45 humeral cuts were analyzed. There was no statistically significant difference between the three phases for the NSA, 3D COR shift, or the retroversion of the cuts ($p>0.05$). Statistical significance was observed between phases 1 and 2 for calculating the M-L COR shift ($p = 0.043$). Use of planning and standard instrumentation significantly reduced the percentage of varus head cuts (NSA<130º) ($p = 0.046$ for phase 1:3 and phase 2:3)

DISCUSSION: The study's results highlight the importance of preoperative planning by showing how the introduction of pathologic humeral head anatomy can significantly affect COR restoration. Future instrumentation development is needed to allow surgeons to make accurate judgments and corrections on NSA and versions of their cuts intraoperatively. Furthermore, this study also highlights the importance of 3D printing and the ability to repeatedly print specifically chosen pathologies, which are anatomically accurate in look and feel.

SIGNIFICANCE/CLINICAL RELEVANCE: Preoperative CT-based humeral planning may lead to more accurate restoration of COR in anatomic TSA for pathologic humeri.

REFERENCES:
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[2] Werner BC et al. (2024) "The Impact of Three-Dimensional Humeral Planning and Standard Transfer Instrumentation on Reconstruction of Native Humeral Anatomy for Anatomic Total Shoulder Arthroplasty" J Shoulder Elbow Surg. 2025 Jan;34(1):147-153
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IMAGES AND TABLES

Fig 1. (Left) Humeral Resection of 3D Printed Humerus in progress. (Right) Post-op with Humeral Head implanted

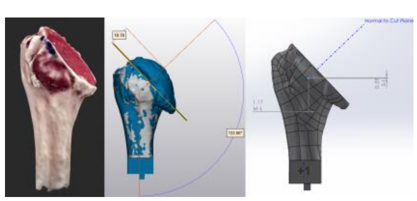

Fig 2. (Left) 3D Scanned post-op humerus for analysis (Centre) Resection Height and NSA measurements with pre-op humerus overlay (Right) M-L and S-I COR Deviations

Parameter	Phase 1		Phase 2		Phase 3		Statistical Comparison (p)		
	Mean	SD	Mean	SD	Mean	SD	Phase 1:2	Phase 1:3	Phase 2:3
Neck Shaft Angle (º)	130	5	130	6	134	7	0.987	0.182	0.238
Deviation in Resection Height (mm)	2.4	1.7	2.2	0.9	1.9	1.2	0.919	0.53	0.77
Center of Rotation (COR) (mm)									
3-D COR Shift	3.7	1.2	2.8	0.9	3.4	1.5	0.127	0.775	0.398
M-L COR Shift	2.8	1.5	1.6	1.2	2.3	1.4	0.043	0.519	0.356
S-I COR Shift	1.7	1.2	1.3	0.9	2	1.4	0.666	0.774	0.28
A-P COR Shift	0.9	0.6	1.1	1	0.7	0.6	0.864	0.669	0.363
	n	%	n	%	n	%	Phase 1:2	Phase 1:3	Phase 2:3
Varus Head Cuts (n)	7	47%	7	47%	2	13%	0.999	0.046	0.046

Table 1. Tabulated Results