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Is there a correlation between humeral osteoarthritis and glenoid morphology according to Walch?

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Aims

The aim of this study was to determine whether there is a correlation between the grade of humeral osteoarthritis (OA) and the severity of glenoid morphology according to Walch. We hypothesized that there would be a correlation.

Methods

Overal, 143 shoulders in 135 patients (73 females, 62 males) undergoing shoulder arthroplasty surgery for primary glenohumeral OA were included consecutively. Mean age was 69.3 years (47 to 85). Humeral head (HH), osteophyte length (OL), and morphology (transverse decentering of the apex, transverse, or coronal asphericity) on radiographs were correlated to the glenoid morphology according to Walch (A1, A2, B1, B2, B3), glenoid retroversion, and humeral subluxation on CT images.

Results

Increased humeral OL correlated with a higher grade of glenoid morphology (A1-A2-B1-B2-B3) according to Walch (r = 0.672; p < 0.0001). It also correlated with glenoid retroversion (r = 0.707; p < 0.0001), and posterior humeral subluxation (*r* = 0.452; p < 0.0001). A higher humeral OL (odds ratio (OR) 1.17; 95% confidence interval (CI) 1.03 to 1.32; p = 0.013), posterior humeral subluxation (OR 1.11; 95% CI 1.01 to 1.22; p = 0.031), and glenoid retroversion (OR 1.48; 95% CI 1.30 to 1.68; p < 0.001) were independent factors for a higher glenoid morphology. More specifically, a humeral OL of ≥ 13 mm was indicative of eccentric glenoid types B2 and B3 (OR 14.20; 95% CI 5.96 to 33.85). Presence of an aspherical HH in the coronal plane was suggestive of glenoid types B2 and B3 (OR 3.34; 95% CI 1.67 to 6.68).

Conclusion

The criteria of humeral OL and HH morphology are associated with increasing glenoid retroversion, posterior humeral subluxation, and eccentric glenoid wear. Therefore, humeral radiological parameters might hint at the morphology on the glenoid side.

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Introduction

Primary osteoarthritis (OA) is associated with progressive joint deformation and osteophyte formation. On the glenoid side, the axial pathomorphology was initially described by Walch,[1] and later modified by Bercik et al.[2] Cases classified as B glenoids involve posterior subluxation of the humeral head (HH) and posterior glenoid erosion. They are more likely to medialize and express higher glenoid retroversion.[3,4] These aspects of posterior humeral subluxation, bony glenoid erosion, and glenoid retroversion may present a surgical challenge and compromise clinical and radiological outcomes,[5-8] mainly due to implant loosening and osteolysis.[9,10] Their high degree of expression is often found in the newly added B3 glenoid, regarded as a possible progression from the biconcave B2 glenoid as indicated by increased bone loss and glenoid retroversion.[3,11,12]

On the humeral side, the Samilson-Prieto classification[13] was originally used for instability OA. Based on this classification,

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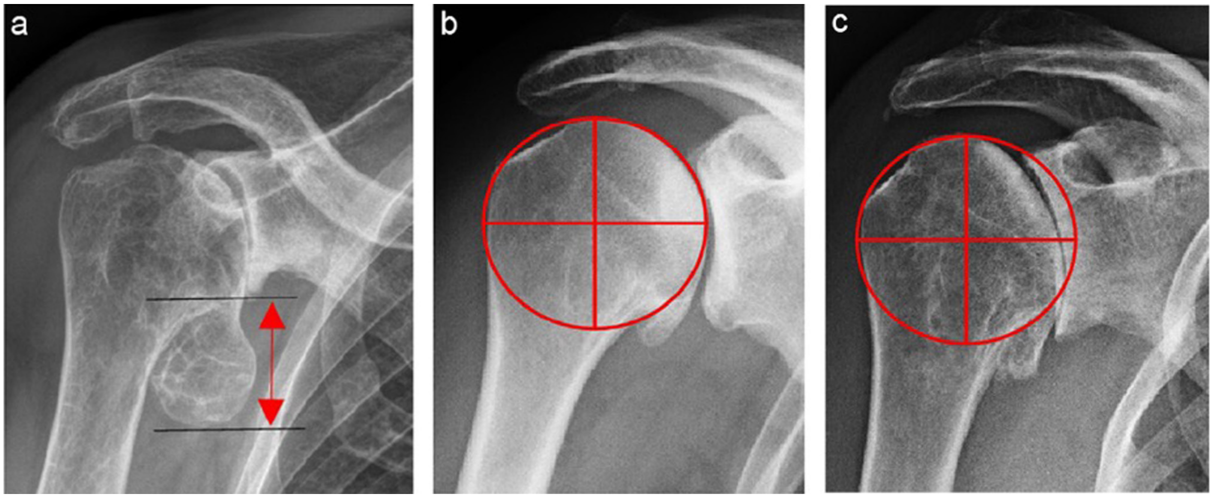

Fig. 1

Assessment of the humeral head in anteroposterior radiographs. a) Measuring the humeral osteophyte length in the supero-inferior direction. b) Spherical humeral head shape: A best-fitting circle is congruent with the cortical boundaries of the humeral head. c) Aspherical head shape: There is no congruency between the best-fitting circle and the humeral head cortex.[14]

Habermeyer et al[14] modified it for the classification of omarthrosis (Samilson-Prieto/Habermeyer (SPH)), where type A describes preserved HH sphericity and type B describes asphericity. Grades I to IV are based on humeral osteophyte length (OL).

Contrary to the extent of research on humeral OA and glenoid morphology, the reliability for humeral OA by using the respective classification is high,[15-17] while agreement on glenoid morphology may be as low as fair.[18-21] In this case, HH characteristics implying information about glenoid morphology could be valuable for treatment decisions and prognosis.

Besides a study investigating patients with low-grade humeral OA,[17] we found no study assessing the correlation between humeral OA and glenoid morphology including advanced stages of glenohumeral OA.

The aim of this study was to determine whether there is a correlation between the grade of humeral OA and glenoid morphology, according to Walch. We hypothesized that there would a correlation. Furthermore, the association with the radiological parameters of posterior humeral subluxation, glenoid retroversion, and HH morphology was evaluated, as these factors are used for characterizing glenohumeral OA.

Methods

A total of 143 shoulders in 135 patients (73 females, 62 males) undergoing total shoulder arthroplasty surgery (TSA) for primary glenohumeral OA with an intact rotator cuff and no previous surgery between 2017 and 2020 were included consecutively. Mean age was 69.3 years (47 to 85). Besides glenoid types A1, A2, B1 and B2, we included types D and B3,[2] as they may be treated with anatomical total shoulder arthroplasty TSA.[12] All patients with type C glenoids[2,3] were excluded due to their dysplastic etiology.[1]

Additional requirements for inclusion were the presence of standardized true anteroposterior (AP) and axillary radiographs, as well as CT imaging to allow radiological assessment.

In AP radiographs with neutral forearm position, the inferior humeral OL was measured in the supero-inferior direction (Figure 1, a) and assigned to the respective grade of humeral OA, according to SPH.[14]

In AP and axillary radiographs, the HH was deemed spherical or aspherical (Figure 1 and Figure 2).[14] Congruency between a best-fitting circle and the cortical boundaries of the HH defines a spherical HH shape, while a missing congruency defines an aspherical HH.

Orientation of the apex (i.e. the highest point of the HH) was assessed in axillary radiographs (Figure 2).[14] For a spherical HH, the apex aligns with the centre of rotation of a best-fitting circle along the cortical HH boundaries. Conversely, a shift of the apex indicates axial decentering.

Glenoid morphology according to Walch[2] was determined on CT. Overall, four cases (3%) were found to be type A1, 28 (20%) were type A2, 49 (34%) were B1, 50 (35%) were B2, and ten (7%) were B3. Two type D glenoids were included for correlation analysis, but not as an independent group. Humeral subluxation relative to the glenoid plane was measured according to Walch.[22]

The method of Friedman et al[23] served for quantification of glenoid retroversion: For B2 glenoids, we measured the retroversion of the intermediate glenoid[7] as it represents the most reliable and clinically useful angle.[24]

Statistical analysis. Statistical analysis was performed using SPSS 25.0 software (IBM, USA). Differences between

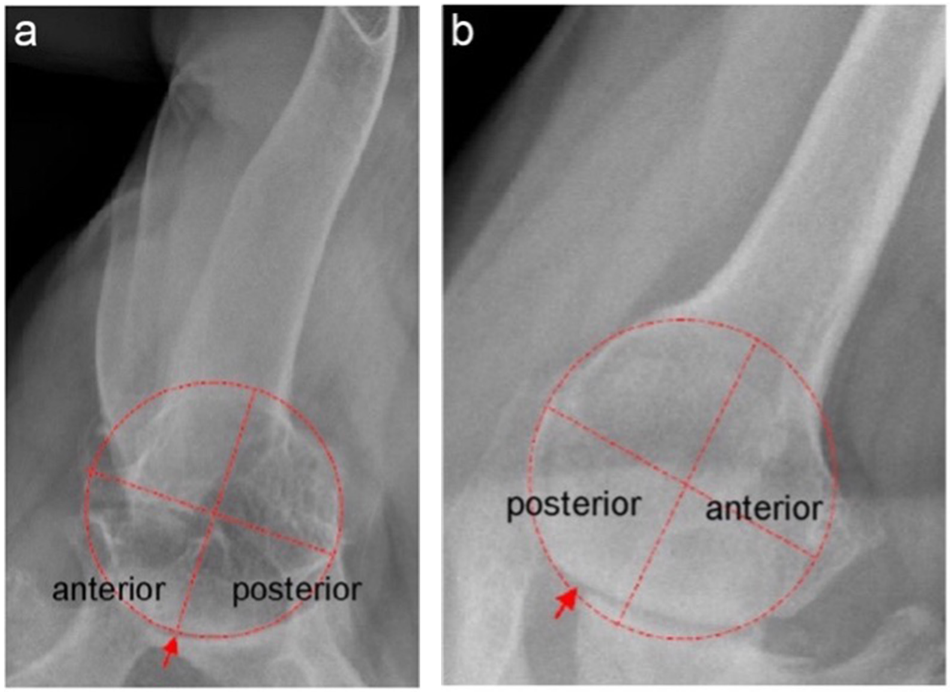

Fig. 2

Assessment of the humeral head in axillary radiographs. a) Centred apex (arrow), in line with the centre of rotation of a best-fitting circle at the humeral head cortex. b) Decentered humeral head apex (arrow). The centre of rotation is not in line with the apex.[14]

Table I. Glenohumeral characteristics according to the grade of humeral osteoarthritis.

Grade of humeral osteoarthritis (osteophyte length, mm)	Frequency, % (n)	Humeral subluxation (SD; range)	Glenoid retroversion, ° (SD; range)	Transverse decentering of humeral head apex, % (n)	Transverse asphericity of humeral head, % (n)	Coronal asphericity of humeral head, % (n)
I (< 3)	5 (7)	0.50 (0.02; 0.47 to 0.53)	3.1 (2.4; 0 to 7)	0 (0)	0 (0)	0 (0)
II (3 to 6)	20 (29)	0.50 (0.03; 0.44 to 0.55)	6.6 (3.6; 1 to 13)	0 (0)	0 (0)	3 (1)
III (≥ 7 to 12)	42 (60)	0.52 (0.05; 0.38 to 0.62)	11.1 (5.3; 1 to 24)	28 (17)	25 (15)	40 (24)
IV (≥ 13)	33 (47)	0.56 (0.04; 0.46 to 0.64)	17.3 (5.8; 9 to 30)	72 (34)	77 (36)	83 (39)

SD, standard deviation.

independent groups were analyzed by applying the Mann-Whitney U test. Regression analysis was performed using Pearson's correlation for two continuous variables or Spearman rank correlation for ordinal variables. If appropriate, multivariate ordinal logistic regression and/or odds ratio (OR) were calculated for identifying factors indicative of a higher glenoid morphology, such as B2 and B3 glenoids. Differences in categorical data were analyzed using the chi-squared test. If not mentioned otherwise, values are presented with standard deviation (SD). Interobserver reliability for humeral and glenoid OA was calculated by calculating an intraclass correlation coefficient (ICC) with a two-way mixed model and absolute agreement, including the 95% confidence interval (CI). The level of significance was set at $p < 0.05$.

All patients provided written consent for the use of their anonymous data. This study was approved by the Institutional Review Board of the ATOS Clinics Heidelberg and Munich (study no. 52021).

Results

Interobserver reliability was 0.90 (95% CI 0.87 to 0.93) for humeral OA according to SPH,[14] and 0.85 (95% CI, 0.80 to 0.90) for glenoid morphology according to Walch.

Humeral osteoarthritis and glenoid morphology. According to Habermeyer et al,[14] the majority of patients showed advanced stages of humeral OA (Table I).

Humeral OL showed a correlation with posterior humeral subluxation ($r = 0.452$; $p < 0.001$, Pearson correlation), a higher glenoid retroversion ($r = 0.707$; $p < 0.001$, Pearson correlation) and with a higher glenoid morphology according to Walch ($r = 0.672$; $p < 0.001$,

Table II. Characteristics of glenoid types according to Walch.

Glenoid type	Osteophyte length, mm (SD; range)	Humeral subluxation (SD; range)	Glenoid retroversion, ° (SD; range)	Transverse decentering of humeral head apex, % (n)	Transverse asphericity of the humeral head, n (%)
A1	2.8 (1.6; 1 to 5)	0.48 (0.03; 0.44 to 0.52)	4.2 (2.0; 1 to 7)	0 (0)	0 (0)
A2	7.9 (3.4; 1 to 16)	0.49 (0.04; 0.39 to 0.55)	5.8 (3.4; 0 to 11)	0 (0)	0 (0)
B1	8.0 (3.8; 1 to 20)	0.52 (0.04; 0.38 to 0.62)	8.8 (2.8; 1 to 15)	14 (7)	12 (6)
B2	14.1 (4.0; 6 to 23)	0.56 (0.04; 0.46 to 0.64)	16.7 (4.4; 5 to 26)	70 (35)	70 (35)
B3	18.8 (4.7; 13 to 26)	0.55 (0.03; 0.52 to 0.62)	23.9 (4.1; 15 to 3)	90 (9)	100 (10)

SD, standard deviation.

Spearman correlation). For each consecutive grade of humeral OA, glenoid retroversion increased significantly (I vs II: $p = 0.001$; II vs III: $p = 0.007$; and III vs IV: $p < 0.001$, Mann-Whitney U test). For grade IV, humeral subluxation was higher than for grade III ($p < 0.001$, Mann-Whitney U test).

Grades I and II of humeral OA showed no case with a decentered HH apex in the transverse plane, but grade III was associated with a higher prevalence of apex decentering than grade II ($p = 0.006$, chi-squared test) and a lower prevalence than grade IV ($p < 0.001$, chi-squared-test).

Similarly, a higher humeral OL was associated with a higher frequency of asphericity in the transverse plane (II vs III: $p = 0.012$, chi-squared test); and III vs IV: $p < 0.001$, chi-squared test) and in the coronal plane (II vs III: $p = 0.001$, chi-squared test; and III vs IV: $p < 0.001$, chi-squared test).

Regarding the correlation between humeral OL and glenoid morphology, the humeral OL associated with A1 glenoids was lower than with A2 and B1 glenoids ($p < 0.001$, Mann-Whitney U test, respectively) (Table II). Humeral OL associated with B2 glenoids was higher than the latter two ($p < 0.001$, Mann-Whitney U test, respectively) but lower than with B3 glenoids ($p = 0.005$, Mann-Whitney U test). A humeral OL of ≥ 13 mm, representing the threshold between humeral OA grade III and IV, was associated with a markedly higher prevalence of eccentric types B2 and B3 compared to concentric types A1, A2 and B1 (81% (38/47) versus 23% (22/96); $p < 0.001$), with an OR of 14.20 (95% CI 5.96 to 33.85).

For glenoid types A1, A2 and B1, average humeral subluxation was centred. For types B2 and B3, the HH was posteriorly subluxated (Table II). Glenoid type B1 was associated with a higher subluxation than type A2 ($p = 0.016$, Mann-Whitney U test), but with a lower subluxation than types B2 ($p < 0.001$, Mann-Whitney U test) and B3 ($p = 0.006$, Mann-Whitney U test).

Furthermore, glenoid type B1 had a higher glenoid retroversion than A1 ($p = 0.008$, Mann-Whitney U test) and A2 glenoids ($p = 0.001$, Mann-Whitney U test). B2 glenoids, in turn, had a higher retroversion than B1 glenoids ($p < 0.001$, Mann-Whitney U test) and B3 glenoids had a higher retroversion than B2 glenoids ($p < 0.001$, Mann-Whitney U test).

For A1 and A2 glenoids, there was no apical decentering or HH asphericity in the transverse plane. Apical decentering was more common in combination with B2 glenoids than B1 glenoids ($p < 0.001$, chi-squared test). The prevalence of transverse asphericity increased in association with B1 glenoids versus B2 glenoids ($p < 0.001$, chi-squared test)) and from B2 glenoids to B3 glenoids ($p = 0.035$, chi-squared test)).

Two type D glenoids presented with a humeral OL of 3 mm and 4 mm (grade II,[14] respectively) and a glenoid retroversion of 1° and 3°, respectively. There was no apical decentering or HH asphericity in both planes.

Humeral head morphology. An analysis between transverse and coronal HH deformity was performed. If the HH apex was transversely decentered or aspherical, then coronal HH asphericity was more common than sphericity (apex decentered 69% (35/51) versus 32% (29/92); transverse asphericity 67% (34/51) vs 32% (29/92); $p < 0.001$, chi-squared test, respectively), suggestive of the aforementioned 3D deformity.[14] Presence of coronal HH asphericity was then compared to glenoid morphology to assess the value of this radiological parameter for indicating glenoid morphology. We found that an aspherical HH in the coronal plane was associated with a twofold prevalence of eccentric types B2 and B3 compared to concentric types A1, A2, and B1 (58% (37/64) versus 29% (23/79); $p < 0.001$, chi-squared test)), resulting in an OR of 3.34 (95% CI 1.67 to 6.68). The analysis by HH morphology in the coronal plane is shown in Table III and Table IV.

Multivariate regression. Multivariate ordinal logistic regression analysis served for identification of independent factors associated a higher degree of glenoid morphology, such as B2 and B3 glenoid types. Besides a higher posterior humeral subluxation (OR 1.11; 95% CI 1.01 to 1.22; Wald $\chi 2 = 4.659$; $p = 0.031$) and glenoid retroversion (OR 1.48; 95% CI, 1.30 to 1.68; Wald $\chi 2 = 36.076$; $p < 0.001$), humeral OL was independently predictive of a higher glenoid morphology (OR 1.17; 95% CI 1.03 to 1.32; Wald $\chi 2 = 6.189$; $p = 0.013$).

Discussion

The main finding of this study is the correlation between a higher humeral OL and eccentric glenoid morphology. Increased humeral OL was also associated with posterior

Table III. Characteristics of spherical humeral heads in the coronal plane.

Osteophyte length, mm	Frequency, % (n)	Glenoid morphology, according to Walch, % (n)					Transverse decentering of humeral head apex, % (n)	Posterior humeral subluxation (≥ 55%, according to Walch), % (n)
		A1	A2	B1	B2	B3		
< 3	8 (6)	33 (2)	33 (2)	33 (2)	0 (0)	0 (0)	0 (0)	0 (0)
3 to 6	35 (28)	11 (3*)	35 (10)	50 (14)	4 (1)	0 (0)	0 (0)	4 (1)
≥ 7 to 12	46 (36)	0 (0)	28 (10)	33 (12)	39 (14)	0 (0)	22 (8)	25 (9)
≥ 13	11 (9)	0 (0)	11 (1)	0 (0)	67 (6)	22 (2)	89 (8)	67 (6)

*Includes 2 type D glenoids.

Table IV. Characteristics of aspherical humeral heads in the coronal plane.

Osteophyte length, mm	Frequency, % (n)	Glenoid morphology, according to Walch, % (n)					Transverse decentering of humeral head apex, % (n)	Posterior humeral subluxation (≥ 55%, according to Walch), % (n)
		A1	A2	B1	B2	B3		
< 3	2 (1)	100 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
3 to 6	2 (1)	0 (0)	0 (0)	100 (1)	0 (0)	0 (0)	0 (0)	0 (0)
≥ 7 to 12	24 (37)	0 (0)	21 (5)	50 (12)	29 (7)	0 (0)	38 (9)	38 (9)
≥ 13	59 (38)	0 (0)	0 (0)	21 (8)	58 (22)	21 (8)	68 (26)	61 (23)

humeral subluxation, a higher glenoid retroversion, and a higher frequency of morphologic humeral changes.

Glenoid OA is well documented.[1-4,11,12,15,16,18] Our results extend the understanding for glenohumeral OA by showing the association between increased humeral OA and an eccentric glenoid morphology.

Among other factors, we interpret the association between humeral OA and eccentric glenoid morphology as a result of humeral osteophyte formation leading to posterior humeral translation, due to the reduced space within the joint capsule. The increased translation, in turn, causes the glenohumeral contact surface to become uneven, promoting deformation of the HH and glenoid.

Humeral OL correlated with posterior humeral subluxation. Analyzing the progression of glenoid morphology in glenohumeral OA, Walker et al[4] suggested initial posterior humeral subluxation as the trigger for subsequent posterior bone loss and progression, adding value to our hypothesis that there is initial posterior subluxation, progressing over time. However, the evidence provided from our study is not based on chronology but defined as changes in subluxation between humeral OA grade I and IV.[14]

Besides subluxation, we found a correlation between humeral OL and glenoid retroversion, indicating that a higher humeral OL is associated with more posterior HH positioning or glenoid bone loss. It is likely that the humeral contact on the posterior glenoid after osteophyte formation serves as the starting point for eventual bone loss, as suggested by Walker et al.[4]

Humeral OL showed a correlation with glenoid morphology, and was identified as an independent predictor for a higher glenoid morphology, such as B2 or B3 glenoids. The increased humeral OL for a higher numerical degree of glenoid morphology (1 and 2 for A glenoids, additionally 3 for B glenoids) can be explained by progression of OA, providing a longer time frame for humeral osteophyte formation. The finding by Walker et al[4] that B glenoids medialize more often (over time) than A glenoids could explain the greater humeral OL associated with B glenoids in our study.

Iannotti et al[3] found a higher medial wear for B3 glenoids compared to B2 glenoids, corroborating the idea that B3 glenoids may result from B2 glenoids.[11] Regarding humeral OL, this might explain the higher values associated with B3 glenoids compared to B2 glenoids.

The humeral OL associated with A2 or B1 glenoids was similar. A possible explanation is that A glenoids may turn into B glenoids, but not vice versa.[4] For example, this would allow B1 glenoids to result from A1 and assume the respective OL from their predecessor. Another study found that posterior glenoid wear is associated with a greater bone loss than central wear,[25] which could also account for the higher OL associated with B glenoids than with A glenoids.

Regarding humeral subluxation and glenoid retroversion, our results are congruent with previous studies.[3,11,12,26]

There was an increasing frequency of asphericity, apical decentering, and posterior humeral subluxation in patients with a higher humeral OL, concordant with a previous study by the senior author.[14] As previously mentioned, we interpret the higher frequency of humeral changes as a result of posterior humeral subluxation caused by an increased OL. This is specifically true for the doubled prevalence of B2 and B3 glenoids in coronally aspherical HH, albeit in a cross-sectional study design. The frequency of asphericity, apical decentering, and posterior humeral subluxation, glenoid retroversion, and humeral subluxation increased markedly between humeral osteoarthritis grades III and IV. Since many of these factors have been shown to complicate surgical treatment or compromise clinical results, the further differentiation of the former grade III into grades III and IV is strongly recommended to allow a better estimation of following procedures and outcomes when assessing humeral osteoarthritis.V.[14]

Besides the present study, Linke et al[17] were the only group assessing the relationship between humeral and glenoid OA in patients with primary glenohumeral OA undergoing TSA. Patients and methods differed substantially from our study. The authors included patients with glenoid types C, and distribution of humeral OA was equally distributed between grades I, II, and III. The predominance of advanced stages of glenohumeral OA in our study is likely due to institutional differences, as our clinic is specialized on shoulder pathologies instead of a broad primary care. There was no differentiation between grade III and IV of humeral OA or analysis of morphological HH changes. In consideration of a different calculation method for interobserver-reliability, our agreement was equally high for humeral OA (0.90 vs 0.88). On the other hand, the interobserver agreement on glenoid morphology was lower in the present study (0.86 vs 0.92). We see the exclusion of C glenoids in the present study as the main reason for this discrepancy, since C glenoids showed a substantially higher interobserver agreement than A and B glenoids.[20]

The diverging results imply that advanced stages of humeral OA and morphology must be considered to note a correlation between humeral OA and glenoid morphology. Differentiation between humeral OA grades III and IV seems crucial as various factors, including glenoid retroversion, humeral subluxation, and frequency of humeral changes, differed substantially between the two grades.

Consideration of morphological HH changes is crucial because their presence was associated with a higher prevalence of B2 or B3 glenoids compared to the native counterparts. Inclusion of glenoid types[2] should be done carefully, since C glenoids increases confounding by differing in etiology.[1]

Regarding limitations, the percentage of the newly described B3 glenoid was rather low. Similar to Iannotti et al,[3] the difficulty was to assign continuous variables to a defined category. We could not specifically quantify how increased humeral OL contributes to eccentric glenoid morphology. Requiring CT scans for inclusion, less advanced deformities might be underrepresented. Furthermore, no conclusions can be made about the chronological order or causation of the morphologic changes, as this study was cross-sectional in design. However, we did provide a comprehensive evaluation of radiological morphology and parameters.

In conclusion, our findings provide evidence for an association between increased humeral OL and HH morphology with posterior humeral subluxation, glenoid morphology, and glenoid retroversion. Increased humeral OL independently suggests a higher type of glenoid morphology with more glenoid retroversion and posterior humeral subluxation. Therefore, humeral radiological parameters might hint at the morphology on the glenoid side. In particular, this would be relevant for judgement of advanced stages of glenohumeral OA, where the presence of eccentric glenoid wear might influence the decision-making on treatment options and prognosis.

More research on aetiology and characterization of humeral and glenoid OA is needed, especially on the humeral side. Future studies should aim at exploring the contribution of humeral OA to the development of (eccentric) glenoid morphology in a longitudinal design.

Im conclusion, a higher humeral OL and presence of HH asphericity are associated with posterior humeral subluxation, higher glenoid retroversion, and eccentric glenoid bone loss. Humeral OL is an independent factor for eccentric glenoid types, while coronal HH asphericity was another aspect to suggest eccentric glenoid types. Therefore, humeral radiological parameters might hint at the morphology on the glenoid side.

In the face of a difficult glenoid assessment, this may be helpful for treatment planning and prognosis. Yet, more studies are needed to not only elaborate on the relationship between humeral and glenoid OA, but also to evaluate the chronological order of occurrence.

Take home message

- Humeral osteoarthritis correlates with glenoid morphology, according to Walch.
- Humeral osteophyte length is an independent factor for an eccentric glenoid morphology.
- Coronal humeral head deformity is suggestive of glenoid types B2 and B3.

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