Three-Dimensional Glenoid Deformity in Patients with Osteoarthritis: A Radiographic Analysis

P. Habermeyer, P. Magosch, V. Luz and S. Lichtenberg
J. Bone Joint Surg. Am. 88:1301-1307, 2006. doi:10.2106/JBJS.E.00622

Three-Dimensional Glenoid Deformity in Patients with Osteoarthritis: A Radiographic Analysis

By P. Habermeyer, PhD, P. Magosch, MD, V. Luz, and S. Lichtenberg, MD

Investigation performed at the Department of Shoulder and Elbow Surgery, ATOS-Clinic, Heidelberg, Germany

Background: In osteoarthritis of the shoulder, the tilt of the glenoid surface undergoes an eccentric deformation not only in the anteroposterior but also in the superoinferior direction. The goals of this study were to analyze glenoid version in the coronal plane and to clarify the relationship between retroversion and inferior inclination of the glenoid.

Methods: Standardized radiographs of 100 consecutive patients with primary osteoarthritis of the shoulder and 100 otherwise healthy patients with shoulder pain (the control group) were included in this study and were analyzed by two independent observers.

Results: We defined four different types of inclination deformity of the glenoid. In a type-0 glenoid, a line at the base of the coracoid process and a line at the glenoid rim run parallel. Both lines intersect below the inferior glenoid rim in a type-1 glenoid. In a type-2 glenoid, the line at the base of the coracoid process and the glenoid line intersect between the inferior glenoid rim and the center of the glenoid. In a type-3 glenoid, the lines intersect above the base of the coracoid process. A significant difference ($p < 0.0001$) in the distribution of glenoid types between the two patient groups was observed. Forty-seven patients with osteoarthritis showed combined posterior and inferior glenoid wear. We found no correlation between the type of inclination and the type of glenoid morphology. The interobserver reliability of our observations was very high.

Conclusions: In osteoarthritis, eccentric inferior glenoid wear is frequent and independent from retroversion deformity of the glenoid. Normalization of glenoid version in both transverse and coronal planes may reduce eccentric loading of the prosthetic glenoid, which has been associated with loosening.

Clinical Relevance: This radiographic classification system can facilitate the decision-making process to normalize glenoid inclination during glenoid replacement.

Posterior eccentric glenoid wear in primary glenohumeral osteoarthritis has been described in the literature[1-4]. Neer et al.[5,6] observed substantial posterior glenoid wear causing static posterior subluxation of the humeral head in patients with primary osteoarthritis. In order to study the natural course and to discriminate retroversion from posterior erosion and dysplasia, Walch et al.[1] classified glenoid morphology in the transaxial plane for primary osteoarthritis.

Normal glenoid posterior tilt (retroversion) has been reported to range from 0° to 10°[7]. An increase in posterior glenoid tilt leads to posterior subluxation of the humeral head. A posterior glenoid tilt of >25° represents congenital dysplasia[1]. Gouaze et al.[8] described three types of inclination of the glenoid in healthy shoulders. Glenoid tilt in the coronal plane was ascendant in 45% of the shoulders (average angle, 3°; range, 1° to 10°), strictly vertical in 22%, and descendant in 33% (average angle, 4°; range, 1° to 12°).

The tilt of the glenoid surface, however, undergoes an eccentric deformation not only in the anteroposterior but also in the superoinferior direction. Edelson[3] assumed that inferior glenoid deformity in addition to posterior glenoid wear occurred in patients with osteoarthritis. In a cadaver study, he found posteroinferior glenoid wear in 3.5% of the 486 specimens with degenerative changes in the glenohumeral joint[9].

The angle of inclination of the glenoid is equivalent to the amount of glenoid tilt in the coronal plane and defines the position of the humeral head relative to the subacromial space. The normal glenoid tilt in the coronal plane has been reported to range from –8° to 15.8° (average, 4° to 5°)[10,11].

Contracture or insufficiency of the active shoulder stabilizers (in particular the rotator cuff) and changes in the passive stabilizers (increased glenoid version or humeral head version) have been discussed as causes of decentralization of the humeral head in osteoarthritis[1,6,12].

In total shoulder arthroplasty, it is important to detect and to correct decentering of the humeral head to avoid early polyethylene wear as well as loosening of the glenoid component caused by the so-called rocking-horse phenomenon. Additionally, the decision-making process to implant a glenoid component is affected by the quantity of glenoid bone stock. The goals of this study were to describe and analyze glenoid version in the coronal plane as well as to describe the relationship between retroversion and inferior inclination of the glenoid.

Materials and Methods

Radiographs of 100 consecutive patients (sixty-two women and thirty-eight men) with a mean age of 67.7 years (range, forty-seven to eighty-five years) who had primary osteoarthritis of the shoulder were analyzed.

One hundred otherwise healthy patients (twenty-five women and seventy-five men) (the control group) with a mean age of 31.8 years (range, twenty-five to thirty-seven years) who had shoulder pain without any clinical, ultrasonographic, or radiographic signs of degenerative changes, rotator cuff tears, or shoulder instability were also studied. True anteroposterior radiographs, with the arm in neutral rotation, and axillary radiographs were analyzed by two independent observers (P.M. and V.L.).

Ninety-five of the 100 patients with primary osteoarthritis received a shoulder replacement, and the state of the rotator cuff was assessed intraoperatively.

Radiographic and Measurement Techniques

The true anteroposterior radiograph was made with the patient standing upright. The scapula was lying against the x-ray cassette behind the patient, and the arm was positioned in neutral rotation at the side. The beam passed in an anterior-to-posterior direction tilted caudad 10° from the perpendicular to the scapula.

The axillary radiograph was made with the patient sitting beside the x-ray table with the arm positioned on the table in 70° to 90° of abduction and with the elbow in 90° of flexion. The x-ray cassette was then placed on the table directly beneath the shoulder, and the x-ray machine was positioned directly over the shoulder so that the beam passed vertically in a superior-to-inferior direction through the shoulder joint onto the cassette.

The glenoid inclination angle was measured with use of one line drawn along the superior and inferior glenoid rim (the glenoid line) and another line drawn along the lateral base of the coracoid process (the coracoid base line) from the superior glenoid rim perpendicular to the bottom margin of the radiograph, as described by Boileau and Walch[13]. The coracoid base line is reproducible because the anteroposterior radiograph is made with the patient in a standardized standing position so that the inferior border of the radiograph is parallel to the floor and the lateral base of the coracoid does not change with rotation of the scapula. By convention, a negative number indicates an inferiorly directed glenoid, and a positive number indicates a superiorly directed glenoid. Superior or inferior decentralization of the humeral head (in the coronal plane) was documented. Decentralization was defined as a deviation of the center of the humeral head of >5 mm superiorly or inferiorly from the center of the glenoid in the coronal plane.

Glenoid wear in the transverse plane was assessed on the axillary radiograph with use of the classification system of glenoid morphology described by Walch et al.[1], and decentralization of the humeral head was documented. Walch et al.[1] defined three types of glenoid morphology (Fig. 1). Type A is characterized by an equal balance of forces acting on the glenoid and a centralized head. Glenoid wear is either minor (type A1) or major with substantial central wear causing a glenoid cup (type A2). Type B has asymmetrical force distribution on

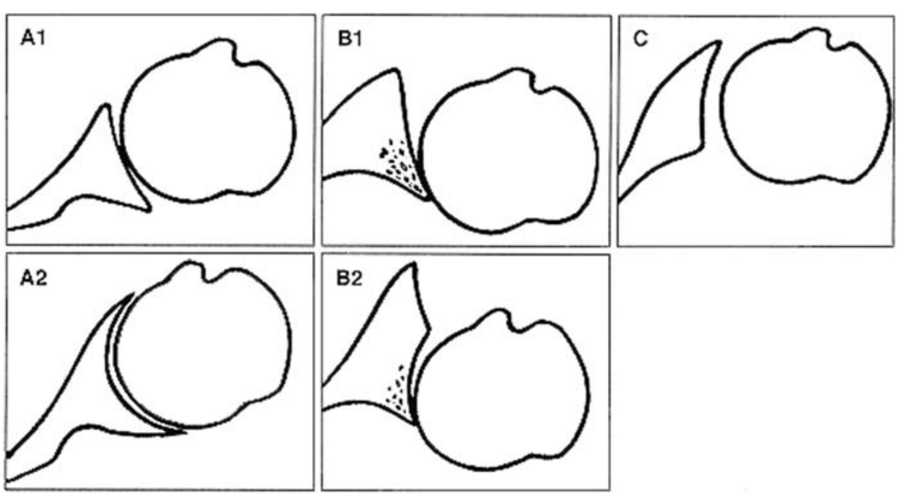

Fig. 1

Classification of glenoid morphology in osteoarthritis in the transaxial plane, according to the system of Walch et al.[1].

the glenoid, leading to a loss of joint space (predominantly posteriorly), subchondral sclerosis (more marked on the posterior edge of the glenoid), and/or multiple posterior geodes (type B1), or to a posterior cup that gives the appearance of a double concavity on the glenoid surface (type B2). Type C is arbitrarily defined as glenoid retroversion of >25° and represents glenoid dysplasia.

The assessment of glenoid morphology with use of this method is not influenced by the rotation of the scapula in patients with osteoarthritis and limited abduction of <90° because the axis of the scapula, which is mapped on the radiograph, does not change with the rotation of the scapula.

Decentering of the humeral head was defined as a deviation of the center of the humeral head in the transverse plane of ±5 mm in relation to the glenoid center line.

Statistical Methods

Univariate analyses of associations between the type of inclination, angle of glenoid inclination, decentralization of the humeral head, intraoperative state of the rotator cuff, and the glenoid morphology in the transverse plane were carried out with use of the Pearson chi-square test for categorical data. The chi-square test was used for differences in the distribution of gender, the distribution of the type of glenoid inclination between patients with osteoarthritis and the control group, as well as the distribution of the type of inclination of the glenoid between women and men. Interobserver variability for the type of inclination and angle of inclination was determined with use of kappa statistics. To identify differences in the distribution of the inclination angle between the several types of inclination, the Kruskal-Wallis test and the Mann-Whitney U test were performed. The level of significance was set at 0.05. All statistical analyses were performed with SPSS (version 11.0 for Windows; SPSS, Chicago, Illinois).

TABLE I Distribution of Shoulders According to Glenoid Morphology in the Coronal Plane with Regard to the Inferior Inclination of the Glenoid

Inclination Type	Osteoarthritis Group (n = 100)	Control Group (n = 100)
0 (normal)	13	45
1	16	49
2	54	6
3	17	0

Results

Overall, no significant difference was observed in the distribution of gender between the patients in the control group

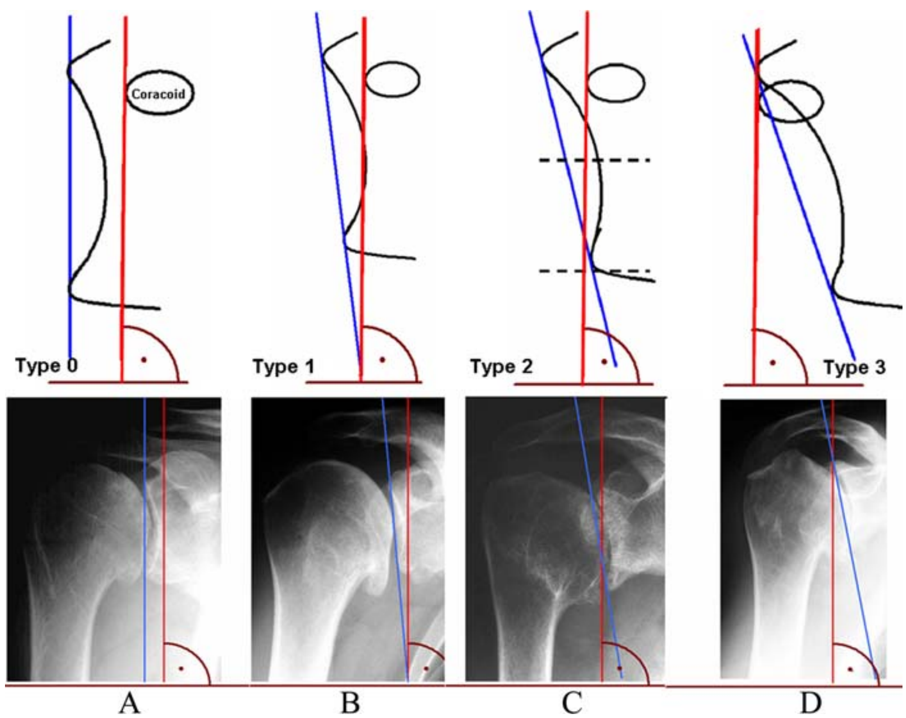

Fig. 2

Classification of glenoid inclination. *A:* In type 0, the coracoid base line (red) and the glenoid line (blue) run parallel (the brown line represents the inferior border of the radiograph). *B:* In type 1, the coracoid base line and the glenoid line intersect below the inferior glenoid rim. *C:* In type 2, the coracoid base line and the glenoid line intersect between the inferior glenoid rim and the center of the glenoid. *D:* In type 3, the coracoid base line and the glenoid line intersect above the coracoid base.

TABLE II Distribution of Angle of Inclination Relating to the Type of Inclination

Inclination Type	Mean Angle of Inclination (Range)	
	Osteoarthritis Group	Control Group
0 (normal)	1.7° (–7° to 7°)	1.3° (–3° to 7°)
1	–7.1° (–16° to –2°)	–4.8° (–10° to –2°)
2	–16.0° (–32° to –5°)	–7.7° (–12° to –4°)
3	–17.7° (–28° to –12°)	

and the patients with osteoarthritis ($p = 0.496$). In the true anteroposterior radiograph, we identified four types of inclination. Type 0 represents the normal glenoid, in which the coracoid base line and the glenoid line run parallel (Fig. 2, *A*). In a type-1 glenoid, the lines intersect below the inferior glenoid rim (Fig. 2, *B*). In a type-2 glenoid, the coracoid base line and the glenoid line intersect somewhere between the inferior glenoid rim and the center of the glenoid (Fig. 2, *C*). In a type-3 glenoid, the lines intersect above the coracoid base (Fig. 2, *D*).

The distribution of inclination type is shown in Table I. Significantly more patients with osteoarthritis were found to have type-2 and type-3 glenoids ($p < 0.0001$) compared with the control patients (Fig. 3).

In patients with osteoarthritis, the mean angle (and standard deviation) of inclination was –12.6° ± 8.7° (range, –32° to 7°). In the control group, the mean inclination angle was –2.2° ± 4.1° (range, –12° to 7°). The mean inclination angle in patients with osteoarthritis was significantly lower ($p < 0.0001$) than that in healthy patients. The distribution of mean inclination angles within the several types of inclination is shown in Table II.

Overall, the distribution of the angle of inclination differed significantly ($p < 0.0001$) among the types of inclination in patients with osteoarthritis as well as in the control patients. In the osteoarthritis group, the mean angle of inclination increased significantly ($p < 0.0001$) between type 0 and type 2. In the control group, we also observed a significant increase ($p < 0.05$) in the mean angle of inclination between type 0 and type 2.

Assessing the glenoid morphology on the axillary radiograph according to the technique of Walch et al.[1], we observed only type-A1 glenoids in the control group. In the osteoarthritis group, we found a type-A1 glenoid in twenty patients, a type-A2 glenoid in twenty-six patients, a type-B1 glenoid in twenty-eight patients, and a type-B2 glenoid in twenty-five patients. It was not possible to assess the glenoid morphology on the axillary radiograph for one patient. The distribution of glenoid morphology in relation to the type of inclination is shown in Table III. Forty-seven patients (47%) with osteoarthritis showed both posterior and inferior glenoid wear. We could not identify a correlation (coefficient of correlation = –0.74; $p = 0.47$) between the type of glenoid inclination and the type of glenoid morphology. A correlation between the type of glenoid morphology and posterior decentralization in the axillary radiograph was detected (coefficient of correlation = 0.538; $p < 0.0001$).

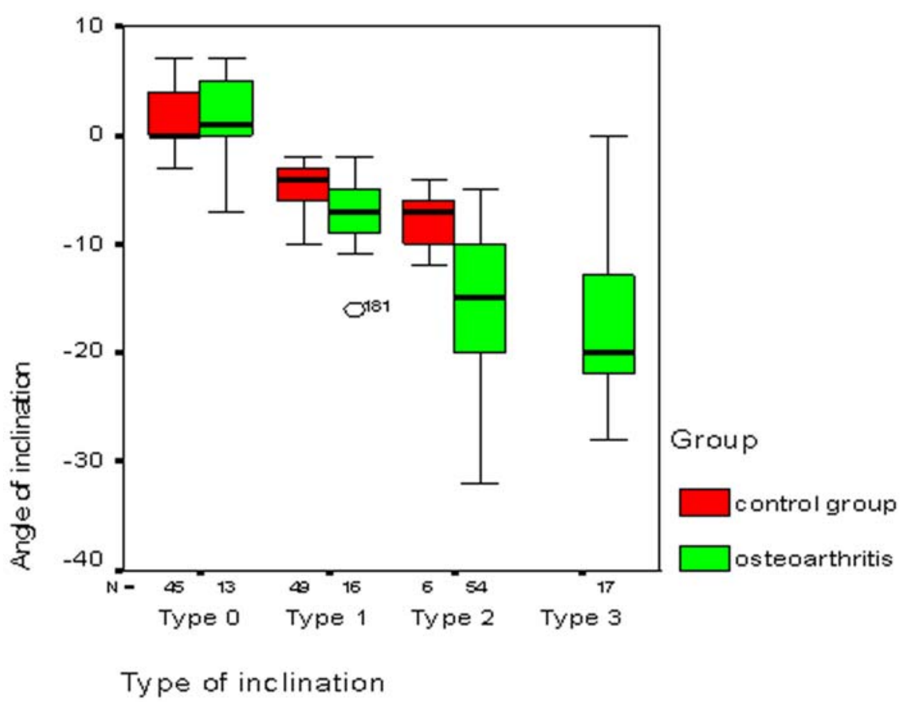

Fig. 3

Distribution of the inclination angle in the different types of inclination as found in the osteoarthritic group and in the control group.

TABLE III Distribution of Glenoid Morphology in Relation to the Type of Glenoid Inclination in Patients with Osteoarthritis

	Classification of Glenoid Morphology According to System of Walch et al.[1] *(no. of shoulders)*				
Inclination Type	A1	A2	B1	B2	C
0	2	5	3	3	0
1	4	1	6	5	0
2	11	14	11	17	0
3	3	6	8	0	0

TABLE IV Frequencies of Glenoid Type in Relation to the Position of the Humeral Head as Assessed on the Axillary Radiograph

	Glenoid Type According to System of Walch et al.[1] *(no. of shoulders)*			
Humeral Head Position	A1	A2	B1	B2
Centered	18	21	21	4
Anterior	3	1	2	0
Posterior	0	4	6	20

Twenty-six (27%) of the ninety-five patients with osteoarthritis who had a shoulder replacement demonstrated a rotator cuff lesion intraoperatively. We observed a deep partial tear of the supraspinatus tendon in twenty-two patients and a complete supraspinatus tendon tear in four patients. With the numbers available, lesions of the rotator cuff did not correlate with the position of the humeral head in the coronal plane.

Overall, fifty-eight (58%) of 100 patients with primary osteoarthritis had a static eccentric position of the humeral head in the coronal plane. We observed a slight correlation between the type of inclination and the humeral head position in the coronal plane ($r = -0.223$; $p = 0.027$).

Decentering of the humeral head in the transverse plane was observed in thirty-six of 100 patients with osteoarthritis. We found a positive correlation ($r = 0.538$; $p < 0.0001$) between the humeral head position in the transverse plane and glenoid morphology (Table IV).

Forty-nine of 100 patients with osteoarthritis showed a centered humeral head on both the anteroposterior and axillary radiographs. Only one patient had both inferior and posterior decentralization of the humeral head. The distribution of humeral head decentralization is shown in Table V.

The interobserver reliability for the classification of glenoid inclination was 0.82 (Cohen's kappa) for the control group and 0.952 for the osteoarthritis group. In the control group, the interobserver correlation for the measurement of the angle of inclination was 0.961. The average difference between the two observers was 0.84°, with a maximum discrepancy of 5°. The interobserver correlation for the osteoarthritis group was 0.989, with an average difference in measurement of 0.92° and a maximum discrepancy of 5°.

Discussion

Several studies have described the anatomy and the degenerative changes of the glenoid in the transverse plane[1,14]. In a cadaver study, Edelson observed posteroinferior glenoid wear in 3.5% of the specimens with degenerative changes in the glenohumeral joint[9]. In contrast to this low rate, we found posteroinferior glenoid wear in forty-seven of 100 patients with osteoarthritis. We detected no significant association between the glenoid morphology in the transverse plane and the glenoid morphology in the coronal plane. Significantly more patients in the osteoarthritis group (seventy-one of 100 patients) demonstrated inferior glenoid wear (type-2 or type-3 inclination) than in the control group (six of 100 patients had type-2 inclination).

The position of the glenoid line depends on the amount

TABLE V Frequencies of the Position of the Humeral Head Observed in the True Anteroposterior and Axillary Radiographs of 100 Patients with Osteoarthritis

	True Anteroposterior Radiograph		
Axillary Radiograph	Humeral Head Centered	Inferior Decentered Humeral Head	Superior Decentered Humeral Head
Humeral head centered	49	5	10
Anterior decentered humeral head	2	1	3
Posterior decentered humeral head	20	1	9

of superior and inferior glenoid wear. We observed no significant difference in the mean angle of inclination in type-2 and type-3 glenoids in patients with osteoarthritis. A type-3 glenoid develops in patients with unequal amounts of superior and inferior glenoid wear and represents a late stage of glenoid erosion in patients with osteoarthritis. Therefore, we believe that measurement of the inclination angle does not describe glenoid wear in the coronal plane sufficiently. The extent of inclination deformity is accurately described with use of a classification system with four different types of severity.

Posterior glenoid wear in osteoarthritis and its surgical management have been well described in the literature[1,2,4]. Glenoid version correlates with an increase in osteoarthritic changes. Posterior humeral head subluxation is commonly associated with posterior glenoid erosion[15]. This was confirmed in our study. We found a positive correlation between posterior decentralization of the humeral head and glenoid morphology as described by Walch et al.[1] Additionally, Walch et al. described a progression of glenoid morphology from B1 to B2 by erosion of the glenoid with age, leading to a biconcave appearance. Primary osteoarthritis can be accompanied by a contracture of the subscapularis muscle. Increasing contracture of the subscapularis muscle may lead to posterior decentralization of the humeral head, which reinforces posterior glenoid wear. With regard to glenoid wear in the coronal plane, we observed no correlation between superior or inferior decentralization of the humeral head and the type of inclination as well as the inclination angle. In a study comparing three-dimensional magnetic resonance imaging of patients with glenohumeral osteoarthritis and healthy control subjects, von Eisenhart-Rothe et al. also found no difference with regard to decentering of the humeral head in the coronal plane between the two groups[16]. The reason for this could be the absence of a muscular force couple in the craniocaudal direction comparable with the one that exists in the anteroposterior direction formed by the subscapularis and the infraspinatus muscles.

In the study by von Eisenhart-Rothe et al.[16], patients with cuff tear arthropathy were found to have a significant ($p < 0.005$) superior decentralization of the humeral head compared with patients with primary osteoarthritis. In contrast, we found no significant association between the state of the rotator cuff and the type of glenoid inclination.

Measurement of the inclination angle with use of conventional, standardized true anteroposterior radiographs without consideration of scapular rotation on the chest seems to represent a weakness of our study. The average inclination angle of normal shoulders has been reported in cadaver studies to be 4° (range, −7° to 15.8°)[10,11]. In our clinical study, we observed an average inclination angle of –2.2° in the control group, thus falling within the normal range measured in the cadaver studies. Therefore, we hypothesize that our technique of measuring the inclination angle is not strongly affected by the highly variable dynamic vertical tilt of the scapula. Additionally, a true anteroposterior radiograph was made with the patient standing upright and with the arm hanging at the side, so that the scapula would rest in a static position to minimize any dynamic component, which could influence scapular tilt.

In conclusion, substantial eccentric inferior glenoid wear is observed in osteoarthritis, leading to an inferior inclination deformity of the glenoid. We consistently found four different types of glenoid version in the coronal plane. In the literature, posterior glenoid wear and its surgical management in osteoarthritis have been well described; however, inferior glenoid wear has been mentioned only occasionally. Almost half of our patients with osteoarthritis showed combined posterior and inferior glenoid wear.

Both inferior glenoid deformity and eccentric posterior glenoid wear should be considered during glenoid replacement. We believe it is prudent to normalize type-2 and type-3 glenoid inclination, as well as any angle of retroversion of >15°, when glenoid replacement is performed in shoulder arthroplasty. Without normalization of the pathologic glenoid tilt, a static uneven stress distribution onto the prosthetic glenoid may occur postoperatively. ■

P. Habermeyer, PhD
P. Magosch, MD
V. Luz
S. Lichtenberg, MD
ATOS-Praxisklinik, Bismarckstrasse 9-15, 69115 Heidelberg, Germany.
E-mail address for P. Magosch: petra.magosch@atos.de

The authors did not receive grants or outside funding in support of their research for or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

doi:10.2106/JBJS.E.00622

References

1. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty. 1999; 14:756-60.

2. Neer CS 2nd, Morrison DS. Glenoid bone-grafting in total shoulder arthroplasty. J Bone Joint Surg Am. 1988;70:1154-62.

3. Edelson JG. Localized glenoid hypoplasia. An anatomic variation of possible clinical significance. Clin Orthop Relat Res. 1995;321:189-95.

4. Steinmann SP, Cofield RH. Bone grafting for glenoid deficiency in total shoulder replacement. J Shoulder Elbow Surg. 2000;9:361-7.

5. Neer CS 2nd. Replacement arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am. 1974;56:1-13.

6. Neer CS 2nd, Watson KC, Stanton FJ. Recent experience in total shoulder replacement. J Bone Joint Surg Am. 1982;64:319-37.

7. Fick R. Handbuch der Anatomie und Mechanik der Gelenke. Jena: Gustav Fischer; 1904. p 171-4.

8. Gouaze A, Castaing J, Soutoul JH, Chantepie G. Sur l'orientation de l'omoplate et de sa cavité glénoïde. [On the orientation of the scapula and of its glenoid cavity]. Arch Anat Pathol. 1962;10:175-81. French.

9. Edelson JG. Patterns of degenerative change in the glenohumeral joint. J Bone Joint Surg Br. 1995;77:288-92.

10. Mallon WJ, Brown HR, Vogler JB 3rd, Martinez S. Radiographic and geometric anatomy of the scapula. Clin Orthop Relat Res. 1992;277:142-54.

11. Churchill RS, Brems JJ, Kotschi H. Glenoid size, inclination, and version: an anatomic study. J Shoulder Elbow Surg. 2001;10:327-32.

12. Mullaji AB, Beddow FH, Lamb GH. CT measurement of glenoid erosion in arthritis. J Bone Joint Surg Br. 1994;76:384-8.

13. Boileau P, Walch G. Normal and pathological anatomy of the glenoid: effects on the design, preparation and fixation of the glenoid component. In: Walch G, Boileau P, editors. Shoulder arthroplasty. New York: Springer; 1999. p 127-40.

14. De Wilde LF, Berghs BM, VandeVyver F, Schepens A, Verdonk RC. Glenohumeral relationship in the transverse plane of the body. J Shoulder Elbow Surg. 2003;12:260-7.

15. Bell RH, Noble JS. The management of significant glenoid deficiency in total shoulder arthroplasty. J Shoulder Elbow Surg. 2000;9:248-56.

16. von Eisenhart-Rothe R, Kroetz M, Wiedemann E, Englmeier KH, Graichen H. Fixierte und funktionelle dezentrierung des humeruskopfes bei patienten mit omarthrose. [Fixed and functional decentering of the head of the humerus in patients with omarthrosis]. Unfallchirurg. 2002;105:517-22. German.