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Clinical and radiological comparison of three different reverse shoulder arthroplasty designs for patients with primary osteoarthritis

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Abstract

Aims In reverse shoulder arthroplasty (RSA), different implant designs range from medializing implants to strongly lateralizing onlay designs with different neck-shaft-angles (NSA). Thus different degrees of lateralization are currently used. Aim of this study was to compare clinical and radiological outcomes of three different implant designs in a homogeneous patient cohort with primary osteoarthritis (OA).

Methods Patients with OA who underwent RSA between 03/2014 and 01/2020 were included and categorized into three groups based on RSA design: group MD (medialized-distalized design: eccentric glenosphere, 155° NSA), group L (lateralized design: + 4 mm centric glenosphere, 135° NSA), group LD (lateralized-distalized design: eccentric glenospheres, + 3 mm baseplate, curved onlay stem 145° NSA). Inclusion criteria were complete clinical and radiological 24 months follow-up (FU) including range of motion (ROM), Constant-Murley score (CS), Subjective Shoulder Value (SSV). In addition, scapular notching and adverse events were recorded.

Results Group MD including 26 patients (81% female; mean age: 77.9 years) reached 71 (range: 60–85) points in CS and 90% (range: 40–100) in SSV. In group L, 46 patients (98% female; mean age: 75.2 years) achieved a CS of 75 (59–85) points and SSV was 95% (60–100). In group LD, 25 patients (68% female; mean age: 76.3 years) presented a CS of 79 (30–100) points and SSV of 93% (50–100). Group L and group LD achieved significantly better abduction, internal and external rotation ($p < 0.001$), forward flexion ($p = 0.023$) and SSV ($p = 0.046$). Scapular notching was present in 22% of MD patients (13% grade 1; 4% grade 2; 4% grade 4), 16% in group L (all grade 1) and 9% in group LD (all grade 2). No prosthesis related complication occurred in any group.

Conclusion In patients with primary OA, the lateralized and lateralized-distalized designs result in superior subjective satisfaction in SSV and improved ROM in all planes compared to the traditional distalized-medialized implant designs. In all three groups, no implant related complications were noted.

Keywords Metal, Lateralization, Bipolar, Baseplate, Offset, Eccentric, Centric, 135, 145, 155

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Introduction

Reverse shoulder arthroplasty (RSA) has gained acceptance as a reliable treatment for patients with cuff arthropathy and primary osteoarthritis (OA) due to current advancements in design [1–3]. In contrast, anatomic systems are utilized for rare indications [4, 5].

To address common issues from previous decades, such as instability and scapular notching, associated with RSAs designed based on Paul Grammont principles [6, 7], lateralization has been introduced. This advancement has successfully resolved these problems while also significantly enhancing range of motion (ROM) [4, 8–11]. Lateralization on the glenoid side has been achieved by increasing the size or offset of the glenosphere or baseplate using metal or bony augmentation [5, 12–14]. However, by shifting the center of rotation more laterally, shearing forces in elevation and abduction increase [15], resulting in greater acromial stress [16, 17] and shearing stress onto the glenoid, which can result in scapular spine stress fractures [18] or glenoid loosening, respectively [19].

An alternative approach, proposed by Mark Frankle [20], involves using a lateralized glenosphere combined with a more anatomical neck-shaft-angle (NSA). This design shifts the greater and lesser tuberosity further laterally from the center of rotation, thereby enhancing stability [21]. Further, resulting in better tensioning and wrapping of the deltoideus muscle [22] as well as the remaining cuff [23] resulting in a natural shoulder contour. This concept is based on tensioning and levering the deltoid through lateralization rather than distalization [15, 24, 25].

In RSA, different concepts ranging from medializing implants to strongly lateralizing onlay designs with different NSA and thus different degrees of lateralization are currently utilized [26]. In contrast to Grammont's RSA, which is based on a medialized-distalized design [6] and Frankle's lateralized approach [20], a new concept was developed that emphasizes a combined lateralization-distalization approach, aiming to create a balance between both [27, 28].

A recently published study of patients with cuff tear arthropathy, demonstrated that the lateralized and distalized design achieved the best results for ROM compared to the designs proposed by Grammont and Frankle [29]. This comparison has not been performed in patients with primary OA. The aim of this retrospective cohort study was to compare clinical and radiographic results of those three different RSA designs in patients with primary OA.

Materials and methods

Patient selection

A retrospective cohort study was conducted based on two institutional local shoulder arthroplasty registries with prospective data collection. Patients treated between June 2012 and June 2020 at one of two specialized shoulder orthopedics departments with a diagnosis of primary OA were included in the study cohort. All patients were treated with a 36 mm glenosphere and completed clinical and radiological preoperative, six-months and two-year postoperative follow-up examination. The following implant configurations were utilized (Fig. 1):

1. A Grammont-design prothesis with no baseplate offset using a 36 mm glenosphere with inferior eccen-

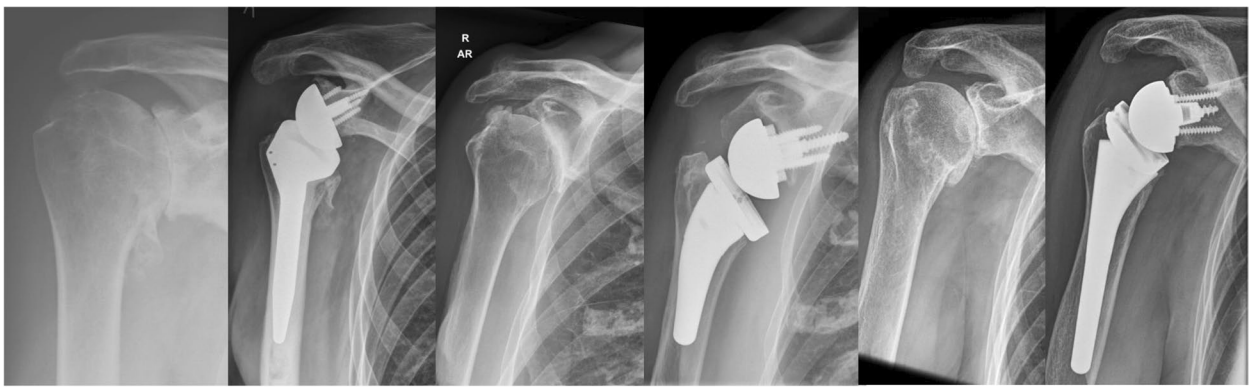

Fig. 1 Three different RSA configurations: Presented are pre- and postoperative (*from left to right*) x-rays of a 155° NSA Grammont-design prothesis with no baseplate offset and eccentricity (+ 2 mm) (Aequalis Reversed II, Tornier/Stryker Inc. Kalamazoo, MI; group MD; medialized and distalized design) and two lateralizing designs either a 135° NSA inlay design (Univers Revers II, Arthrex, Naples, FL) with + 4 mm metallic baseplate offset and centric glenosphere (group L; lateralized design) or a curved onlay short stem with 145° NSA (Perform Ascend Flex, Tornier/Stryker Inc. Kalamazoo, MI) with + 3 mm metallic baseplate augmentation as well as + 2 mm glenosphere eccentricity (group LD; lateralized and distalized design)

tricity (+ 2 mm) in addition to a 155° NSA inlay design stem (Aequalis Reversed II, Tornier/Stryker Inc. Kalamazoo, MI) (group MD; medialized and distalized design).
2. A lateralized arthroplasty with a + 4 mm metallic glenosphere offset and centric 36 mm glenosphere in combination with a 135° NSA inlay design (Univers Revers II, Arthrex, Naples, FL) (group L; lateralized design).
3. A lateralizing and distalizing design using a + 3 mm metallic baseplate augmentation, a 36 mm glenosphere with +2 mm inferior eccentricity with a curved onlay design short stem with 145° NSA (Perform Ascend Flex, Tornier/Stryker Inc. Kalamazoo, MI) (group LD; lateralized and distalized design).

Theoretical global lateralized offset (tGLO) for those specific configurations was 15.6 mm (group MD), 24.7 mm (group L) and 27.5 mm (group LD), respectively [30]. The tGLO is an in vitro lateralization evaluation measuring the distance from a vertical line passing through the middle of the humerus diaphysis to a vertical line passing through the bone-glenoid baseplate interface using a 36-mm glenosphere and the thinnest polyethylene humeral insert.

In case of bilateral RSA implantation for bilateral OA, the second treated shoulder was excluded from the analysis. Ethical approval for both retrospective evaluations of prospective data were obtained from both institutions (KEK-ZH-Nr. 2014–0483; EA2/173/18).

Surgical technique and postoperative protocol

All patients were treated in beach chair position using a deltopectoral approach under general anesthesia in combination with an interscalene block for pain management. A tenotomy of the subscapularis tendon was performed in all cases, it was later reattached using FiberWire® sutures (Arthrex, Naples, FL) in Mason-Allen technique. Intraoperatively, the cuff was evaluated. All three arthroplasty systems were implanted according to the manufacturers' guidelines. The humeral head was resected at 20° of retroversion, however, due to three different NSA, the resection plane was performed according to surgeons' intraoperative assessment using guides.

Postoperatively, patients were immobilized for four weeks using a sling in internal rotation. Starting with guided physiotherapy on day 1, passive mobilization up to 90 degrees abduction was trained in the first four weeks. Then active assisted mobilization was introduced, gaining progressive active mobilization after six weeks of surgery. Forced internal rotation was prohibited for six weeks.

Clinical evaluation

All patients underwent clinical examination preoperatively (baseline) and at six, twelve and twenty-four months after surgery. Clinical outcomes were documented using Constant-Murley score (CS) [31], including its pain subscale and abduction strength, in addition to the patient-reported Subjective Shoulder Value (SSV) [32] and Shoulder Pain and Disability Index (SPADI) [33]. Active ROM was documented for forward flexion, abduction, and external rotation with arm at side. Internal rotation was documented using Apley's scratch test.

Radiological evaluation

Baseline (preoperative) and two-year postoperative imaging included standard anteroposterior, Y- and axillary radiographs.

Radiographic measurements according to Freislederer et al. [34] and Boutsiadis et al. [35] were performed on the following anteroposterior radiographs: Scapular neck length (SNL), Scapular neck angle (SNA), Global lateralized offset (GLO), Glenosphere inclination angle (GSIA), Inferior glenosphere overhang (IGO), Lateralization Shoulder Angle (LSA) and Distalization Shoulder Angle (DSA). An additional assessment was performed to evaluate the distance from the glenoid to the lateral point of greater tuberosity (along the axis of the scapular spine [Glenoid-Greater-Tuberosity-Distance; [GGTD]) at baseline and postoperatively (Fig. 2). The difference between these two measurements was defined as the net lateralization, representative for the overall elongation of the remaining cuff after RSA implantation.

At final follow-up examination a radiological core set, based on an international consensus [36] was obtained, which included an assessment of scapular notching according to Sirveaux [37]. Postoperative complications, like loosening, component migration or breakage and periprosthetic fractures were documented throughout the 24 month follow-up post-surgery.

Data management and statistical analysis

Register data managed using the REDCap (Research Electronic Data Capture) system [38] was exported and statistical analysis was performed using Intercooled Stata version 17 (StataCorp LP, College Station, TX). Baseline patient demographics, radiological and functional parameters were summarized by group using standard descriptive statistics. Comparisons were made by calculating effect size changes (ES; Eta-squared for continuous parameters, Cramer's V for categorical parameters)

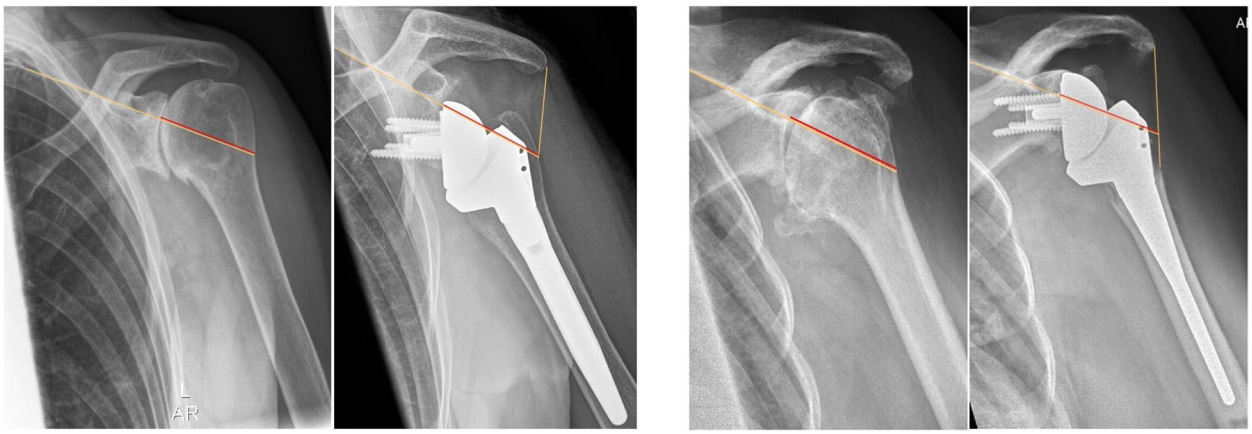

Fig. 2 Glenoid-Greater-Tuberosity-Distance (GGTD) measurements performed at pre- and postoperative radiographs for two separate cases. On the left, the distance from the glenoid to the lateral point of greater tuberosity along the axis of the scapular spine is performed. In cases where the extension of the scapular spine (yellow line) does not cut the greater tuberosity, it was measured to its intersection with a line connecting the lateral greater tuberosity and the lateral acromion (as demonstrated on the postoperative radiograph on the right). The difference between those two measurements was defined as the net lateralization, which describes the net elongation of the remaining cuff after RSA implantation

ensuring validity and data representation. The lower the ES, the lower the risk of respective parameter to confound the group comparison with regards to post-operative outcomes. Values closest to 0.15 or lower indicate stronger group similarity) and clinical judgment. Comparative analyses of two-year follow-up examination were conducted using standard linear regression analyses. Generalized linear mixed models were conducted to account for repeated measurements when outcome data was available at each clinical follow-up examination. For all models, we included the demographic parameters of age and sex as well as respective baseline preoperative values. All eligible patients from both databases were included, so there was no predetermined sample size based on comparative analyses; all analyses were exploratory. Level of significance was set at 0.05.

Results

A total of 97 patients met the eligibility criteria and were included in the final analysis (Fig. 3). The surgeries were performed by eight specialized shoulder surgeons at two clinics using the same surgical procedure, with 87 patients (89.7%) treated by three senior surgeons. Baseline characteristics differed slightly between the groups (Table 1): Group LD had a higher proportion of women, while the average age was similar across all three groups.

Patients in group LD presented with the worst baseline function regarding ROM, CS, SSV, SPADI, abduction strength and pain while intraoperatively evaluated cuff status was significantly better with a greater proportion of intact supraspinatus (56% vs 11–12%), intact infraspinatus (84% vs 23–48%), intact subscapularis (80% vs 43–46%) and teres minor tendons (100% vs. 85–92%). Patients in group LD had the lowest baseline scores but demonstrated the greatest improvement, achieving a gain of 52.7 CS points (group L: 40.7; group MD: 43.1).

At the two-year follow-up, significant differences were observed in SSV ($p = 0.046$) and active ROM across all planes, including forward flexion ($p = 0.023$), abduction ($p < 0.001$), internal rotation (Apley's test; $p < 0.001$) and external rotation with arm at side ($p < 0.001$) (Fig. 4; Supplement file 1). The most substantial functional improvement occurred within the first six months, approaching a plateau thereafter. There was a trend towards increased improvement in SPADI ($p = 0.085$) and abduction strength ($p = 0.084$) towards both lateralized designs, however no differences regarding CS and pain were observed.

Radiological outcomes

Comparing the radiological measurements, there was a statistically significant difference in the amount of lateralization measured in the net change of GGTD (Table 2). While both lateralized designs in group L and LD presented a lateralization of 1.1 and 1.2 mm on average, respectively, group MD presented a medialization of 3.6 mm. This aligns with the measurements of Global lateral offset (GLO), which were 37.3 and 38.2 mm respectively, but significantly lower in the MD group at 29.2 mm. Greater GLO was associated positively with better abduction ($p = 0.036$), internal rotation ($p = 0.048$), forward flexion ($p = 0.099$) and external rotation ($p = 0.110$).

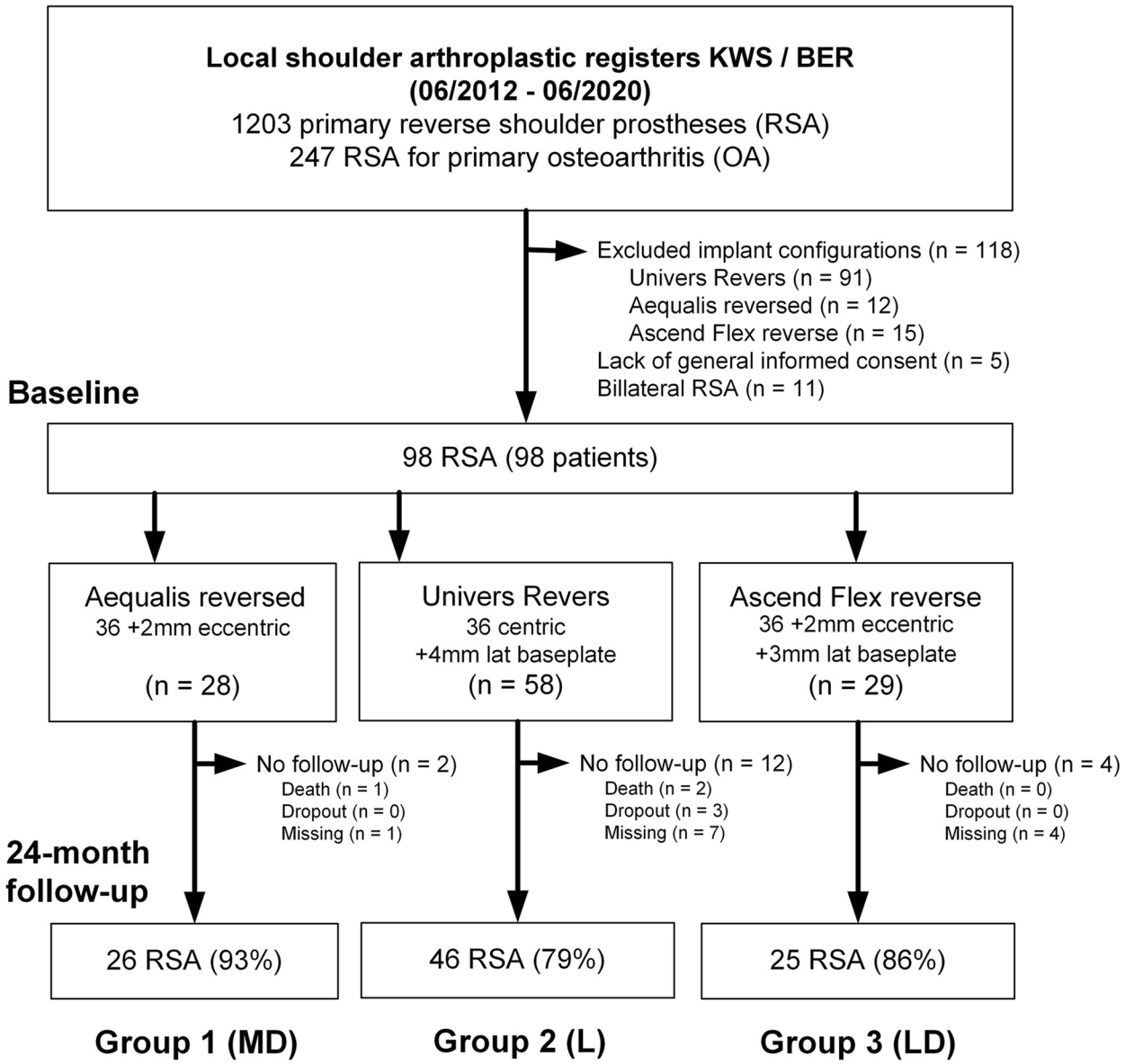

Fig. 3 Patient selection and follow-up flowchart

IGO was greatest in group LD (7.7 mm), followed by the group MD (5.5 mm), significantly greater than compared to group L with a non-eccentric glenosphere (3.6 mm).

Scapular notching was visible in 22% of patients in group MD (13% grade 1; 4% grade 2; 4% grade 4), 16% in group L (all grade 1) and 9% in group LD (all grade 2).

There were no signs of osteolysis, radiolucency, bone resorption, ossification, implant migration, breakage, loosening or scapular spine fractures during the two-year follow up period.

Adverse events

A total of six adverse events were documented, none of which required revision surgery. One patient from the MD developed Complex Regional Pain Syndrome (CRPS) stage I postoperatively, characterized by hand and finger swelling and stiffness in all finger joints. This condition persisted for six months postoperatively and was managed with conservative treatment. Another patient (group L) presented with postoperative hematoma which did not require reoperation. One patient (group LD) presented with postoperative Herpes zoster infection of the operated shoulder two weeks postoperatively which was

Table 1 Baseline patient and shoulder characteristics according to the defined prosthesis groups

	Group 1 (MD)		Group 2 (L)		Group 3 (LD)		Effect size
	n (%)	mean (SD)	*n* (%)	mean (SD)	*n* (%)	mean (SD)	
Age at surgery	26	77.9 (5.5)	46	75.2 (7.1)	25	76.3 (6.1)	0.030
Sex							0.357
Female	21 (81)		45 (98)		17 (68)		
Male	5 (19)		1 (2)		8 (32)		
Supraspinatus							0.373
Intact tendon	3 (12)		5 (11)		14 (56)		
Partial tear	14 (54)		35 (76)		8 (32)		
Complete tear	9 (35)		6 (13)		3 (12)		
Infraspinatus							0.376
Intact tendon	6 (23)		22 (48)		21 (84)		
Partial tear	15 (58)		24 (52)		3 (12)		
Complete tear	5 (19)				1 (4)		
Subscapularis							0.276
Intact tendon	12 (46)		20 (43)		20 (80)		
Partial tear	12 (46)		26 (57)		5 (20)		
Complete tear	2 (8)						
Arthrosis according to Walch							0.222
A1	4 (15)		4 (9)		1 (4)		
A2	8 (31)		12 (26)		6 (24)		
B1	3 (12)		6 (13)		8 (32)		
B2	6 (23)		18 (39)		5 (20)		
C	1 (4)		2 (4)		1 (4)		
B3	4 (15)		4 (9)		4 (16)		

SD Standard deviation, Effect size = Eta-squared for continuous parameters, Cramer's V for categorical parameters. The lower the effect size, the lower the risk of respective parameters to confound the group comparison with regards to post-operative outcomes. Values close to 0.15 or lower indicate stronger group similarity with regards to the related parameters

treated with antiviral drugs and disappeared after three months postoperatively. The final three patients (group LD) all presented pain of the ventral deltoid muscle which began between three and six months postoperatively and this symptom persisted at the two-year follow up. The three patients were elderly women, aged 81, 82 and 84 years at the time of surgery, with a height of 158, 153 and 154 cm, respectively.

Discussion

The aim of this study was to compare clinical and radiological differences of three different implant designs in a homogeneous patient cohort with primary osteoarthritis (OA).

Our main findings demonstrate that both the lateralized (group L) and the distalized-lateralized design (group LD) significantly improve SSV and ROM in all planes compared to the Grammont design (group MD) in a cohort of 97 patients with primary osteoarthritis. Due to the curved onlay design of the 145° design stem, the radiological postoperative offset (GLO) and change in offset (difference in GGTD) is comparable for both lateralized designs (group L and LD). Radiographic measurements show that the shift of greater tuberosity was nearly 5 mm greater with both lateralized designs, compared to the Grammont design (group MD). Both lateralized designs (group L and LD) eliminated higher grades of scapular notching (grade 3 or 4) two-years postoperatively.

In a similar study focused on patients with cuff deficient shoulders a similar trend was observed, where lateralized designs present significant greater improvements in internal and external rotation, however the lateralized and distalized concept (145° NSA onlay design, identical to group LD) outscored patients treated with the L and MD design in abduction, forward flexion, external and internal rotation in a cohort of 279 patients [29]. This concurs with our data for patients with primary OA where L and LD patients presented better ROM in all planes and additionally greater SSV compared to patients with MD design. Here, there were no differences in flexion and abduction as opposed to patients with CTA. One

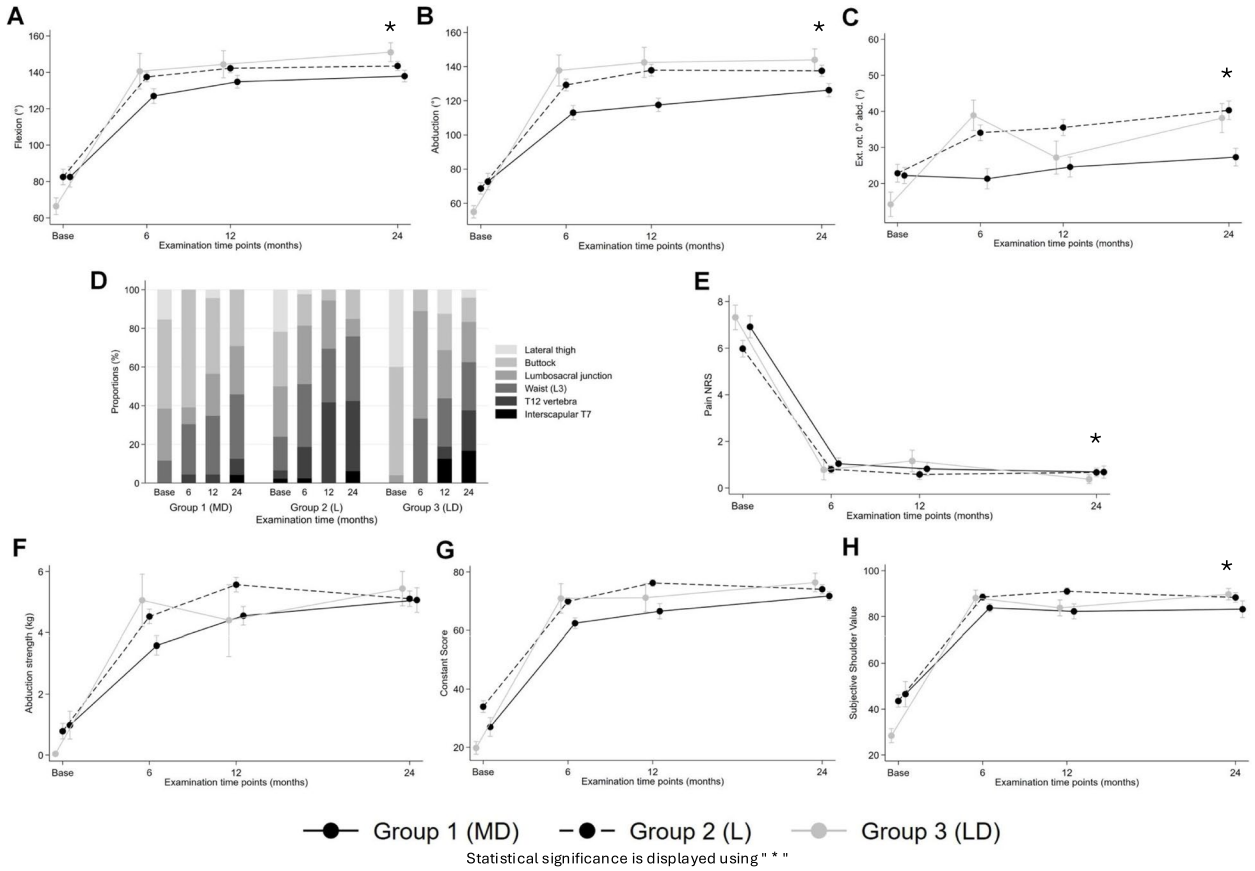

Fig. 4 Line graphs presenting the improvement in outcome regarding active **a**) forward flexion, **b**) abduction, **c**) external rotation, **d**) internal rotation (Apley's test), **e**) pain levels, **f**) abduction strength, **g**) CS and h) SSV at baseline, six, twelve and twenty-four months postoperatively for all three groups. Statistical significant differences are displayed using "*"

Table 2 Comparison of baseline scapula anatomy and 2-year postoperative prosthesis position measurements between defined study groups

	Group 1 (MD)		Group 2 (L)		Group 3 (LD)		
	n	mean (SD)	*n*	mean (SD)	*n*	mean (SD)	Effect size
Scapular anatomy							
Scapular neck length (SNL) (mm)	26	12.7 (4.5)	46	10.5 (4.7)	22	13.6 (5.7)	0.072
Scapular neck angle (SNA) (°)	26	84.8 (10.0)	46	84.0 (8.3)	22	82.6 (17.8)	0.004
Glenoid-Greater-tuberosity-Distance (mm)	26	51.8 (4.1)	46	49.7 (4.1)	22	44.9 (8.7)	0.175
							P-value
Prosthesis position							
Global lateral Offset (GLO) (mm)	26	29.2 (5.2)	46	37.3 (4.5)	24	38.2 (6.6)	< 0.001
Glenosphere inclination (GSIA) (°)	26	102.3 (14.9)	46	103.3 (6.0)	24	98.9 (20.5)	0.430
Distalization angle (DSA) (°)	26	55.4 (12.7)	46	52.0 (12.4)	24	62.5 (11.3)	0.004
Inferior glenosphere overhang (IGO) (mm)	26	5.5 (2.9)	46	3.6 (1.8)	24	7.7 (2.4)	< 0.001
Lateralization angle (LSA) (°)	26	72.6 (9.7)	46	80.7 (7.3)	24	75.1 (10.9)	0.001
Glenoid-Greater-Tuberosity-Distance (mm)	26	48.2 (5.9)	46	50.9 (5.3)	24	45.9 (10.6)	0.020
Change GGTD to follow-up (mm)	26	−3.6 (6.4)	46	1.2 (5.5)	22	1.1 (6.5)	0.004
Change Glenoid to Baseplate inclination (°)	26	1.6 (13.0)	45	2.5 (7.0)	22	−7.5 (19.4)	0.009

SD Standard deviation, *GGTD* Glenoid-Greater-Tuberosity-Distance

possible explanation could be the supporting intact cuff in high elevation. When focusing on massive rotator cuff tears (Hamada and Fukuda [39] stage I to III) similar results with improved external rotation and a trend towards better internal rotation with significantly lower rates of scapular notching for lateralized (135° NSA and 4 mm lateralized glenosphere) over non-lateralized RSAs (155° NSA and 2 mm eccentric glenosphere) were reported [34]. Similarly, patients with additional glenohumeral arthritis (Hamada and Fukuda [39] stage IV and V) outscore the Grammont design in external rotation when a lateralized design (+ 4 mm baseplate offset with a 135° NSA) is introduced, however not reducing scapular notching significantly [40].

Reducing NSA creates a more impingement-free range of motion (ROM) and axial motion by creating a more anatomical vector and more tension of the remaining anterior and posterior rotator cuff muscles [5, 20, 41, 42]. By using an eccentric glenosphere, notching can be reduced similar to lateralizing on the humeral side [43]. Eccentric glenospheres were used in both group LD and MD. This concurs with our radiographic measurements, which present the smallest inferior overhang measured in group L where centric glenosphere were used.

Less notching achieves a better impingement-free movement under the scapular neck and improves rotational movements. The curved onlay stem design additionally emphasizes lateralization (and distalization) of the greater tuberosity and results in a greater amount of lateralization in theory [26], which concurs with our radiographic measurements. Lower rates of scapular notching were achieved with both lateralized designs preventing severe notching (grade 3 and 4).

Although ideal amount of lateralization has not yet been established, excess lateralization can lead to postoperative shoulder pain due to overstuffing or even spine or acromion fatigue fractures that diminish those great results [28]. For example, three elderly women with a height below 159 cm, were subject to postoperative anterior deltoid pain (adverse events), one presenting also the worst clinical function as a possible result of overstuffing in group LD. Literature shows, that relative lateralization adjusted to patientts' skeletal size is much greater with onlay stem systems [44]. Therefore, baseplate offset has a bigger impact of stress on baseplate fixation in small patients.

However, our data demonstrates similar good results of lateralized and distalized implants compared to lateralized designs, implicating that using a moderate lateralization and distalization may minimize problems of both concepts (mainly distalized implants and mainly lateralized implants) and provide improved outcomes.

The artificial inverted shoulder joint constitutes a three-dimensional space, which, depending on the amount of lateralization and distalization results in tensioning of the deltoid muscle of which its ideal amount of tension has yet to be established. Therefore, lateralization and distalization both act synergetic in this concept and should not be evaluated independently but rather as one. Therefore, we have conceptualized a new measurement to evaluate the net amount of lateralization within the vector of the remaining cuff muscles. However, this measurement has its bias, where rotation of the humerus as well as smallest changes in angulation of radiation impact the measurement. Nonetheless, the GGTD allows a descriptive analysis in net change of lateralization along the cuff vector as this measurement can be applied in both preoperative and postoperative x-rays.

As expected, LSA was the largest in group L and DSA being the largest in group LD, which concurs with the results of Freislederer et al. [29]. However, along the vector of the remaining cuff this equals each other out. This may explain why we did not observe any scapular spine or acromion stress fracture in our cohort in either group, although the lateral shift of center of rotation with lateralization increases shearing forces [15] and consequently acromial stress [16, 17].

Patients in group LD demonstrated greater level of pain and worse clinical function in all parameters measured with significantly lower active flexion and abduction strength at baseline but presented significantly greater proportion of intact rotator cuff muscles. One possible explanation is, that more severe arthritic joint deformation in group LD resulted in higher levels of pain and hence in poorer outcome overall with less abduction strength although the cuff itself was less impaired. Moreover, patients in group MD were oldest at time of surgery.

It is possible that as greater and lesser tuberosity are more lateralized with humeral lateralization, this may improve tension of the remaining cuff [23], stability [21] as well as the lever arm [15, 24, 25] for rotational movement as well as deltoid wrapping [22] and resulting in better recruitment of anterior and deltoid muscle fibers. This might explain, why a greater GLO is associated with better ROM in all planes and both humeral lateralized designs perform so well in internal and external rotation, significantly greater than compared to the medialized-distalized design. Moreover, there is an improved trend towards a greater abduction strength ($p = 0.084$) for both lateralized designs.

Limitation and strengths

Several strengths and limitations of the study should be considered when interpreting the results. This study's strengths are the homogeneous patient cohort of patients

with primary osteoarthritis treated with three exact same designs with the same glenosphere size, same lateralization and ec-/centricity throughout the groups. Each surgeon selected a preferred implant design and there was no implant design variability based on patient's characteristics, pathology or anatomy. Therefore, choice of implant was preset and there was no selection bias a far as the surgeon's choice of implant is concerned. Although multiple surgeons were involved, three senior surgeons performed 87 surgeries of those 97 patients included with each their preferred implant. Strengths include that all three patient cohorts were each treated with the exact same implant configuration and diagnosis as well as rigorous monitoring and follow-up examination protocol. Furthermore, we have carried out meticulous radiographic measurements, trying to capture the change in biomechanics from preoperative, anatomic biology to artificial, inverted status by using a brand-new measurement rather than focusing on lateralization or distalization by themselves individually. Nonetheless, limitations of this study includes the retrospective design, its observational nature and its short follow-up period and the number of shoulder surgeons at two orthopedic centers. Radiographic measurements published were all performed by one experienced investigator; any estimations of inter-rater or intra-rater reliability are not available. Moreover, this study solely investigates the influence of implant design and other possible patient-related or biological factors like patients' constitution regarding spine kyphosis, bone or soft tissue quality i.e. deltoid muscle size and function or scapulothoracic motion are not considered. Further studies are needed to investigate the effects of preoperative soft tissue status and scapulothoracic movement with RSA on outcome.

Conclusion

Patients treated with RSA for primary OA using the lateralized and lateralized-distalized designs present superior subjective satisfaction in SSV and improved ROM in all planes compared to the traditional distalized-medialized prosthesis. No implant related complications occurred across the groups.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08749-y.

Supplementary Material 1.

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Authors' contributions
J.I wrote the main manuscript, J.I., Y.A., A.T. contributed to data acquisition, L.A. and T.S. performed data analysis, J.I., M.S. conceptualized the investigation, J.I., M.S., F.F. and L.A. interpreted the data, all authors reviewed the manuscript and revised it substantively.

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Data availability
Data of this study is available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate
The study was performed in accordance with the standards of the Ethics Committee of Zurich (Kantonale Ethikkommission [KEK], Stampfenbachstrasse 121, CH-8090 Zurich, Switzerland; KEK-ZH-Nr. 2014–0483), Institutional Board Committee at Charité Universitaetsmedizin Berlin (Ethikausschuss am Campus Virchow-Klinikum, Charitéplatz 1, DE-10117 Berlin, Germany; Antragsnr. EA2/173/18) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All patients provided written informed consent prior to patient enrolment/data collection and use of their data for research purposes.

Consent for publication
Not applicable.

Competing interests
F. Freislederer and M. Scheibel are consultants for Stryker Corp. The remaining authors declare no competing interests.

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