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Serial 3D CT analysis of humeral head alignment in relation to glenoid correction and outcomes after total shoulder arthroplasty

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A R T I C L E I N F O

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Glenoid version
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Level of evidence: Level IV; Case Series; Prognosis Study

Background: Posterior humeral head (HH) subluxation after anatomic total shoulder arthroplasty (aTSA) is associated with worse outcomes, but it is unclear how corrective glenoid reaming correlates with HH alignment and whether HH alignment changes over time. Therefore, it was aimed to analyze the relationship between HH alignment and the scapula following aTSA to identify anatomic and surgical factors that contribute to realignment of the HH, glenoid loosening, and clinical outcomes.

Methods: Three-dimensional scapulohumeral alignment was assessed on three-dimensionally reconstructed computed tomography scans of 23 patients: preoperative (T0), 2 years post-aTSA (T1), and ≥5 years post-aTSA (T2). Anterior-posterior (AP), superior-inferior (SI), and medial-lateral offset measures of the HH center to the scapula were referenced to the HH diameter (scapulohumeral subluxation index). Glenoid version and inclination were measured at T0 and T1. Central peg osteolysis, rotator cuff fatty infiltration, and vault perforation were assessed on two-dimensional computed tomography. Relative Constant Score at T2 measured clinical outcome.

Results: Glenoid correction correlated strongly with AP and SI position of the HH (r = 0.733 and r = 0.797, respectively). Each degree of retroversion correction resulted in 0.9% AP scapulohumeral subluxation index offset change toward anterior. Each degree of inclination correction to superior resulted in a 1.0% offset change toward superior. A gradual postoperative proximal (mean difference [MD], −3%; $P = .019$), anterior (MD, 2%; $P = .025$), and medial (MD, 3 mm; $P < .001$) HH migration was observed. Asymmetric progressive rotator cuff fatty infiltration was associated with the direction of change in AP alignment over time (odds ratio, 2.04; $P = .046$), with progressive subscapularis fatty infiltration as the primary factor associated with gradual anterior HH translation (odds ratio, 15.61; $P = .028$). Gradual HH medialization was an indicator of glenoid components at risk for loosening (difference between medians, 4 mm; $P = .003$). Osteolysis around the central glenoid peg was influenced by overcorrection of glenoid version (MD, 7°; $P = .038$). Preoperative glenoid inclination was the sole anatomical or surgical factor predicting clinical outcome, as larger inferior inclination at T0 was associated with worse relative Constant Score at T2 ($P = .016$).

Conclusion: Corrective glenoid reaming was an effective surgical technique to correct HH alignment in the AP and SI direction. Gradual anterior HH translation after aTSA was associated with progressive subscapularis fatty infiltration, and substantial HH medialization was an important indicator for potential glenoid loosening. While postoperative glenoid version and AP HH alignment were important for radiographic outcome, preoperative glenoid inclination predicted clinical outcome, as larger preoperative inferior inclination resulted in worse clinical scores.

Ethical approval for this study was obtained from the local Ethics Committee (Ghent University) Nr: EC/2016/0527.
Investigation performed at the Department of Orthopaedics and Traumatology, Ghent University Hospital, Ghent, Belgium and at the Orthopaedic Research Laboratory, Department of Orthopaedics, University of Utah, Salt Lake City, UT, USA.
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Anatomic total shoulder arthroplasty (aTSA) is an effective treatment for patients suffering from end-stage osteoarthritis, yielding long-term pain relief and improved function.[13,14,25] However, longevity of the glenoid component remains a concern as it is the most common cause of failure.[14,25,29] Static posterior humeral head subluxation, which characterizes most types of primary shoulder osteoarthritis,[17,18] is an important factor for poor clinical outcome and glenoid component loosening following aTSA.[10,13,32] Glenoid correction to recenter the humeral head has been considered an important surgical goal when performing aTSA because eccentric loading of the glenoid component is thought to drive glenoid loosening.[10,32] Yet, it remains unclear how intraoperative glenoid correction correlates with clinical humeral head alignment. Moreover, the change of humeral head alignment over time remains poorly understood.

Although radiographic imaging is the standard of care following aTSA, it has limitations regarding reliability, accuracy, and reproducibility when assessing scapulohumeral anatomy and implant-related outcomes on serial radiographs.[12,34] While follow-up using computed tomography (CT) can improve the assessment of radiolucencies around the implant, three-dimensional (3D) imaging is an important tool to analyze scapular and humeral anatomy.[3,16,17,19,22,26-28,34] The latter provides a standardized viewing perspective, primarily using the plane of the scapula, which allows for a reliable and accurate 3D assessment of humeral head alignment and glenoid parameters.[3,16,17,22,28]

Therefore, with serial 3D CT imaging analysis, it was aimed to analyze the relationship between humeral head alignment and the scapula following aTSA to identify anatomic and surgical factors that contribute to realignment of the humeral head, glenoid loosening, and clinical outcomes.

Methods

Patients with primary OA who were treated with primary aTSA by a single surgeon (L.D.W.) using an uncemented polyethylene Anchor Peg Glenoid component (DePuy Synthes Johnson & Johnson, Raynham, MA, USA) were considered for this retrospective diagnostic study. These patients underwent aTSA using a standardized technique including a deltopectoral approach, an osteotomy of the lesser tuberosity, extensive capsular release, and glenoid retroversion correction to neutral using asymmetric high side reaming in cases of asymmetric glenoid wear with standard instrumentation[6,7] (Fig. 1). Preoperative planning was performed on conventional two-dimensional (2D) CT. Patients with preoperative and postoperative CT scans in the context of prior studies were recruited for evaluation at a minimum 5-year follow-up.[6,7]

After informed consent was obtained, the Constant Score (CS) and standardized CT scans of the shoulder were assessed. All subjects underwent a CT scan (Siemens Somatom Volume Zoom System; Siemens, Munich, Germany, 140 kVp tube voltage, 512 × 512 acquisition matrix, ≤1.5 mm slice thickness, 500 mm field of view, 0.97 mm pixel size) at 3 different points in time (T0: preoperative; T1: postoperative at 2-year follow-up; T2: postoperative at a minimum 5-year follow-up) in a standardized supine position with an orthosis holding the arm in a neutral position, as previously described.[16,30,31] In the cohort of patients with a CT scan at T0 and T1, seven patients already underwent a third CT scan at T2 with the above CT scan protocol as part of preoperative planning for aTSA of the contralateral side. These patients were included after informed consent without undergoing an additional CT scan.

Three-dimensional protocol

Preoperative and postoperative CT image data were imported into 3D imaging software (Mimics; Materialise, Leuven, Belgium) and reconstructed via semiautomated segmentation techniques (Fig. 2). The 3D surface of the preoperative scapula was aligned to a scapular-based coordinate system (3-Matic; Materialise), as previously described.[4,16,17,20] The postoperative 3D bony surfaces of the scapulae (T1 and T2) were matched to the corresponding preoperative scapula, while respecting the spatial relationship between the humeral component and the scapula.

Three-dimensional measurements

To address glenoid correction following corrective reaming, preoperative (T0) and postoperative (T1) glenoid version and inclination were measured by the best-fit plane to the articular surface referenced to the z-axis of the scapular-based coordinate system (Fig. 3).[15,18] Negative values represented retroversion and inferior inclination of the glenoid, respectively. The center of the humeral head was defined by the best-fit sphere to noneroded segments of the articular surface of the humeral head (T0) or the articular surface of the humeral component (T1 and T2).[17,18,27,35] The position of the center of the humeral head in relation to the scapula determined anterior-posterior (AP), superior-inferior (SI), and medial-lateral humeral head alignment (Fig. 4). When referenced to the humeral head diameter as a ratio, the term scapulohumeral subluxation index (SHSI) was used, with negative offset values representing posterior alignment for AP-SHSI offset and inferior alignment for SI-SHSI offset of the center of the humeral head in relation to the coordinate system. The humeral head was considered centered when the AP-SHSI fell within the previously determined normative threshold of 49% and 61%.[16] Note that all 3D measurements have demonstrated a high degree of inter-rater reliability in prior studies.[15-17]

Two-dimensional measurements

Preoperative glenoid morphology was classified by the modified Walch classification.[1] Perforation of the glenoid vault by glenoid pegs and central peg osteolysis of the glenoid component was evaluated on the postoperative CT scan slices. Central peg osteolysis was graded as previously described[11,27]: grade 1 indicated marked osteolysis around the central peg and was considered to be at risk of glenoid loosening, grade 2 indicated bone integration around but not within the flanges of the central peg, and grade 3 indicated bone integration within the flanges of the central peg (Fig. 5).

Fatty infiltration of the transverse rotator cuff force couple muscles, assessed on the sagittal oblique slice medial to the spinoglenoid notch preoperatively and postoperatively, was graded according to the Goutallier rating (Fig. 6).[8,9] Rotator cuff balance was determined by the difference in fatty infiltration between the posterior (mean Goutallier rating of infraspinatus and teres minor) and anterior (subscapularis) rotator cuff muscles, with positive values representing a predominant fatty infiltration of the posterior rotator cuff muscles.

Statistics

An a priori power analysis using the 3D data of the seven patients who already underwent a third CT scan at T2 showed that, for a significance level of 0.05, a sample size of 22 patients was sufficient to provide a power of 80% to determine differences in humeral head alignment in all 3 directions between all 3 points in time with an effect size ranging from 0.64 to 1.65.

Data normality was tested by the Shapiro-Wilk test. Differences in glenoid measures between preoperative and postoperative points in time (T0 vs. T1) were assessed with paired t tests. Alignment differences between 3 different points in time were assessed

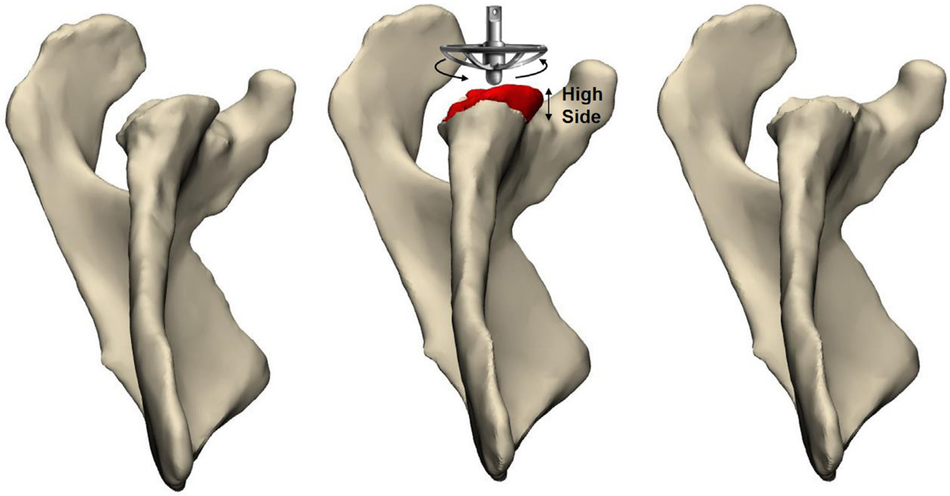

Figure 1 Illustration of asymmetric reaming of a biconcave glenoid by reaming on the high side. This technique aims to recenter the humeral head by resecting an asymmetric part of the glenoid articular surface (red).

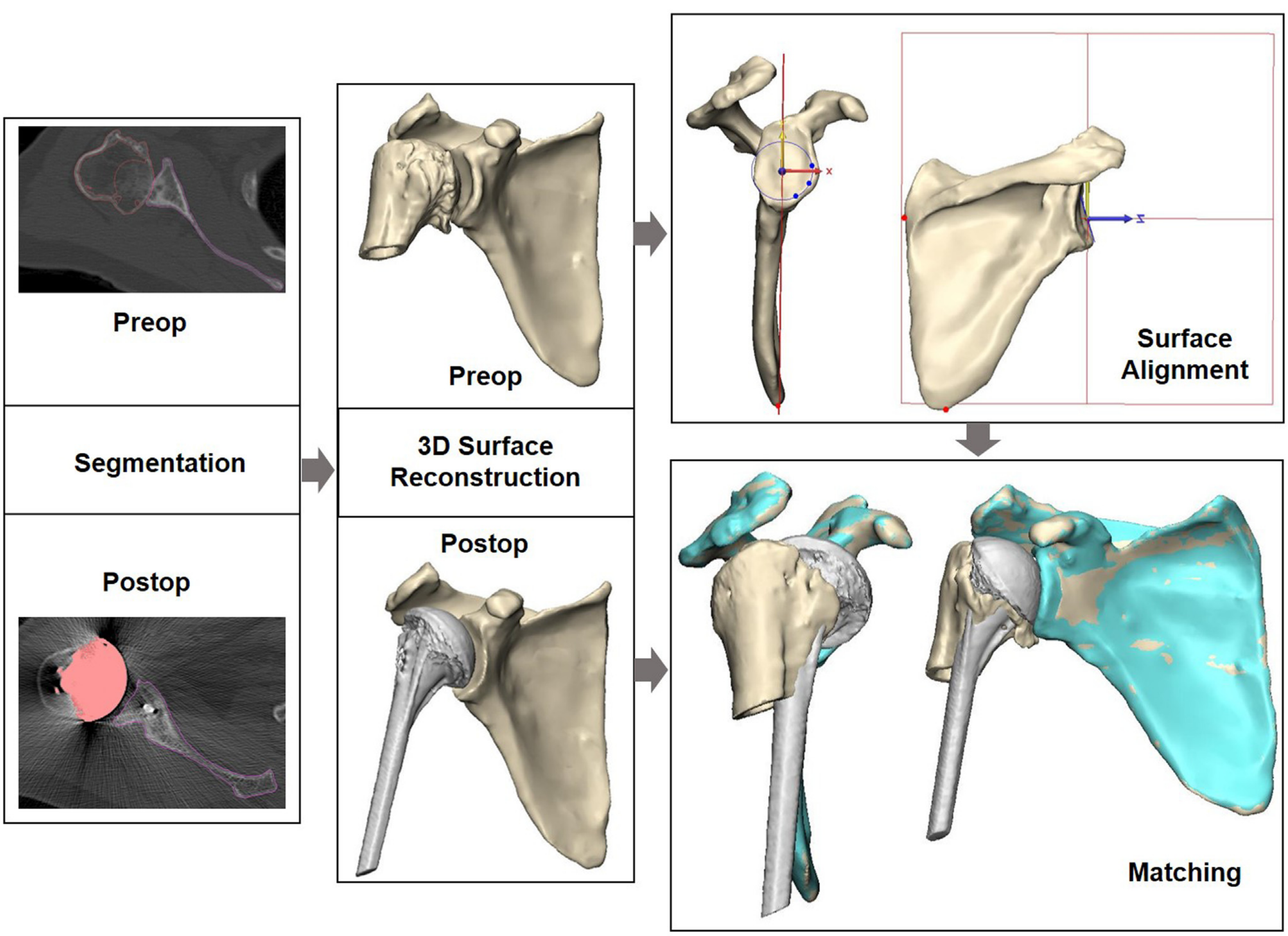

Figure 2 The figure demonstrates the three-dimensional (3D) protocol. Preoperative scapulae and humeri were separated by semiautomated segmentation techniques. On the postoperative scans, humeral components were reconstructed by selecting the Hounsfield units corresponding with metal. Semiautomated techniques also segmented postoperative scapulae. 3D surfaces of the preoperative scapulae were aligned to a scapular-based coordinate system: The center of the best-fit circle to 3 points on noneroded segments of the anterior glenoid rim defined the origin; the z-axis was directed laterally, running from the trigonum spina scapulae to the origin; the YZ plane, with the normal directed anteriorly, was defined by the plane to the scapula, created by the origin, inferior angle and trigonum spina scapulae. Postoperative 3D bony surfaces of the scapulae were then matched to the corresponding preoperative scapula using an iterative closest point algorithm.

using repeated measures one-way ANOVA with Greenhouse-Geisser corrections and post hoc Tukeýs multiple comparisons tests. Comparisons between 2 groups of unpaired continuous variables were performed using Welch's two sample t tests or Wilcoxon's rank-sum tests, as appropriate. Nominal variables were compared between groups by Fisher's exact tests. Univariate

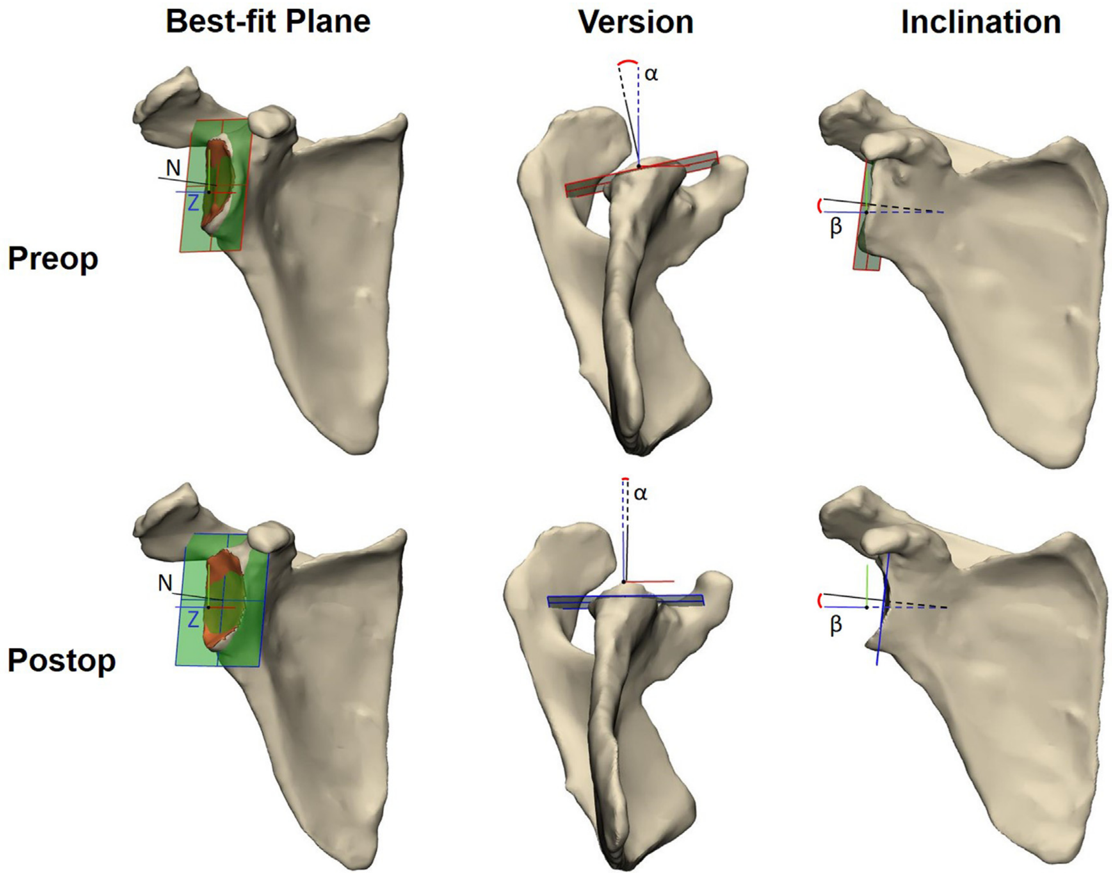

Figure 3 The figure illustrates the assessment of glenoid measures. The orientation of the best-fit plane to the preoperative and postoperative articular surface with corresponding normal (N) was referenced to the scapular-based coordinate system in terms of glenoid version and inclination. Version was defined as the angle between the normal and z-axis in the XZ plane (α), with negative values representing retroversion. Inclination was defined as the angle between the normal and z-axis in the YZ plane (β), with negative values representing inferior inclination.

regression analyses were conducted to determine associations between variables and clinical or radiological outcomes. Pearson correlation coefficients (r) with corresponding regression lines determined the correlations between continuous variables and were interpreted as follows: $|r| < 0.300$, no correlation; $0.300 \leq |r| < 0.500$, weak correlation; $0.500 \leq |r| < 0.700$, moderate correlation; $|r| \geq 0.700$, strong correlation. Significance level was set at $P \leq .05$. Analyses were performed with SPSS Statistics software (IBM Corp., Armonk, NY, USA).

Results

Included were a total of 23 shoulders (11 right, 12 left) in 23 patients (5 males, 18 females) with a mean age of 65 years at surgery (range, 42 to 75 years) and a mean follow-up of 8 years (range, 5 to 10 years). The glenoid type was type A1 in 5 shoulders, A2 in 8 shoulders, B1 in 1 shoulder, and B2 in 9 shoulders. There were no type B3, C, or D glenoids.

A mean preoperative version (T0) of $-10 \pm 7°$ (range, $-28°$ to $6°$) was corrected to a postoperative version (T1) of $-4° \pm 9°$ (range, $-20°$ to $15°$) ($P < .001$), resulting in an AP-SHSI reduction from 60% preoperative version (T0) to 52% postoperative version (T1) ($P = .013$). Posterior subluxation shifted to a centered AP alignment in 3 patients (13%) and overcorrected to anterior in 2 (9%). A centered AP alignment was overcorrected to anterior in 7 patients (30%). Version correction was strongly correlated with AP-SHSI offset change ($r = 0.733$; $P < .001$), with the resulting regression line demonstrating a 0.9% AP-SHSI offset change to anterior for each degree of retroversion correction (Fig. 7, *A*).

A mean preoperative inclination (T0) of $4° \pm 7°$ (range, $-6°$ to $21°$) was corrected to a postoperative inclination (T1) of $1° \pm 8°$ (range, $-16°$ to $19°$) ($P < .001$). Although corrective glenoid reaming did not alter SI-SHSI offset (T0: 10% ± 4% vs. T1: 10% ± 8%; $P = .974$), there was a strong correlation between inclination correction and change in SI-SHSI offset ($r = 0.797$; $P < .001$). The resulting regression line demonstrated a 1.0% change in SI-SHSI offset to proximal for each degree inclination correction to superior (Fig. 7, *B*).

Over time, a mean anterior translation of the center of the humeral component was seen with a mean AP-SHSI at T1 of 52% ± 10% progressing to a mean AP-SHSI at T2 of 49% ± 12% ($P = .025$). Overall, 18 cases (78%) demonstrated a progressive anterior translation and 5 cases (22%) a progressive posterior translation. Progressive asymmetric fatty infiltration, as assessed by the proposed scaling system for the balance of the transverse rotator cuff force couple, was associated with the direction of AP translation (odds ratio 2.04; $P = .046$). Progressive fatty infiltration of the subscapularis was the most important factor associated with anterior translation over time (odds ratio 15.61; $P = .028$). The extent of glenoid version correction did not influence the direction of AP translation (regression coefficient, 0.028; $P = .812$).

The center of the humeral component also progressed to a more proximal orientation with SI-SHSI offset progressing from 10% ± 8% at T1 to 13% ± 8% at T2 ($P = .019$) and migrated medially on average 3 mm ($P < .001$).

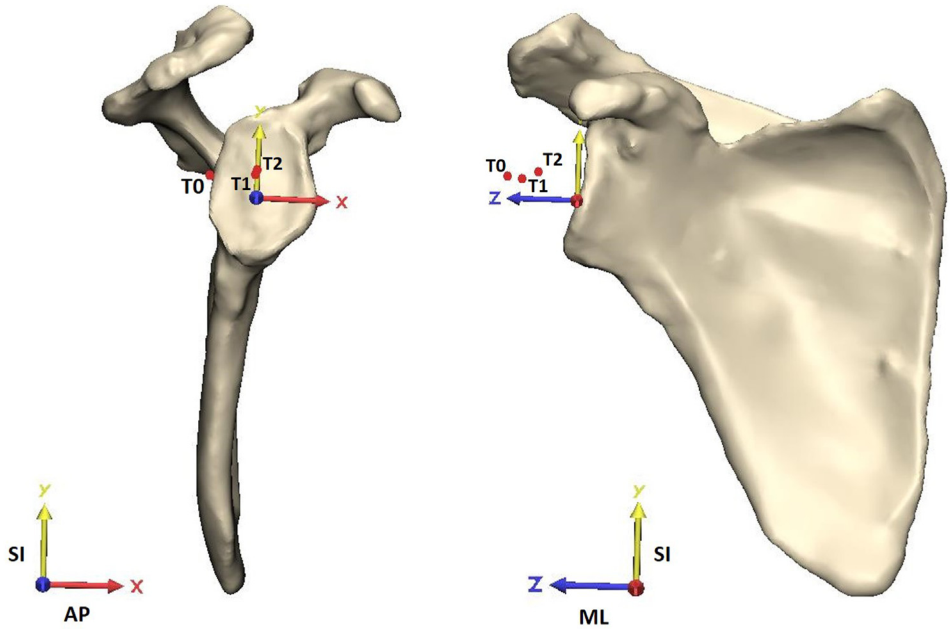

Figure 4 The position of the humeral center was addressed in relation to the scapular-based coordinate system at 3 different points in time (T0: preoperative; T1: postoperative at 2-year follow-up; T2: postoperative at a minimum 5-year follow-up). This allowed for three-dimensional analysis of the humeral head with the x-axis representing an anterior-posterior (AP) alignment, the y-axis a superior-inferior (SI) alignment, and the z-axis a medial-lateral (ML) alignment.

Serial postoperative CT imaging demonstrated glenoid components at risk of loosening, as defined by grade 1 osteolysis of the center peg at T2, in 9 of 23 patients (39%). While glenoid version did not differ preoperatively ($-11^\circ \pm 6^\circ$ vs. $-10 \pm 9^\circ$; $P = .800$), a larger version correction was seen in the at-risk group with a total correction of $11^\circ \pm 9^\circ$ when compared with the version correction of $4^\circ \pm 6^\circ$ seen in patients without at-risk glenoids ($P = .038$) (Supplementary Table S1). This resulted in an overcorrected, anteverted glenoid in the at-risk group when compared to the mild retroversion in those without signs of loosening ($1^\circ \pm 6^\circ$ vs. $-7^\circ \pm 9^\circ$; $P = .030$). Alteration of AP-SHSI offset from T1 to T0 showed a marginally significant trend toward a more anteriorly directed humeral head in patients with at-risk glenoids compared with those without at-risk glenoids (13% ± 8% vs. 5% ± 9%; $P = .051$). Although aTSA initially did not influence the medial-lateral alignment of the humeral head (T0: 22 mm ± 3 mm vs. T1: 22 mm ± 3 mm; $P = .971$), a more medialized humeral head at T1 with a mean deterioration of 6 mm over time was seen in patients with at-risk glenoids compared with those without at-risk glenoids (T1: mean difference, 2 mm; $P = .035$; T2 to T1 difference: 1 ± 1 mm vs. 6 mm ± 3 mm; difference between medians, 4 mm; $P = .003$). No other variables differed between groups ($P \geq .069$; Supplementary Table S1).

At a mean follow-up of 8 years, the mean absolute and relative CS were 65 ± 15 points (range, 19 to 87 points) and 94% ± 23% (range, 27 to 136%) of the value for an age-, side-, and sex-matched normal shoulder. Linear regression demonstrated that a longer follow-up time and a more inferior inclination preoperative (T0) were associated with worse relative CS at the latest follow-up (regression coefficient, −1.796; $P = .042$, and regression coefficient, 7.418; $P = .016$, respectively). No other measured variables, including postoperative inclination and inclination correction, were predictors of relative CS ($P \geq .120$; Supplementary Table S2).

Discussion

The findings of this study demonstrated a predictable change in AP and SI humeral head orientation when correcting version and inclination during aTSA, respectively. Over a time, a discrete, yet significant proximal, anterior, and medial migration of the humeral head was seen. While asymmetric progressive fatty infiltration of the rotator cuff muscles was associated with the direction of change in AP alignment over time, progressive medialization of the humeral head was identified as an indicator of glenoid components at risk for loosening. Osteolysis around the central glenoid peg was further influenced by an overcorrection of the glenoid version with a resulting anterior subluxation of the humeral head. Of all investigated anatomic and surgical factors potentially influencing clinical outcome, preoperative inclination was the sole predictor, with a more inferior inclination preoperatively yielding lower clinical scores at the latest follow-up.

In the present study, a high correlation between corrective glenoid reaming and change in humeral head alignment was identified. Each degree of retroversion correction resulted in 0.9% AP-SHSI offset change to anterior. A similar relationship was found between inclination correction and SI humeral alignment. Therefore, our findings support this surgical technique, as corrective glenoid reaming was an effective method to alter humeral alignment with a predictable change in AP and SI humeral head orientation.

This study highlights the challenges associated with corrective glenoid reaming when using standard instrumentation and 2D preoperative planning, as glenoid version overcorrection was noted in a substantial number of cases. Postoperative anteversion resulted in an anterior orientation of the humeral head component and was associated with osteolysis of the central glenoid peg. Thus, glenoid version correction was important for glenoid component survival. Correcting the glenoid version to neutral to recenter the humeral head is common practice when performing aTSA. Several authors have focused on calculating and reconstructing premorbid glenoid version using advanced imaging.[2,23,24,26] Given the demonstrated correlation between AP-SHSI change and version correction, a mean version correction to 5° retroversion would have been necessary to recenter the humeral head, when using a mean AP-SHSI of 55% as a reference for healthy shoulders as previously

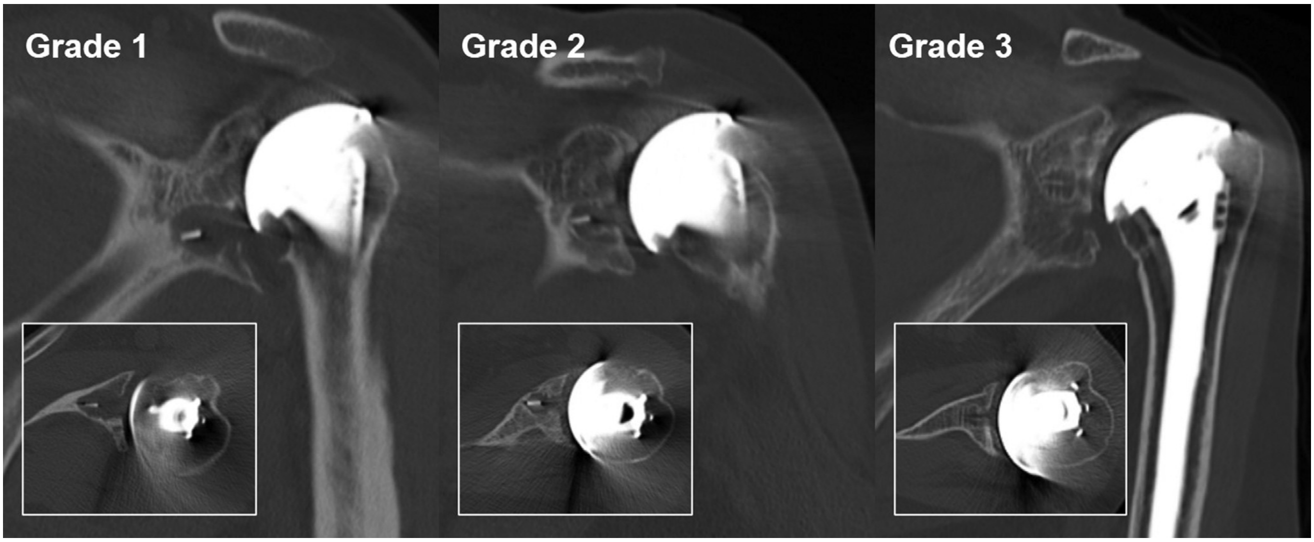

Figure 5 Grading system of central peg osteolysis of the glenoid component determined on computed tomography scans, as described by Richetti et al.[27] Grade 1 indicated marked osteolysis around the central peg and was considered to be at risk of glenoid loosening. Grade 2 and 3 indicated bone integration around and within the flanges of the central peg, respectively. Glenoid components classified as grade 2 or 3 were not considered at risk of loosening.

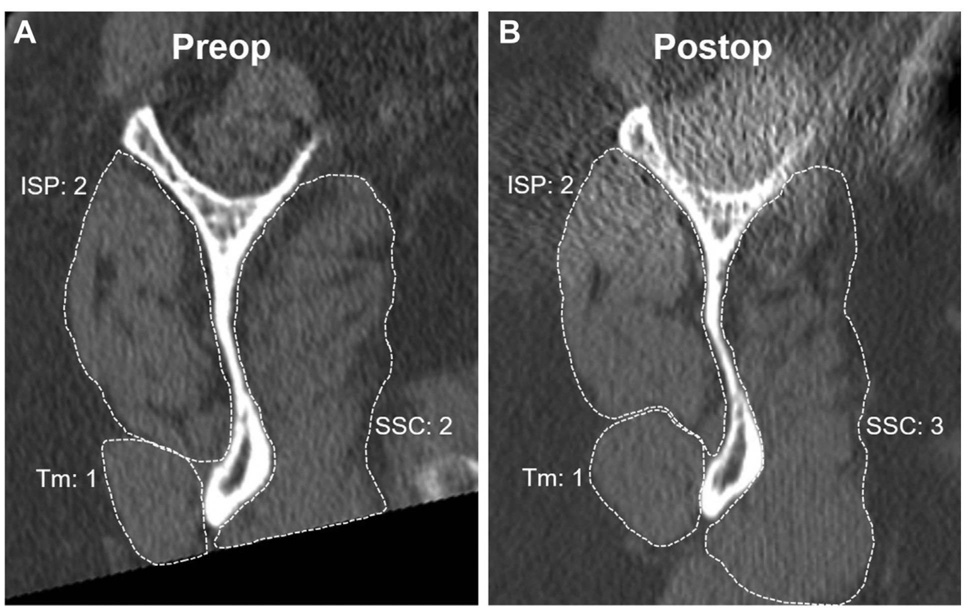

Figure 6 (**A**) and (**B**) The figure depicts the sagittal oblique computed tomography scan slice medial to the spinoglenoid notch (**A**) preoperatively and (**B**) postoperatively at the latest follow-up. The muscles of the transverse rotator cuff force couple, ie, subscapularis (SSC), infraspinatus (ISP), and teres minor (Tm), are outlined. Fatty infiltration grading was performed according to Goutallier[9] and was assigned to each of these muscles (grade from 0 to 4). Deduction of the Goutallier rating of the anterior cuff muscles (SSC) from the mean Goutallier rating of the posterior cuff muscles (ISP and Tm) determined the balance of the transverse rotator cuff force couple at each point in time. The presented case scored -0.5 preoperatively ($[2+1]/2-2=-0.5$) and -1.5 postoperatively at the latest follow-up ($[2+1]/2-2=-1.5$) on the proposed scaling system (potential range of -4 to 4), demonstrating a progressive imbalance of the rotator cuff force couple driven by the fatty infiltration of the anterior rotator cuff (SSC) over time.

described.[16] Therefore, glenoid version correction to a premorbid state seems to be a more appropriate approach, while correcting to neutral can result in an overcorrection of AP humeral head alignment.

Proximal migration of the humeral head is a known phenomenon in aTSA.[36] Although it has been associated with rotator cuff insufficiency, the discrete proximal migration in the present study did not influence radiographic and clinical outcome. Also, a discrete change in AP alignment was seen over time. Prior studies have associated glenoid morphology and posterior humeral head translation progression in primary osteoarthritis with fatty infiltration of the teres minor.[8,33] Ho et al associated persistent postoperative posterior subluxation with a high degree of preoperative fatty infiltration of the teres minor.[10] This role of the transverse rotator cuff force couple on humeral head alignment was deepened herein, as progressive asymmetric fatty infiltration of the rotator cuff was associated with the direction of AP humeral head translation post-aTSA. In the present study, the anterior rotator cuff was the primary factor affecting the assessed ratio between anterior and posterior rotator cuff, with progressive fatty infiltration of the subscapularis muscle being associated with anterior translation of the humeral head over time. Several studies

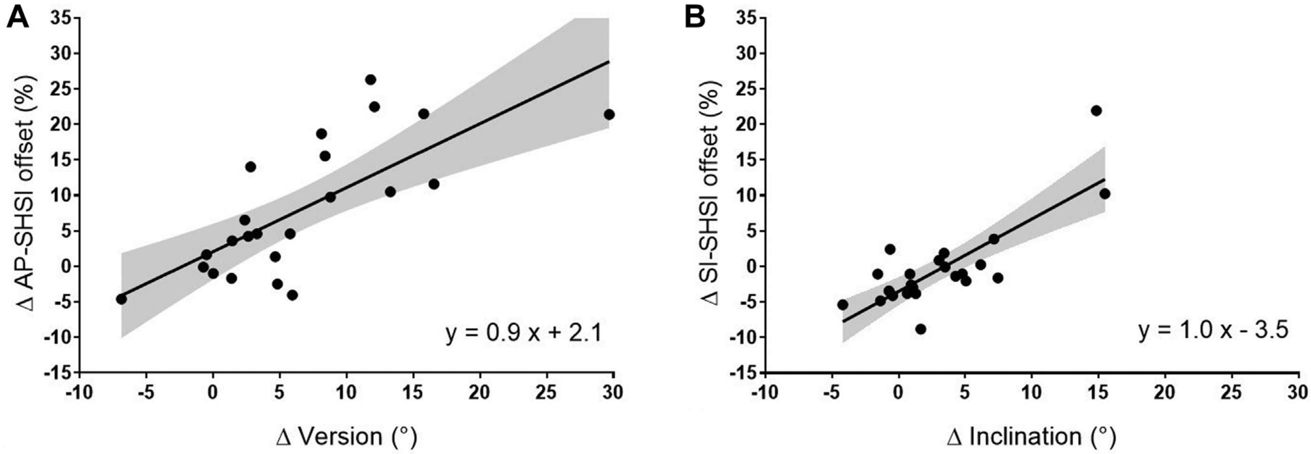

Figure 7 (**A**) and (**B**) Scatterplots with corresponding regression lines and 95% confidence intervals (gray area) demonstrate a high correlation between glenoid correction with respect to the alteration of (**A**) version and (**B**) inclination and humeral head alignment regarding anterior-posterior (AP) and superior-inferior (SI) scapulohumeral subluxation index, respectively ($r = 0.733$ and $r = 0.797$). (**A**) The resulting regression line formula demonstrates that every 1° of retroversion correction translated to a 0.9% change in subluxation to anterior. (**B**) Similarly, every 1° of correction into superior inclination resulted in a 1.0% alteration in subluxation to proximal. *SHSI*, scapulohumeral subluxation index.

have shown an increase of fatty infiltration of the subscapularis muscle after aTSA, regardless of subscapularis management technique.[5,21] Nevertheless, this study cannot resolve the question whether fatty infiltration of the subscapularis muscle is the cause or the effect of progressive anterior humeral head translation following aTSA.

Patients with grade 1 osteolysis of the central peg (at risk for loosening) had a more medialized center of the humeral head postoperatively compared with those having grade 2 and 3 (not at-risk group). An association between humeral head shift and grade 1 osteolysis has been previously reported in a similar serial 3D CT study.[27] The authors found that glenoid component migration between a direct postoperative CT and a CT at 2-year follow-up was associated with osteolysis of the center peg and shift of the humeral head. These findings suggest that the humeral head medialization seen in our study in patients with grade 1 osteolysis implies glenoid component migration. Therefore, humeral head medialization must be considered an indirect sign of glenoid components at risk of loosening.

Severity of the pathology with a high degree of retroversion and posterior subluxation has been previously associated with inferior outcomes after aTSA.[13,32] Although we demonstrated an association between postoperative version and osteolysis around the glenoid component, version and subluxation were not predictors of the relative CS. Preoperative inclination was the only anatomic factor that predicted postoperative relative CS, with a more inferior inclination preoperatively yielding lower clinical scores at the latest follow-up. The heterogenicity in predictors of clinical outcome between our 3D study and earlier studies using standard radiographs or uncorrected CT might be explained by the applied imaging modality, similarly as previously seen for posterior subluxation of the humeral head.[16,22] When assessed in 3D, maximum glenoid erosion in biconcave glenoids is orientated in the posterior-inferior quadrant of the glenoid.[2] As the 3D coordinate system neutralizes the inherent protraction of the scapula to create controlled viewing perspectives, it can be assumed that in the less controlled imaging modalities with inherent scapular protraction the maximum glenoid erosion will be depicted more posteriorly than inferiorly. As erosion is located not only posteriorly but also inferiorly in 3D, a more severe erosion with joint line medialization might influence the inclination measurement. Therefore, our findings could indicate that a more severe erosion had a negative impact on clinical outcome and that the assessment of inclination might be more important than previously thought when addressing glenoid erosion in a standardized 3D viewing perspective.

This study was limited by the disadvantages of a retrospective study design and a small study cohort. No specific subtypes of glenoid morphology were selected, which led to the inclusion of only 4 patients with severe retroversion (version $\leq -15°$). Although these are considered the more challenging cases, including the most common glenoid subtypes was necessary to cover a broad spectrum for meaningful regression analyses. The results must be seen within the spectrum of the included patients, and thus, our findings should be interpreted with caution when applied to cases with severe retroversion or dysplastic glenoids. Because only 1 radiopaque marker was integrated by the manufacturer in the polyethylene glenoid component, it was not possible to perform a virtual implantation of glenoid component. Therefore, conclusions regarding joint line reconstruction, overstuffing, and glenoid component migration or subsidence are limited. The results of corrective reaming can guide surgeons in preoperative planning and intraoperative decisions regarding glenoid correction and the resulting humeral alignment. Nevertheless, validation is needed to determine whether these results can be generalized to other techniques of glenoid correction including augmented glenoid components.

Conclusions

Glenoid reaming was an effective surgical technique to correct humeral head alignment in the AP and SI direction for cases with mild to moderate glenoid retroversion. Each degree of version and inclination correction altered humeral head alignment by approximately 1% in its respective direction. The direction of gradual postoperative AP humeral head translation was associated with asymmetric fatty infiltration of the rotator cuff, and substantial postoperative medialization of the humeral head was associated with osteolysis around the glenoid component. While postoperative glenoid version and AP humeral head alignment were important for radiographic outcome, preoperative glenoid inclination predicted clinical outcome, as larger preoperative inferior inclination was associated with worse clinical scores.

Disclaimers:

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Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jseint.2023.02.007.

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