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ORIGINAL ARTICLE

The influence of three-dimensional planning on decision-making in total shoulder arthroplasty

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Background: Long-term results and complication rates in shoulder arthroplasty are related to implant positioning. Current literature reports increased precision in glenoid component positioning using 3-dimensional (3D) computed tomography (CT) planning tools. This study evaluated the accuracy of glenoid version and inclination measurements using 2D CT scans compared with a validated 3D software program and its influence on decision making on implant selection.

Methods: Preoperative CT scans were obtained from 50 patients undergoing total shoulder arthroplasty. Glenoid version and inclination measurements were performed in random order by 3 independent qualified orthopedic surgeons on reformatted 2D CT scans. Indication for anatomic or reverse shoulder arthroplasty was based on glenoid deformity and on rotator cuff conditions. Results were compared with those from a validated 3D computer software program, and the final decision was made according to the 3D planning.

Results: Mean preoperative glenoid retroversion on reformatted 2D CT scans was 11.9° ± 9.6° and mean superior inclination was 10.7° ± 8.6°. When the 3D software was used, glenoid retroversion averaged 15.1° ± 10.6° and superior inclination averaged 8.9° ± 9.9°. The 2D CT demonstrated good interobserver and intraobserver reliability for glenoid version and inclination. Decision on the choice of implant was adjusted in 7 patients after the 3D planning.

Conclusions:: Our findings show that measurements of glenoid version and inclination on reformatted 2D CT scans are less accurate compared with 3D measurements. A preoperative 3D planning software allows for improvement of virtual glenoid positioning and influences the decision making process.

Level of evidence: Level III; Diagnostic Study

Keywords: glenoid version; glenoid inclination; 3D measurements; preoperative planning; shoulder arthroplasty; computed tomography

Long-term results and complication rates in total shoulder arthroplasty are substantially related to glenoid implant positioning.[9,14,43] The incidence of radiological loosening in anatomic total shoulder arthroplasty varies from 24% to 87% at long-term follow-up,[2,7,25] resulting in a revision burden of up to 10%.[10,28,37,44,45] Several factors contributing to implant failure have been identified: excessive glenoid reaming leading to loss of the subchondral bone stock,[4,15,43] excessive glenoid

All investigations confirmed to ethical principles of research, and informed consent for participating in this study was obtained from all patients. Institutional Review Board approval was not required because all radiographic interventions followed routine assessment and were in line with the consistent practice.

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retroversion,[5,8,32] and implant malpositioning.[14,19,22] Biomechanical studies further demonstrated the lack of reproducibility in accurate reaming of biconcave glenoids[24] and correction of moderate to severe glenoid retroversion[21] as well as a high risk of glenoid vault perforation in retroverted glenoids,[13,21] justifying the need for guided surgery.

Traditional 2-dimensional (2D) computed tomography (CT) imaging has been found to be unreliable in measurements of glenoid version and inclination.[3,6,18] Computer-assisted navigation has been proposed to increase intraoperative reproducibility of the preoperative planning.[26,31,40] To avoid potential disadvantages of these techniques, different surgeons have focused on the use of 3D CT planning tools and patient-specific instrumentation. Recent literature reports an improved precision in glenoid component placement for anatomic and reverse shoulder arthroplasty in cadaveric and clinical settings.[16,20,27,35,38,39,42] However, these guides cause an additional financial burden that has not yet been proven to be justified by an improved outcome.

The aim of our study was to evaluate the accuracy of glenoid version and inclination measurements on reformatted 2D CT scans compared with a validated 3D software program. We hypothesized that the use of a 3D CT planning would influence decision making in anatomic and reverse shoulder arthroplasty.

Materials and methods

The study enrolled 50 patients (22 men, 28 women) who underwent or were planned to undergo total shoulder arthroplasty for primary or secondary osteoarthritis, with or without rotator cuff pathology, between March and December 2015. The study cohort was an average age of 67.8 years (range, 35-81 years). Distribution according to the modified Walch classification is provided in Table I.

Before the operation, all patients received a 2D CT scan of the shoulder, reformatted to the scapular axis with the scapula fully visible. The CT was performed with the patient supine on the CT table using an Optima CT 660 scanner (GE Healthcare, Fairfield, CT, USA) in increments of 0.3 mm. Acquisition parameters were the same in all patients (140 kV, 300 mAs, 0.625 mm collimation, no gantry tilt, pixel size 512 × 512).

The 2D CT measurements were performed by 3 independent qualified shoulder surgeons. Glenoid version was calculated at the level of the middle glenoid, according to the method of Friedman et al.[11] The β-angle, as described by Maurer et al,[29] determined the glenoid inclination. All measurements were performed again after 6 weeks.

Table I Distribution according to the Walch classification

Walch classification	No.
A1	14
A2	10
B1	3
B2	14
B3	8
C	1

The CT scans were then processed to a previously validated 3D software program (Imascap, Brest, France).[42] After an automatic segmentation process, the software program determines the scapular and glenoid plane based on a 3D point cloud of the scapula, thus providing measurements of glenoid version and inclination as well as humeral head subluxation with regard to the scapular plane. These measurements were considered as the reference for accuracy of the 2D measurements. An observer very experienced using the 3D imaging software performed virtual glenoid implantation. This observer did not participate in the 2D measurements.

The observers decided from glenoid measurements and rotator cuff integrity whether to implant an anatomic or reverse shoulder arthroplasty. The rotator cuff was assessed for atrophy and fatty infiltration on the CT scan. In preoperative grade 3 and 4 fatty infiltration according to the Goutallier classification,[12] a reverse shoulder arthroplasty was selected. Before performing the glenoid measurements, all observers agreed on the threshold between anatomic and reverse shoulder arthroplasty. A superior inclination greater than 10° was considered an exclusion criterion for an anatomic prosthesis because superior glenoid tilting has been observed in massive rotator cuff tears and is accused to lead to superior eccentric loading leading to implant failure.[23,43] Consensus was obtained on decision making in Walch B2 glenoids. Based on the recommendations in the literature,[30,41] surgeons chose a reverse shoulder arthroplasty in case of a glenoid retroversion greater than 27° of the neoglenoid as well as subluxation of the humerus greater than 80%. Results were compared with the final decision made according to the 3D planning.

Statistics

Intraobserver and interobserver reliability was calculated using the intraclass correlation coefficient (ICC). Values between 0.80 and 0.89 were rated as very good, and values of 0.9 and more were categorized excellent. The paired *t* test was used for differences between 2D and 3D measurements. The level of significance was set at $P < .05$.

Results

The 2D CT demonstrated very good interobserver reliability for glenoid version (ICC = 0.87; 95% confidence interval, 0.82-0.92) and inclination (ICC = 0.84; 95% confidence interval, 0.78-0.89; Table II). Intraobserver reliability was very good to excellent for glenoid version (ICC = 0.86- 0.93) and glenoid inclination (ICC = 0.87-0.95).

Mean preoperative glenoid retroversion on reformatted 2D CT scans was 11.9° ± 9.6°, and mean superior inclination was 10.7° ± 8.6°. The 3D CT measurements averaged 15.1° ± 10.6° for glenoid retroversion and 8.9° ± 9.9° for superior glenoid inclination. The difference between the mean 2D and 3D measurements was statistically significant for glenoid version ($P = .003$). The difference for glenoid inclination was not statistically significant ($P = .18$). Mean deviation in 2D measurements compared with 3D values was −3.1° (range, −30° to 20°; standard deviation, 7.0) for glenoid version and −1.7° (range, −26 to 20°; standard deviation, 8.4) for glenoid inclination (Table III). Measurements differed more than 5° in 44% of patients for glenoid version and in 36% for glenoid