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Glenoid lateralization in reverse shoulder arthroplasty: metal vs. bone offset in different implant designs

Thomas Wittmann, MD[a,b,*], Patrick J. Denard, MD[c,d], Brian C. Werner, MD[e], Patric Raiss, MD[a]

[a]OCM Clinic, Department for Shoulder and Elbow Surgery, Munich, Germany
[b]Department of Orthopaedics and Trauma Surgery, Musculoskeletal University Center Munich (MUM), LMU University Hospital, LMU Munich, Munich, Germany
[c]Department of Orthopaedic & Rehabilitation, Oregon Health & Science University, Portland, OR, USA
[d]Oregon Shoulder Institute, Medford, OR, USA
[e]Department of Orthopaedic Surgery, University of Virginia, Charlottesville, VA, USA

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Background: Higher bone or metal glenoid offset in reverse shoulder arthroplasty (RSA) reduces scapular notching, improves range of motion (ROM), and reduces postoperative instability. This retrospective multicenter study compared two implant designs to evaluate the short-term clinical and radiologic results of bone increased offset RSA (BIO-RSA) and metal increased offset RSA (MIO-RSA) in reverse shoulder. We hypothesized no difference between groups.

Methods: This study analyzed n = 62 BIO-RSA and n = 90 MIO-RSA cases with a mean follow-up of 29.7 ± 6.0 months (BIO-RSA, range 24-49 months) and 24.0 ± 1.1 months (MIO-RSA, range 22-28 months). A 145°-onlay humeral stem was utilized in BIO-RSA cases, while a 135°-semi-inlay humeral stem was implanted in all MIO-RSA cases. Preoperative and postoperative radiologic imaging was reviewed to identify signs of scapular notching. Additionally, lateralization was evaluated according to Erickson et al. The constant score, subjective shoulder value, and ROM were evaluated during the baseline and follow-up consultations, and the findings of both groups were subsequently compared.

Results: Scapular notching was observed in 7.0% (n = 8) of MIO-RSA cases and 8.1% (n = 5) of BIO-RSA cases ($P = .801$). MIO-group had a higher lateralization angle ($P = .020$) and the BIO-group had a higher distalization angle ($P = .005$). At baseline, mean constant score in the MIO-RSA group was higher than in the BIO-RSA group ($P < .001$), and it significantly increased to 67.8 ± 12.1P (MIO-RSA) and 69.5 ± 12.3P (BIO-RSA) to a similar level ($P = .399$). ROM improved in both groups with no significant difference between the two groups at follow-up.

Conclusion: BIO-RSA and MIO-RSA in two distinct implant designs provide comparable short-term outcomes with a similar increase in shoulder function with notable variations in the lateralization and distalization angles between both implants. Scapular notching was rarely seen and unaffected by the method of glenoid lateralization. Follow-up investigations of both techniques are necessary to complement and track changes in the long-term outcome.

Reverse shoulder arthroplasty (RSA) has proven to be an effective treatment option for a variety of degenerative and traumatic shoulder disorders.[3,4] Especially in cases with irreparable major cuff tears, cuff tear arthropathy, or primary osteoarthritis with severe bone loss, RSA is the recommended approach for restoring shoulder function.[8,26]

Traditionally, RSA medializes the rotational center and distalizes the humerus to improve the deltoid lever arm.[5,8] Although investigations reported significantly improved shoulder function, a growing number of problems were observed in the long term.[1,2,4,9,27,28] As a result of the medialized rotational center combined with a high neck-shaft angle (NSA), the early generations of RSA systems suffered from a very high risk for mechanical impingement between the prosthesis and the inferior pillar of the scapular neck resulting in bone loss on follow-up imaging (scapular notching) and polyethylene wear.[9,27,29] Shah et al recently

The institutional review board of the Bavarian medical chamber ethics committee (IRB Nr. 22003) approved this study.

This study was conducted at the OCM Clinic, Munich, Germany.

*Corresponding author: Thomas Wittmann, MD, Department of Orthopaedics and Trauma Surgery, Musculoskeletal University Center Munich (MUM), LMU University Hospital, LMU Munich, Marchioninistraße 15, Munich 81377, Germany.

E-mail address: th-wittmann@gmx.de (T. Wittmann).

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conducted a systematic review of 113 studies from 2010 to 2018 involving 8258 cases and reported a scapular notching rate of 27.6% in a 5-year follow-up period, which climbed to 43.4% with a longer follow-up of more than 5 years.[27] Apart from the increasing rate over time and the adverse bone loss on the glenoid, scapular notching was also associated with a poorer clinical outcome.[27,29]

Consequently, various strategies were suggested for addressing the issue of scapular notching.[8,9,13,16,27,31,32] For instance, the implementation of a lower 135° or 145° NSA compared to the original 155° NSA Grammont-style lowers the risk of notching on the scapula neck.[9,31,32] Different biomechanical and clinical studies have demonstrated a decreased prevalence of scapular notching in combination with a wider impingement-free range of motion (ROM) for this approach.[9,31,32] Alternatively, lateralization of the rotational center on the glenoid side has been shown to lower the likelihood of early bone impingement while enhancing the lever and moment arm and probably optimizing activation of the anterior and posterior muscle fibers of the deltoid.[8,9,13,16,27] Glenoid lateralization can be accomplished with either a bone graft between the baseplate and the native glenoid surface (bony increased offset [BIO]) or metallically lateralized baseplates and glenospheres with an incorporated increased offset (metal increased offset [MIO]).[11,12,16,18,30] For the implantation of increased offset components, the native glenoid bone must be reamed to suit the baseplate, while for bony increased offset, an autologous bone graft is typically harvested from the humeral head and contoured to address bone deficiencies with minimal to no reaming.[11] Although bone grafts have high adaptability, final stability of the glenoid component depends on their healing into the native bone stock.[11,12,16] Good long-term results of BIO-RSA have been reported, and studies on MIO-RSA with positive short-term outcomes have been published recently.[12,16,18,30] However, there is still a lack of information about potential differences in clinical and radiological outcomes between MIO-RSA and BIO-RSA in different implants. Thus, the purpose of this retrospective study was to compare both techniques in two distinct implant designs with a minimum of a 24-month follow-up. We hypothesized that the clinical and radiological outcomes of both techniques and implants were equal.

Materials and methods

Study design, case inclusion, and data collection

This study is a retrospective, multicenter comparative study with two nonconsecutive case cohorts who underwent RSA with either a bone or metal increased glenoid offset and with a minimum 24-month follow-up. All data was collected prospectively and analyzed retrospectively. Patients with BIO-RSA underwent surgery at one specialized shoulder center in Munich (Germany) and were registered in an anonymous institutional database. Cases with MIO-RSA were available for review in a prospective multicenter registry (ShARC database, Arthrex Inc., Naples, FL, USA) and were treated at multiple shoulder centers. The institutional review board of the Bavarian medical chamber ethics committee (IRB Nr. 22003) approved this study.

All available BIO-RSA cases between January 2017 and December 2020 were reviewed, and the following inclusion and exclusion criteria were applied. All cases with (1) a primary osteoarthritis, cuff tear arthropathy, or massive cuff tears who underwent (2) primary RSA with (3) bony increased glenoid offset and a (4) minimum of +6 mm glenoid lateralization using (5) the same uncemented RSA system (Ascend Flex Shoulder System; Stryker, Kalamazoo, MI, USA) with (6) complete clinical and radiologic follow-up of more than 24 months were included. Cases with (1) different implant systems, (2) without bony increased glenoid offset, (3) other indications for a shoulder replacement, (4) revision cases, (5) infections, (6) acute fractures, (7) neurologic diseases, or (8) rheumatic diseases were excluded.

Subsequently, suitable MIO-RSA cases were identified in the prospective multicenter registry using the same inclusion criteria. Only a different uncemented short RSA system (Univers Apex; Arthrex Inc., Naples, FL, USA) with lateralized glenoid components (Modular Glenoid System; Arthrex, Inc., Naples, FL, USA) with a minimum glenoid offset of +6 mm was implemented as inclusion criteria for MIO-RSA cases. To assure comparability with the BIO-RSA cohort, cases with a glenosphere diameter of 33 mm were excluded since they were not implanted in the BIO-group.

Initially, a total of n = 138 BIO-RSA cases were available, and after the application of the inclusion criteria, n = 62 BIO-RSA cases and further n = 90 MIO-RSA cases were included in this study.

Surgical technique

In all cases, a deltopectoral approach with soft-tissue tenodesis of the long head of the biceps was performed, while the subscapularis was managed per surgeon discretion. Lateralization was preoperatively planned according to glenoid morphology and reevaluated intraoperatively by each surgeon. In all cases that met the specified indications for RSA, a lateralization of either metal or bone was performed with a minimum intended lateralization of +6 mm.

For BIO-RSA, the Ascend Flex short stem (Wright Medical, Memphis, TN, USA) with a fixed inclination angle of 145° and the Reversed II glenoid system with a 25 mm central peg (Wright Medical, Memphis, TN, USA) were implanted. A bone graft was harvested from the humeral head using a cutting guide and shaped to address eccentric bone defects.[11] In each case, the bone graft had a thickness of +10 mm, which resulted in a total offset of approximately +7 mm after the shaping process. Before implanting the final components, the subchondral bone was lightly reamed, and penetration holes were drilled to facilitate ingrowth. The baseplate was positioned flush to the inferior glenoid border with a 10° inferior tilt respecting the reverse shoulder angle. The component was fixed by two compression and two locking screws. Subsequently, a nonlateralized glenosphere with a diameter of 36-42 mm was placed based on surgeon discretion, humeral size, glenoid size, and soft tissue tension.

In all MIO-RSA cases, the uncemented Apex short stem system (Univers Apex; Arthrex, Inc., Naples, FL, USA) with a fixed 135° stem inclination was utilized. The accompanying baseplate and glenospheres offer a variety of metallic lateral offset options from 0 mm to 8 mm in 2 mm increments. Central fixation can be accomplished with a screw or a variable-length post. The ultimate lateralization and optimal baseplate contact were determined by the surgeon's preference. Humeral spacers can be utilized in this system to augment humeral distalization after humeral stem impaction to improve stability and soft tissue tension.

Both implants have distinct geometric and design characteristics. Comparatively, the neck shaft angle of the Apex system (Arthrex, Inc., Naples, FL, USA) is lower in comparison to that of the Ascend Flex system (Stryker, Kalamazoo, MI, USA). Combining the Apex stem with glenoid components and a baseplate without an integrated offset provides a broad variety of lateral offset options,

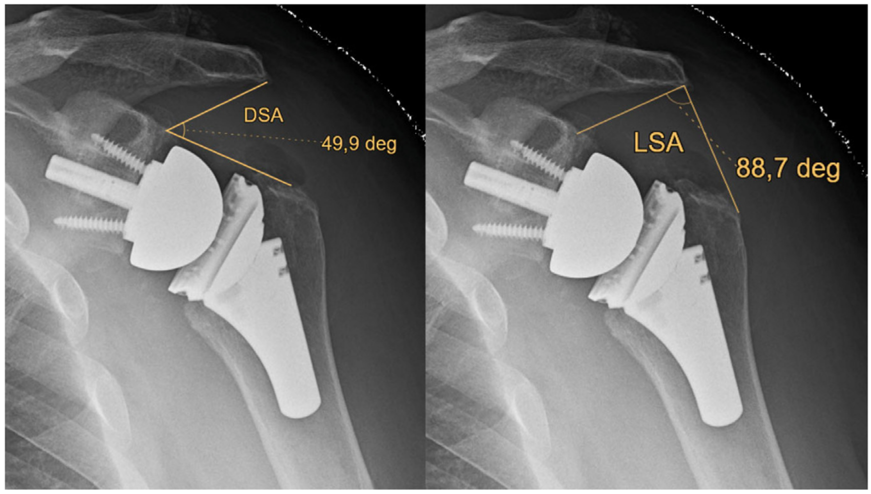

Figure 1 Reverse shoulder arthroplasty with metal increased glenoid offset (MIO-RSA) using the Apex shoulder system (Arthrex Inc.) with measurement of the lateralization angle (LSA) and distalization angle (DSA).

ranging from 20.7 mm to 30.8 mm (with a range of 10.1 mm) for the Ascend flex system (with a range of 24.5 mm to 41.5 mm and a range of 17 mm).[32] In comparison to the 8 mm lateral offset of the apex stem, the Ascend Flex system offers a 14.2 mm lateral offset of the humerus.[32] The overall lateral offset increases in proportion to the sum of the lateral offsets incorporated into each system and the lateral offset applied to the glenoid when either metal (MIO) or bone (BIO) is utilized to increase glenoid offset.

Clinical and radiologic evaluation

All patients underwent and completed preoperative and follow-up clinical and radiologic examinations performed at each study center. Clinical shoulder function was evaluated at each center by the treating surgeon using the Constant-Murley Score (CS), the Subjective Shoulder Value or the Single Assessment Numeric Evaluation at baseline and at follow-up.[14] Active ROM with forward flexion, and external rotation was measured at each consultation by a fellowship-trained shoulder surgeon using a goniometer.

True anterior-posterior radiographs were examined for graft healing in BIO-RSA cases, signs of scapular notching according to Sirveaux et al and lateralization was measured according to Erickson et al.[17,29] The latter method involves measuring the lateralization (LSA) and distalization (DSA) shoulder angles (Fig 1) as well as the distance between (3) the most lateral point of the glenosphere and (2) the lateral edge of the acromion. In addition, the distances between (4) the native glenoid joint line and the lateral border of the acromion as well as (2) the lateral acromion and (1) the most lateral aspect of the greater tuberosity were determined (Fig 2). Glenoid erosion in cases with primary osteoarthritis was assessed according to Walch et al, and the classification according to Sirveaux et al was used for cases with cuff tear arthropathy.[7,29]

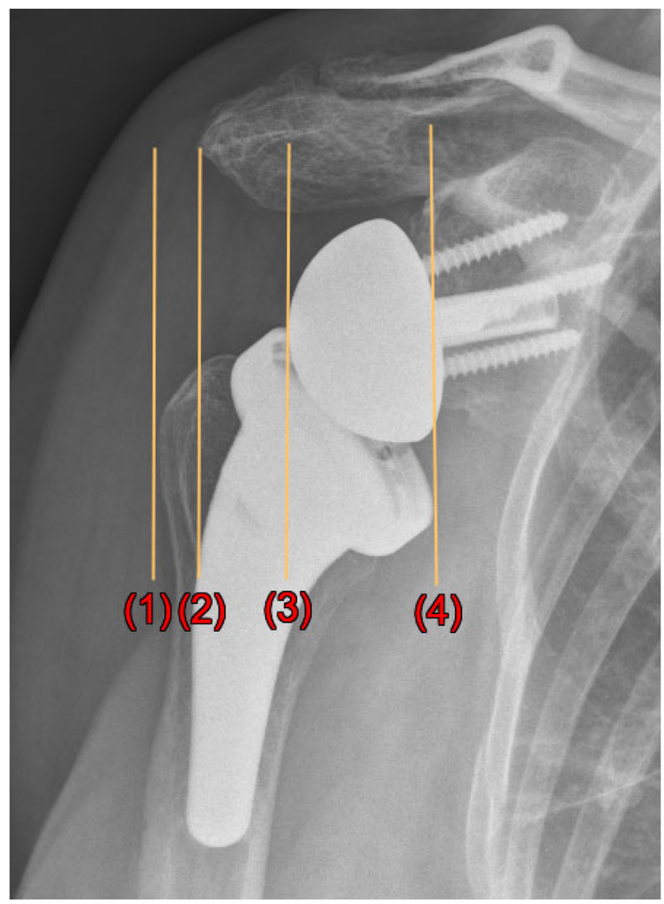

Figure 2 Bony increased offset with an autologous bone graft and the Ascend shoulder system (Wright Medical, Stryker). Lateralization is measured according to Erickson et al.[17] (1 = greater tuberosity, 2 = lateral edge acromion, 3 = lateral edge glenosphere, 4 = native glenoid joint line).

Statistics

Continuous variables such as age, PROs, ROM, and radiographic parameters were analyzed using student's T tests. The categorical variables including sex and glenosphere diameter were analyzed with chi-square tests. All statistical analyses were performed in SPSS version 28 (IBM Corp., Armonk, NY, USA). For all comparisons, $P < .05$ was considered significant.

Table I
Patient demographics and implant variables.

Variable	Metallic lateralization (n = 90)		Bony lateralization (n = 62)		*P*
Patient demographics					
Age (years, Std. Dev.)	69.3	7.5	74.7	7.9	<.001
Sex: male (n, %)	72	80.0%	20	32.3%	<.001
Glenosphere diameter					
36 mm (n, %)	23	25.6%	46	74.2%	<.001
39 mm (n, %)	45	50.0%	3	4.8%	<.001
42 mm (n, %)	22	24.4%	13	21.0%	.617

Table II
Clinical outcome measurements (PROs) and range of motion (ROM) at baseline and follow-up.

Variable	Metallic lateralization (n = 90)		Bony lateralization (n = 62)		*P*
	Mean	Std. Dev.	Mean	Std. Dev.	
Baseline					
Constant (P)	33.3	11.8	21.9	10.0	<.001
SANE/SSV (%)	31.1	19.9	23.8	9.7	.008
Active FF (°)	91°	32°	76°	40°	.011
Active ER at Side (°)	26°	18°	14°	17°	<.001
2 Year postop					
Constant (P)	67.8	12.1	69.5	12.3	.399
SANE/SSV (%)	78.1	22.3	77.1	15.6	.761
Active FF (°)	138°	23°	144°	25°	.129
Active ER at Side (°)	46°	16°	51°	17°	.067

SANE, Single Assessment Numeric Evaluation; *SSV*, Subjective Shoulder Value; *FF*, forward flexion; *ER*, external rotation.

Results

A total of 152 cases with either BIO-RSA (n = 62) or MIO-RSA (n = 90) were included in the study. Patient demographics differed significantly in patient age and sex (Table I). The BIO-RSA group consisted of n = 8 cases with an A1 glenoid, n = 4 cases with an A2 glenoid, n = 6 cases with a B1 glenoid, and n = 5 cases with a B2 glenoid.[7] Additionally, n = 18 cases were classified as E0, n = 11 cases were classified as E1, n = 5 cases were classified as E2, n = 1 case was classified as E3, and n = 4 cases were classified as E4.[29] In the MIO-RSA group, n = 30 cases exhibited an A1 glenoid, n = 5 cases had an A2 glenoid, n = 10 cases had an B1 glenoid, n = 21 cases had a B2 glenoid, n = 18 cases were classified as E0, and n = 6 cases had an E1 glenoid.[7,29]

Mean follow-up was 29.7 ± 6.0 months (BIO-RSA, range 24-49 months) and 24.0 ± 1.1 months (MIO-RSA, range 24-28 months). N = 49 MIO-RSA cases had a +4 mm glenosphere and +2 mm baseplate resulting in a total metallic lateralization of +6 mm. The remaining n = 41 cases had a +4 mm glenosphere and +4 mm baseplate for a total lateralization of +8 mm.

The mean constant score was preoperatively higher in the MIO-RSA group (mean $CS_{MIO\text{-}RSA}$ = 33.3P ± 11.8P; mean $CS_{BIO\text{-}RSA}$ = 21.9P ± 10.0P; $P < .001$) and increased in both groups to the follow-up examination (mean $CS_{MIO\text{-}RSA(FU)}$ = 67.8P ± 12.1P; mean $CS_{BIO\text{-}RSA(FU)}$ = 69.5P ± 12.3P). A difference in constant score was observed at follow-up, which was not statistically significant ($P = .399$). At baseline evaluation, mean forward flexion ($P = .011$) and external rotation ($P < .001$) were higher in the MIO-RSA cohort and increased significantly in both groups to a similar level without significant differences (Table II). Mean Subjective Shoulder Value and Single Assessment Numeric Evaluation was preoperatively higher in the MIO-RSA group ($P = .008$) and reached an equal level at follow-up ($P = .761$).

Scapular notching was observed in 7.0% (n = 8) of MIO cases and in 8.1% (n = 5) of BIO cases ($P = .801$). Mean lateralization (mean $LSA_{MIO\text{-}RSA}$ = 88° ± 10°; mean $LSA_{BIO\text{-}RSA}$ = 84° ± 10°; $P = .020$) and distalization angles (mean $DSA_{MIO\text{-}RSA}$ = 45° ± 9°; mean $DSA_{BIO\text{-}RSA}$ = 49° ± 10°; $P = .005$) significantly differed between the two groups. There was no significant difference observed in the distance between the greater tuberosity and the glenoid joint line between the two study groups ($P = .590$). The BIO-RSA group had a greater distance between the lateral edge of the acromion and the glenosphere ($P = .011$), while the MIO-RSA group had a greater distance between the lateral edge of the acromion and the greater tuberosity ($P < .001$) (Table III).

At follow-up, no baseplate or stem loosening were registered in both groups. Bone grafts in all BIO-RSA cases showed full healing. In the BIO-RSA group, two patients had a periprosthetic fracture and were revised to a longer stem. One patient had a superficial hematoma and another had a superficial infection, both treated without removing the implant. Another patient had a nondisplaced acromial stress fracture managed conservatively four months post-surgery. In the MIO group, one patient had a postoperative hematoma treated without revising the prosthesis. There was one case of pulmonary embolism and one acromion fracture, both managed conservatively. No revisions or complications related to the glenoid component were observed in the MIO group's case cohort.

Discussion

This retrospective comparative study examined two distinct implant designs with increased bone or metal offset and revealed similar improved shoulder function paired with good radiographic outcomes regardless of the method chosen for increased glenoid offset. Both evaluated implants represent the latest RSA implant generation that intend to improve ROM and minimize scapular notching.[2,4,29]

The Grammont prosthesis, with a NSA of 155° and a medialized rotational center, yielded a favorable long-term outcome, although rising incidence of scapular notching were observed.[2,4,5,8,27] To address this issue, implants with a higher glenoid offset and a lower NSA to lateralize the rotating center and humerus have been devised.[5,8,32] In lateralized designs, the improved biomechanics enhanced not only impingement-free ROM but also torque and shear forces on the glenoid component, potentially increasing the risk of loosening.[6,8,10,25] Rojas et al reviewed 103 studies involving a total of 6583 reverse arthroplasties and reported a pooled rate of 1.16% for aseptic baseplate loosening.[25] A subsequent meta-regression analysis revealed many risk factors, but a greater glenoid offset was not associated with baseplate loosening. Similar findings were reported by Bitzer et al, who retrospectively examined 202 RSAs and found no connection between glenoid offset and aseptic baseplate loosening.[10]

Increased glenoid offset is currently achieved with either bone autografts or offset-increased components.[11,12,18,30] BIO-RSA was first proposed by Boileau et al, who utilized an autologous bone graft from the humeral head to lateralize the rotational center.[11,12] Particularly for eccentric glenoid erosion, this technique offers a bone-conserving method as extensive reaming is not required to achieve proper posterior component seating. The initial analysis of n = 42 BIO-RSAs revealed an improved shoulder function and no baseplate failures. Despite these favorable short-term outcomes, scapular notching was still observed in 19% of cases.[11] Recently, the same research group published the long-term findings of n = 140 BIO-RSA cases.[12] With a mean follow-up of 75 months, no baseplate failures were observed but the incidence of scapular notching increased to 56%.[11,12]

Table III
Comparison of radiographic lateralization measurements in both groups.

Variable	Metallic lateralization		Bony lateralization		*P*
	Mean	Std. Dev.	Mean	Std. Dev.	
Lateralization shoulder angle (LSA,°)	88°	10°	84°	10°	.020
Distalization shoulder angle (DSA,°)	45°	9°	49°	10°	.005
Acromion-glenosphere distance (mm)	13.6	5.8	15.8	4.3	.011
Glenoid - GT distance (mm)	51.9	5.9	51.4	6.1	.590
Acromion - GT distance (mm)	12.1	6.3	8.8	5.2	<.001

GT, greater tuberosity.

Graft healing is crucial for BIO-RSA, and there remains a risk of bone resorption or stress shielding.[11,12,16,22] Merolla et al conducted a comprehensive study comparing the radiographic and clinical outcomes of n = 44 BIO-RSA cases and n = 39 MIO-RSA cases.[22] While both groups exhibited a similar outcome, the study revealed a graft healing rate of only 63% after an average follow-up of 35.9 months. The authors consequently raised concerns about following baseplate failures, which were previously associated to graft resorption.[22] In contrast, all BIO-RSA cases in our study demonstrated full graft healing, which aligns with the outcomes published by Boileau et al with a healing rate of 98% at the two-year follow-up and 96% in the long-term follow-up.[11,12]

Modern implant systems provide increased offset components that lateralize the joint line without prior bone grafting. Furthermore, Denard et al reported fewer micromotions with metallic lateralization compared to BIO-RSA in their 3D finite element analysis of stress loads and micromotions in BIO- and MIO-RSA configurations.[15] Therefore, the utilization of MIO-components may reduce baseplate loosening in the long term while simultaneously eliminating the possibility of graft resorption.[15,18,22,30]

Positive short-term outcomes for MIO-RSA have already been described at this time.[18,19,30] Imiolczyk et al assessed n = 42 MIO-RSA cases with an 145° NSA onlay stem with a mean follow-up of 24.8 months.[18] In this study, shoulder function improved significantly, and neither baseplate loosening nor scapular notching were observed. Katz et al examined the effect of metal increased glenoid offset on the clinical and radiological outcome of n = 140 RSA cases with a mean follow-up of 45 months utilizing a 135° neck shaft angle stem.[19] Shoulder function improved significantly compared to baseline; however, scapular notching was found in 29% of cases at final follow-up. Van de Kleut et al published a comparative analysis of wedge-augmented lateralized baseplates against BIO-RSA with a short-term follow-up.[30] In this study, n = 41 RSAs had no differences in the clinical and radiologic outcome two years after the procedure were reported with a low incidence of scapular notching in only 3 cases.

In our study, two distinct implant systems with either an increased bone or metal glenoid offset and different NSA were examined, and the prevalence of scapular notching was low in both groups. Despite significant disparities between both groups at baseline, shoulder function improved noticeably in both groups at follow-up to a comparable level, as documented in studies of a similar kind.[11,12,18,19,22,23,30] In a comparative analysis, Merolla et al evaluated n = 36 cases with Grammont-style inlay prostheses with a 155°-NSA and n = 38 cases with a modern onlay short stem with a NSA of 145°.[23] Although no differences in constant score or rate of complications between both groups were found, scapular notching was seen less frequently in the short stem component with a lower NSA (39% Grammont style prosthesis vs. 5% lateralized short stem). Our case-series evaluation found no significant difference in the occurrence of scapular notching between the two different humeral stem geometries. However, both designs had a lower NSA compared to the Grammont design, which may account for the observed results.

In previous studies, increased distalization and lateralization in RSA was associated with stress fractures and nerve injuries, thus necessitating cautious application.[20,21,24] In this study, the acromion-greater tuberosity distance of the onlay group was only 4 mm higher than that of the inlay group with a comparable degree of total lateralization. Despite observing greater distalization in the BIO-RSA group, the incidence of acromial stress fracture was found to be equivalent in both groups. Still, distalization was not measured objectively in this study.

Components with built-in offset provide options for humeral and glenoid-sided lateralization without the need for additional bone grafting. Still, autologous bone grafts can be shaped to address individual glenoid bone loss while also implementing the required lateralization. Our study revealed that MIO-RSA and BIO-RSA in two distinct implant designs exhibit comparable clinical and radiological short-term outcomes, with a negligible occurrence of scapular notching and no evidence of loosening. To identify cases that are suitable for each technique and maximize its benefits, cases must be examined preoperatively and intraoperatively for glenoid erosion and bone deformities. Preoperative planning software can help the surgeon select appropriate cases and determine the best graft size or metal offset for each specific instance.

The study's retrospective methodology and evaluation of two different implant systems are the primary limitations that restrict the generalizability of its conclusions. The examination concentrated exclusively on the short-term clinical and radiographic outcomes. Therefore, long-term variations cannot be inferred due to the potential increase in scapular notching or complications. Standardizing the increase in offset in cases involving a bony defect and an individually shaped bone allograft presents a challenge. Hence, the application of lateralization during the intraoperative procedure may have exhibited variability within the BIO-RSA cohort. The implant systems demonstrated variability in their design, geometry, and size options, together with discrepancies in the extent of humeral lateralization applied, which imposes limitations on the generalizability of the results. Furthermore, the investigation did not include an assessment of glenoid erosion in either of the cohorts. Each surgeon evaluated the lateralization necessary and intraoperative glenoid reaming in a subjective manner, taking into account the specific degree of bone loss. Finally, the study protocol did not evaluate either the healing of bone grafts or the phenomenon of stress shielding.

This study analyzed a significant number of cases with increased metal and bony offset in two comparable groups with a minimum follow-up period of two years. The surgical procedure used in all cases was consistent and performed by specialized shoulder surgeons at different shoulder centers. In summary, this study provided preliminary findings of potential differences in the clinical and radiographic short-term outcomes between MIO-RSA and BIO-RSA.

Conclusion

The study evaluated two distinct implant designs and identified notable variations in the lateralization distalization angle. The incidence of scapular notching was minimal and remained unaltered by the surgical approach used for glenoid lateralization. Although these short-term results are similar, each method offers distinct surgical benefits. The utilization of a shaped bone allograft presents a viable alternative for addressing eccentric bone erosion on the glenoid without necessitating extensive reaming or significant bone loss. The increased offset components have the potential to reduce the risk of malunion or resorption of the bone graft. However, further investigations are necessary to assess the long-term results and observe subsequent variations in shoulder function or the frequency of complications for both techniques.

Disclaimers:

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References

1. Arenas-Miquelez A, Murphy RJ, Rosa A, Caironi D, Zumstein MA. Impact of humeral and glenoid component variations on range of motion in reverse geometry total shoulder arthroplasty: a standardized computer model study. J Shoulder Elbow Surg 2021;30:763-71. https://doi.org/10.1016/j.jse.2020.07.026.
2. Ascione F, Domos P, Guarrella V, Chelli M, Boileau P, Walch G. Long-term humeral complications after Grammont-style reverse shoulder arthroplasty. J Shoulder Elbow Surg 2018;27:1065-71. https://doi.org/10.1016/j.jse.2017.11.028.
3. Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). Hip, Knee & Shoulder Arthroplasty: 2021 Annual Report. Adelaide; 2021.
4. Bacle G, Nové-Josserand L, Garaud P, Walch G. Long-term outcomes of reverse total shoulder arthroplasty: a follow-up of a previous study. J Bone Joint Surg Am 2017;99:454-61. https://doi.org/10.2106/JBJS.16.00223.
5. 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.
6. Bedeir YH, Grawe BM, Eldakhakhny MM, Waly AH. Lateralized versus non-lateralized reverse total shoulder arthroplasty. Shoulder Elbow 2021;13:358-70. https://doi.org/10.1177/1758573220937412.
7. Bercik MJ, Kruse K, Yalizis M, Gauci M-O, Chaoui J, Walch G. A modification to the Walch classification of the glenoid in primary glenohumeral osteoarthritis using three-dimensional imaging. J Shoulder Elbow Surg 2016;25:1601-6. https://doi.org/10.1016/j.jse.2016.03.010.
8. Berliner JL, Regalado-Magdos A, Ma CB, Feeley BT. Biomechanics of reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2015;24:150-60. https://doi.org/10.1016/j.jse.2014.08.003.
9. Berton A, Gulotta LV, Longo UG, Salvatore Sde, Piergentili I, Bandini B, et al. Medialized versus lateralized center of rotation in reverse total shoulder arthroplasty: a systematic review and meta-analysis. J Clin Med 2021;10:5868. https://doi.org/10.3390/jcm10245868.
10. Bitzer A, Rojas J, Patten IS, Joseph J, McFarland EG. Incidence and risk factors for aseptic baseplate loosening of reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2018;27:2145-52. https://doi.org/10.1016/j.jse.2018.05.034.
11. Boileau P, Moineau G, Roussanne Y, O'Shea K. Bony increased-offset reversed shoulder arthroplasty: minimizing scapular impingement while maximizing glenoid fixation. Clin Orthop Relat Res 2011;469:2558-67. https://doi.org/10.1007/s11999-011-1775-4.
12. 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.
13. Collin P, Liu X, Denard PJ, Gain S, Nowak A, Lädermann A. Standard versus bony increased-offset reverse shoulder arthroplasty: a retrospective comparative cohort study. J Shoulder Elbow Surg 2018;27:59-64. https://doi.org/10.1016/j.jse.2017.07.020.
14. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987:160-4.
15. Denard PJ, Lederman E, Parsons BO, Romeo AA. Finite element analysis of glenoid-sided lateralization in reverse shoulder arthroplasty. J Orthop Res 2017;35:1548-55. https://doi.org/10.1002/jor.23394.
16. Dimock R, FathiElabd M, Imam M, Middleton M, Godenèche A, Narvani AA. Bony increased-offset reverse shoulder arthroplasty: a meta-analysis of the available evidence. Shoulder Elbow 2021;13:18-27. https://doi.org/10.1177/1758573220916848.
17. Erickson BJ, Werner BC, Griffin JW, Gobezie R, Lederman E, Sears BW, et al. A comprehensive evaluation of the association of radiographic measures of lateralization on clinical outcomes following reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2022;31:963-70. https://doi.org/10.1016/j.jse.2021.10.010.
18. Imiolczyk J-P, Audigé L, Harzbecker V, Moroder P, Scheibel M. Metallic humeral and glenoid lateralized implants in reverse shoulder arthroplasty for cuff tear arthropathy and primary osteoarthritis. JSES Int 2022;6:221-8. https://doi.org/10.1016/j.jseint.2021.10.009.
19. Katz D, Valenti P, Kany J, Elkholti K, Werthel J-D. Does lateralisation of the centre of rotation in reverse shoulder arthroplasty avoid scapular notching? Clinical and radiological review of one hundred and forty cases with forty five months of follow-up. Int Orthop 2016;40:99-108. https://doi.org/10.1007/s00264-015-2976-3.
20. Kim HJ, Kwon TY, Jeon YS, Kang SG, Rhee YG, Rhee S-M. Neurologic deficit after reverse total shoulder arthroplasty: correlation with distalization. J Shoulder Elbow Surg 2020;29:1096-103. https://doi.org/10.1016/j.jse.2019.11.014.
21. Kirzner N, Paul E, Moaveni A. Reverse shoulder arthroplasty vs BIO-RSA: clinical and radiographic outcomes at short term follow-up. J Orthop Surg Res 2018;13:256. https://doi.org/10.1186/s13018-018-0955-2.
22. Merolla G, Giorgini A, Bonfatti R, Micheloni GM, Negri A, Catani F, et al. BIO-RSA vs. metal-augmented baseplate in shoulder osteoarthritis with multiplanar glenoid deformity: a comparative study of radiographic findings and patient outcomes. J Shoulder Elbow Surg 2023;32:2264-75. https://doi.org/10.1016/j.jse.2023.04.028.
23. Merolla G, Walch G, Ascione F, Paladini P, Fabbri E, Padolino A, et al. Grammont humeral design versus onlay curved-stem reverse shoulder arthroplasty: comparison of clinical and radiographic outcomes with minimum 2-year follow-up. J Shoulder Elbow Surg 2018;27:701-10. https://doi.org/10.1016/j.jse.2017.10.016.
24. Nabergoj M, Denard PJ, Collin P, Trebše R, Lädermann A. Mechanical complications and fractures after reverse shoulder arthroplasty related to different design types and their rates: part I. EFORT Open Rev 2021;6:1097-108. https://doi.org/10.1302/2058-5241.6.210039.
25. Rojas J, Choi K, Joseph J, Srikumaran U, McFarland EG. aseptic glenoid baseplate loosening after reverse total shoulder arthroplasty: a systematic review and meta-analysis. JBJS Rev 2019;7:e7. https://doi.org/10.2106/JBJS.RVW.18.00132.
26. Rugg CM, Coughlan MJ, Lansdown DA. Reverse total shoulder arthroplasty: biomechanics and indications. Curr Rev Musculoskelet Med 2019;12:542-53. https://doi.org/10.1007/s12178-019-09586-y.
27. Shah SS, Gaal BT, Roche AM, Namdari S, Grawe BM, Lawler M, et al. The modern reverse shoulder arthroplasty and an updated systematic review for each complication: part I. JSES Int 2020;4:929-43. https://doi.org/10.1016/j.jseint.2020.07.017.
28. Shah SS, Roche AM, Sullivan SW, Gaal BT, Dalton S, Sharma A, et al. The modern reverse shoulder arthroplasty and an updated systematic review for each complication: part II. JSES Int 2021;5:121-37. https://doi.org/10.1016/j.jseint.2020.07.018.
29. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br 2004;86:388-95. https://doi.org/10.1302/0301-620x.86b3.14024.
30. vandeKleut ML, Yuan X, Teeter MG, Athwal GS. Bony increased-offset reverse shoulder arthroplasty vs. metal augments in reverse shoulder arthroplasty: a prospective, randomized clinical trial with 2-year follow-up. J Shoulder Elbow Surg 2022;31:591-600. https://doi.org/10.1016/j.jse.2021.11.007.
31. 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.
32. 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.