Glenoid deformity in the coronal plane correlates with humeral head changes in osteoarthritis: a radiographic analysis

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\textbf{Background:} A variety of measurements can be used to assess radiographic osteoarthritic changes of the shoulder. This study aimed to analyze the correlation between the radiographic humeral-sided Samilson and Prieto classification system and 3 different radiographic classifications describing the changes of the glenoid in the coronal plane.

\textbf{Methods:} The study material included standardized radiographs of 50 patients with idiopathic osteoarthritis before anatomic shoulder replacement. On the basis of radiographic measurements, the cases were evaluated using the Samilson and Prieto grading system, angle $\beta$, inclination type, and critical shoulder angle by 2 independent observers.

\textbf{Results:} Classification measurements showed an excellent agreement between observers. Our results showed that the humeral-sided Samilson and Prieto grading system had a statistically significant good correlation with angle $\beta$ (observer 1, $r = 0.74$; observer 2, $r = 0.77; P < .05$) and a statistically significant excellent correlation with the inclination type of the glenoid (observer 1, $r = 0.86$; observer 2, $r = 0.8; P < .05$). A poor correlation to the critical shoulder angle was observed ($r = -0.14$, $r = 0.03; P > .05$).

\textbf{Conclusions:} The grade of humeral-sided osteoarthritis according to Samilson and Prieto correlates with the glenoid-sided osteoarthritic changes of the glenoid in the coronal plane described by the angle $\beta$ and by the inclination type of the glenoid. Higher glenoid-sided inclination is associated with higher grade of osteoarthritis in primary shoulder osteoarthritis.

\textbf{Level of evidence:} Level III; Cross-Sectional Design; Epidemiology Study

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Keywords: Glenohumeral osteoarthritis; radiographic classification; inclination type; angle $\beta$; critical shoulder angle; Samilson and Prieto; shoulder; osteoarthritis

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Glenohumeral arthritic joint disease is a common shoulder disorder. Therapeutic options include joint-preserving approaches that vary by stage and the patient’s age as well as joint replacement procedures.\textsuperscript{1,7,21} To determine stage,
osteoarthritis of the shoulder is often defined using radiographic examination, following the grading system of Samilson and Prieto, which was originally introduced to evaluate instability arthropathy by describing the humeral-sided size of the osteophyte.

On the other hand, several authors have reported different methods of radiographic evaluation of the scapula anatomy. Ricchetti et al described that patients with glenohumeral osteoarthritis do not appear to have abnormal premorbid glenoid inclination or retroversion. Edelson described a relationship between posterosuperior glenoid wear and osteoarthritis in the glenohumeral joint.

Habermeyer et al introduced a classification system for grading of the glenoid inclination type based on the intersection of a vertical line at the base of the coracoid process and a line at the glenoid rim. This classification system combines the inclination of the glenoid in the coronal plane with the inferior protrusion of the humeral head respectively glenoid. Concerning scapular-specific anatomy, Maurer et al analyzed several radiographic measurements and described angle β (the angle between the floor of the supraspinatus fossa and the glenoid fossa line) as a reproducible indicator of glenoid inclination. Finally, Moor et al described a radiographic parameter—the critical shoulder angle—that combines the glenoid inclination and the lateral extension of the acromion (acromion index).

Osteoarthritic changes of the glenoid in the axial plane are already described in the literature. This study aimed to determine the correlation of humeral-sided arthropathy according to Samilson and Prieto with glenoid-sided pathology in primary osteoarthritis based on angle β according to Maurer et al, inclination type according to Habermeyer et al, and critical shoulder angle according to Moor et al.

**Materials and methods**

Our study material included radiographs of 68 consecutive patients with osteoarthritis before anatomic shoulder arthroplasty in a retrospective study design. All patients had no previous surgical intervention of the shoulder. All radiographs were analyzed in the true anteroposterior view. Seven patients with post-traumatic osteoarthritis and 3 patients with osteonecrosis were excluded from this study. Four patients were excluded because of an upward-tilted glenoid, which is described by the classification system of Favard et al and is not included in the classification system of the inclination type described by Habermeyer et al. Four patients were excluded from the study because of an insufficient radiograph. The mean age of the patients was 70.4 ± 9.2 years, and the gender distribution was 24 female and 26 male patients. Twenty-one arthroplasties were performed on the right shoulder and 29 on the left shoulder.

Measurements were performed by 2 independent shoulder-trained orthopedic surgeons (N.H. and F.M.). The cases were categorized by several systems: classification according to Samilson and Prieto, with the modification of adding grade IV for all patients having an inferior humeral osteophyte extending >12 mm; angle β according to Maurer et al; inclination type according to Habermeyer et al; and critical shoulder angle according to Moor et al. Figure 1 shows examples of these classifications.

**Radiographic and measurement techniques**

A true anteroposterior radiograph was acquired of all patients in a standing upright position. The scapula was situated against the cassette of the X-ray behind the patient. The patient’s arm was positioned at the side in strictly neutral rotation. The beam was passed in an anterior to posterior direction, tilted caudal 10° from the perpendicular line to the scapula. Trained and experienced staff performed all radiographs.

**Samilson and Prieto classification of humeral-sided arthropathy**

The Samilson and Prieto classification system grades an inferior humeral head osteophyte by millimeters of extension. In the original system, an extension of <3 mm is considered grade I; 3 to 7 mm, grade II; and >7 mm, grade III. To emphasize the degree of osteoarthritis and to allow a proper discrimination between groups, we modified this classification and included the classification of an osteophyte between 8 and 12 mm as grade III and that >12 mm as grade IV (Table I).

**Angle β as described by Maurer et al**

Angle β was measured as the degree of the angle between the floor of the supraspinatus fossa (sclerotic line) and a line drawn along the superior and inferior glenoid tubercle (rim line).

**Inclination type as described by Habermeyer et al**

Inclination type was determined on the basis of the relationship between a vertical line set at the lateral base of the coracoid process, perpendicular to the radiograph bottom margin, and a line drawn along the superior and inferior glenoid tubercle. Parallel lines were classified as type 0. In cases of line intersection, the type was determined by where that intersection occurred, with intersection below the inferior glenoid rim considered type I, intersection between the inferior rim and the center of glenoid considered type II, and intersection above the coracoid base considered type III.

**Critical shoulder angle as described by Moor et al**

Critical shoulder angle was measured as the degree of the angle between a line from the inferior glenoid rim and the most lateral border of the acromion and a line drawn along the superior and inferior glenoid tubercle.

**Statistical methods**

Descriptive analyses were performed and all data are presented as mean, range, and standard deviation. Spearman correlation was used to analyze the relationships between classification methods (Samilson and Prieto, angle β, inclination type, and critical shoulder angle). Interobserver reliability was assessed using intraclass correlation...
analysis. All measurements were performed using SPSS 11.5 (SPSS Inc, Chicago, IL, USA).

The significance level for all tests was set to \( \alpha = 0.05 \). The following conventional benchmark values were used: a value between 0 and 0.19 describes a poor agreement; 0.20 to 0.39, a fair agreement; 0.40 to 0.59, a moderate agreement; 0.60 to 0.79, a good agreement; and 0.80 to 1.00, an excellent agreement.\(^{10}\)

### Results

Using the modified Samilson and Prieto classification system,\(^{18}\) observer 1 found the following distribution of grades of humeral-sided osteoarthritis: 2 patients were classified as grade I, 16 as grade II, 9 as grade III, and 23 as grade IV. Observer 2 classified 2 patients as grade I, 14 as grade II, 10 as grade III, and 24 as grade IV—showing excellent agreement between observers (ICC, 0.92; \( P < .05 \); Table II). With regard to inclination type, observer 1 classified 8 patients as type I, 18 as type II, and 24 as type III. Observer 2 classified 8 patients as type I, 25 as type II, and 17 as type III—showing excellent agreement between observers (ICC, 0.9; \( P < .05 \); Table III). The mean measurement of critical shoulder angle was 29° ± 4° according to observer 1 and 30° ± 3° according to observer 2—showing excellent agreement between observers (ICC, 0.86; \( P < .05 \); Table III).

Analysis of the correlations between the different classification types revealed that the grade of osteoarthritis described by the Samilson and Prieto classification showed a significant and good correlation with the angle \( \beta \) as measured by both observers (\( r = 0.74, r = 0.77; P < .05 \)) as well as a significant and excellent correlation to the inclination type as measured by both observers (\( r = 0.86, r = 0.8; P < .05 \)). On the other hand, grade of osteoarthritis according to Samilson and Prieto classification was not significantly associated with

### Table I

<table>
<thead>
<tr>
<th>Extent of inferior humeral osteophyte</th>
<th>Stage</th>
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<tr>
<td>&lt;3 mm</td>
<td>I</td>
</tr>
<tr>
<td>3-7 mm</td>
<td>II</td>
</tr>
<tr>
<td>8-12 mm</td>
<td>III</td>
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<tr>
<td>&gt;12 mm</td>
<td>IV</td>
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</table>

### Table II

<table>
<thead>
<tr>
<th>Samilson and Prieto classification</th>
<th>Observer 1</th>
<th>Observer 2</th>
<th>Interobserver reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2</td>
<td>2</td>
<td>ICC = 0.92, ( P &lt; .05 )</td>
</tr>
<tr>
<td>II</td>
<td>16</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>23</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

*ICC*, intraclass correlation coefficient.

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**Figure 1** (A) Patient with glenohumeral osteoarthritis Samilson and Prieto grade II, 69° angle \( \beta \) (orange), inclination type I (blue), and critical shoulder angle of 35° (pink). (B) Patient with glenohumeral osteoarthritis Samilson and Prieto grade III, 76° angle \( \beta \) (orange), inclination type II (blue), and critical shoulder angle of 31° (pink). (C) Patient with glenohumeral osteoarthritis Samilson and Prieto grade IV, 87° angle \( \beta \) (orange), inclination type III (blue), and critical shoulder angle of 31° (pink). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
the critical shoulder angle as measured by either observer ($r = -0.14$, $r = 0.03$; $P > .05$, poor correlation; Table IV).

**Discussion**

Osteophytes are a radiographic pattern characteristic of degenerative joint disease. In cases of osteoarthritic shoulder joint degeneration, decisions are made primarily on the basis of plain radiographs of the joint. Staging of glenohumeral joint diseases is an important tool for determining appropriate therapeutic options and for identifying early stages of joint disease. The arthropathy grading system of Samilson and Prieto was initially described for instability patterns but is widely used for grading arthropathy in general.

Edelson described localization of glenohumeral osteophytes particularly in the lower half of the glenohumeral joint. However, Kircher et al demonstrated a correlation between osteophyte extension and shoulder function. In a previous study, we reported significantly greater inferior glenoid wear in patients with osteoarthritis compared with a control group. Despite that all patients showing this kind of morphology were excluded from our study (n = 4), Suter et al could show that a little deviation in the anteroposterior radiographs can result in a poor correlation between the extent of humeral-sided osteophyte and the degree of angle $\beta$.

The inclination type describes the extent of inclination deformity, with categorization into 4 different types of severity. This measurement is adapted for patients with a downward tilt of the glenoid. The inclination type also reflects the intra-articular stage of osteoarthritis of the glenoid and is independent from extra-articular parameters. We found that inclination type showed an excellent correlation to the stage of humeral-sided osteophyte in the coronal plane.

Secondary osteoarthritides like cuff tear arthropathy starts especially in the superior aspect of the glenoid. von Eisenhart-Rothe et al reported in these cases a superior decentration of the line of the fossa supraspinata and the glenoid line. This angle likely describes the intra-articular deformity of the glenohumeral joint. Our measurements indicated that there was a good correlation between the extent of humeral-sided osteophyte and the degree of angle $\beta$.

In contrast to angle $\beta$ and the inclination type, the critical shoulder angle combines the glenoid inclination with the acromion morphology. We did not identify a correlation between the critical shoulder angle and the humeral-sided stage of osteophyte extent in the coronal plane. Despite that all patients with insufficient anteroposterior radiographs were excluded from our study (n = 4), Suter et al could show that a little deviation in the anteroposterior radiographs can result in relevant changes of the critical shoulder angle.

It is accepted worldwide that the extent of osteophytes corresponds with the degree of osteoarthritis as described by Samilson and Prieto. Both the angle $\beta$ and the inclination type are measured immediately to the glenohumeral joint aspect. The combination of the glenohumeral joint and the extra-articular extent of the acromion in the critical shoulder angle

| Table III Measurements of angle $\beta$, inclination type, and critical shoulder angle |
|-----------------|-----------------|-----------------|-----------------|
| Angle $\beta$   | Observer 1      | Observer 2      | Interobserver reliability |
| Critical shoulder angle | 79° ± 6° | 80° ± 7° | ICC = 0.91, $P < .05$ |
| Inclination type | 29° ± 4° | 30° ± 3° | ICC = 0.86, $P < .05$ |
| I               | 8               | 8               | ICC = 0.9, $P < .05$ |
| II              | 18              | 25              |               |
| III             | 24              | 17              |               |

*ICC*, intraclass correlation coefficient.

| Table IV Correlations of Samilson and Prieto classification with glenoid morphology parameters |
|-----------------------------------------------|-----------------------------------------------|
| Samilson and Prieto classification            | Angle $\beta$                                 |
|                                              | Observer 1 | Observer 2 | $r = 0.74$ | $r = 0.77$ | $P < .05$ | $P < .05$ |
| Critical shoulder angle                      | Observer 1 | Observer 2 | $r = -0.14$ | $r = 0.03$ | $P > .05$ | $P < .05$ |

*Angle $\beta$ reflects the degree of glenoid inclination through the line of the fossa supraspinata and the glenoid line. This angle likely describes the intra-articular deformity of the glenohumeral joint. Our measurements indicated that there was a good correlation between the extent of humeral-sided osteophyte and the degree of angle $\beta$. The inclination type describes the extent of inclination deformity, with categorization into 4 different types of severity. This measurement is adapted for patients with a downward tilt of the glenoid. The inclination type also reflects the intra-articular stage of osteoarthritis of the glenoid and is independent from extra-articular parameters. We found that inclination type showed an excellent correlation to the stage of humeral-sided osteophyte in the coronal plane. Secondary osteoarthritides like cuff tear arthropathy starts especially in the superior aspect of the glenoid. von Eisenhart-Rothe et al reported in these cases a superior decentration of the humeral head. An upward-tilted glenoid deformity is described by the classification system of Favard et al. Thus, patients showing this kind of morphology were excluded from our present analysis to make all measurements comparable.

In contrast to angle $\beta$ and the inclination type, the critical shoulder angle combines the glenoid inclination with the acromion morphology. We did not identify a correlation between the critical shoulder angle and the humeral-sided stage of osteophyte extent in the coronal plane. Despite that all patients with insufficient anteroposterior radiographs were excluded from our study (n = 4), Suter et al could show that a little deviation in the anteroposterior radiographs can result in relevant changes of the critical shoulder angle.

It is accepted worldwide that the extent of osteophytes corresponds with the degree of osteoarthritis as described by Samilson and Prieto. Both the angle $\beta$ and the inclination type are measured immediately to the glenohumeral joint aspect. The combination of the glenohumeral joint and the extra-articular extent of the acromion in the critical shoulder angle...
could indicate that primary glenohumeral osteoarthritis is an intra-articular process that is sufficiently described by angle \( \beta \) and the inclination type of the glenoid. Our results are in contrast to results published before by Daggett et al, who could show in a radiographic and computed tomography study in 50 shoulders a correlation between the glenoid inclination and the critical shoulder angle. In our opinion, this is due to the different inclusion criteria. This study included only patients with primary osteoarthritides undergoing anatomic shoulder replacement with intact rotator cuff. In the study of Daggett et al, 25 patients received anatomic replacement and the other 25 patients had massive rotator cuff tears.

A weak point of the inclination type as described by Habermeyer et al seems to be that the measurements are performed on true anteroposterior radiographs with reference to a vertical line next to the coracoid process. Cadaver studies show a wide range of glenoid inclination, between \(-7\) and \(15.8\). A true anteroposterior radiograph of the glenohumeral joint detects the true functional position of the joint. Therefore, using a true anteroposterior radiograph with the patient standing upright and with the arm hanging along the patient’s side could be advantageous for classification.

### Conclusions

The grade of humeral-sided osteoarthritis interpreted by the modified Samilson and Prieto classification system was correlated with the angle \( \beta \) of the scapula and the inclination type of the glenoid. Humeral-sided osteoarthritis was not correlated with the critical shoulder angle.

Higher glenoid-sided inclination is associated with higher grade of osteoarthritis in primary shoulder osteoarthritis.

### Disclaimer

Peter Habermeyer, Mark Tauber, Sven Lichtenberg, and Frank Martetschlager are consultants for Arthrex, Inc. The other 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.

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