J Shoulder Elbow Surg (2017) ■■, ■■–■■

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

The influence of humeral neck shaft angle and glenoid lateralization on range of motion in reverse shoulder arthroplasty

Birgit S. Werner, MD[a,b,*], Jean Chaoui, PhD[c], Gilles Walch, MD[b]

[a]*Clinic for Shoulder and Elbow Surgery, Bad Neustadt, Saale, Germany*
[b]*Centre Orthopédique Santy, Hôpital Jean Mermoz, Lyon, France*
[c]*Imascap, Brest, France*

Background: Recent developments in reverse shoulder arthroplasty (RSA) have focused on changes in several design-related parameters, including humeral component design, to allow for easier convertibility. Alterations in humeral inclination and offset on shoulder kinematics may have a relevant influence on postoperative outcome. This study used a virtual computer simulation to evaluate the influence of humeral neck shaft angle and glenoid lateralization on range of motion in onlay design RSA.
Methods: Three-dimensional RSA computer templating was created from computed tomography (CT) scans in 20 patients undergoing primary total shoulder arthroplasty for concentric osteoarthritis (Walch A1). Two concurrent factors were tested for impingement-free range of motion: humeral inclination (135° vs. 145°) and glenoid lateralization (0 mm vs. 5 mm).
Results: Decreasing the humeral neck shaft angle demonstrated a significant increase in impingement-free range of motion. Compared to the 145° configuration, extension was increased by 42.3° (–8.5° to 73.5°), adduction by 15° (10° to 23°), and external rotation with the arm at side by 15.1° (8.5° to 26.5°); however, abduction was decreased by 6.5° (–1° to 12.5°). Glenoid lateralization led to comparable results, but an additional increase in abduction of 7.6° (–1° to 16.5°) and forward flexion of 26.6° (6.5° to 62°) was observed.
Conclusion: Lower humeral neck shaft angle and glenoid lateralization are effective for improvement in range of motion after RSA. The use of the 135° model with 5 mm of glenoid lateralization provided the best results in impingement-free range of motion, except for abduction.
Level of evidence: Basic Science Study; Computer Modeling

Keywords: Reverse shoulder arthroplasty; range of motion; onlay design; humeral inclination; impingement; preoperative planning

Reverse shoulder arthroplasty (RSA) is a beneficial treatment option for cuff-deficient shoulders. The traditional Grammont prosthesis relies on medialization and inferiorization of the center of rotation to restore mobility. However, some problems have been observed at long-term follow-up because

The Centre Orthopédique Santy/Hôpital Privé Jean Mermoz, Lyon, France, Institutional Review Board and Ethics Committee approved this study (ref. study 2016-15).

*Reprint requests: Birgit S. Werner, MD, Clinic for Shoulder and Elbow Surgery, Salzburger Leite 1, Bad Neustadt, D-97616 Bad Neustadt/Saale, Germany.

E-mail address: birgitwerner@hotmail.com (B.S. Werner).

1058-2746/$ - see front matter © 2017 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
http://dx.doi.org/10.1016/j.jse.2017.03.032

of the prosthetic design. Scapular notching is the most common complication, occurring in up to 88% of patients, with an increasing rate of grade 3 and 4 notching over time.[6,13,14,17,18,21] In addition to a mechanical abutment of the humeral component at the scapular neck, Lädermann et al[11] recently described the friction-type, occurring in a combined movement of extension and rotation with the arm at side. Moreover, some authors observed a decrease in active rotation,[4,21] despite an improvement in active elevation and abduction for the Grammont-type prosthesis.[4,6,17,18,21]

The concept of bony or metallic lateralization of the glenoid component has been reported to be a viable option to increase impingement-free range of motion (ROM),.[3,7,8,20] Lateralization of the glenoid component leads to increased internal and external rotation[3,7,8] and has been reported to decrease the incidence of scapular notching.[1] Prostheses with new designs have been developed to allow for easier convertibility from anatomic shoulder arthroplasty to RSA. Some authors have suggested that more anatomic humeral inclination would reduce scapular notching.[5,9,10]

To date, there are no guidelines for the ideal configuration of both humeral and glenoid positioning to obtain the best functional results in elevation and rotation. This study used computer simulation to evaluate the influence of humeral neck shaft angle and glenoid lateralization on ROM as well as impingement in onlay design RSA. We hypothesized that decreased humeral inclination and glenoid lateralization would increase impingement-free mobility.

Materials and methods

We analyzed 20 computed tomography (CT) scans obtained from patients for whom primary total shoulder arthroplasty for concentric osteoarthritis (Walch A1) by the senior author (G.W.) was planned. Patients met inclusion criteria if they demonstrated an anteroposterior glenoid width of less than 30 mm to exclude any bony overhang with use of a 29-mm baseplate.

All CT scans were processed by Glenosys, a validated 3-dimensional (3D) software program (Imascap, Brest, France).[15] After segmentation and 3D reconstruction, the software automatically provides measurements of glenoid version with respect to the scapular plane and glenoid inclination in the frontal plane with respect to the transverse axis of the scapula. The mean superior inclination was 7.6° (standard deviation, 6.4°), and glenoid retroversion averaged 7.8° (standard deviation, 5.5°). The software program allows for virtual implantation of the humeral and glenoid components. Inclination of the humeral component is related to the level of the humeral cut with respect to the diaphyseal axis.

A virtual RSA model was used to test 4 different configurations in all 20 patients. In all cases, a 29-mm baseplate was positioned at the inferior part of the glenoid with the central peg placed in the middle of the glenoid width to avoid bony overhang. All configurations consisted of a 36-mm glenosphere with 2-mm inferior eccentricity. A neutral position was used for inclination and version. The humeral cut was virtually performed at the anatomic neck, respecting the patient's anatomic humeral version. The onlay design prosthesis (Aequalis Ascend Flex; Wright Medical, Bloomington, MN, USA) was inserted with the humeral tray inevitably positioned in the same offset position at the level of the greater tuberosity.

Two concurrent factors were tested: glenoid lateralization and humeral neck shaft angle. The glenoid component was inserted flush with the inferior rim of the glenoid, with or without additional 5 mm of bony lateralization. The neck shaft angle of 135° or 145° was simulated using a prosthetic inclination of 127.5° combined with an asymmetric 7.5° polyethylene insert and a prosthetic inclination of 132.5° with a 12.5° polyethylene insert, respectively (Fig. 1).

All configurations were tested for impingement-free ROM in abduction-adduction, forward flexion-extension, and external and internal rotation with the arm at side. Global ROM defined as a sum of all 6 motions using the Glenosys 3D software. The ROM simulation is based on collision detection between 2 or more objects. The 3D computer model allows for a resolution of 1°. The maximum values for each motion until encountering bone-to-bone or bone-to-implant impingement on the scapula or acromion were documented.

Statistics

All statistical analysis was performed using MedCalc 12.0 software (MedCalc Software bvba, Ostend, Belgium). A multivariable linear regression analysis was used to analyze the effect of glenoid lateralization and humeral inclination on ROM. A multivariate analysis of variance was performed for each of the ROM variables. The level of significance was set at $P < .05$.

Results

Influence of humeral inclination on ROM

The use of a 135° model demonstrated a mean increase in impingement-free ROM of 77.5° (20° to 112.5°, $P < .0001$), with superior values for each motion tested but abduction. This was statistically significant for adduction ($P < .001$), external rotation ($P < .05$), extension in the lateralized glenoid configuration ($P < .001$), and internal rotation in standard glenoid positioning ($P = .02$). The results for pairwise comparison are presented in Table I. The 135° configuration led to doubled values for extension, with a mean increase of 42.3° (−8.5° to 73.5°). Adduction was improved by 15° (10° to 23°), whereas a mean decrease of 6.5° (−1° to 12.5°) in abduction was observed. Internal rotation with the arm at side was increased by 7° (2.5° to 15°), and external rotation improved by 15.1° (8.5° to 26.5°) with the 135° model. There was no significant difference in forward flexion.

Influence of glenoid lateralization on ROM

Glenoid lateralization of 5 mm in the center of the peg resulted in significantly improved ROM, with a mean of 106.3° (44° to 148°, $P < .0001$), regardless of the humeral inclination. This was statistically significant for adduction, with a mean increase of 14.2° (10.5° to 19°), forward flexion, external rotation, and extension with use of the 135° model.