Unlocking the secrets of reverse shoulder arthroplasty: A radiological appraisal

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ABSTRACT

Reviewing the literature on radiological evaluation of reverse shoulder arthroplasty (RSA), this paper looks at recent findings. Plain radiographs and computed tomography (CT) scans are among the imaging modalities discussed to assess this procedure's effectiveness. The various radiological assessment methods for glenoid bone loss evaluation, implant position assessment, and early and late potential problem detection are also reviewed in this article. It also goes over the correlations that have been documented between various radiological parameters and clinical outcomes. The study concludes that radiological assessment is a valuable tool for assessing the effectiveness of reverse shoulder arthroplasty and that more research is required to increase its precision.

Keywords: Arthroplasty, shoulder, radiological, version, RSA-angle, CT scans.

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INTRODUCTION

A credible treatment for rotator cuff (RC) deficiency was introduced with the introduction of reverse shoulder arthroplasty (RSA)[1]. Its increasingly broad surgical indications, which include non-reconstructable proximal humeral fractures in old age, glenohumeral arthritis, failed arthroplasty, and massive RC tears, have recently made it more well-liked[2,3]. Numerous factors about surgical indication, surgeon experience, implant design, and surgical technique may have an impact on the result of RSA[4].

It is crucial to evaluate the results of RSA using various imaging modalities and relate them to radiological parameters. There isn't much information currently available about radiographic measures of RSA, and what is available isn't entirely conclusive. By using computed tomography (CT) scans and radiographs, radiologists can assess preoperative bone loss, guide surgical technique, determine postoperative prosthetic positioning, forecast complications, and guide the treatment of those complications[5]. A summary of recent studies on the relationship between these radiological parameters and clinical outcomes will be given, along with a discussion of the various radiological assessment parameters.

I- True Anteroposterior (AP) radiographs

The Habermeyer et al. classification[6] is used to evaluate glenoid bony deficiency in the coronal plane pre-surgery. This classification shows the supero-inferior bone erosion via the inferior glenoid tilt. According to the relationship between the coronal glenoid plane and another longitudinal plane at the level of the coracoid, this classification divides the glenoid tilt into four types (Fig. 1). Similarly, the Favard-Sirveaux classification, which shows four types of erosions, can be used to address superior glenoid erosion in patients with RCA (Fig. 2). Following the loss of restraint to this migration, higher grades are typically linked to superior migration of the humeral head[7]. To prevent excessive shearing forces across the glenoid-bone interface and ensure long-term prosthetic survival, coronal glenoid alignment correction is essential.[3,8]

Maurer et al.[9] radiographically demonstrated global glenoid coronal inclination, which they expressed as β-angle. This angle denotes the distance between the supraspinatus fossa floor and the glenoid plane line (Fig. 3). According to Chalmers et al., the normal β-angle ranges from 66° to 99°, with an average of 80°±6°. They also showed that a β-angle of 80° corresponds to a superior inclination of 10°[10]. A comparison was made between the corresponding three-dimensional (3D)-CT and the radiographic β-angle. There was a noticeable average difference of 3° and 5° between the radiographic and 3D-CT β-angles, as reported by Chalmers et al., and Daggett et al. Therefore, the 3D-CT gold standard measurements can be equalized with an additional 5° to the radiographic calibration finding[11].

High-valued β-angles represent inferior glenoid inclinations in RSA, while low-valued β-angles represent superior glenoid inclinations. After adjusting for other potential confounding variables for instability, Tashjian et al.[12] showed an incidence of 13% of postoperative subtle prosthetic instability with no complete dislocation after superiorly inclined baseplates with less corrected β-angle. They stated that inferior impingement was the cause of this relationship and that it was merely an association[13]. Although the β-angle may be more descriptive in anatomic arthroplasties, where the baseplate fills the entire glenoid, its significance in RSA, where the baseplate is specifically positioned at the inferior glenoid portion, is still under question. Furthermore, there is no evidence to support the validity of this angle in RSA and anatomic shoulder replacement. At the RSA baseplate level, the focal inclination is consistently underestimated by the β-angle[14].

Each prosthesis's glenoid inclination should be assessed separately. Therefore, Boileau et al.[15,16] created a new radiological parameter called the RSA-angle that precisely targeted the inferior glenoid portion where the RSA base plate was to be implanted. The inferior glenoid and a perpendicular to the supraspinatus fossa (SSF)-line form this angle (Fig. 4). The SSF-line is thought to be a reliable reference line that is simple to see on CT and radiographs as a distinct sclerotic line. It also shows where the RC muscles are located[17]. With a neutrally inclined baseplate implantation, the RSA-angle is preoperatively planned to rectify nearly to 0°, leading to more effective orthogonal vectors of the remaining RC muscles[17,18]. Coronal 2D-CT, reconstructed 3D-CT, and radiographs are used to calibrate the RSA angle. In patients with RCA, Boileau et al. reported a mean RSA-angle of 21°±5°. Therefore, in these patients, a neutrally inclined glenoid implant with 0° requires correction to an angle of 15° to 25° of superior inclinations[15,16]. The baseplate is perpendicular to the SSF line and its central peg is oriented parallel to it, with correction[14]. A correction of the RSA-angle average to ≤ 5° is frequently linked to better forward elevation and abduction.[3,19]

Applying the β-angle to evaluate cases of centric concentric erosion (Favard E1), where the RSA-angle is approximately 20° to 25°, typically undervalues the risk of baseplate implantation with a superior tilt in the context of the Favard classification[15]. It is dangerous for the RSA baseplate to tilt superiorly. Increased shearing stresses cause impingement, reduced range of motion (ROM), scapular notching with polyethylene wear, and unavoidable glenoid loosening at the baseplate-glenoid interface[20]. Although the optimal method for correcting superior glenoid inclination is still up for debate, it is crucial to position the RSA baseplate in an inferior or neutral inclination to achieve impingement-free ROM and prevent potential notching and loosening[14].

Compared to neutral and superior tilt, an inferior tilt of 15° is thought to have the least tensile forces, the most consistent compressive forces, and the least micromotion[21,22]. Superior baseplate inclination is frequently associated with the best functional outcome and range of motion[3,23], However, at short-term follow-up, there is no discernible difference between superior, neutral, and inferior inclination[3].

Although it is preferable to have an aspirational inferior inclination, this is not the only factor that affects functional outcomes. A posterior inclination may require the scapular neck to be shortened, which could result in medialization, raise the risk of impingement in the ER, and increase the risk of adduction, which could cause notching and instability. Tilt is not sufficient on its own. By offering a uniform distribution of forces, the use of a Lateralized COR design with inferior tilting can prevent the aforementioned drawbacks[21,22].

The critical shoulder angle (CSA) can be used to assess the inclination of the glenosphere[16]. The inferior glenoid pole and the lateral acromial edge, as well as a line joining the superior and inferior glenoid rims, define the preoperative boundaries of this angle (Fig. 3). Comparably, postoperative CSA is measured to the edge of the acromion and between a line that connects the inferior and superior aspects of the glenosphere base[19,24]. Lower CSA results from a more inferiorly inclined glenosphere, which causes the deltoid to compress more forcefully than a less inclined glenosphere would shear. The average CSA is 33.1° in patients who are asymptomatic and have an intact RC, 38.0° in patients who have an RC tear, and 28.1° in patients who have osteoarthritis, according to Moor et al.[23]. Better abduction and forward elevation were linked to CSA correction that was close to normal[3,19].

The lateral acromion angle (LAA) was proposed by Banas et al. and is by the intersection of a parallel line to the acromion's undersurface and the superior-inferior glenoid plane line (Fig. 3)[16,25]. The typical LAA is between 64° and 99°; cases with RC discontinuity have lower values. A possible correlation with full-thickness RCT is LAA <70°. Worse still, the literature on the relationship between LAA and RSA outcomes is scant[23,26].

Based on the preoperative and postoperative acromiohumeral intervals (AHI), respectively, the center of rotation (COR) of native and reconstructed shoulder joints is determined. Measured from the acromial undersurface to the greater tuberosity (GT) perpendicular to the acromial body's longitudinal axis, this interval is shown in Fig. 5[19,24].

Normal shoulders have an average AHI of 7–14 mm[27], whereas an increment in RCA is linked to a decrease in AHI[24,28]. Preoperatively, the COR location can be defined in the same way by following a perpendicular trajectory from the center of a perfect circle encircling the humeral head to the glenoid center; postoperatively, the COR is calibrated from the center of the glenosphere to the center of the native glenoid (Fig. 5).

According to earlier reports, there was a 1.57–2.3 cm increase in average AHD with no correlation to ROM or outcome[3,19,29]. In a similar vein, several studies reported an increase in average arm lengthening of 1.5–2.7 cm[3,19,29]. The deltoid muscle, which is taut, provides stability for the implant through this incline. 1.5 cm of lengthening can be enough to provide tension; anything more than 2.5 cm is deemed excessive and may be dangerous due to the possibility of acromial fractures and nerve damage[19,29]. Just as arm lengthening is a net result of several factors, such as glenosphere position, tilt, and size, polyethylene thickness, and humeral stem type and height, the question of whether arm lengthening affects range of motion is never settled. The aforementioned factors can all affect results in different ways. Compared to patients without an inferior glenosphere overhang, those with an overhang exhibit better results and range of motion. Although it is within the range of 2–5 mm, the ideal inferior overhang is still up for debate[3,30,31].

The acromion index (AI), which is calculated as the ratio of the distance between the glenoid and the lateral acromial aspect over the distance between the glenoid and the humeral head lateral aspect[16], is used to assess humeral lateralization both before and after surgery (Fig. 5). The altered variable in postoperative AI is typically humeral lateralization, while the lateral acromial edge remains in the same position. Therefore, a more medial humerus leads to an inclined AI. Lateralization can, within reason, re-tension the remnants of the RC; however, overly aggressive lateralization carries a risk of acromial fractures[19]. According to Nyffeler et al., the full-thickness RCT, osteoarthritic shoulder, and sound shoulder had mean AIs of 0.73, 0.60, and 0.64, respectively[32]. Few studies have published the findings about the relationship between AI and clinical outcomes[3,19]. With the use of medialized implants, a prior study found a decrease in the mean AI from 87.8% to 63.8% with non-significant improvements in ROM and outcome; however, the impact of glenoid lateralization was not reported separately[3].

The pre-and post-operative deltoid lever arm (DLA) is depicted perpendicular to the previously dawn line to the CORs using a drawn line that extends from the acromial lateral aspect to the deltoid tuberosity (Fig. 5). With respect to the deltoid muscle, the DLA symbolizes the inferiorization as well as the medialization of the prosthetic shoulder joint[19]. Previous studies[3,19] found no significant correlation between ROM and an average increase of 1.5 cm in this parameter.

Using three non-altered bony landmarks postoperatively—the superior glenoid tubercle, the acromial lateral border, and the most superolateral border of GT—Boutsiadis et al. developed two angles that represent the lateralization and distalization of the RSA prosthesis[33]. Clinical outcomes and postoperative ranges of motion were found to be correlated with both lateralization and distalization shoulder angles (DSA, DSA) (Fig. 6). Patients with DSA of 40°–65° were found to have improved active abduction and flexion, and patients with LSA of 75°–95° were found to have improved ER[33]. Though Beltrame et al. did not find evidence to support the associations between DSA and LSA and their respective outcomes, they did find that both measures correlated with AHI and lateralization [34]. Even though ROMs improved, various reports found that the variations in angles had no clinical significance for either the ROMs or the outcomes[3, 34-36].

II- Axillary radiographs

To account for humeral subluxation and posterior glenoid erosion per the Walch classification, the axillary lateral view is thought to be useful during preoperative planning. The assessment of glenoid erosion based solely on radiographic examination may not be accurate because variations in scapular rotation and radiographic projection can vary by up to 27°[37]. The following can be seen on postoperative axillary radiographs: radiolucency at the component-bone or cement-bone interface, prosthetic instability, base plate position to the glenoid, and base plate screws' position within the glenoid[38].

III- Computed tomography (CT)

Preoperative RC muscle status, bone osteoporosis, glenoid version, vault depth, and humeral subluxation have all been addressed with CT for a long time. The bone mineral density (BMD) of the shoulder region cannot be definitively measured. A prior investigation linked BMD to Hounsfield units (HUs) derived from glenoid neck CT scans, concluding that HUs < 197 indicated low BMD and HUs > 257 probably indicated normal BMD[39]. Bone health optimization and screening should be taken into consideration before surgery in patients with lower HUs undergoing elective arthroplasties[40]. It is advised to use cemented stemmed stems to prevent intraoperative fracture associated with press-fitting a cementless stem[42], as patients demonstrated an increased risk of periprosthetic fracture and revision surgery within 2 years[41].

On the sagittal-oblique slices (Y-view), where the scapular spine and scapular body are continuous, fatty infiltration within the RC muscles is assessed concerning the Goutallier grading[43]. Grade 0 on this 5-point scale denotes no muscle fat, Grade 1 the presence of fatty streaks, Grade 2 less than 50% muscle fat, Grade 3 the equal ratio of muscle to fat, and Grade 4 more fat than muscle bulk[44]. Additionally, using a four-category scale to describe atrophy as none, mild, moderate, or severe, the Warner atrophy grading can evaluate the RC muscle area. None signifies a mild extension of the supraspinatus (SS) muscle superior to a line connecting the superior tip of the scapular spine and the superior tip of the coracoid. SS goes up to this point, but not past it. Moderate and severe atrophy occurs at higher levels[45]. The same scale can also be used to grade infraspinatus atrophy concerning a line that connects the inferior tip of the scapular body and the tip of the scapular spine[45].

By implementing the Freidman measurement technique, the angle between the glenoid plane line and a perpendicular to the transverse scapular axis[5] is used to calibrate the glenoid version at the mid-axial slice or slightly below the level traversing coracoid tip (Fig. 7). Retroversion is more pronounced in arthritic glenoids than in sound ones[46,47]. The coracoid tip level is typically not constant due to the debatable version measurement level; therefore, relying on the mid-axial level for assessment may be more representative[48]. The prosthetic version and postoperative clinical outcome as well as ROMs have not been inextricably linked in recent studies[3,49,50]. More retroversion may be associated with improved IR. After inclined bone-cement interface micromotion, prosthesis longevity may be hampered by >10° retroversion. Generally speaking, a neutral or <10° retroverted glenoid is preferred[49,50].

The evaluation of the glenoid vault depth before surgery aids in preoperative planning and directs the necessary amount of intraoperative lateralization. A perpendicular line drawn from the endosteal wall to the center of the glenoid endosteal face represents the depth of the glenoid vault (Fig. 7). For normal and arthritic glenoids, respectively, Poon et al. reported an average depth of 24 ± 3 mm and 20 ± 5 mm[46]. For the screws that anchor the metaglene to be purchased appropriately, there must be sufficient bone stock. Between the glenoid articular surface and the area where the glenoid narrows at the scapular neck, there should be at least 2 cm of space available centrally[51].

By dividing the percentage of the humeral head behind the Freidman line relative to the widest part of the head, one can estimate the humeral head subluxation using the humeral head subluxation index (HSI) (Fig. 7) as reported by Badet et al[52,53]. 45% and 55%, respectively, are the currently recognized HSI cut-off values for anterior and posterior subluxations[52]. Patients with advanced glenohumeral osteoarthritis and excessive glenoid retroversion typically exhibit subluxation[52,54]. Assessment of humeral subluxation can inform treatment choices, forecast results, and evaluate realignment techniques[55,56].

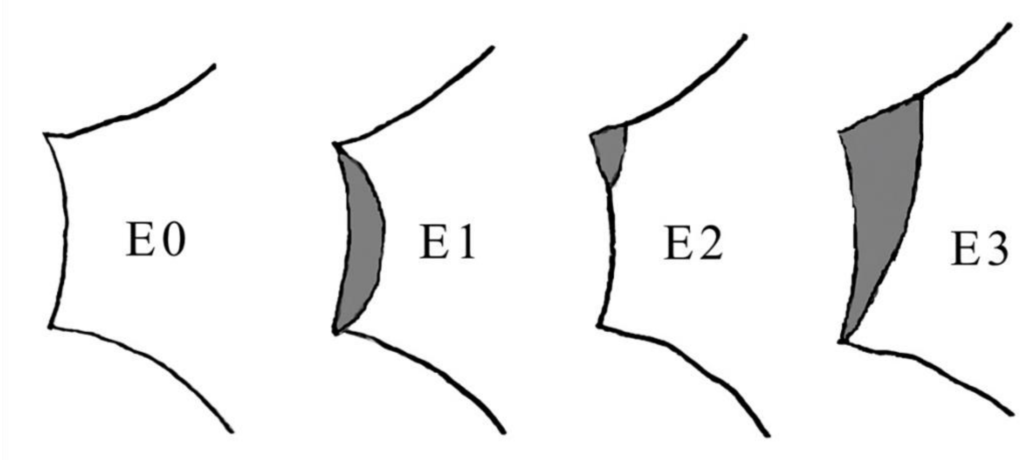

Figure 1. Habermeyer classification of glenoid coronal inclination. **(A)** Type 0: parallel lines, **(B)** Type 1: intersection of the lines below the glenoid, **(C)** Type 2: intersection at glenoid level, and **(D)** Type 3: intersection above the coracoid[57].

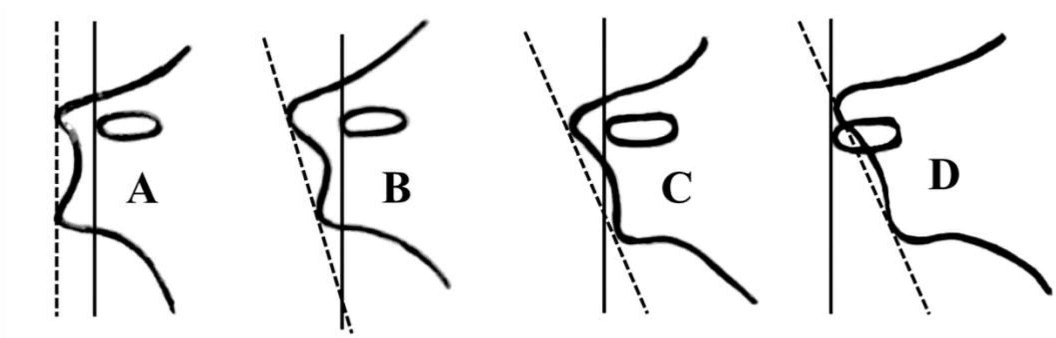

Figure 2. Favard classification of superior glenoid deficiency. **E0:** Superior migration with no erosion, **E1:** Concentric glenoid erosion, **E2:** Superior glenoid erosion, and **E3:** Progression to inferior glenoid erosion[57].

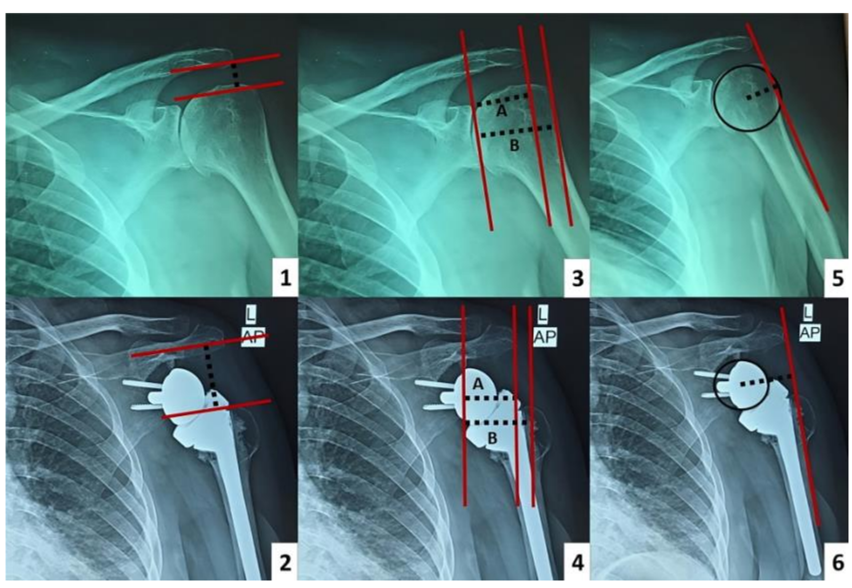

Figure 3. (A, B) shows pre- and postoperative global inclination angles, **(C, D)** shows pre- and postoperative CSA, and **(E, F)** shows pre- and postoperative LAA.

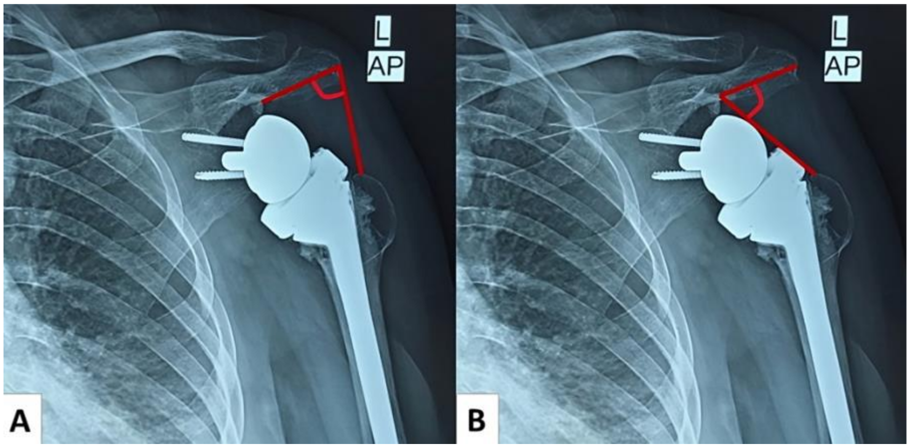

Figure 4. Preoperative **(A)** and postoperative radiographs **(B)** of RSA angles measured between the dotted and vertical red lines.

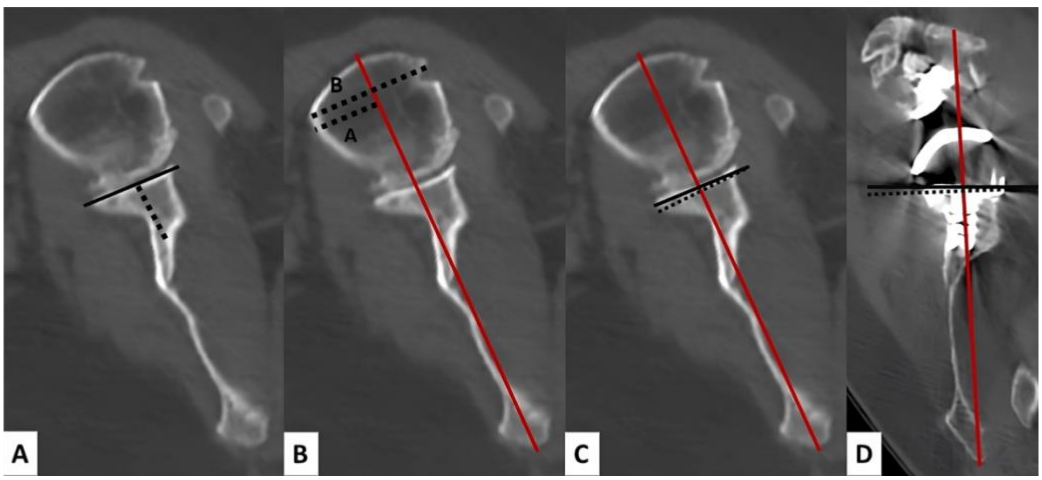

Figure 5. (1,2): pre- and postoperative AHI (black dotted line), **(3.4):** pre- and postoperative AI calculated as a net result of A/B distance, and **(5.6):** pre- and postoperative deltoid lever arm measured to COR (black dotted line).

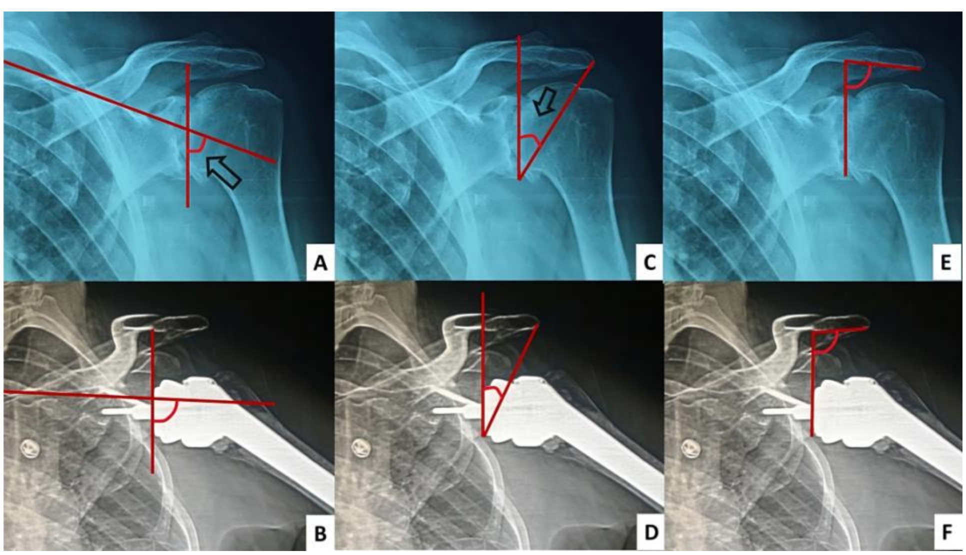

Figure 6. Postoperative radiographs showing **(A)** LSA and **(B)** DSA.

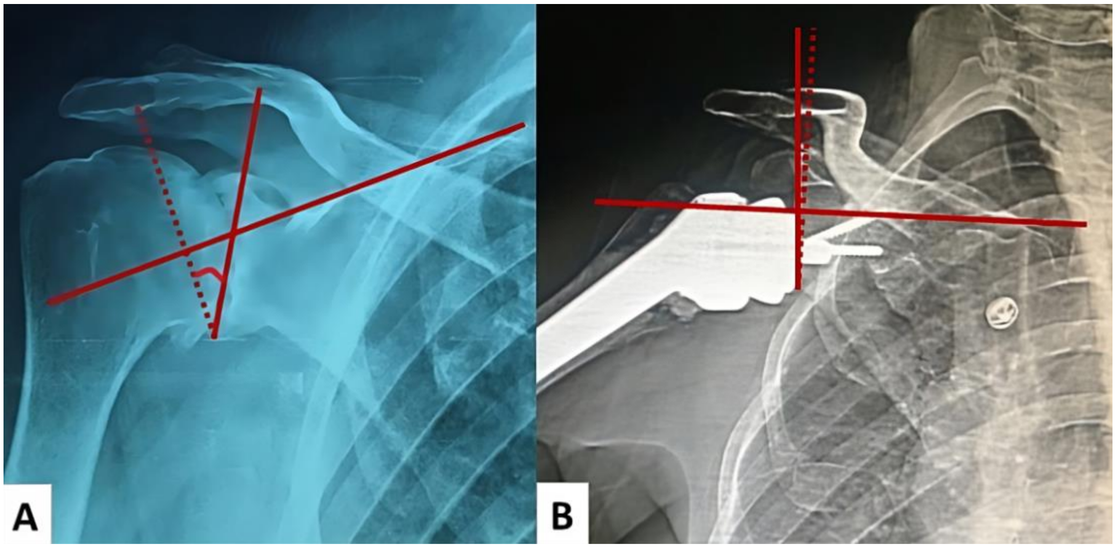

Figure 7. CT midaxial slice showing; **(A)** glenoid vault depth, **(B)** humeral subluxation index calculated as A/B distances, **(C)** glenoid version angle measured between the two black lines, and **(D)** version of glenoid component measured the two black lines.

CONCLUSIONS

Preoperative and postoperative radiological evaluation of RSA is thought to be significant and helpful. A radiographic evaluation can yield important details about bone stock, soft tissue integrity, joint stability, and implant placement. It can also be used to evaluate side effects like fractures, instability, notching, or component loosening. Utilizing cutting-edge imaging methods like CT can improve the assessment's accuracy even more. Ultimately, the success of RSA depends on a comprehensive radiological evaluation.

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