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SECTION II
ORIGINAL ARTICLES

Recentering the Humeral Head for Glenoid Deficiency in Total Shoulder Arthroplasty

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Substantial posterior glenoid wear causing static posterior subluxation of the humeral head in patients with primary osteoarthritis has been described. Persistent humeral head subluxation after total shoulder arthroplasty can result in early polyethylene wear and glenoid component loosening. In our prospective cohort study, we hypothesized that in patients with posterior glenoid wear from osteoarthritis, static posterior decentering of the humeral head could be recentered during total shoulder arthroplasty by surgical correction of glenoid alignment in the transverse plane with soft tissue balancing. We performed total shoulder arthroplasties in 77 patients with primary osteoarthritis and a mean age of 67.6 years. The mean clinical and radiographic followup was 2 years (range, 1–7 years). Patients with preoperative posteriorly decentered humeral heads did not have posterior decentering develop postoperatively. Twenty patients (83.3%) had centered humeral heads and four patients (16.6%) had anterior decentering. Midterm results of total shoulder arthroplasties in shoulders with humeral head decentering caused by glenoid deficiency in the transverse plane showed correction of the decentering by lowering the high side or by bone grafting with soft tissue balancing can be well maintained.

Level of Evidence: Level II, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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Neer et al[14,16] observed that substantial posterior glenoid wear caused static posterior subluxation of the humeral head in patients with primary osteoarthritis (OA). To study its natural course and discriminate retroversion between posterior erosion and dysplasia, Walch et al[19] classified morphologic features of the glenoid in the transaxial plane for primary OA (Fig 1).

Reasons for decentering of the humeral head in primary arthritis are not fully understood. Apart form a contracture or insufficiency of the active stabilizers (the rotator cuff and joint capsule), changes in the passive stabilizers (an increased glenoid version or humeral head version) are likely the cause of decentralization of the humeral head in OA.[13,16,19]

Humeral-head decentering in the transverse plane is defined as deviation of the center of rotation of the humeral head from the glenoid center-line.[11] For a total shoulder arthroplasty (TSA), it is important to detect and correct decentering of the humeral head to avoid early polyethylene wear and loosening of the glenoid component caused by an eccentric posterior rim loading.[4,11] Moskal et al (Moskal MJ, Duckworth D, Matsen FA. An analysis of 122 failed shoulder arthroplasties [abstract]. *J Shoulder Elbow Surg.* 1999;8:554) compared 80 successful TSAs with 53 failed TSAs. Forty-six percent of glenoid compo-

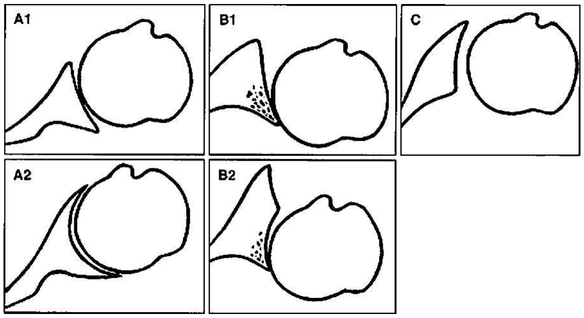

Fig 1. The three classifications of morphologic features of the glenoid as described by Walch et al[19] are shown. Type A is characterized by an equal balance of forces acting on the glenoid and a centralized head. Glenoid wear is minor (Type A1) or major with substantial central wear causing a glenoid cup (Type A2). Type B has asymmetric force distribution on the glenoid leading to either a loss of joint space (predominantly posterior), subchondral sclerosis (more marked on the posterior edge of the glenoid), and/or multiple posterior geodes (Type B1), or by a posterior cup which gives the appearance of a double concavity on the glenoid surface (Type B2). Type C is defined arbitrarily as glenoid retroversion greater than 25° and represents glenoid dysplasia.

nents of the failed group were malverted (angled > 0° anterior or > 20° posterior to the plane of the scapula) compared with none in the successful group. Of the failed TSAs, glenoid components had lucent lines in 76% of patients, were loose in 66%, and migrated in 26% compared with 29%, 0%, and 0%, respectively, in patients with successful TSAs. There was a correlation for posterior glenohumeral instability with posterior glenoid component malversion. In addition, Nyffeler and Gerber reported[17] that version of the glenoid component and direction of the force vectors of the rotator cuff muscles influence the position of the humeral head. If the glenoid is inserted in retroversion, the center of the humeral component is displaced posteriorly by 0.5 mm per degree of version leading to posterior loading and tilting, resulting in glenoid component loosening. Boulahia and Kempf[3] reported a series of 481 TSAs in patients with primary OA in relation to the glenoid morphology with a mean followup of 45 months. There was a higher complication rate after TSA for Type B2 glenoids. In this study 30% of the patients who received a bone graft for correction of the glenoid retroversion experienced failure of the graft to incorporate. Posterior subluxation of the humeral head occurred in 85% of patients with uncorrected glenoid retroversion greater

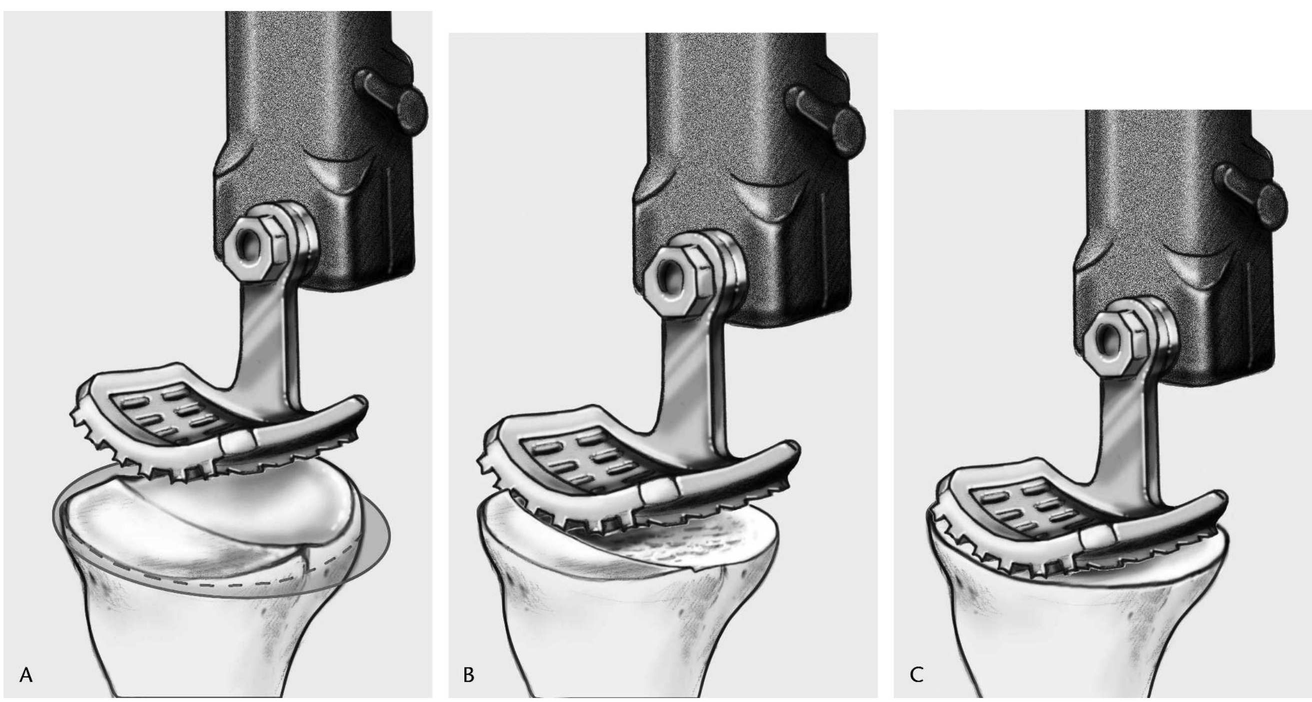

Fig 2A–C. (A) The illustration shows anterior glenoid reaming. The glenoid must be reamed up to the plane indicated by the lightly shaded area (extending from the dashed lines outward to the solid dark line) by lowering the high side. (B) This illustration shows anterior glenoid reaming. The anterior high side was partially reamed. (C) This illustration shows a completely reamed glenoid with a concentric bony surface.

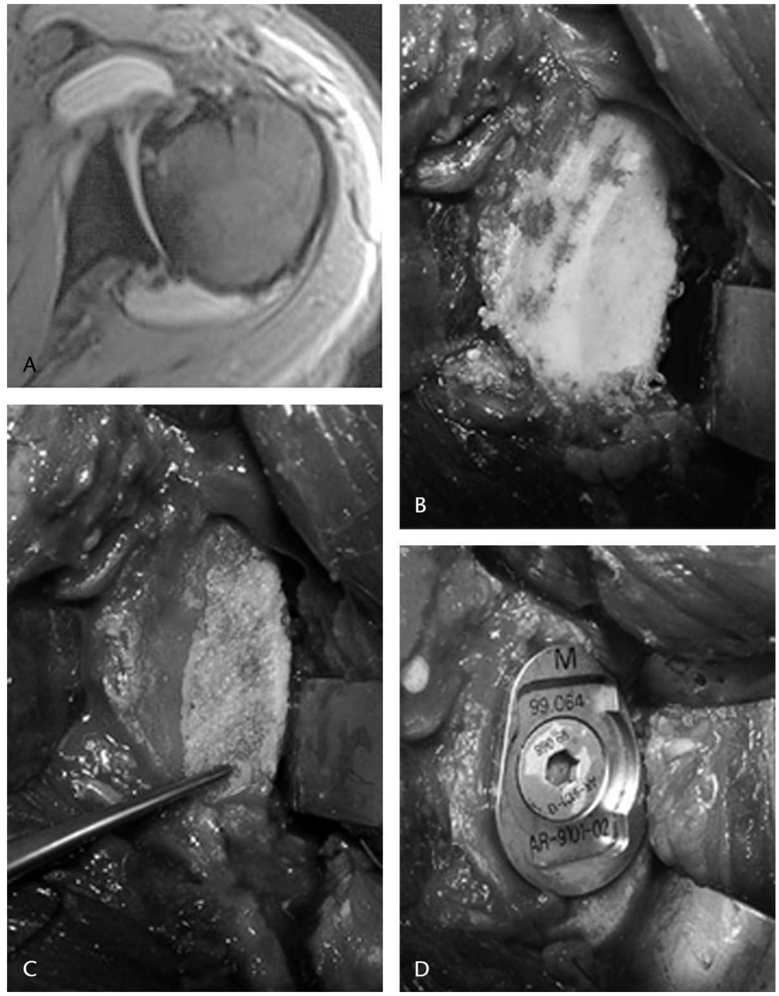

Fig 3A–D. (A) A CT scan shows the transaxial plane with posterior glenoid wear and a posterior decentered humeral head. (B) Intraoperative photographs show eccentric glenoid wear before reaming, and (C) an eccentric glenoid after reaming of the anterior high side with a bone graft posteriorly. (D) This intraoperative photograph shows the implanted metal-back component supported by a bone graft.

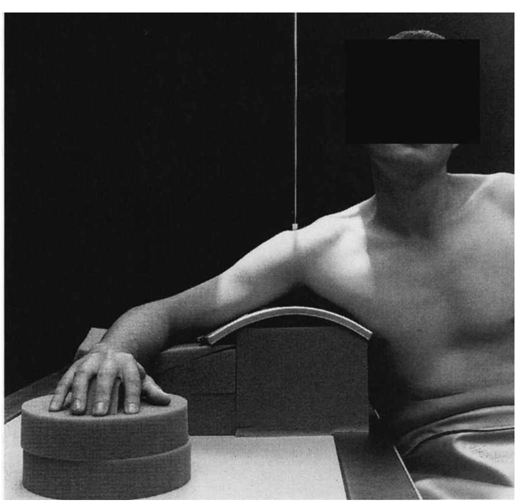

Fig 4. The technique for taking an axillary view radiograph is shown.

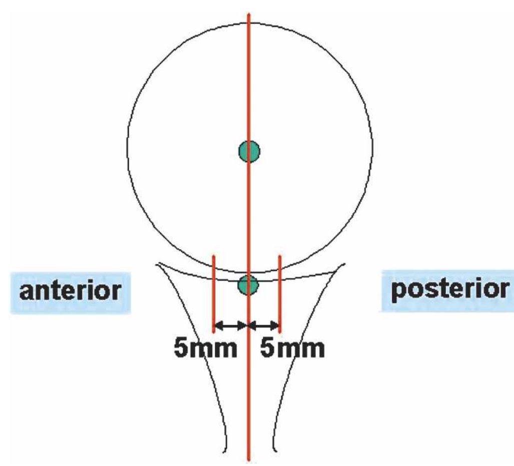

Fig 5. The method for assessing decentering of the humeral head in the transversal plane is shown. Decentering of the humeral head was defined as a deviation of the center of the humeral head greater than 5 mm anteriorly and posteriorly respectively from the center of the glenoid.

TABLE 1. Intraoperative State of Rotator Cuff in Relation to Glenoid Wear

State of Rotator Cuff Intraoperatively	Total	Concentric Glenoid Wear	Eccentric Glenoid Wear	Type A1 Glenoid	Type A2 Glenoid	Type B1 Glenoid	Type B2 Glenoid
Rotator cuff intact	58 (75.3%)	19 (67.9%)	39 (79.6%)	8 (80%)	11 (61.1%)	21 (84%)	18 (75%)
Deep partial tear of supraspinatus	17 (22.1%)	8 (28.6%)	9 (18.4%)	1 (10%)	7 (38.9%)	3 (12%)	6 (25%)
Complete supraspinatus tear	2 (2.6%)	1 (3.6%)	1 (2%)	1 (10%)	0	1 (4%)	0

than 20°. Iannotti and Norris[10] examined 128 patients treated with TSAs for primary OA after a mean followup of 46 months. They found significantly better functional results after TSAs in patients with severe or moderate eccentric glenoid erosion than for hemiarthroplasty. In patients with postoperative posterior subluxation, hemiarthroplasties and TSAs achieved lower final scores and were more painful than in patients with a centered humeral head. Ten of the 12 patients with glenoid loosening and posterior subluxation had moderate to severe glenoid erosion or subluxation of the humeral head preoperatively. Based on this experience, Iannotti and Norris stated that glenoid erosion should be corrected by reaming the high side with implantation of a glenoid component to recenter the humeral head. They also stated that humeral head subluxation is associated with a less favorable result regardless of the type of shoulder arthroplasty and must be considered in the preoperative planning.

We sought to evaluate if static posterior decentering of the humeral head in patients with OA could be recentered by surgical glenoid alignment in the transverse plane along with soft tissue balancing in patients having TSAs. We wished to determine how preoperative glenoid deformity affects the ability to recenter the humeral head with a TSA. We also wished to correlate how the preoperative state of humeral head position and morphologic features of the glenoid influence postoperative functional results as measured by the Constant and Murley score.[5]

MATERIALS AND METHODS

Seventy-seven consecutive patients (47 women, 30 men) with OA of the shoulder were treated by TSA using one type of shoulder prosthesis (Arthrex, Karlsfeld, Germany). All patients were prospectively enrolled in this study. Patients with etiologies of glenohumeral arthritis other than idiopathic OA were excluded. The average age of the patients was 67.6 years (range, 47–85 years) at the time of surgery. All patients were clinically and radiographically followed up for a mean of 2 years (range, 1–7 years) by one observer (PM).

During the TSA we did not correct the glenoid anatomy in Type A glenoids. In Type B glenoids (41 patients) (Fig 2), deformities of the high anterior side were lowered by eccentric reaming. In eight patients, bone grafting also was done after reaming the high side (Fig 3). Indications for bone grafting were massive excentric glenoid deformity in which reaming the anterior high side would lead to weakening of the anterior scapular neck. The bone graft was sized to fit between the metal back of the glenoid component and the bony surface. Seventy-five patients received a cementless metal-backed glenoid component and two patients received a cemented glenoid component. Release of the subscapularis tendon, as described by Matsen et al,[11] was performed in all 77 patients.

It consisted of release of the pectoralis major tendon in patients with massive contraction of the pectoralis major muscle, mobilization of the posterosuperior rotator cuff, release of the coracohumeral ligament, release of the subscapularis tendon as described by Matsen et al,[11] and capsular release using bifocal capsulotomy. The bifocal capsulotomy starts with preliminary ligation of the anterior humeral circumflex artery and vein, followed by horizontal incision of the rotator interval to the base of the coracoid. The subscapularis tendon is completely vertically incised adjacent to the bicipital groove downward to the latissimus dorsi tendon (hockey-cut). The subscapularis tendon then is detached completely subperiosteal from the humeral shaft together with the inferior capsule from anterior to posterior around the humeral neck (humeral capsulotomy). The coracohumeral ligament is released around the base of the coracoid. Subsequently the juxtaglenoid semicircular incision of the capsule is made below the basis of the coracoid in the area of the anterior scapular neck along the glenoid rim up the 7 o'clock position posteriorly (rim-side capuslotomy). The long head of the biceps

TABLE 2. Intraoperative State of Rotator Cuff Related to Preoperative Humeral Head Position

State of Rotator Cuff Intraoperatively	Humeral Head Centered Preoperatively	Humeral Head Decentered Anteriorly Preoperatively	Humeral Head Decentered Posteriorly Preoperatively
Rotator cuff intact	33 (70.2%)	5 (83.3%)	20 (83.3%)
Deep partial tear of supraspinatus	12 (25.5%)	1 (16.7%)	4 (16.7%)
Complete supraspinatus tear	2 (4.3%)	0	0

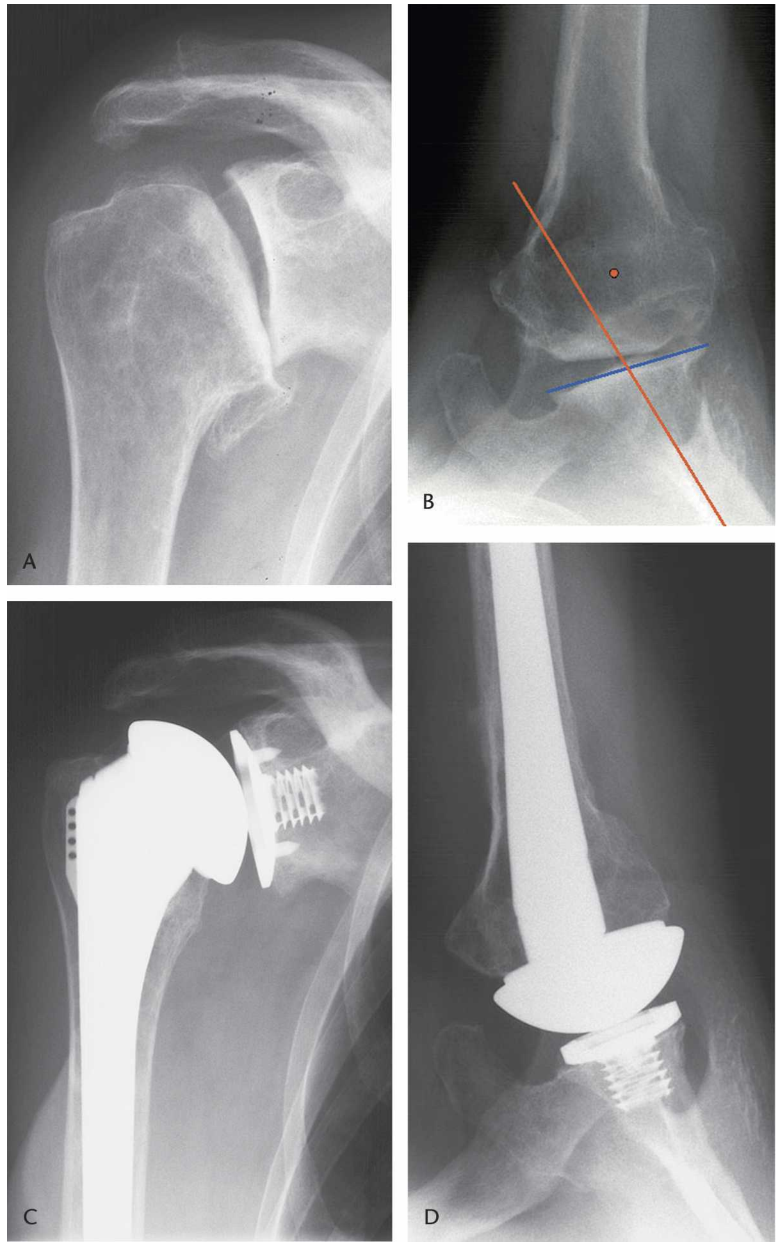

Fig 6A–D. (A) A true AP radiograph shows a patient with severe OA. (B) The axillary view shows posterior glenoid wear and posterior decentering of the humeral head. (C) The true AP radiograph control taken 2 years postoperatively shows a centered humeral head in the coronal plane. (D) The axillary radiograph control taken 2 years postoperatively shows a recentered humeral component.

tendon then is partially tenotomized and the subscapularis muscle is mobilized subfascially in the subscapular fossa.

Functional results were documented using the age- and gender-related Constant and Murley score[5,8] to exclude a potential impact of age and gender on shoulder function. This evaluation was performed preoperatively and at 3 months, 6 months, and then annually during the postoperative period. The patients had standardized radiographic examinations in three planes (true AP in neutral rotation, axillary and y views) preoperatively, and at 6 weeks, 3 months, 6 months, and then annually after surgery.

The true AP view was taken standing. The xray cassette is positioned in the plane of the scapula behind the patient with the arm positioned in neutral rotation at the side. The beam passes in an anterior-to-posterior direction 10° tilted to the perpendicular to the scapula. The axillary radiograph was taken with the upright patient sitting laterally at the xray table and positioning the arm in 70° to 90° abduction and 90° flexion of the elbow on the xray table. The xray cassette was placed on the table directly beneath the shoulder, and the xray machine was situated directly over the shoulder so that the beam passed in a superior-to-inferior direction through the shoulder (Fig 4).

Glenoid wear in the transversal plane was assessed in the axillary view using the classification of glenoid morphology according to Walch et al.[19] Decentralization of the humeral head was documented using the technique described below on the

TABLE 3. Distribution of Glenoid Wear Related to Decentering of the Humeral Head

Humeral Head Position	Total (percent)		Concentric Glenoid Wear (percent)		Eccentric Glenoid Wear (percent)		Type A1 Glenoid (percent)		Type A2 Glenoid (percent)		Type B1 Glenoid (percent)		Type B2 Glenoid (percent)	
	Pre-operative	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*
Centered	47 (61)	62* (80.5)	22 (78.6)	20 (71.4)	25 (51)	42* (85.7)	8 (80)	8 (80)	14 (77.8)	12 (66.7)	20 (80)	22 (88)	5 (20.8)	20* (83.3)
Anterior	6 (7.8)	15* (19.5)	4 (14.3)	8 (28.6)	2 (4.1)	7* (14.3)	2 (20)	2 (20)	2 (11.1)	6 (33.3)	2 (8)	3 (12)	0	4* (16.7)
Posterior	24 (31.2)	0*	2 (7.1)	0	22 (44.9)	0*	0	0	2 (11.1)	0	3 (12)	0	19 (79.2)	0*

*Significant difference in distribution of humeral head position preoperatively versus postoperatively

axillary radiograph. Morphologic features of the glenoid also were assessed intraoperatively by the surgeon.

We defined decentering of the humeral head as a deviation of the center of the humeral head in the transverse plane of ± 5 mm in relation to the glenoid center line (Fig 5). The glenoid center line is defined as the plane of the scapula passing through the center of the glenoid.[11] Measurement of decentering was performed preoperative and postoperatively using this technique. The condition of the rotator cuff also was assessed intraoperatively. The rotator cuff was categorized as being intact, or having a deep partial tear or complete tear. Univariate analyses of an association between morphologic features of the glenoid in the transverse plane classified according to Walch et al,[19] decentralization of the humeral head, and intraoperative state of the rotator cuff were done using Pearson's chi square test for categorical data.

We performed Wilcoxon signed rank tests for differences in distribution of preoperative and postoperative centering of the humeral head. The Mann-Whitney U test was used to assess for differences in distribution of age, length of followup, and preoperative and postoperative Constant and Murley score as a function of the different types of glenoid wear. Constant and Murley score improvements were determined using the Wilcoxon test. Significance was set at $p < 0.05$.

All statistical analyses were performed using SPSS version 11.0 for Windows (SPSS Inc, Chicago, IL).

RESULTS

Radiographically, preoperative posterior glenoid wear was observed in 63.7% (49 patients) of the patients and concentric glenoid wear was documented in 36.4% (28 patients) (Table 1). There was no association between glenoid wear and state of the rotator cuff. There also was no relationship between the state of the rotator cuff and the type of glenoid wear or preoperative position of the humeral head (Table 2).

For all patients postoperative centering of the humeral head in the transversal plane was improved ($p < 0.0001$). A preoperatively, posteriorly, decentered humeral head position was corrected in all patients (Fig 6). Two of the six patients with anterior decentering preoperatively had anterior decentering postoperatively. The other four patients had recentering of the humeral head as a result of the surgery. Anterior decentering occurred in 15 patients postoperatively. Preoperatively, eight of these patients had centered humeral heads, five had posteriorly decentered humeral heads, and two had anteriorly decentered humeral heads (Table 3).

At followup there was no difference in the distribution of humeral head position regardless of the preoperative state of glenoid wear. In the 28 patients with concentric glenoid wear (Type A glenoid), no surgical correction of the glenoid anatomy was performed. Of these 28 patients, 22 (79%) had a centered humeral head and two (7.1%) had a posterior decentered humeral head preoperatively. Postoperatively, two (7%) of these patients had anterior decentering. No posterior decentering was observed in this group at followup.

In the 49 patients with eccentric glenoid wear (Type B glenoid), surgical correction of the glenoid deformity was performed. Preoperatively, only 25 of these patients (51%) had a centered humeral head and 22 patients (44.9%) had posterior decentering of the humeral head. No posterior decentering was observed in any of these patients postoperatively, and in 42 patients (86%) the humeral head was centered.

Overall, there was significant improvement ($p < 0.05$) in the Constant and Murley score from preoperative to postoperative. There were no differences in the preoperative and postoperative Constant and Murley scores between patients with preoperatively centered and posteriorly decentered shoulders (Table 4). Futhermore, the preoperative Constant and Murley score was not correlated with the type of glenoid wear. The overall Constant and Murley score and the subcategories for pain, activities of daily living, total range of motion , and strength improved ($p < 0.05$) postoperatively regardless of the types of preoperative glenoid wear (Table 5).

Postoperatively, patients with eccentric glenoid wear had lower ($p = 0.008$) overall Constant and Murley scores and lower scores in the subcategories of activities of daily living ($p = 0.013$) and range of motion ($p = 0.013$). There was no difference in the subscore for pain and strength. Postoperatively, patients with a Type A2 glenoid achieved better Constant and Murley scores than patients with a Type B1 glenoid ($p = 0.012$) or Type B2 glenoid ($p = 0.007$). Patients with a Type A2 glenoid had better ($p = 0.006$) pain relief compared with patients who had a Type A1 glenoid. There was no difference in postoperative shoulder function in patients with a Type B1 glenoid compared with patients who had a Type B2 glenoid.

There were complications (2.6%) from the implantation technique. Bone-graft resorption occurred in one of eight patients followed by glenoid loosening requiring revision surgery 32 months postoperatively. In another patient, incongruence of the bony surface of the glenoid and the metal back of the glenoid component led to loosening with breakage of a fixation screw requiring revision 20 months postoperatively. In both cases the cementless glenoid component were replaced using a cemented glenoid component. No radiolucencies around the glenoid or humeral components were observed on any of the postoperative radiographs.

DISCUSSION

We evaluated whether static posterior decentering of the humeral head in patients with glenohumeral OA and posterior glenoid wear could be recentered during TSA.

Because all 77 patients received soft tissue balancing during shoulder arthroplasty and the fact that we found no difference in distribution of the position of the humeral head at followup between patients with preoperative concentric wear and patients with eccentric glenoid wear suggests that correction of the glenoid deformity by reaming seems possible in TSA.

Assessing the centering of the shoulder using an axillary xray instead of an axillary CT scan is a potential weakness of our study. However, during CT scanning the patient must lie in a supine position with the arm internally rotated relaxing the anterior capsule and permitting artifactual posterior subluxation of the humeral head simulating posterior decentering of the humeral head. Assessment of morphologic features of the glenoid according to Walch et al[19] was performed using the axillary view, and through intraoperative assessment by the surgeon, therefore, a CT scan is not necessary.

Studies of the anatomy and degenerative changes of the glenoid in the transverse plane in OA have been done.[6,19] Posterior glenoid wear and its surgical management are well-described.[16,18,19] Glenoid version can be correlated to the severity of osteoarthritic changes. Posterior humeral head subluxation is commonly associated with posterior

TABLE 4. Constant and Murley Scores Related to the Different Types of Decentering

Constant and Murley Score	Centered Shoulder (preoperative)		Posterior Decentered Shoulder (preoperative)		Anterior Decentered Shoulder (preoperative)	
	Preoperative	*Postoperative*	*Preoperative*	*Postoperative*	*Preoperative*	*Postoperative*
Relative Constant and Murley score (percent)	51.6	102*	47.6	90*	25.6	94.9*
Pain (points)	5.4	13.8*	6.4	12.7*	4.2	14*
Activities of daily living (points)	8	18.1*	8.2	15.8*	5.8	17.7*
Range of motion (points)	19.8	33.5*	16.7	29.9*	13.6	30.3†
Strength (points)	4.7	8.3*	4.3	7.6*	0.4	7.2

*Difference between preoperative and postoperative Constant and Murley score and its subcategories; †trend ($p = 0.08$) for improvement in range of motion

TABLE 5. Preoperative and Postoperative Constant and Murley Scores

Constant and Murley Score	Total		Concentric Glenoid Wear		Eccentric Glenoid Wear		Type A1 Glenoid		Type A2 Glenoid		Type B1 Glenoid		Type B2 Glenoid	
	Pre-operative	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*
Relative Constant and Murley score (percent)	49.4	97.5*	49.6	106.2*	48.7	92.1*	47.5	100*	50.8	110.6*	48.3	95.6*	49.2	89.1*
Pain (points)	5.7	13.5*	5.4	14.3*	5.8	13*	4.6	13.5*	5.9	14.9*	5.4	13.1*	6.2	12.8*
Activities of daily living (points)	7.9	17.3*	8.8	18.7*	7.3	16.5*	9.4	18*	8.4	13.31*	6.7	17.1*	8	15.9*
Range of motion (points)	18.4	32*	17.8	34.8†	18.7	30.4*	18.4	33*	17.5	35.9*	19.2	31.3*	18.1	29.6*
Strength (points)	4.4	8*	4.6	8.1	4.1	7.9*	4.6	9.6*	4.6	6.8	3.9	8.7*	4.3	7.1*

glenoid erosion.[2] Radiographic studies of osteoarthritic shoulders show that posterior subluxation of the humeral head is not correlated with the presence of glenoid retroversion,[1,19] but to the morphologic type of glenoid wear.[19] These findings are corroborated by our study. We found a positive correlation between posterior decentralization of the humeral head and morphologic features of the glenoid as described by Walch et al.[19]

Rotator cuff disease is uncommon in patients with primary OA, occurring in 10% to 23% of patients.[1,7] In our study, a supraspinatus tendon tear was seen intraoperatively in 24.7% (19 patients) of patients. Only two of these patients had a complete supraspinatus tendon tear. There was no association between the state of the rotator cuff and centering of glenohumeral joint or glenoid deficiency.

Reconstruction of glenoid bone stock using bone grafting and screw fixation and the resulting postoperative functional results, rates of radiolucency, and complications have been reported.[9,18] However, we found no studies describing recentering of the glenohumeral joint after correction of glenoid alignment during TSA. Neer and Morrison[15] were the first to report on bone grafting for severe glenoid deficiency. In their series of 463 consecutive TSAs, only 4.3% of their patients required glenoid bone grafting. After a mean followup of 4.4 years, they reported approximately 15% of patients (three patients) had complications. In two patients the fixation screws broke, and in another patient the fixation screw was worn as a result of contact with the humeral component. Eighty-five percent of their patients achieved satisfactory and excellent functional results. In a series of 953 TSAs reported by Steinmann and Cofield,[18] 28 patients (3.2%) required glenoid bone grafting. After a mean followup of 5.3 years, they observed three loose glenoids (10.7%). Nonetheless, 82% of their patients achieved excellent and satisfactory functional results. They concluded that the clinical and radiographic results are similar to those for a TSA overall. Hill and Norris[9] performed bone grafting for glenoid deficiency in 16% (21 patients) of their TSAs. Seventeen patients were followed up after a mean 70 months. Overall five (29%) glenoid components were symptomatically loose and required revision surgery. The graft failed in 18% (three patients) because of nonunion or shift of the graft. Forty-seven percent had unsatisfactory functional results. In our series, bone grafting was performed for severe glenoid deficiency in eight patients (10.4%) who had a TSA. One of these eight patients had failed results because of nonunion of the bone graft requiring revision surgery. With a mean followup of 39 months in the patients who required bone grafting, a relative Constant and Murley score of 95.6% was achieved which is comparable to the Constant and Murley score of the patients with concentric glenoid wear.

Miller et al[12] examined 41 patients who had TSAs with a mean clinical followup of 1.9 years. They found a positive lift-off test in 67% and a positive belly-press test in 66.6% of the patients,[12] indicating an insufficiency of the subscapularis muscle. Postoperative anterior and anterosuperior decentering of the humeral component can be caused by subscapularis deficiency, therefore the influence of surgical glenoid alignment for patients with postoperative anterior or anterosuperior decentering is unclear.

Our midterm results suggest a decentered humeral head caused by glenoid deficiency in the transversal plane can be recentered by lowering the high side, and in severe glenoid deficiency by bone grafting with soft tissue balancing. Because of the recentering, the preoperative posterior humeral head position does not influence the postoperative functional result. The complication rate for our patients with this technique was low and complications were observed only in patients who had eccentric glenoid wear preoperatively. We recommend normalizing posterior glenoid wear during glenoid preparation during TSA to avoid early glenoid loosening.

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