



# Can we separately measure glenoid vs. humeral lateralization and distalization in reverse shoulder arthroplasty?

Philipp Schippers, MD<sup>a,\*</sup>, Juan-David Lacouture, MD<sup>b</sup>, Marius Junker, MD<sup>c</sup>,  
Andreas Baranowski, MD<sup>a</sup>, Philipp Drees, MD<sup>a</sup>, Erol Gercek, MD<sup>a</sup>,  
Pascal Boileau, MD<sup>b</sup>

<sup>a</sup>Department of Orthopedics and Traumatology, University Medical Center of the Johannes Gutenberg University, Mainz, Germany

<sup>b</sup>Institute for Sports & Reconstructive Surgery (ICR), Nice, France

<sup>c</sup>Department of Orthopedics, Tabea Hospital, Hamburg, Germany

**Background:** Lateralization and distalization in reverse shoulder arthroplasty (RSA) can be measured on anteroposterior (AP) radiographs using 2 previously described angles: lateralization shoulder angle (LSA) and distalization shoulder angle (DSA). However, these 2 angles measure *global* lateralization and distalization but do not allow to differentiate how much lateralization or distalization are attributable to the glenoid and the humerus. We hypothesized that new angles could allow us to separately measure glenoid vs. humeral lateralization and distalization. A more precise understanding of independent glenoid and humeral contributions to lateralization and distalization may be beneficial in subsequent clinical research.

**Method:** Retrospective analysis of postoperative AP radiographs of 100 patients who underwent primary RSA for cuff-tear arthropathy, massive cuff tear, or glenohumeral osteoarthritis were analyzed. The new angles that we proposed use well-known bony landmarks (the acromion, glenoid, and humerus) and the most lateral point of the glenosphere, which we termed the “glenoid pivot point” (GPP). For lateralization, we used the GPP to split LSA into 2 new angles: glenoid lateralization angle (GLA) and humeral lateralization angle (HLA). For distalization, we introduced the modified distalization shoulder angle (mDSA) that can also be split into 2 new angles: glenoid distalization angle (GDA) and humeral distalization angle (HDA). Three orthopedic surgeons measured the new angles, using the online tool Tyche. Mean values with overall and individual standard deviations as well as intraclass correlation coefficients (ICCs) were calculated.

**Results:** Because the angles form a triangle, the following equations can be made:  $LSA = GLA + HLA$ , and  $mDSA = GDA + HDA$ . All angles showed excellent inter- and intraobserver reliability ( $ICC = 0.92-0.97$ ) with low means of individual standard deviations that indicate a precision of  $2^\circ$  for each angle.

**Conclusion:** Use of the most lateral part of the glenosphere (termed *glenoid pivot point*) allows us to separately measure glenoid vs. humeral lateralization and distalization. The 4 new angles (HLA, GLA, GDA, HDA) described in the present study can be used on true AP radiographs, routinely obtained after shoulder replacement, and the measured angles may be used with all types of reverse prostheses available.

Institute for Sports and Reconstructive Bone and Joint Surgery approved this study (no. ICR-SHR-2022-07-01).

\*Reprint requests: Philipp Schippers, MD, Department of Orthopedics and Traumatology, University Medical Center of the Johannes Gutenberg University, Langenbeckstr. 1, Mainz 55131, Germany.  
E-mail address: [philipp.schippers@gmail.com](mailto:philipp.schippers@gmail.com) (P. Schippers).

**Level of evidence:** Basic Science Study; Validation of Radiographic Outcome Measurements

© 2023 The Author(s). This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

**Keywords:** Reverse shoulder arthroplasty; glenoid lateralization; glenoid distalization; humeral lateralization; humeral distalization; LSA; DSA

Reverse shoulder arthroplasty (RSA) can be considered the standard of care for end-stage cuff tear arthropathy, failed anatomic arthroplasty, and severe fractures or fracture sequelae.<sup>12,14</sup>

The Grammont Concept is aimed at distalizing and medializing the center of rotation in RSA.<sup>2</sup> However, this concept has been challenged, and researchers have tried to find the best alignment strategy to optimize impingement-free range of motion and stability.<sup>36</sup> Evidence can be found in the literature that favors glenoid lateralization.<sup>1,4,17,33</sup>

To capture lateralization and distalization after RSA on anteroposterior (AP) radiographs, Boutsiadis and Barth<sup>8</sup> introduced 2 angles: the lateralization shoulder angle (LSA) and the distalization shoulder angle (DSA) (Fig. 1). However, these 2 angles do not allow to differentiate how much lateralization or distalization are attributable to the glenoid and the humerus, and their clinical significance is still debated.<sup>3,16,22</sup> It was shown that for a given implant configuration, there was a negative correlation between the 2 angles: lower values for LSA resulted in higher values for DSA. Furthermore, the authors showed that the 2 angles had an influence on the range of motion with a positive correlation between active forward elevation (AFE) and DSA (possibly because of increased tension of the deltoid) and active external rotation (AER) and LSA.<sup>8</sup>

Lateralization and distalization after RSA are very variable and depend on the implant design and the surgical technique, which both affect the implant positioning. Both the glenoid (G) and the humeral (H) components can be either medialized or lateralized.<sup>28,35</sup> Surgeons can choose between 4 possible combinations: (1) medialized G + medialized H, (2) lateralized G + medialized H, (3) lateralized G + lateralized H, and (4) medialized G + lateralized H. These different combinations can possibly be impactful on the clinical outcome.<sup>5,20,21,34</sup> However, the ideal amount of distalization and/or lateralization after RSA is still unknown, and the localization of such distalization and/or lateralization (humerus vs. glenoid) remains a controversial topic.<sup>19</sup>

Our purpose was to study whether new angles could be reliably used on postoperative radiographs to separately measure how much lateralization and distalization are attributable to the glenoid and the humerus after RSA.

## Material and methods

### Study design

We performed a retrospective radiographic analysis including 100 consecutive RSAs performed between January 2022 and January 2023 by the senior surgeon (P.B.). Inclusion criteria were a primary RSA for cuff-tear arthropathy, massive cuff tear, or glenohumeral osteoarthritis. We excluded revision RSA, RSA for proximal humeral fracture, RSA for fracture sequelae, or tumors. Only radiographs that qualified as “true AP” views were selected. Features of a true AP view are a superimposition of the anterior and posterior rim of the glenoid and no foreshortening of the scapular body.

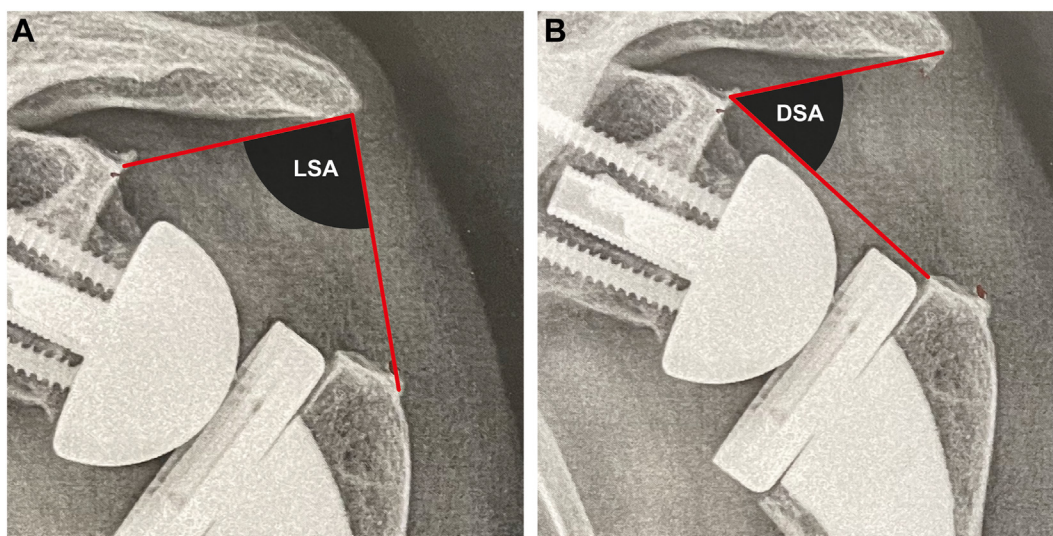
### Surgical procedure

All procedures were performed by the senior surgeon systematically using the BIO-RSA technique on the glenoid side and an onlay humeral component (Aequalis Ascend Flex Reverse Prosthesis; Stryker, Kalamazoo, MI, USA) on the humeral side. For BIO-RSA, a (10-mm-thick, angled 12°) disc of cancellous bone graft was harvested from the humeral head and placed under a long peg (25 mm) glenoid baseplate.<sup>5-7</sup> A glenoid guide was placed flush with the inferior border of the glenoid with 10° of inferior tilt to ream 2-3 mm inferiorly (“smiley face”). The baseplate and sphere were chosen according to the patient size and gender: 25-mm baseplate with a 36-mm sphere for small female patients and 29-mm baseplate with 42-mm sphere for large male patients. The humeral short stem Ascend Flex was used with asymmetrical polyethylene to result in a final inclination of 145° and implanted with 20° to 30° of retroversion. A standard, 6-mm-thick polyethylene insert was used in most patients. A subscapularis tendon repair was systematically performed when the tendon was still present.

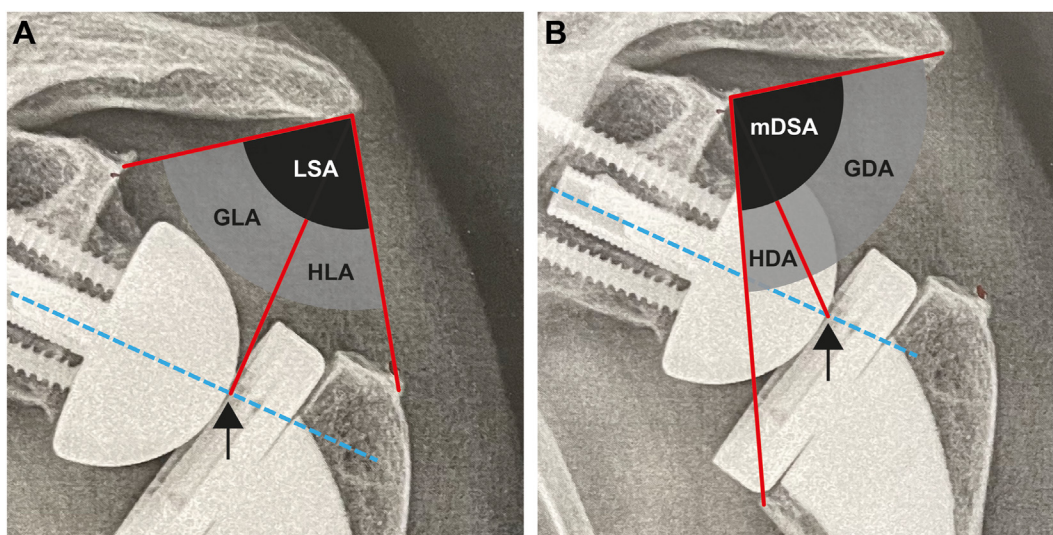
### New angles proposed

#### Lateralization

The lateralization shoulder angle (LSA) proposed by Boutsiadis and Barth<sup>8</sup> in 2018 represents global lateralization. As we proposed in 2020,<sup>25</sup> using the most lateral part of the glenosphere, the “glenoid pivot point” (GPP), as a reference, LSA can be subdivided into 2 new angles: the medial part was termed the *glenoid lateralization angle* (GLA), and the lateral part was termed the *humeral lateralization angle* (HLA) (Fig. 2, A). This leads to the following equation:  $LSA = GLA + HLA$  (Table 1). Because the angles form a triangle, it is possible to determine only LSA and GLA as HLA can be calculated by subtracting GLA from



**Figure 1** Distalization shoulder angle (DSA) and lateralization shoulder angle (LSA) are well-established angles in RSA. LSA and DSA only capture global lateralization and distalization and cannot show how much lateralization and distalization are attributable to the glenoid and the humerus.



**Figure 2** New angles to describe glenoid and humeral alignment in RSA. (A) Lateralization shoulder angle (LSA) can be subdivided into glenoid lateralization angle (GLA) and humeral lateralization angle (HLA). (B) The modified distalization shoulder angle (mDSA) can be subdivided into glenoid distalization angle (GDA) and humeral distalization angle (HDA). The  $\blacktriangleright$  shows the glenoid pivot point (GPP), which is the most lateral point of the glenosphere. An auxiliary line (-----) can be used to determine it.

LSA:  $HLA = LSA - GLA$ . An auxiliary line can be used to determine the most lateral part of the glenosphere.

**Distalization**

Applying the concept mentioned above for measuring distalization, we proposed the *modified distalization shoulder angle* (mDSA). Utilizing again the GPP, mDSA can be further subdivided into the *glenoid distalization angle* (GDA) and the *humeral distalization angle* (HDA) (Fig. 2, B). Likewise, the following equation can be proposed:  $mDSA = GDA + HDA$  (Table I).

**Image analysis**

One hundred postoperative radiographs were fully anonymized and analyzed by 3 fellowship-trained orthopedic surgeons. Image analysis was performed using the recently introduced online tool Tyche ([www.tyche.expert](http://www.tyche.expert)).<sup>29,30</sup> Using Tyche, images were presented in random order without displaying any metadata inside a web browser with the means to store results on the same window. Observers were able to use standard tools like zoom and contrast, employ angle tools, and create annotations like auxiliary lines. To access the images, observers were provided with a temporarily valid URL. After the analysis, the results were immediately

**Table I** New angles and their compositions

	Glenoid	Humerus	Equation
Lateralization	Glenoid lateralization angle (GLA)	Humeral lateralization angle (HLA)	$GLA + HLA = LSA$
Distalization	Glenoid distalization angle (GDA)	Humeral distalization angle (HDA)	$GDA + HDA = mDSA$

*LSA*, lateralization shoulder angle; *mDSA*, modified distalization shoulder angle.

**Table II** Intraclass and Spearman correlation coefficients with interpretations

ICC	Interpretation*	Spearman	Interpretation†
>0.9	Excellent	>0.9	Very strong
>0.75	Good	>0.7	Strong
>0.5	Moderate	>0.4	Moderate

ICC, intraclass correlation coefficient.

\* Koo and Li (2016).<sup>18</sup>

† Schober et al (2018).<sup>31</sup>

computed and visible to the project manager. Fifty percent of the images were analyzed twice.

On every image, the observers determined 2 established angles: LSA and DSA. Besides, for glenoid lateralization, observers measured the GLA. The HLA was measured indirectly by subtracting GLA from LSA (Table I). Finally, for glenoid distalization, observers measured the GDA. The HDA was measured indirectly by measuring the mDSA and subtracting GDA from mDSA.

## Statistical analysis

For statistical analysis, Prism 9.4 (GraphPad Software, Boston, MA, USA) and SPSS version 27 (IBM, Armonk, NY, USA) were used. For all angles, mean values and standard deviations (SDs) were calculated for every observer individually and for all observers combined. To estimate measurement accuracy, we employed the following method as described by Popović<sup>27</sup>: for every measurement on every image, the SD between all 3 observers was calculated. Then, the average from all SDs was calculated and termed the “mean of individual SDs.” A lower value indicates higher accuracy.

To assess inter- and intraobserver agreement for the measurements, intraclass correlation coefficients (ICC<sub>2,1</sub>) were calculated. ICCs were interpreted according to Koo and Li<sup>18</sup> as shown in Table II. Furthermore, correlations between the angles were calculated using Spearman correlation coefficient. Correlation coefficients were interpreted according to Schober et al<sup>31</sup> as shown in Table II.

## Results

### Angle measurements

The measurement results are summarized in Table III and Figure 3. The mean values can be summarized in the following 2 equations:

$$LSA(83^\circ) = GLA(55^\circ) + HLA(28^\circ)$$

$$mDSA(99^\circ) = GDA(71^\circ) + HDA(28^\circ)$$

### Inter- and intraobserver reliability

Inter- and intraobserver agreement was calculated using ICCs and shown with confidence intervals and *P* values in Tables IV and V. All angles showed excellent inter- and intraobserver agreement (ICC > 0.9).

### Precision

Precision can be estimated by the mean of individual SDs and is shown in the last column of Table III. A measurement of one angle on one radiograph, performed (here) by 3 observers, has an SD of 2° on average.

### Correlation analysis

Spearman correlation coefficients were calculated between all angles and shown in Table VI. LSA and DSA had a strong negative correlation ( $r = -0.75$ ,  $P < .001$ ). Besides, mDSA and GDA had a strong positive correlation ( $r = 0.87$ ,  $P < .001$ ).

## Discussion

### Summary of results

Global lateralization and distalization in RSA can be measured on AP radiographs using the 2 angles proposed by Boutsiadis and Barth<sup>8</sup>: the lateralization shoulder angle and the distalization shoulder angle. However, these 2 angles do not allow to differentiate how much lateralization or distalization are attributable to the glenoid and the humerus (Fig. 1).

The most important finding of the present study is that by using new angles, it is possible to separately measure the part related to the humerus and the one related to the glenoid for lateralization and distalization in RSA. The key message is that the most lateral point of the glenosphere, which we termed the *glenoid pivot point*, can be used to separate the glenoid component from the humeral component for both lateralization and distalization (Fig. 2). Using

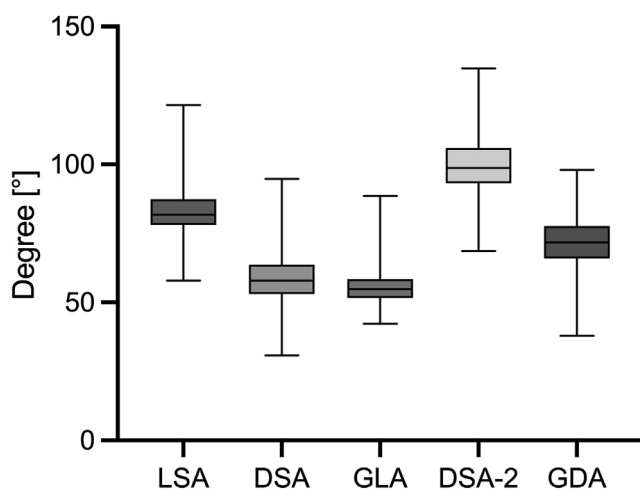
**Table III** Measurement results for all 3 observers

Angles	Observer 1		Observer 2		Observer 3		Mean (SD)	Mean of individual SDs (relative to mean)
	Mean (SD)	Min-Max ( $\Delta$ )	Mean (SD)	Min-Max ( $\Delta$ )	Mean (SD)	Min-Max ( $\Delta$ )		
LSA	84 (9)	59-121 (62)	82 (8.2)	56-116 (60)	83 (9)	59-122 (64)	83 (9)	2 (2.4)
DSA	57 (10)	31-95 (64)	58 (9.4)	32-95 (63)	59 (10)	31-95 (64)	58 (10)	2 (3.4)
GLA	56 (6)	40-88 (47)	55 (5.9)	41-90 (49)	54 (7)	35-70 (35)	55 (6)	2 (3.6)
mDSA	98 (10)	70-135 (65)	100 (10)	67-134 (67)	100 (10)	73-138 (65)	99 (10)	2 (2.0)
GDA	70 (10)	39-100 (61)	71 (10)	37-98 (61)	73 (10)	50-102 (52)	71 (9)	2 (2.8)

LSA, lateralization shoulder angle; DSA, distalization shoulder angle; GLA, glenoid lateralization angle; mDSA, modified distalization shoulder angle; GDA, glenoid distalization angle; SD, standard deviation; Min, minimum; Max, maximum,  $\Delta$ , delta.

Three observers determined 2 established (LSA and DSA) and 3 new angles (GLA, mDSA, and GDA) on 150 anteroposterior radiographs of patients who underwent RSA. Mean, SD, Min, and Max values were calculated. Besides, SDs were calculated between the 3 observers for every measurement on every single image. Then, a mean value of these SDs from all images was calculated and stored as the "mean of individual SDs" to estimate the measurement accuracy of single measurements.

All results are in degrees.



**Figure 3** Box and whisker plot for all measured angles. Lateralization shoulder angle (LSA) and distalization shoulder angle (DSA) are established angles. For lateralization, the glenoid lateralization angle (GLA) was measured. The humeral lateralization angle was calculated by subtracting GLA from LSA (compare Table I). For distalization, the modified distalization shoulder angle (mDSA) and glenoid distalization angle (GDA) were measured. The humeral distalization angle can be calculated by subtracting GDA from mDSA. The box and whisker plot shows the median, upper and lower quartiles, and maximum and minimum values.

our new angles, it is possible to reliably (Tables IV and V) measure how much lateralization after RSA is attributable to the glenoid (GLA) and humerus (HLA). The same applies for measuring glenoid distalization (GDA) and humeral distalization (HDA).

### New angles proposed

The new angles that we propose are based on reliable and already used bony landmarks (the most lateral part of the

acromion, the superior glenoid edge, the most medial part of the proximal humerus, and the most lateral part of the greater tuberosity). The originality of our work is that we propose to use the most lateral point of the glenosphere, which we termed the *glenoid pivot point*. This point allows the separation of the glenoid from the humeral component for both lateralization and distalization.

For lateralization, the GPP allows splitting the established angle LSA into 2 different and new angles: GLA (glenoid lateralization angle) and HLA (humeral lateralization angle). This results in the following equation:  $LSA = GLA + HLA$  (Fig. 2, A, and Table I).

For distalization, it is not possible to split DSA into 2 angles since DSA remains above the glenosphere (at the level of the greater tuberosity) and does not consider the humeral distalization (Fig. 1, B). To appreciate humeral distalization, we propose a new angle: the *modified distalization shoulder angle* (mDSA). Utilizing again the most lateral part of the glenosphere (GPP), mDSA can be further subdivided into GDA (glenoid distalization angle) and HDA (humeral distalization angle). Thus, we get the following equation:  $mDSA = GDA + HDA$  (Fig. 2, B and Table I).

### Reliability and precision

The mean results for LSA and DSA in this study align with those recommended in the literature.<sup>23</sup> The means of individual SDs were low ( $2^\circ$ ), and ICCs showed excellent inter- and intraobserver reliability. Finally, as reported by the authors,<sup>8</sup> LSA and DSA had a strong negative correlation ( $r = -0.75$ ). Thus, the measurement reliability of LSA and DSA in this study was confirmed and can serve as a comparison for the new angles.

Inter- and intraobserver agreement for the new angles was as high as that of LSA and DSA. Overall SDs for the new angles range between  $6^\circ$  and  $10^\circ$ , which are

**Table IV** Interobserver agreement for all angles

	LSA	DSA	GLA	mDSA	GDA
ICC	0.95	0.97	0.92	0.97	0.96
CI	0.93-0.96*	0.95-0.97*	0.88-0.94*	0.96-0.98*	0.95-0.97*

ICC, intraclass correlation coefficient; CI, confidence interval; LSA, lateralization shoulder angle; DSA, distalization shoulder angle; GLA, glenoid lateralization angle; mDSA, modified distalization shoulder angle; GDA, glenoid distalization angle.

The interobserver agreement was found to be excellent for all angles.

\*  $P \leq .001$ .

**Table V** Intraobserver agreement for all angles

	LSA	DSA	GLA	mDSA	GDA
Observer 1					
ICC	0.97	0.96	0.96	0.98	0.96
CI	0.94-0.98*	0.93-0.98*	0.93-0.98*	0.98-0.99*	0.93-0.98*
Observer 2					
ICC	0.94	0.98	0.92	0.97	0.97
CI	0.89-0.97*	0.97-0.99*	0.85-0.95*	0.95-0.84*	0.95-0.99*
Observer 3					
ICC	0.97	0.98	0.88	0.96	0.94
CI	0.95-0.98*	0.96-0.99*	0.78-0.93*	0.92-0.98*	0.9-0.97*
Mean					
ICC	0.96	0.97	0.92	0.97	0.96

ICC, intraclass correlation coefficient; CI, confidence interval; LSA, lateralization shoulder angle; DSA, distalization shoulder angle; GLA, glenoid lateralization angle; mDSA, modified distalization shoulder angle; GDA, glenoid distalization angle.

The intraobserver agreement was found to be excellent for all angles.

\*  $P \leq .001$ .

**Table VI** Correlations between angles

	GDA	mDSA	GLA	DSA
LSA	-0.38*	-0.77*	0.57*	-0.75*
DSA	0.49*	0.87*	-0.18	
GLA	-0.4*	-0.3*		
mDSA	0.6*			

LSA, lateralization shoulder angle; DSA, distalization shoulder angle; GLA, glenoid lateralization angle; mDSA, modified distalization shoulder angle; GDA, glenoid distalization angle.

Spearman correlation coefficients ( $r$ ) were calculated between all angles. LSA and DSA show a strong negative correlation. DSA and mDSA have a positive strong correlation.

\*  $P \leq .001$ .

comparable to SDs of LSA ( $9^\circ$ ) and DSA ( $10^\circ$ ). This shows that the new angles can capture a variety of alignments. Besides, single measurements, estimated by means of individual SDs, were as low as those of LSA and DSA, partially even lower, which indicates high accuracy. The new angles could thus be used to formulate treatment algorithms based on measurements.

A strong positive correlation ( $r = 0.87$ ) was noted between DSA and mDSA, which shows that the modified

Distalization Shoulder Angle (mDSA) is a valid alternative for DSA and can be used to separately assess distalization for the glenoid and humeral side.

### Why use angles and not distance measurements?

Being able to reliably capture the alignment of RSAs in a simple and straightforward manner is crucial for planning operations, evaluating results, and conducting studies.<sup>26</sup> Computed tomography (CT) provides multiplanar reconstruction, and there is no need for manual calibration. Hence, precise measurements of distances can be performed if the appropriate software is accessible.<sup>11,13</sup> However, CTs are not always available, especially postoperatively, and radiation needs to be considered. In contrast, radiographs are easily available, usually pre- and postoperatively; nevertheless, because they are rarely performed with a calibration object, length measurements cannot be reliably performed. Thus, angle measurements on radiographs are a simple and reliable method of capturing alignment. Other authors have suggested capturing humeral alignment using the humeral offset<sup>9</sup>; however, this requires length measurements, which can be inaccurate because radiographs are not usually calibrated.

## Correct radiographs are crucial

The new angles presented in this study were tested and validated on images from our database labeled as true “anteroposterior” (AP) views. Research has proven that angle measurements produce discrepant results with different radiographic viewing perspectives.<sup>10,15,32</sup> Hence, researchers need to ensure that they only apply the new angles on “true” AP radiographs. No clinical conclusions should be drawn from angle measurements performed on incorrect images, even though measurements might be radiographically reliable. In case of doubt, CTs should be used.<sup>24</sup>

## Future development

Our next step is to perform clinical studies to look for correlations between the functional outcome and range of motion after RSA and the corresponding values of the new angles. This could provide a more precise understanding of the optimal configuration in RSA. Although our new angles are used to measure lateralization and distalization *after* RSA in 2D, that is, on AP radiographs, they could be used *before* RSA on 2D or 3D CT scans with specific planning software.

## Strengths and limitations of the study

The main strength of our study is that it introduces new angles for estimating lateralization and distalization after RSA based on a large cohort study of 100 patients. These angle measurements are made on postoperative true AP radiographs (which are easy to obtain in clinical practice), and the measurements have been made by 3 different observers. The use of an angle as a radiologic index can be simpler and more reproducible than using length or distance measurements. Finally, the goal of our radiographic study was not to correlate the new angles with patient outcomes, and thus, the clinical significance of the new angles is still unknown.

## Conclusion

This radiologic study presents a clinically applicable and reproducible measurement to evaluate how much lateralization and distalization after RSA are attributable to the glenoid and the humeral side. The 4 new angles (HLA, GLA, GDA, and HDA) described in the present study are based on readily identifiable landmarks (glenoid, acromion, greater tuberosity, most lateral part of the glenosphere) and can be used on true AP radiograph, routinely obtained after shoulder replacement. The measured angles may be used with all types of reverse prostheses available.

Future research may benefit from use of this measurement system in determining optimal implant configuration to achieve the best clinical outcome after RSA. Using this information, these angles could be further integrated with preoperative planning software to adjust the surgical technique and choice of implants to improve clinical outcomes.

## Disclaimers:

Funding: No funding was disclosed by the authors.  
Conflicts of interest: Philipp Schippers invented and created Tyche. Pascal Boileau has received consulting fees from Smith & Nephew and royalties from Stryker. The other authors, their immediate families, and any research foundations 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.

## References

1. Bauer S, Corbaz J, Athwal GS, Walch G, Blakeney WG. Lateralization in reverse shoulder arthroplasty. *J Clin Med* 2021;10:5380. <https://doi.org/10.3390/jcm10225380>
2. Baulot E, Sirveaux F, Boileau P. Grammont's Idea: the story of Paul Grammont's functional surgery concept and the development of the reverse principle. *Clin Orthop Relat Res* 2011;469:2425-31. <https://doi.org/10.1007/s11999-010-1757-y>
3. Berthold DP, Morikawa D, Muench LN, Baldino JB, Cote MP, Creighton RA, et al. Negligible correlation between radiographic measurements and clinical outcomes in patients following primary reverse total shoulder arthroplasty. *J Clin Med* 2021;10:809. <https://doi.org/10.3390/jcm10040809>
4. Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased offset-reversed shoulder arthroplasty (BIO-RSA). *JBJS Essent Surg Tech* 2017;7:e37. <https://doi.org/10.2106/jbjs.st.17.00006>
5. Boileau P, Morin-Salvo N, Bessière C, Chelli M, Gauci M-O, Lemmex DB. Bony increased-offset-reverse shoulder arthroplasty: 5 to 10 years' follow-up. *J Shoulder Elbow Surg* 2020;29:2111-22. <https://doi.org/10.1016/j.jse.2020.02.008>
6. Boileau P, Morin-Salvo N, Gauci M-O, Seeto BL, Chalmers PN, Holzer N, et al. Angled BIO-RSA (bony-increased offset-reverse shoulder arthroplasty): a solution for the management of glenoid bone loss and erosion. *J Shoulder Elbow Surg* 2016;26:2133-42. <https://doi.org/10.1016/j.jse.2017.05.024>
7. Boileau P, O'Shea K, Moineau G, Roussane Y. Bony increased-offset reverse shoulder arthroplasty (BIO-RSA) for cuff tear arthropathy. *Oper Tech Orthop* 2011;21:69-78. <https://doi.org/10.1053/j.oto.2010.11.003>
8. Boutsiadis A, Lenoir H, Denard PJ, Panisset J-C, Brossard P, Delsol P, et al. The lateralization and distalization shoulder angles are important determinants of clinical outcomes in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2018;27:1226-34. <https://doi.org/10.1016/j.jse.2018.02.036>
9. Carrazana-Suarez LF, Panico LC, Smolinski MP, Blake RJ, McCroskey MA, Sykes JB, et al. Humeral offset as a predictor of outcomes after reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2022;31:S158-65. <https://doi.org/10.1016/j.jse.2022.02.029>

10. Chalmers PN, Suter T, Jacxsens M, Zhang Y, Zhang C, Tashjian RZ, et al. Influence of radiographic viewing perspective on glenoid inclination measurement. *J Shoulder Elb Arthroplast* 2019;3:2471549218824986. <https://doi.org/10.1177/2471549218824986>
11. Combes D, Lancigu R, de Cepoy PD, Caporilli-Razza F, Hubert L, Rony L, et al. Imaging of shoulder arthroplasties and their complications: a pictorial review. *Insights Imaging* 2019;10:90. <https://doi.org/10.1186/s13244-019-0788-5>
12. Erickson BJ, Bohl DD, Cole BJ, Verma NN, Nicholson G, Romeo AA, et al. Reverse total shoulder arthroplasty: indications and techniques across the world. *Am J Orthop (Belle Mead NJ)* 2018;47:1-5. <https://doi.org/10.12788/ajo.2018.0079>
13. Gustas-French C, Petscavage-Thomas J, Bernard SA. Imaging of shoulder arthroplasties. *Am J Roentgenol* 2018;211:485-95. <https://doi.org/10.2214/ajr.18.19529>
14. Hatzidakis AM, Norris TR, Boileau P. Reverse shoulder arthroplasty indications, technique, and results. *Tech Shoulder Elb Surg* 2005;6:135-49. <https://doi.org/10.1097/01.bte.0000169730.36840.4b>
15. Henninger HB, Suter T, Chalmers PN. Editorial commentary: is your critical shoulder angle accurate? Only if you can verify that you have the correct images. *Arthroscopy* 2021;37:447-9. <https://doi.org/10.1016/j.arthro.2020.11.021>
16. Imiolczyk J-P, Imiolczyk T, Scheibel M, Audige L, Freisleder F. Lateralization and distalization shoulder angle in reverse shoulder arthroplasty – what do they tell? *J Shoulder Elbow Surg* 2022;31:e152-3. <https://doi.org/10.1016/j.jse.2022.01.058>
17. Kerrigan AM, Reeves J, Langohr GDG, Johnson JA, Athwal GS. Reverse shoulder arthroplasty glenoid lateralization influences scapular spine strains. *Shoulder Elbow* 2020;13:610-9. <https://doi.org/10.1177/1758573220935567>
18. Koo TK, Li MY. A Guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 2016;15:155-63. <https://doi.org/10.1016/j.jcm.2016.02.012>
19. Lädermann A, Collin P, Denard PJ. Range of motion after reverse shoulder arthroplasty: which combinations of humeral stem and glenosphere work best? *Obere Extremität* 2020;15:172-8. <https://doi.org/10.1007/s11678-020-00599-5>
20. Lädermann A, Denard PJ, Collin P, Zbinden O, Chiu JC-H, Boileau P, et al. Effect of humeral stem and glenosphere designs on range of motion and muscle length in reverse shoulder arthroplasty. *Int Orthop* 2020;44:519-30. <https://doi.org/10.1007/s00264-019-04463-2>
21. Lee H-H, Park S-E, Ji J-H, Jun H-S. Mid-term comparative study between the glenoid and humerus lateralization designs for reverse total shoulder arthroplasty: which lateralization design is better? *BMC Musculoskelet Discord* 2023;24:290. <https://doi.org/10.1186/s12891-023-06383-0>
22. Mahendraraj KA, Colliton E, Muniz A, Menendez ME, Jawa A. Assessing the validity of the distalization and lateralization shoulder angles following reverse total shoulder arthroplasty. *Semin Arthroplast JSES* 2020;30:291-6. <https://doi.org/10.1053/j.sart.2020.09.004>
23. Marsalli M, Errázuriz JDD, Cartaya MA, Paz JDL, Fritis DN, Alsúa PI, et al. Similar optimal distalization and lateralization angles can be achieved with different reverse shoulder arthroplasty implant designs. *J Orthop* 2021;28:5-9. <https://doi.org/10.1016/j.jor.2021.10.004>
24. Nyffeler RW, Jost B, Pfirrmann CWA, Gerber C. Measurement of glenoid version: conventional radiographs versus computed tomography scans. *J Shoulder Elbow Surg* 2003;12:493-6. [https://doi.org/10.1016/s1058-2746\(03\)00181-2](https://doi.org/10.1016/s1058-2746(03)00181-2)
25. Pelletier Y, Gauci M-O, Boileau P. Humeral Lateralization in two humeral reverse designs. *Nice Shoulder Course* 2020.
26. Petscavage-Thomas J. Preoperative planning and postoperative imaging in shoulder arthroplasty. *Semin Musculoskelet Radiol* 2014;18:448-62. <https://doi.org/10.1055/s-0034-1384833>
27. Popović ZB, Thomas JD. Assessing observer variability: a user's guide. *Cardiovasc Diagn Ther* 2017;7:317-24. <https://doi.org/10.21037/cdt.2017.03.12>
28. Routman HD, Flurin P-H, Wright TW, Zuckerman JD, Hamilton MA, Roche CP. Reverse shoulder arthroplasty prosthesis design classification system. *Bull Hosp Jt Dis (2013)* 2015;73:S5-14.
29. Schippers P, Drees P, Gercek E, Wunderlich F, Müller D, Ruckes C, et al. The controversial definition of normal Toe alignment. *J Clin Med* 2023;12:3509. <https://doi.org/10.3390/jcm12103509>
30. Schippers P, Meurer A, Schnetz M, Ewald L, Ruckes C, Hoffmann R, et al. A novel tool for collaborative and blinded orthopedic image analysis. *Life* 2023;13:1805. <https://doi.org/10.3390/life13091805>
31. Schober P, Boer C, Schwart LA. Correlation coefficients. *Anesth Analg* 2018;126:1763-8. <https://doi.org/10.1213/ane.0000000000002864>
32. Suter T, Popp AG, Zhang Y, Zhang C, Tashjian RZ, Henninger HB. The influence of radiographic viewing perspective and demographics on the critical shoulder angle. *J Shoulder Elbow Surg* 2015;24:e149-58. <https://doi.org/10.1016/j.jse.2014.10.021>
33. Valenti P, Sauzières P, Katz D, Kalouche I, Kilinc AS. Do less medialized reverse shoulder prostheses increase motion and reduce notching? *Clin Orthop Relat Res* 2011;469:2550-7. <https://doi.org/10.1007/s11999-011-1844-8>
34. Werner BS, Chaoui J, Walch G. The influence of humeral neck shaft angle and glenoid lateralization on range of motion in reverse shoulder arthroplasty. *J Shoulder Elbow Surg* 2017;26:1726-31. <https://doi.org/10.1016/j.jse.2017.03.032>
35. Werthel J-D, Walch G, Vegehan E, Deransart P, Sanchez-Sotelo J, Valenti P. Lateralization in reverse shoulder arthroplasty: a descriptive analysis of different implants in current practice. *Int Orthop* 2019;43:2349-60. <https://doi.org/10.1007/s00264-019-04365-3>
36. Wilde LD. Unresolved questions in reverse total shoulder arthroplasty. *Obere Extremität* 2017;12:4-5. <https://doi.org/10.1007/s11678-017-0390-8>