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The base plate orientation angle: a plain radiographic technique for designing the base plate's inclination in reverse shoulder arthroplasty

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Background: Superior inclination of the base plate in reverse shoulder arthroplasty (RSA) is underestimated and may lead to major setbacks in terms of functional outcomes due to the altered biomechanics. Joint instability, scapular notching, and loosening of the glenoid component are considered the most serious sequelae. Therefore, a thorough preoperative radiological assessment of the affected shoulder joint and customized design of the prosthesis according to the glenoid morphology are decisive and directly correlated to the outcome. In this article, we propose a simple radiographic technique to assess the inclination of the glenoid preoperatively, which identifies the need for intraoperative correction.

Materials and Methods: One hundred inconspicuous shoulder radiographs were included in the control group (CG) to define the normal ranges of the base plate orientation angle (BOA) and the base plate correction angle (BCA). Further, both angles were measured on 2-dimensional (2D) computed tomography scans of patients with proximal humerus fractures as well as radiographs, 2D and 3-dimensional (3D) computed tomography scans of patients with cuff tear arthropathy who underwent RSA between 2018 and 2021. The interobserver reliability among three independent testers was evaluated by calculating the intraclass correlation coefficient. In cuff tear arthropathy cases, the BOA and BCA measurements on different imaging modalities were compared using the Wilcoxon test. Possible variations of both angles' values based on glenoid erosion types, according to the Favard classification, were also investigated.

Results: Regardless of the imaging modality used, the interobserver reliability was excellent among three independent observers. In the CG, the mean BOA and BCA values were 118° ± 6° and 17° ± 5°, respectively. The mean corrected BOA values of the CG and fracture group were 136° ± 5° and 140° ± 5°, respectively. In contrast to the BCA values, the BOA measurements on radiographs showed a statistically significant difference compared to those obtained on 2D- and 3D scans in the cuff arthropathy group. Further, both angles' values varied according to the extent and location of the glenoid erosion. The lowest mean BOA and highest mean BCA values were observed in cases with Favard glenoid type E3.

Conclusions: The BOA and the BCA are reliable tools proposed to aid in precisely positioning the glenoid component in RSA in the preoperative setting. Whereas, the BOA determines the inclination of the inferior glenoid segment, the BCA represents the extent of correction required to obtain a neutral inclination of the base plate. Glenoid type E3 of the Favard classification with superior wear is particularly susceptible to base plate superior tilt.

This study was approved by the ethics committee of the joint association of the State Chambers of Physicians in Stuttgart (no. F-2023-005).

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The first ball-and-socket shoulder prosthesis, constructed in 1970 to treat cuff-deficient arthritic shoulders, yielded poor results.[12,33,39,50] Consequently, the reverse ball-and-socket prosthesis was designed in numerous iterations during the ensuing years.[28,31,43] The unsatisfactory results observed with these

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implants were owed to the excessive torque and shear forces at the glenoid component-bone interface.[9] However, Paul Grammont's original design[16] from 1985, which underwent several modifications, successfully overcame that obstacle by medializing the center of rotation and reducing the torque on the glenoid component.[4,9] Since then, reverse shoulder arthroplasty (RSA) has grown in popularity for treating a variety of conditions, including failed anatomical total shoulder arthroplasty, pseudoparalysis of the shoulder, irreparable cuff tears, cuff tear arthropathies (CTAs), complex proximal humerus fractures, and tumors.[52] The latest version of the prosthesis promoted by Grammont (Delta prosthesis), which is still used today, is comprised of 5 functional units: the glenoid base plate, the glenosphere, the polyethylene cup, the humeral neck, and the humeral stem.[16] Due to the significance of proper glenoid component orientation regarding the biomechanics of RSA, the literature demonstrated the growing emphasis that several studies dedicated to the base plate inclination and its relation to the glenoid morphology prior to implantation of RSA.[1,3,15,30,62] Thereupon, radiographic techniques were described in an effort to aid in quantifying the required amount of deformity correction and customized designing of the glenoid component according to the individual morphometry of the glenoid cavity.[6,42] While controversy rages over whether neutral or mild inferior tilt is desirable,[14,35,44,53] superior tilt should be avoided at all costs since it is proven to be associated with increasing tensile base plate forces leading to early loosening.[17,18] Risk factors commonly associated with glenoid component superior tilt are the degree/location of the glenoid erosion and the employed surgical approach.[10,40] Since there is an agreement among researchers that positioning the metaglene at the inferior portion of the sagittal glenoid surface prevents scapular notching and is linked to enhanced range of motions, it is only the inclination of the inferior segment of the glenoid that is relevant in RSA.[14,18,45,46]

This study aims at introducing straightforward and precise radiographic parameters that can be employed preoperatively to assess the risk of superior inclination of the glenoid component prior to RSA. We hypothesized that the base plate orientation angle (BOA) and the base plate correction angle (BCA) would accurately estimate the inclination of the glenoid preoperatively, based on which the amount of surgical deformity correction to accomplish neutral inclination of the base plate can be determined. The impact of different glenoid forms on the indicated angles is also to be investigated.

Materials and Methods

Patient population

To define the average values of the BOA/BCA, inconspicuous radiographs of patients who presented in a secondary referral hospital following a mild impact to the shoulder from January 2019 to December 2019 were employed. A total of 100 radiographs clear of skeletal lesions or other pathologies were included in this control group (CG). The age limit was set between 18 and 60 years to avoid possible age-related degenerative findings. On the other hand, preoperative X-rays, as well as 2-dimensional (2D) and 3-dimensional (3D) computed tomography scans (CT scans) of patients with CTA and only 2D-CT scans of those with multifragmentary proximal humerus fractures (AO/OTA 11C1/11C3) who underwent RSA during the period between 2018 and 2021 in our institution were retrospectively reviewed. Regarding the fracture group (FG), the measurement was confined to 2D-CT scans due to the anticipated mispositioning of the afflicted shoulder by the patients during radiological assessment in an attempt to compensate for their acute discomfort. The extent of glenoid erosions on radiographs and CT scans of the cuff tear arthropathy group (CTAG) was determined according to the Favard classification[34] as agreed on by two experienced shoulder surgeons and two senior orthopedic residents. The lateral border of the scapula must be clearly visible in all radiographs and CT scans. The absence of one or more of the preceding requirements was taken into consideration as grounds for exclusion.

Radiological measurements and geometric principles

The BOA (Fig. 1*A*) is the angle created by two lines, the first drawn parallel to the lateral scapular border as described by Maurer et al,[38] and the other joining the first line's intersection with the anterior glenoid rim and the infraglenoid tubercle. This angle presents the inclination of the inferior portion of the glenoid (where the base plate rests) and must be corrected intraoperatively for adequate base plate positioning. To correct the BOA, we propose the BCA (Fig. 1*B*), an auxiliary angle. The BCA is made up of two lines; the first is identical to the second line of the BOA and connects the infraglenoid tubercle with the junction of a line drawn parallel to the lateral scapular border with the anterior glenoid rim. Meanwhile, the second line connects the superior and inferior glenoid tubercles (this line runs perpendicular to the scapular neck and is a key element for determining the subsequent alignment of the base plate).

The two angles mentioned above form a triangle (Fig. 1*C*) in which they share one line. The line (BC) of the triangle is a reference to correct the angle BOA, as previously mentioned. Regarding the BOA, however, only one of the two lines that make up the angle can be modified to correct the base plate inclination; this line is the line (OA), while the line parallel to the lateral scapular border remains constant. When positioning the base plate, the line (OA) of the BOA (***line X***) should just be parallel to the line (BC) of the BCA (***line Y***), as shown in (Fig. 1*D*); this can be accomplished by applying the “same-side interior angles theorem,” which states: If a transversal intersects two parallel lines, each pair of the same-side interior angles is supplementary (their sum is 180°).

However, since **1)** the BOA and the BCA form the same triangle (Fig. 1*C*), and **2)** the sum of the triangle angles = 180°, we conclude that **3)** BOA + BCA = supplementary (∡2) of the interior (∡1) provided the ***lines X*** and ***Y*** are parallel to each other (Fig. 1*D*).

The parallelogram theorem, which also stipulates that the opposite angles of a parallelogram are equal (Fig. 2), indicates that all paths ultimately lead to the same outcome. The cBOA stands for corrected BOA (Fig. 3).

Conventional radiographs in an anteroposterior view were confined to the CG and cases of CTA. 2D-CT scans displaying the entire body of the scapula were obtained using a multislice spiral CT (Aquilion PRIME; Toshiba, Otawara, Japan) for both the FG and CTAG. The acquired images of the CTAG were then exported to a postprocessing workstation (VitreaCore, version 6.9.87.1; Minnetonka, MN, USA), which provided an automatic, complete 3D reconstruction of the scapula.

Both plain radiographs and 3D-CT scans were subjected to the identical manual measurement procedure by all testers. For an accurate analysis of the glenoid inclination on 2D-CT scans, the glenoid joint surface was chosen as a criterion for the optimal layer as far as conceivable in its whole shape with exhibiting both supra and infraglenoid tubercules (Fig. 4*A*). The projection of the gantry line along the corpus scapulae in the axial view was verified (Fig. 4*B*) before the measurement procedure commenced (Fig. 4*C* and *D*). All measurements were made using the digital SYNAPSE viewing and editing software (SYNAPSE PACS View, version 5.7.102; Bedford, UK).

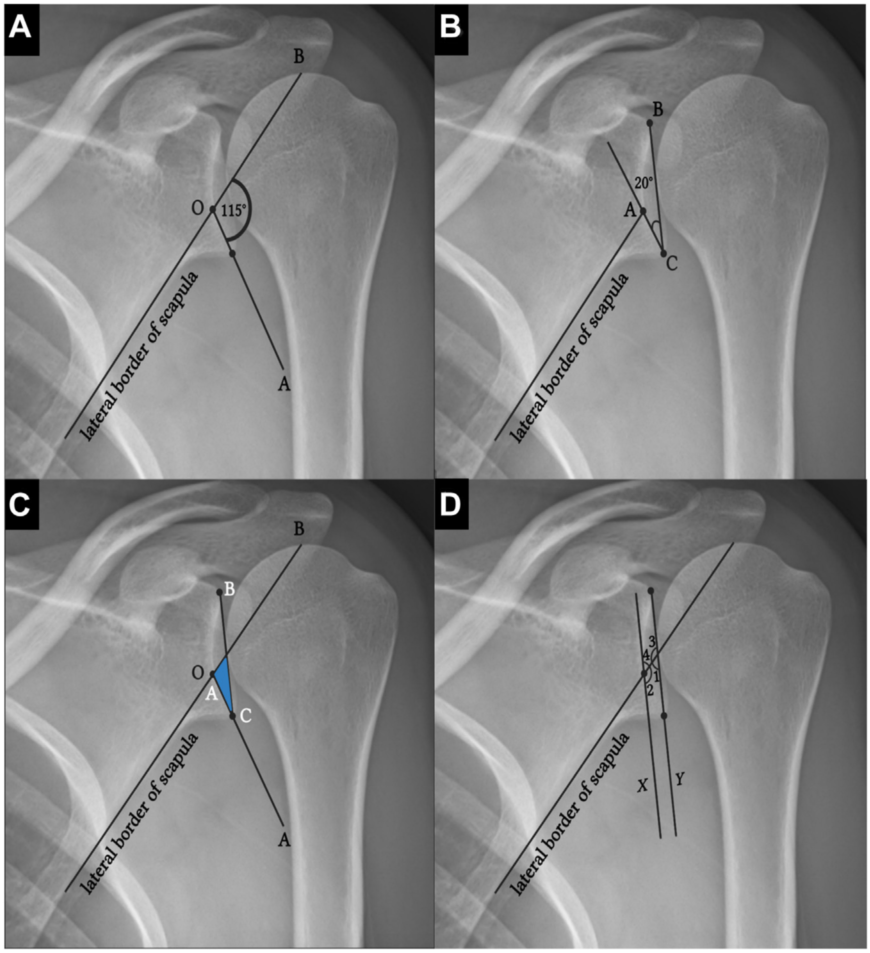

Figure 1 The base plate orientation angle (BOA) **(A)** The base plate correction angle (BCA) **(B)** Both angles form a triangle of which they share one line **(C)** The same-side interior angles theorem **(D)**.

Statistical analysis

The intraclass correlation coefficient (ICC) with a confidence interval of 95% was employed to test the reliability of the BOA and BCA on conventional radiographs, 2D, and 3D scans for all groups among three observers (A.S., A.M., and M.M.). ICC of > 0.7 was interpreted as excellent, 0.4-0.7 as good, and <0.4 as poor agreement.[5] Further, the values of both angles within the CTAG on plain radiographs were compared with those obtained from 2D and 3D scans using the Wilcoxon test. The remainder analysis was conducted using descriptive statistics. SPSS Software (version 13.0; SPSS Inc., Chicago, IL, USA) was used for the data analysis.

Results

Demographics

At a mean age of 33 years, the male/female ratio in the CG was 59/41, and the right- to left-sided radiographs ratio was 54/46 (Table I). The male/female ratios for the FG and the CTAG were 11/32 and 5/19, respectively. The left-sided radiographs and CT scans predominated in both groups with ratios of 17/26 and 10/14, respectively (Table I). The mean age of the patients included in both groups was 76 years for the FG and 85 years for the CTAG. After applying the inclusion and exclusion criteria, 43 and 24 cases were included for the FG and the CTAG, respectively. The 24 cases with CTA included in the present study were further subdivided as per the glenoid bone loss classification presented by Favard et al[34] as follows: eleven patients with E0-Glenoid, eleven cases with E1-Glenoid, and 2 cases with E3-Glenoid.

Glenoid inclination

In the CG, the highest and lowest values of the BOA were 130 and 101, respectively. As for the BCA, the highest and lowest values in the same population were 30 and 10, respectively (Table II). The highest and lowest values of the sum of both angles (cBOA) were 122 and 147 for the CG. Regarding the FG, the highest and lowest BOA values measured on 2D-CT scans were 133 and 106, respectively. At the same time, the highest and lowest BCA values were 35 and 12, respectively. The highest and lowest cBOA values in the same group were 153 and 127, respectively (Table II).

The radiographs included in the CTAG were subdivided into three groups according to the most common patterns of glenoid bone loss described by Favard.[34] The corresponding values of the BOA and BCA to the extent of glenoid erosion are demonstrated in Table III. The lowest mean BOA values and the highest mean BCA values were noted for cases with an E3 glenoid type (Table III).

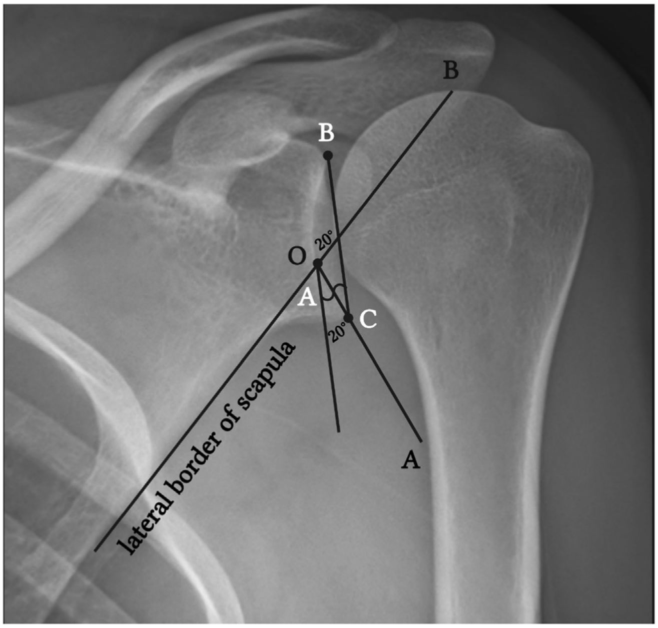

Figure 2 The parallelogram theorem validates the relationship between the BOA and BCA and their relevance in correcting the base plate inclination. *BOA*, base plate orientation angle; *BCA*, base pate correction angle.

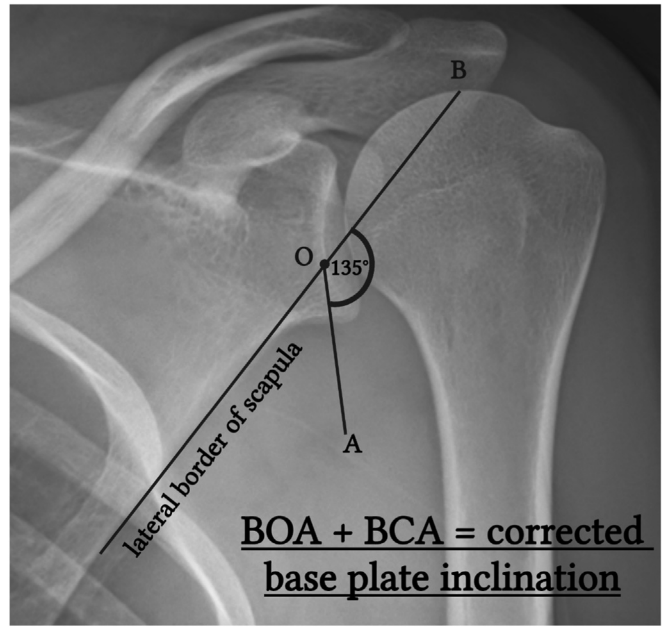

Figure 3 The corrected base plate orientation angle.

Reliability

The interobserver reliability of both radiographic metrics (BOA/BCA) among three independent observers, which was evaluated using the ICC, revealed excellent results in all groups and various imaging modalities (radiographs, 2D and 3D scans). The ICC values (with a 95% confidence interval) of the BOA and BCA in the CG and FG were 0.97, 0.95, and 0.93, 0.92, respectively (Table IV). As for the CTAG, the ICC values for the BOA and BCA were 0.97 and 0.93 on radiographs, 0.98 and 0.99 on 2D scans, and 0.97 and 0.98 on 3D scans, respectively (Table V).

Paired comparisons

The Wilcoxon test comparing the BOA values on conventional radiographs in the CTAG to those obtained from 2D and 3D scans yielded *P* values of 0.019 and 0.023, respectively. The results of the same test comparing the BCA values in the same group revealed *P* values of 0.75 and 0.85, respectively.

Descriptive statistics

The drop-line chart in Fig. 5 demonstrates the negative correlation between both angles. Further, the boxplots in Fig. 6 highlight the low mean BOA values and high mean BCA values in cases with E3 glenoid.

Discussion

The detrimental consequences of the base plate's superior tilt in RSA have been extensively investigated and documented in the scientific literature.[7,34,40,53,57,63] On the other hand, there is still a dispute over whether an inferior tilt of the base plate is favored regarding functional outcomes and construct stability. According to Nyffeler et al,[46] a 15°-20° inferior tilt of the base plate and glenosphere increased survival rates and minimized the incidence of inferior scapular notching. Contrarily, Patel et al[48] have demonstrated that a 10° inferior tilt of the base plate led to medialization of the humeral component and scapular neck impingement during external rotation and adduction, which is associated with a high risk of scapular notching, glenoid component instability, and loss of joint motion.[26,41,49,53,54] In the same context, Favard et al[15] recommended placing the base plate at 0° inclination (ie, neutral inclination). Previously, efforts were made to determine the glenoid inclination by implementing consistently distinguishable radiographic landmarks. Hughes et al[22] defined glenoid inclination as the superolateral angle between a line connecting the top and bottom of the ellipse formed by the anterior and posterior glenoid margins and a second line drawn across two points along the supraspinatus fossa. While Maurer et al[38] defined it as the angle created by the junction of two planes; a vertical plane represented by a line connecting the infra- and supraglenoid tubercules and a horizontal plane displayed by the floor of the supraspinatus fossa. These measurements reflect the global glenoid inclination, which might be useful for planning anatomical shoulder arthroplasty. In RSA, however, it is significant to comprehend the surface area of the glenoid that is in contact with the base plate. Nyffeler et al[46] recommended placing the base plate flush with the inferior glenoid margin in RSA, which, according to their cadaveric study, improved the range of motions and prevented inferior impingement of the polyethylene cup against the scapular pillar. Similarly, Simovitch et al[53] proposed overhanging the glenosphere below the inferior edge of the glenoid. These recommendations were corroborated by several clinical and biomechanical investigations.[25,34,35] In light of this, it is the inclination of the inferior glenoid segment that is relevant in RSA. The radiographic tools proposed in this study are intended to act as reliable metrics to assess the risk of superior tilt of the base plate and establish the extent of glenoid deformity correction required to obtain neutral inclination of the base plate prior to RSA. Preoperatively, the inclination of the inferior glenoid segment can be measured using the BOA (Fig. 1*A*). However, to align the base plate properly, the BCA (Fig. 1*B*) must be considered. This angle serves two purposes: 1) it acts as a complementary angle of the BOA to correct the inclination of the base plate. 2) serves as a

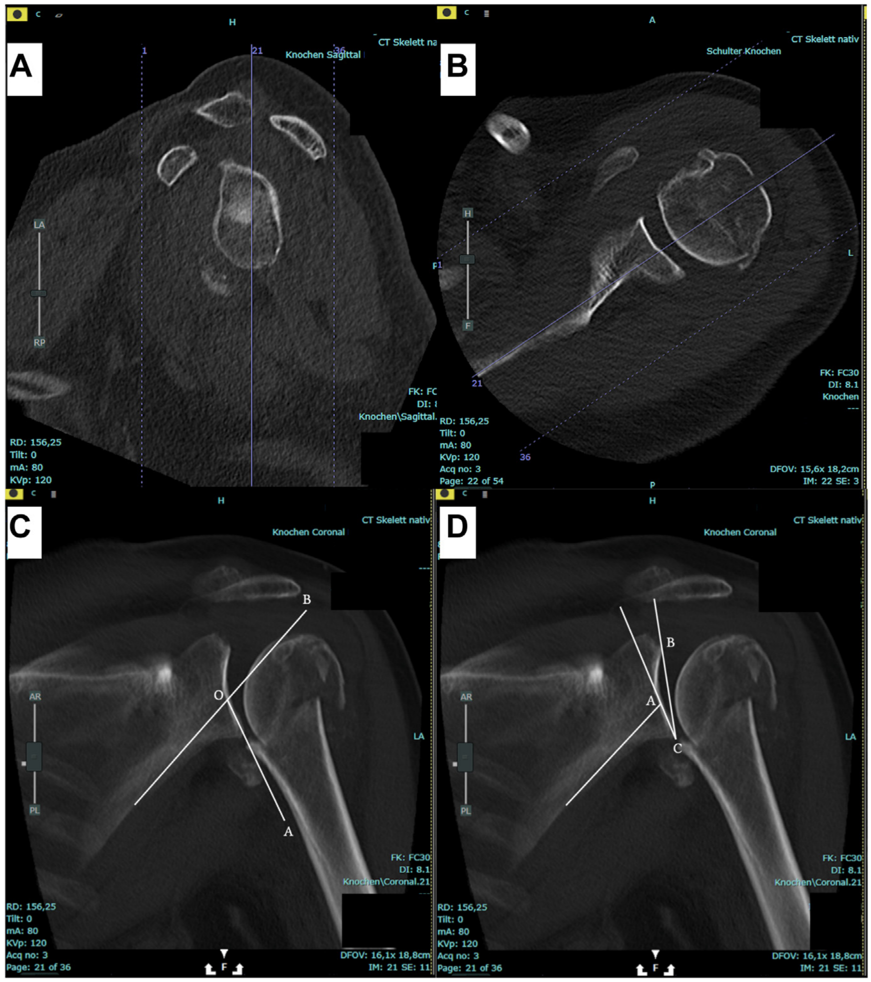

Figure 4 Preoperative 2-dimensional computed tomography of an 84-year-old male patient with multifragmentary proximal humerus fracture, exhibiting maximum glenoid surface on the sagittal view **(A),** Gantry projected along the corpus scapulae on the axial view **(B),** Measurement of the BOA/BCA on the coronal view **(C, D)**.

Table I
Demographic data of all three groups.

	Control group (n = 100)	Fracture group (n = 43)	Cuff arthropathy group (n = 24)
Age	33 (18–53)	76 (59–96)	85 (50–90)
Gender (m/f)	59/41	11/32	5/19
Side (right/left)	54/46	17/26	10/14

Table II
Values of the BOA, BCA, and cBOA in the control group (N = 100) and 2-dimensional CT scans of the fracture group (N = 43).

Angles	Control group (Radiographs)	Fracture group (2-DCT scans)
BOA	118 ± 6 (101-130)	119 ± 5 (106-133)
BCA	17 ± 5 (10-30)	21 ± 5 (12-35)
cBOA	136 ± 5 (122-147)	140 ± 5 (127-153)

BOA, base plate orientation angle; *BCA*, base plate correction angle; *cBOA*, corrected base plate orientation angle; *CT*, computed tomography.

reference to attain neutral lateralization of the anatomical glenoid concavity. The authors define neutral lateralization of the base plate as lateralization limited to a line connecting the infra and supraglenoid tubercles. The amount of correction required to obtain neutral lateralization is represented by the blue triangle in Fig. 1*C*. As previously stated, the mean value of the BOA in the CG was 118° ± 6° (101°-130°) (Table I). These values represent the inclination of the inferior glenoid surface measured on unremarkable shoulder radiographs. Therefore, fixing the base plate without adjustment of the glenoid concavity will automatically result in superior tilt and medialization of the glenoid component. The mean value of the BCA in the CG was 17° ± 5° (10°-30°) (Table I). The drop-line chart illustrated in Fig. 5 demonstrates the negative correlation between both angles. In other words, the lower the BOA values (representing a high risk of superior base plate tilt), the higher the BCA values are to correct the base plate alignment. The cBOA (Fig. 3) had an average value of 136° ± 5° (122°-147°) in the CG, and it represents the sum of both angles (BOA/BCA) after correcting the inclination of the inferior glenoid segment (Table I). The mean values of the BOA and BCA, measured on 2D-CT scans, were 119° ± 5° (106°-133°) and 21° ± 5° (12°-35°), respectively (Table II).

Since the osseointegration between the base plate and the glenoid surface is a key element determining joint function and stability in RSA,[24,58] it is crucial to optimize the glenoidal base plate's bed prior to fixation. Among several strategies dedicated to that cause are the eccentric reaming to obtain the so-called "cancellous smile", the employment of iliac crest allografts, humeral head autografts, or augmented metallic base plates.[11,13,21,27,51,59] Eccentric reaming should, however, be handled cautiously, for it may turn

Table III
Values of the BOA and BCA in the cuff tear arthropathy group by Favard glenoid type on radiographs, 2-D, and 3-DCT scans (N = 24).

Glenoid erosion type according to Favard	Radiographs		2-DCT scans		3-D CT scans	
	BOA	BCA	BOA	BCA	BOA	BCA
E0 (n = 11)	117 ± 11 (101-137)	22 ± 7 (12-33)	123 ± 9 (104-138)	17 ± 5 (11-29)	122 ± 10 (102-143)	18 ± 7 (10-38)
E1 (n = 11)	105 ± 7 (90-115)	24 ± 7 (12-39)	106 ± 4 (98-114)	29 ± 4 (20-38)	107 ± 7 (90-119)	27 ± 5 (19-41)
E3 (n = 2)	99 ± 16 (83-117)	29 ± 2 (27-31)	92 ± 3 (88-97)	33 ± 10 (31-34)	92 ± 2 (90-95)	32 ± 4 (28-36)

2D, two-dimensional; *3D*, three-dimensional; *BOA*, base plate orientation angle; *BCA*, base plate correction angle; *CT*, computed tomography.

Table IV
Interobserver reliability of both the control and fracture groups.

Groups	Control group (radiographs)		Fracture group (2D-CT scans)	
	BOA	BCA	BOA	BCA
ICC (95% confidence interval)	0.97 (0.96-0.98)	0.95 (0.93-0.96)	0.93 (0.89-0.96)	0.92 (0.87-0.95)

2D, two-dimensional; *BOA*, base plate orientation angle; *BCA*, base plate correction angle; *CT*, computed tomography; *ICC*, interclass correlation coefficient.

Table V
Interobserver reliability of the CTAG.

Imaging modality	Radiographs		2D-CT scans		3D-CT scans	
	BOA	BCA	BOA	BCA	BOA	BCA
ICC (95% confidence interval)	0.97 (0.95-0.99)	0.93 (0.88-0.97)	0.98 (0.96-0.99)	0.99 (0.98-0.99)	0.97 (0.95-0.98)	0.98 (0.96-0.99)

2D, two-dimensional; *3D*, three-dimensional; *BOA*, base plate orientation angle; *BCA*, base plate correction angle; *CT*, computed tomography; *CTAG*, cuff tear arthropathy group; *ICC*, interclass correlation coefficient.

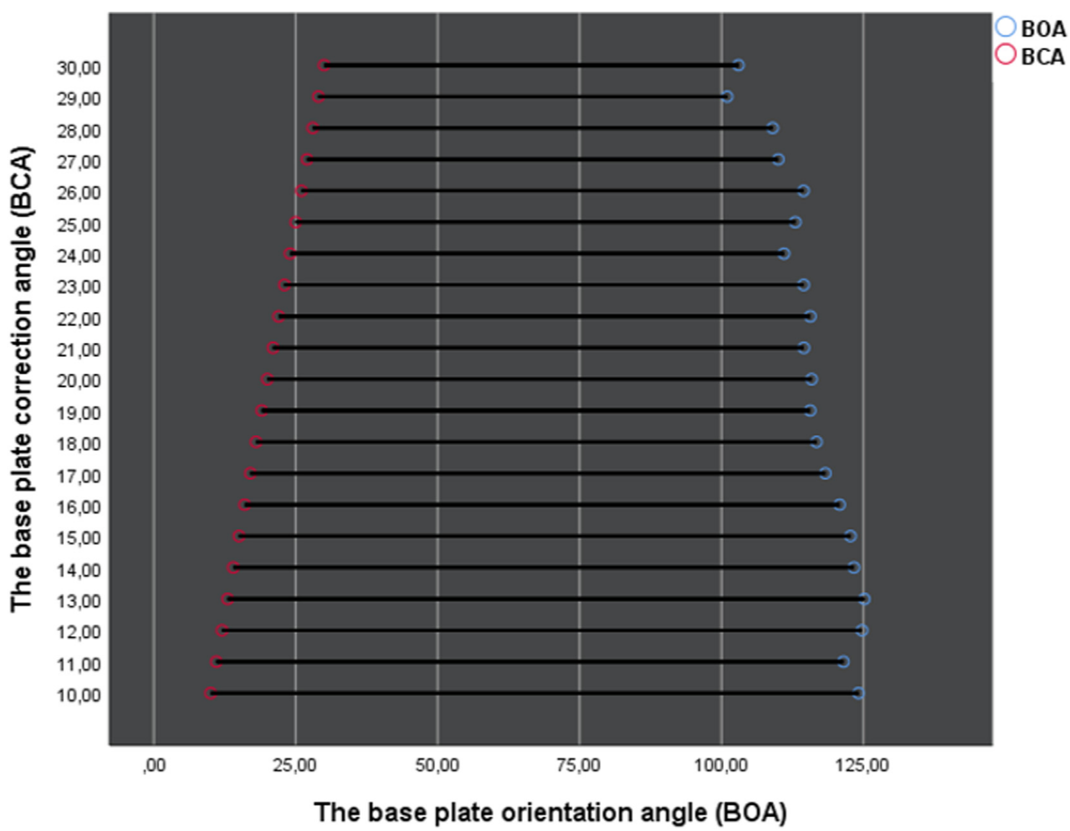

Figure 5 Drop-line chart demonstrating the negative correlation between the BOA (blue circles) and BCA (red circles) values in the control group. *BOA*, base plate orientation angle; *BCA*, base plate correction angle.

counterproductive in cases of significant glenoid bone loss, leading to unsatisfactory medialization of the joint line.[55] On the other hand, excellent functional outcomes were reported for cases managed using allografts, humeral head autografts, or augmented base plates, with each strategy's proponents highlighting distinct benefits.[8,29,56]

The twenty-four cases included in the CTAG were further categorized into subgroups based on the Favard classification of glenoid

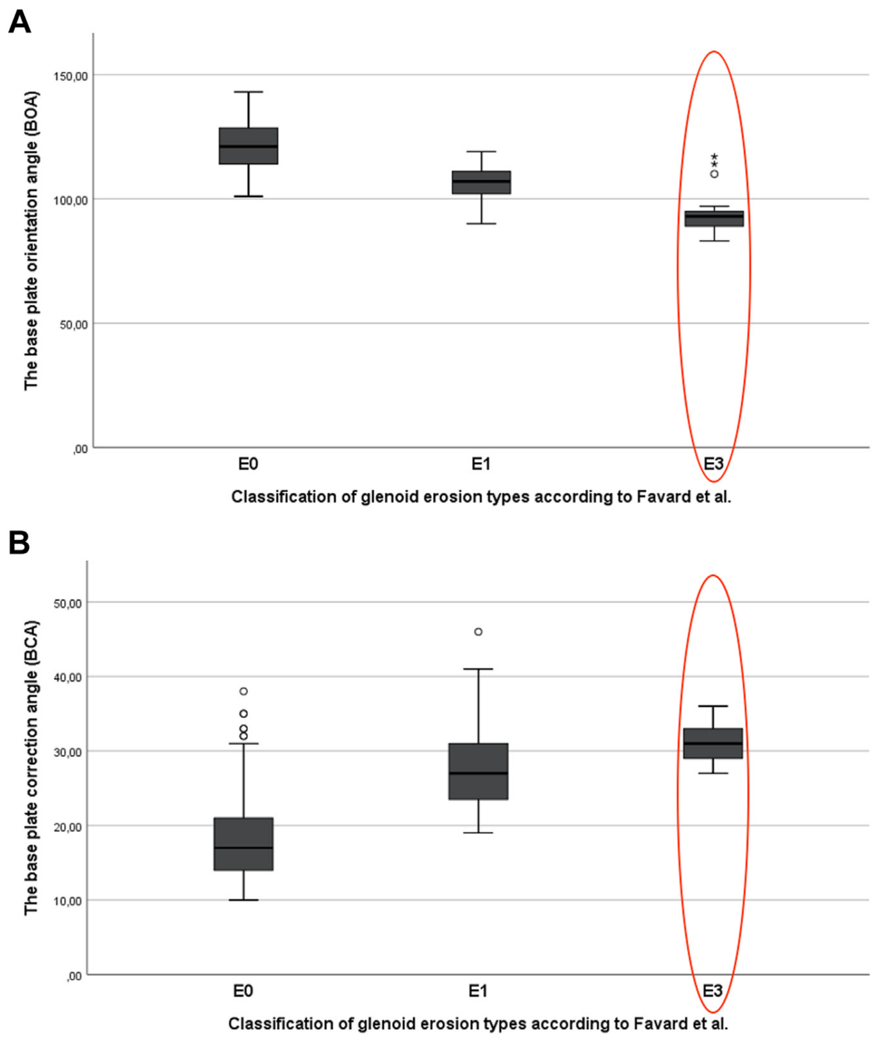

Figure 6 Boxplots showing the distribution of the BOA **(A)** and BCA **(B)** values in different Favard glenoid subtypes of the cuff tear arthropathy group. The red circles highlight the lowest BOA **(A),** and highest BCA mean values **(B)** observed in E3-Glenoids. *BCA*, base plate correction angle; *BOA*, base plate orientation angle.

bone loss.[34] The extent of glenoid erosion was classified as E0 in eleven cases, E1 in eleven cases, and E3 in the remaining two cases. The measurements in these cases varied according to the morphological changes of the glenoid, as shown in Table III. Of all three Favard glenoid types included in this study, cases with an E3-Glenoid had the lowest mean BOA values and highest mean BCA values (Table III), making it the subtype mostly at risk of a base plate superior tilt (Fig. 6), followed by those with central glenoid erosion (E1-Glenoid). Similarly, previous works have established a relationship between superior glenoid wear and susceptibility to a superior inclination of the glenoid component in RSA.[32,37] The boxplots in Fig. 6 demonstrate the low mean values of BOA in cases of peripheral and central glenoid erosions (E3 and E1) and the correspondingly high values of BCA, again confirming the complementary relationship between both angles.

The authors' suggested algorithm for preoperative proper base plate settlement is as follows:

1) start by measuring the BOA and BCA (Fig. 7 *C* and *D*).
2) lateralize the point "O" of the BOA to the point at which the line drawn along the lateral scapular border intersects the line BC of the BCA (Fig. 7 *C*–*E*).
3) add the sum of both angles to correct the inclination of the base plate (cBOA) (Fig. 7*E*).
4) adjust the BOA so that the BCA = 0° (Fig. 7*E*).

Further lateralization from this point can be done according to the surgeon's preference.

Finally, postoperative radiographic evaluation of the base plate's inclination should be based on the cBOA values in the CG (136° ± 5°) (Fig. 8). The BCA can be taken as a reference if neutral lateralization of the base plate is obtained (Fig. 7*F*), in which case a value of 0° would represent neutral inclination. If further lateralization is performed (eg, via BIO-RSA or augmented base plates), however, the amount of correction performed is beyond the BCA's scope (Fig. 8). Thus, the angle becomes inapplicable.

When discussing RSA, the evolving role of patient-specific-instrumentation (PSI) in preoperative planning cannot be overlooked. Even though no correlation has yet been established connecting the employment of PSI to clinical outcomes, researchers have concurred on the precision of PSI in the preoperative setting, facilitating appropriate glenoid component positioning on a case-by-case basis.[20,23,36,60,61] In an interesting comparative study, however, Parsons et al[47] revealed substantial discrepancies among

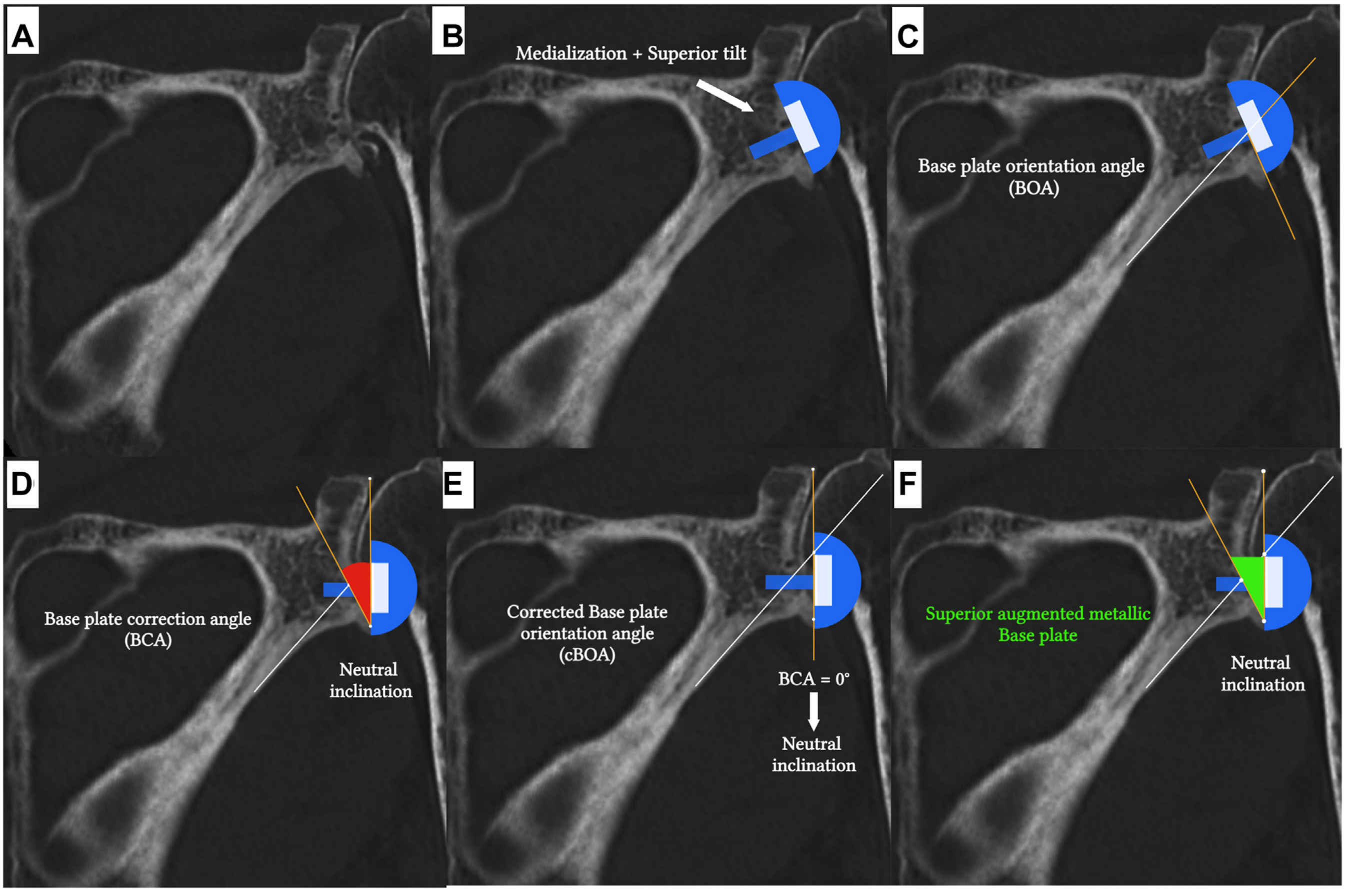

Figure 7 Preoperative 2-dimensional computed tomography of an 82-year-oldfemale patient with cuff tear arthropathy of the left shoulder joint (Hamada and Fukuda stage II)[19] with central glenoid erosion of type E1 (according to Favard)[34] **(A)** Implantation of the base plate without regarding the BOA/BCA results in medialization and superior tilt of the glenoid component **(B)** Measurement of the BOA **(C)** Measurement of the BCA to determine the amount of deformity correction required **(D)** Correction of the BOA results in neutral inclination of the base plate, the BCA = 0° at this point **(E)** Neutral inclination of the glenoid component obtained using a superior augmented base plate **(F)**. *BCA*, base plate correction angle; *BOA*, base plate orientation.

nine shoulder surgeons, particularly in implant selection, adequate positioning, and correction of the glenoid inclination and retroversion, even though all surgeons used the same 3D planning software to design the RSA components. This conclusion underlines the importance of reproducible radiographic measurements based on reliably identifiable anatomical landmarks in the preoperative planning process of RSA. Still, the fact that the X-ray projection may influence the measurement of the glenoid inclination on radiographs certainly poses a limitation to this study. As previously indicated, the Wilcoxon test used to compare the BCA values in the CTAG on conventional radiographs to those obtained via 2D- and 3D scans revealed high *P* values; thus, supporting the null hypothesis (no significant difference between the values of different groups). On the contrary, the null hypothesis was rejected based on the results of the same test comparing the BOA values in the same group on different imaging modalities.

Even though the measurement process was conducted in a manual fashion in the present study, regardless of the imaging modality used, the interobserver reliability of the BOA and BCA was excellent in all groups among three independent observers with different experience levels (Table IV) (Table V). These findings corroborate the statement made by Maurer et al[38] that a reliable assessment of the glenoid inclination on radiographs is possible. Nevertheless, incorporating the parameters presented in this study into PSI would have some advantages including reducing the time and effort associated with the manual measurement process and eliminating possible interobserver discrepancies.

The results of this study must be considered in view of its limitations. The first issue is the small sample size of the cuff arthropathy group; presuming a greater sample size could have yielded different results from those presented in this study. Moreover, the same group lacked, in particular, two glenoid types according to the Favard classification (E2 and E4). Thus, the authors urge future studies to investigate the impact of a larger population, including these two glenoid types, on both angles. Finally, the BOA's inability to account for glenoid deformities in the axial plane, such as substantial glenoid retroversion and subsequent humeral head subluxation, is another limitation. These conditions are classified according to Walch and colleagues (Bercik et al)[2] and must be considered when planning RSA.

Conclusion

Based on the statistical data revealed in this study, also from a geometrical perspective, the BOA and the BCA share a complementary relationship with the aim of obtaining a neutral inclination of the base plate in RSA. The reproducibility of both radiographic parameters across three testers was also exceptionally high. These parameters can be relied on to accurately predict the risk of superior inclination of the base plate and the amount of

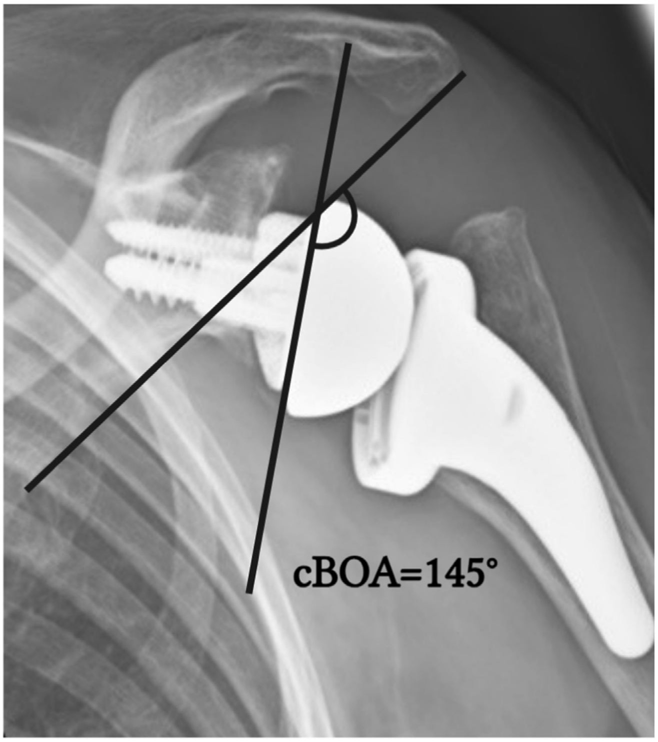

Figure 8 Postoperative anteroposterior left shoulder radiograph of a female patient with cuff tear arthropathy and central glenoid erosion managed via short stem reverse shoulder arthroplasty with a superior augmented metallic base plate. The base plate orientation anglevalue is 4° higher than the normal values (136° ± 5°), indicating a slight inferior tilt of the base plate. *cBOA*, corrected base plate orientation angle.

glenoid deformity correction needed to place the base plate in neutral alignment. Type E3 glenoid of the Favard classification is at high risk of a base plate superior tilt and must be adequately addressed to avoid adverse outcomes.

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