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Restoration of External Rotation Following a Lateral Approach for Glenoid Bony Increased-Offset Reverse Shoulder Arthroplasty

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Background: Reverse shoulder arthroplasty (RSA) is a recognized therapeutic modality for a massive rotator cuff tear. Some authors recommend lateralization of the center of rotation by bony increased offset (BIO) of the glenoid for improvement of external rotation, while others refute its effects. RSA through the conventional deltopectoral approach sacrifices the subscapularis tendon during the approach. We hypothesized that a lateral approach (LA) for RSA, with less soft-tissue resection, would restore external rotation by allowing retensioning of the remaining rotator cuff with use of a BIO graft.

Methods: We retrospectively investigated 36 nonlateralized inlay RSAs performed through a lateral approach (LA non-BIO group) and 40 inlay RSAs performed through a lateral approach with BIO (LA BIO group) for a massive rotator cuff tear. There were 5 patients with a combined loss of active elevation and external rotation (CLEER) in the LA non-BIO group and 6 in the LA BIO group. The Constant score, the UCLA (University of California Los Angeles) score, and range of motion, in particular, external rotation with the arm at 0° (ER0) and at 90° of abduction (ER90), were compared.

Results: The mean ER90 in the LA BIO group improved significantly, from 45.8° ± 21.6° to 65.9° ± 15.8° ($p = 0.012$). Postoperative ER90 in the LA BIO group was significantly higher than in the LA non-BIO group (mean, 65.9° ± 15.8° compared with 53.0° ± 12.3°; $p = 0.026$). The mean ER0 for the patients with CLEER status significantly improved in the LA BIO group, from −15.8° ± 9.8° to 11.0° ± 15.6° ($p = 0.0072$). The mean postoperative anterior elevation, UCLA score, and Constant score in the LA BIO group and the LA non-BIO group improved significantly, but there was no difference between the 2 groups (anterior elevation: 131.5° ± 17.6° compared with 121.5° ± 14.1°, $p = 0.07$; UCLA: 25.5 ± 6.4 compared with 23.4 ± 5.4, $p = 0.2$; Constant: 74.3 ± 12.0 compared with 73.6 ± 10.1, $p = 0.43$).

Conclusions: LA BIO-RSA was associated with a significant improvement in range of motion, particularly external rotation. Improvements in anterior elevation, the Constant score, and the UCLA score were not significantly different from those noted for LA non-BIO-RSA.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Reverse shoulder arthroplasty (RSA) restores elevation of the shoulder by (1) vertically elongating the arm to increase the deltoid tension and (2) medializing the center of rotation to enhance the moment arm for elevation. RSA is indicated for a massive rotator cuff tear for which a primary rotator cuff repair is likely to fail[1].

Early reports on medialized RSA did not show improvements in external rotation[2-4]. Although RSA restores elevation, its restoration of external rotation has been unpredictable. It was found in a previous study that the only predictive factor for deterioration of external rotation was the preoperative atrophy of the teres minor[5].

Medialized RSA results in decreases in muscle pretensioning and the rotational capacity of the remaining rotator cuff[6]. This alteration can theoretically be prevented by lateralizing the center of rotation[7]. Moreover, lateralization optimizes the external rotation moment arm of the deltoid[8], and the lateralized glenosphere leads to maximal impingement-free rotational capacity[9].

RSA is usually performed through a deltopectoral approach, in which the anterior capsular ligaments and the subscapularis tendon are opened, making an intraoperative, horizontal retensioning of the remaining rotator cuff hardly possible. It is recommended to reattach the subscapularis tendon to the

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minor tuberosity, and it is usually possible to repair the subscapularis tendon with an adequate release. Implantation of lateralized implants can make repair of the subscapularis difficult. When using such implants, the anterior soft tissues including the subscapularis tendon might even be left open. Surgeons can increase arm lengthening to restore the joint stability.

To my knowledge, there have been no reports on intraoperative attempts to retension the remaining rotator cuff horizontally. The more anterior tissues are released, the more comfortably a surgeon can insert a lateralized RSA implant with a complete view of the humeral neck and glenoid. This contradiction between the theoretical advantage of the rotator cuff retensioning and lack of intraoperative retensioning stems from implanting a prosthetically lateralized RSA with the anterior soft tissues widely opened.

The present procedure uses a lateral approach that splits the deltoid muscle. It involves an osteotomy that is incrementally performed until a desired retensioning of the anterior and posterior portions of the rotator cuff is achieved. However, it is distinct from the so-called anterosuperior approach[10], in which the anterior and posterior portions of the capsule are resected, as is the inferior labrum, to achieve a complete view of the joint. In turn, the present procedure allows only intermittent access to the glenoid.

In this study, the clinical outcomes of inlay RSA performed through the lateral approach with bony increased offset (LA BIO-RSA) and those of nonlateralized inlay RSA performed through the lateral approach (LA non-BIO-RSA) were compared.

Materials and Methods

Ethics approval was granted by the institutional review board. The present procedure is not universally applicable; its applicability is specific to massive rotator cuff tears involving the supraspinatus, infraspinatus, and at least some portion of the subscapularis. Primary osteoarthritis and cuff tear arthropathy were excluded because a large amount of soft tissue must be released to fit implants into the severely deformed joints. Humeral head insufficiency fracture due to severe

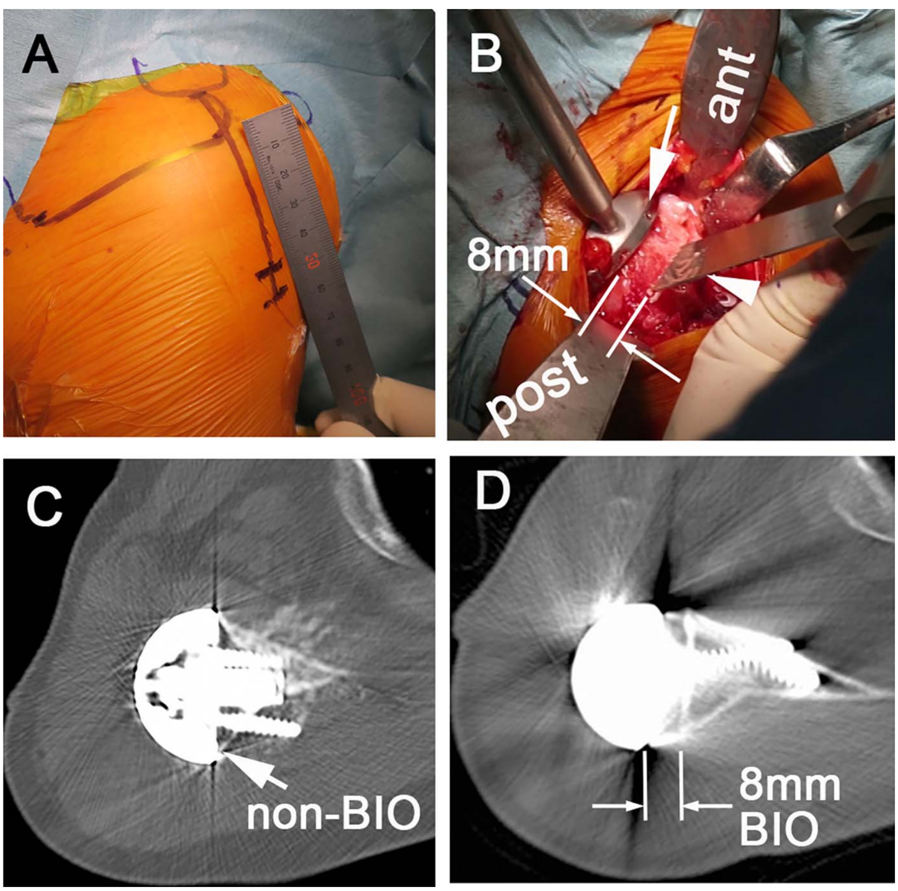

Fig. 1

A modified direct-lateral approach to the shoulder is used. **Fig. 1-A** A 6-cm skin incision begins 1 cm medially to the acromion, with the remaining 5 cm extending to the axillary nerve. **Fig. 1-B** Anterior (ant) and posterior (post) retractors are inserted subperiosteally under the remaining subscapularis and the teres minor. A cutting guide is set under the deltoid (arrow). The bone saw (arrowhead) is aimed at 8 mm distal to the cutting guide. **Fig. 1-C** A postoperative axial computed tomography (CT) image showing an absence of BIO graft in an LA non-BIO-RSA case (arrow). **Fig. 1-D** A postoperative axial CT image showing a BIO graft of 8-mm thickness in an LA BIO-RSA case.

osteoporosis was also grounds for exclusion because bone quality of the humeral head would not be good enough to create a BIO graft. Patients with substantial glenoid deformity were also excluded because of the possible need for complex bone-grafting. LA BIO-RSA was performed between 2014 and 2016, and LA non-BIO-RSA, between 2016 and 2018, by a single surgeon (S.I.).

Surgical Technique

A modified direct-lateral approach is used. A 6-cm skin incision begins 1 cm medially to the acromion, with the remaining 5 cm extending to the axillary nerve (Fig. 1-A, Video 1 [00:03]). Due to the absence of the supraspinatus and infraspinatus, the humeral head emerges subsequent to the deltoid split (Video 1 [00:33]). Anterior and posterior retractors are inserted subperiosteally under the remaining subscapularis and the teres minor (Fig. 1-B).

A cutting guide is set under the deltoid muscle, and the humerus is osteotomized amply at 8 mm distal to the guide (Fig. 1-B, arrowhead; Video 1 [00:23]). This is in a clear contrast to the conventional deltopectoral maneuver, in which a minimal osteotomy along the cutting guide is recommended to allow a subsequent correction to minimize instability. As opposed to a non-BIO glenoid component (Fig. 1-C), the osteotomized humeral head is used to lateralize the glenoid component as a BIO graft (Fig. 1-D). The baseplate alignments of both groups were checked by postoperative radiographs (Fig. 2).

The vertical humeral retractor is hooked under the glenoid (Figs. 3-A and 3-B, Video 1 [00:52]) and vertical tension

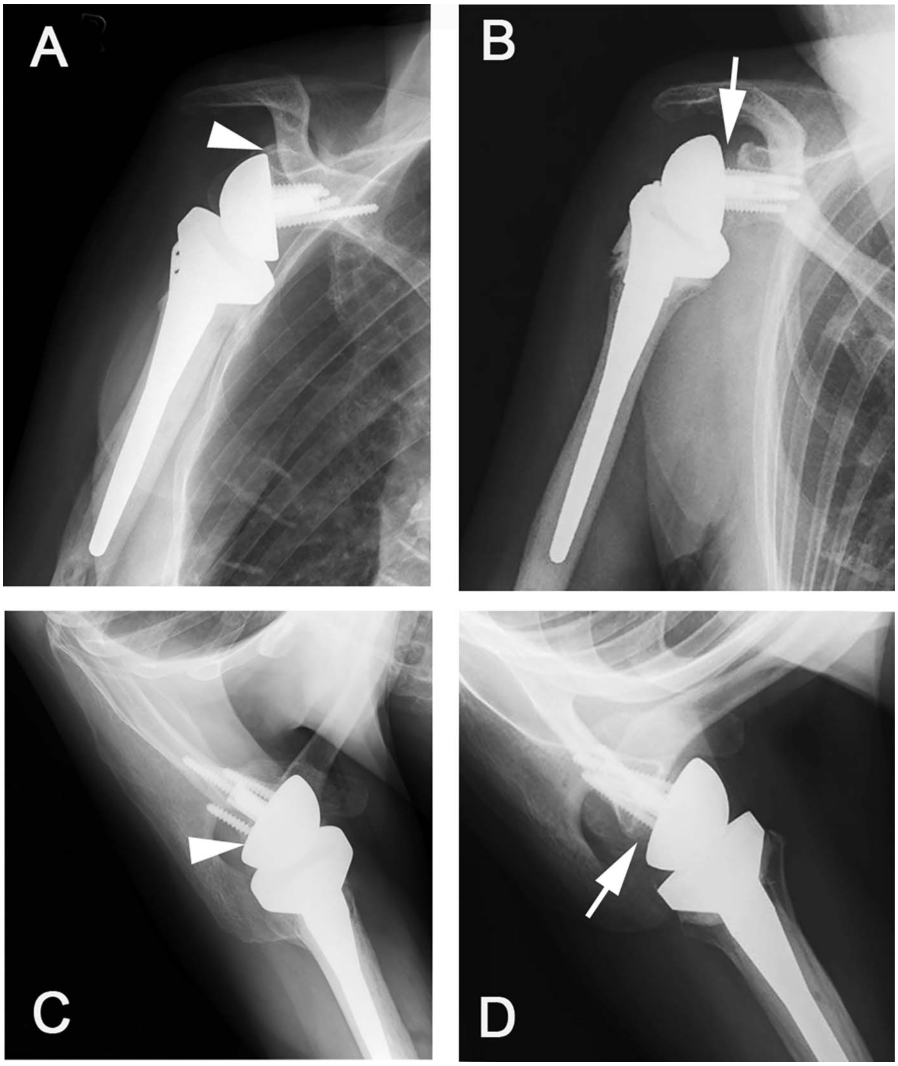

Fig. 2

Postoperative radiographs of both LA non-BIO-RSA and LA BIO-RSA cases. **Figs. 2-A and 2-C** Postoperative anteroposterior radiograph of the baseplate position (**Fig. 2-A**) and axial radiograph (**Fig. 2-C**) in a patient treated with LA non-BIO-RSA. Note the absence of a BIO graft (arrowhead). **Figs. 2-B and 2-D** Postoperative anteroposterior radiograph of the baseplate position (**Fig. 2-B**) and axial radiograph (**Fig. 2-D**) in a patient treated with LA BIO-RSA. An 8 mm-thick BIO graft is indicated by the arrow.

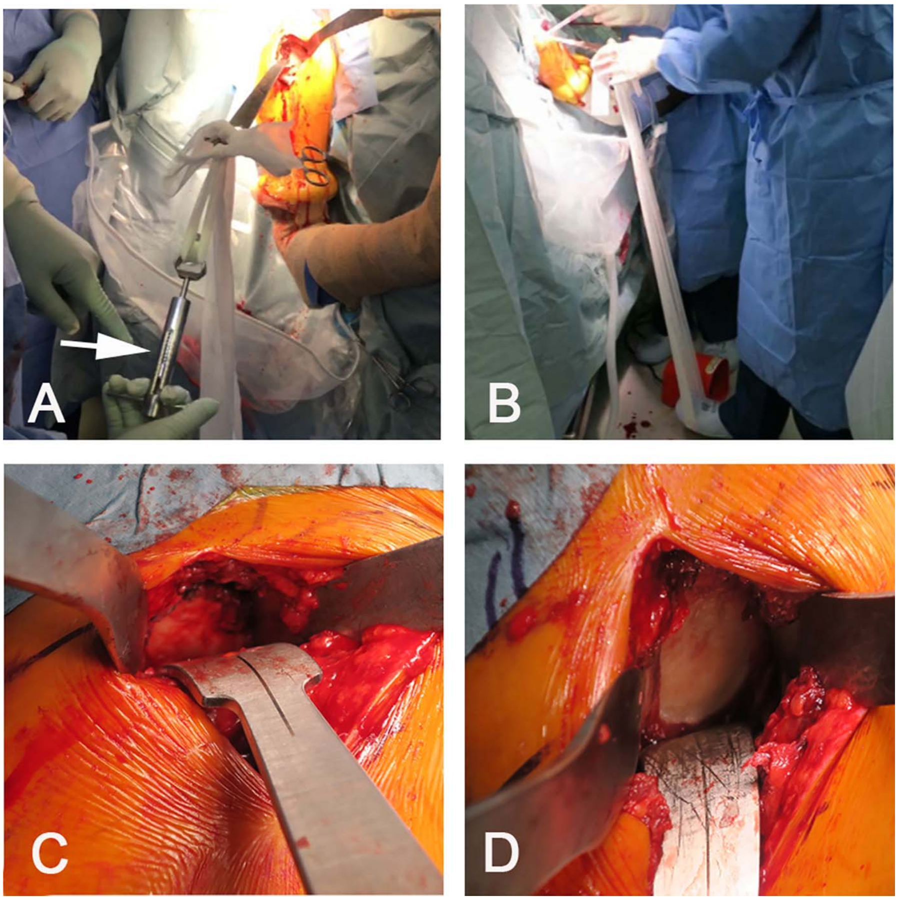

Fig. 3

Measurement of vertical tension and intermittent access to the joint. **Fig. 3-A** Vertical tension to access the glenoid is measured (arrow). A humeral osteotomy is performed in 3-mm-thick increments until the glenoid becomes accessible with a vertical tension of 40 N. **Fig. 3-B** The vertical tension to access the glenoid is controlled by pedaling the forefoot. **Fig. 3-C** The joint is intermittently closed to avoid nerve traction. **Fig. 3-D** The joint is intermittently opened to treat the glenoid.

to access the glenoid is measured (Fig. 3-A, arrow; Video 1 [01:07]). A humeral osteotomy is performed in 3-mm-thick increments until the glenoid becomes accessible with a vertical tension of 40 N. The joint is intermittently closed to avoid nerve traction (Fig. 3-C) and opened to treat the glenoid (Fig. 3-D) by "pedaling" the forefoot (Fig. 3-B, Video 1 [01:17]). This threshold tension of 40 N also depends on the horizontal lever arm (A), the vertical lever arm (B), and the angle and radius of the angle between A and B of the retractor (Figs. 4-A and 4-B). By using a retractor with a 5-cm horizontal arm, a 15-cm vertical arm, and a 60° angular segment with a 5-cm radius, the intermittent opening of the joint is controlled (Figs. 4-C and 4-D).

An 8 mm-thick BIO graft is made by slicing the osteotomized humeral head (Fig. 5-A, Video 1 [01:53]) and trimming the remnant (Fig. 5-B, Video 1 [03:08]). The remaining subscapularis and the teres minor were thereby retensioned 8 mm horizontally as compared with LA non-BIO RSA (Fig. 5-C, Video 1 [04:04]). In the current study, the humeral components were set by press-fitting in 54 RSAs and with cement in 22 RSAs, with a targeted retroversion of 20°. At the end of the surgery, the deltoid is closed, the only soft-tissue closure in the present procedure (Fig. 5-D).

Clinical Evaluation

The present study was a retrospective investigation of the cases of 36 patients treated with LA non-BIO-RSA and 40 treated with LA BIO-RSA. All implants were a Delta III inlay type. In the LA non-BIO group, 24 patients were treated with use of the Aequalis Reverse II (Tornier) implant, and 12 were treated with use of the Delta Xtend (DePuy Orthopaedics) implant. In the LA BIO group, 32 patients were treated with use of the Aequalis Reverse II implant and 8, with the Delta Xtend implant. In all cases, the implants received neutral polyethylene inserts, with a 36-mm glenosphere for the Aequalis Reverse II and a 38-mm glenosphere for the Delta Xtend.

Range of motion, including anterior elevation, abduction, external rotation, and internal rotation, was measured by 2 examiners, i.e., fellow shoulder surgeons but not the author (S.I.). Active anterior elevation, active external rotation with the arm at 0° (ER0), active external rotation with the arm at 90° of abduction (ER90), the Constant score, and the UCLA (University of

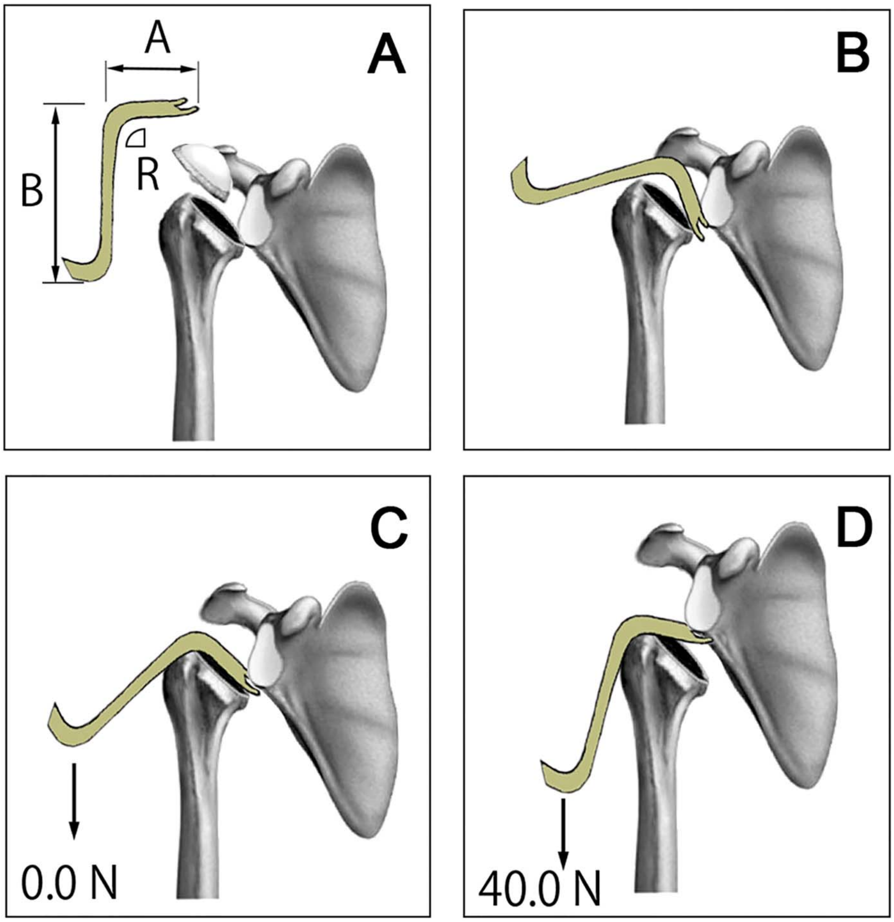

Fig. 4

Schematic drawings of the osteotomized humerus, the scapula, and the vertical humeral retractor. **Fig. 4-A** The threshold tension of 40 N to access the glenoid also depends on (A) the horizontal lever arm, (B) the vertical lever arm, and (R) the angle and the radius of the angle between (A) and (B) of the retractor. **Fig. 4-B** The vertical humeral retractor is hooked with the inferior capsular attachments preserved. **Fig. 4-C** The vertical tension of 40 N is released when the joint is closed to avoid nerve traction. **Fig. 4-D** The vertical tension of 40 N is applied to open the joint to treat the glenoid.

California Los Angeles) score were compared between the LA BIO group and LA non-BIO group. Preoperative ER90 was measured with an examiner holding the patient's arm at 90° of abduction.

Patients with negative ER0 and active elevation of <60° were considered as having a combined loss of active elevation and external rotation (CLEER). Five patients in the LA non-BIO group and 6 in the LA BIO group were classified as having CLEER status.

Patients initiated active-assisted elevation without restriction of external rotation on postoperative day 2.

Evaluation of Fatty Infiltration

Preoperative magnetic resonance imaging (MRI) scans were available for all 76 patients, and fatty infiltration of the infraspinatus and teres minor was assessed according to the Goutallier classification[11].

Statistical Methods

Statistical analysis was performed using paired and unpaired t tests. Subgroup comparisons were made according to disease type and CLEER versus non-CLEER status.

Results

The average age at the time of the surgery (and standard deviation) was 73.6 ± 5.2 years, and the mean follow-up was 39.4 ± 14.5 months (range, 24 to 66 months). An external rotation lag sign was noted preoperatively for all CLEER patients.

Anterior Elevation and Clinical Scores

The average active anterior elevation in the LA non-BIO group improved significantly, from 64.3° ± 35.7° preoperatively to 121.5° ± 14.1° postoperatively ($p < 0.001$) (Table I, Video 1 [04: 08]). The average active anterior elevation in the LA BIO group also improved significantly, from 65.9° ± 36.2° preoperatively (Fig. 6-A) to 131.5° ± 17.6° postoperatively ($p < 0.001$) (Video 1 [04:14]; Fig. 6-B). There was no significant difference between the LA non-BIO group and the LA BIO group either preoperatively (64.3° ± 35.7° compared with 65.9° ± 36.2°; $p = 0.49$) or postoperatively (121.5° ± 14.1° compared with 131.5° ± 17.6°; $p = 0.07$) (Table I).

The average Constant score in the LA non-BIO group improved from 32.7 ± 19.4 preoperatively to 73.6 ± 10.1

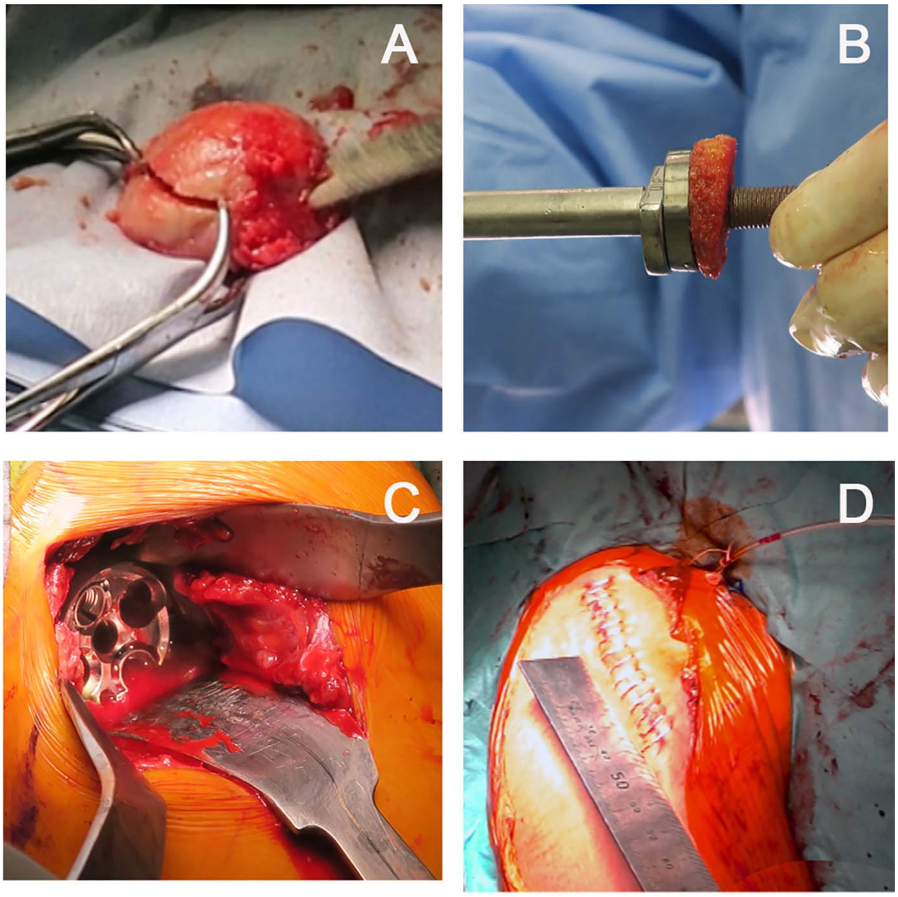

Fig. 5
The creation and application of implantation of a BIO-RSA graft in an LA manner. **Fig. 5-A** An 8 mm-thick BIO graft is made by slicing the osteotomized humeral head. **Fig. 5-B** The long central peg penetrating the BIO graft. **Fig. 5-C** Because of the thickness of the BIO graft (8 mm), the baseplate is laterally implanted. **Fig. 5-D** At the end of surgery, the deltoid is closed in a lateral-to-lateral manner, which is the only soft-tissue closure in the present procedure.

postoperatively ($p < 0.001$), and the UCLA score, from 10.7 ± 4.5 preoperatively to 23.4 ± 5.4 postoperatively ($p < 0.001$) (Table I). The Constant score in the LA BIO group improved from 39.6 ± 18.5 preoperatively to 74.3 ± 12.0 postoperatively ($p < 0.001$), and the UCLA score, from 12.1 ± 4.1 preoperatively to 25.5 ± 6.4 postoperatively ($p < 0.001$) (Table I). In

TABLE I Comparison of Preoperative and Postoperative Anterior Elevation and Clinical Scores*

	Preop.	Postop.	P Value (Preop. Vs. Postop.)
Anterior elevation			
LA non-BIO group	64.3° ± 35.7°	121.5° ± 14.1°	<0.001†
LA BIO group	65.9° ± 36.2°	131.5° ± 17.6°	<0.001†
P value	0.49	0.07	
Constant score			
LA non-BIO group	32.7 ± 19.4	73.6 ± 10.1	<0.001†
LA BIO group	39.6 ± 18.5	74.3 ± 12.0	<0.001†
P value	0.33	0.43	
UCLA score			
LA non-BIO group	10.7 ± 4.5	23.4 ± 5.4	<0.001†
LA BIO group	12.1 ± 4.1	25.5 ± 6.4	<0.001†
P value	0.18	0.19	

*Measurement and score values are given as the mean and standard deviation. †Highly significant.

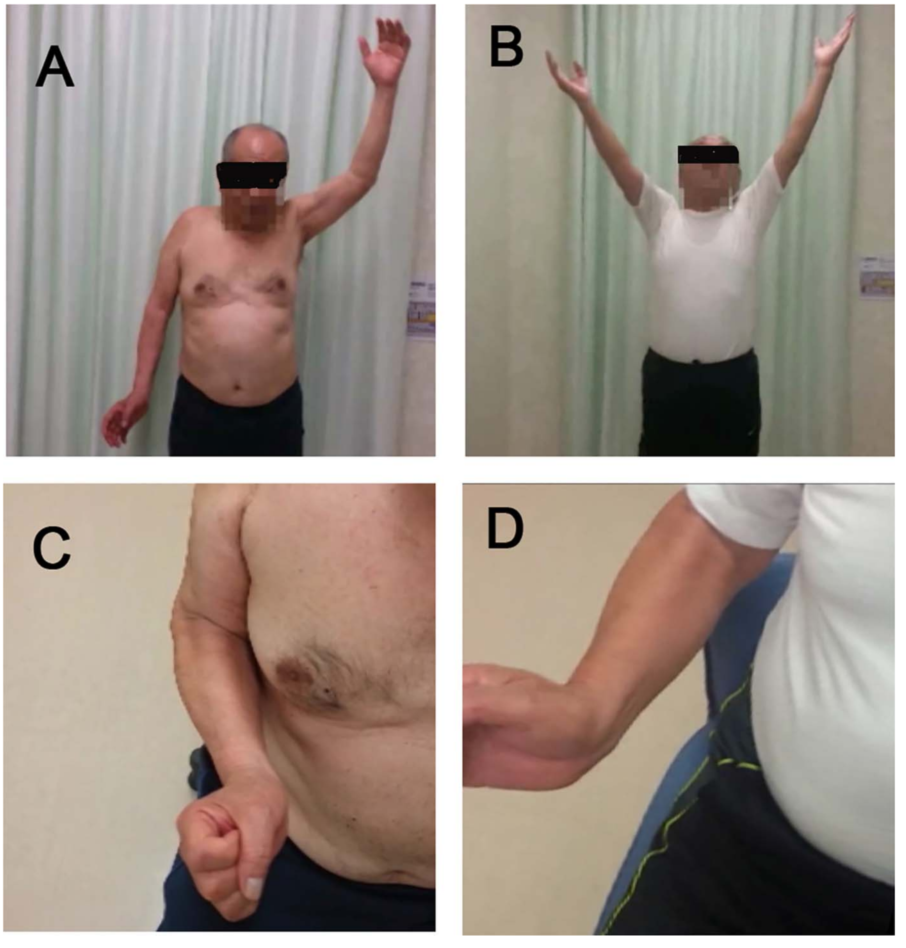

Fig. 6

Figs. 6-A through 6-D An example of a patient with CLEER (combined loss of active elevation and external rotation) treated by LA BIO-RSA. **Fig. 6-A** Preoperatively, the patient could not elevate the involved arm >15°. **Fig. 6-B** Postoperatively, the patient could elevate the arm >145° both anteriorly and laterally. **Fig. 6-C** The patient could not externally rotate the involved arm >10° preoperatively, and an external rotation lag sign was present. **Fig. 6-D** Postoperatively, external rotation was >20°, and the external rotation lag sign disappeared.

summary, both the LA non-BIO group and the LA BIO group demonstrated significant improvement in anterior elevation, the Constant score, and the UCLA score from preoperatively to postoperatively, with no significant differences noted between the 2 groups (Table I).

Fatty Infiltration of the Infraspinatus and Teres Minor

Infraspinatus Atrophy

In the LA non-BIO group, all 5 (100%) of the CLEER patients had grade-3 or 4 fatty infiltration of the infraspinatus and 28 (90.3%) of the 31 non-CLEER patients had grade-2 or 3. The average Goutallier score was 3.6 and 2.6 for the CLEER and non-CLEER subgroups, respectively (Table II). In the LA BIO group, all 6 (100%) of the CLEER patients had grade-3 or 4 fatty infiltration of the infraspinatus and 30 (88.2%) of the 34 non-CLEER patients had grade-2 or 3. The average score was 3.7 and 2.2, respectively (Table II). In summary, the infraspinatus atrophy in CLEER patients was similar between the LA non-BIO and BIO groups (average, 3.6 versus 3.7). However, among non-CLEER patients, infraspinatus atrophy tended to be more severe in the LA non-BIO group than in the LA BIO group (average, 2.6 versus 2.2).

Teres Minor

In the LA non-BIO group, all 5 (100%) of the CLEER patients had grade-3 or 4 fatty infiltration of the teres minor and 22 (71.0%) of the 31 non-CLEER patients had grade-2 or 3. The average Goutallier score was 3.6 and 2.1 in the CLEER and non-CLEER subgroups, respectively (Table II). In the LA BIO group, all 6 (100%) of the CLEER patients had grade-3 or 4 fatty infiltration of the teres minor and 29 (85.3%) of the 34 non-CLEER patients had grade-2 or 3. The average score was 3.8 and 2.2, respectively (Table II). In summary, teres minor atrophy in the CLEER patients was similar between the LA non-BIO and BIO groups (average, 3.6 versus 3.8). Teres minor atrophy in the non-CLEER patients was also similar between the LA non-BIO and BIO groups (average, 2.1 versus 2.2).

TABLE II Distribution of Muscle Atrophy in the Infraspinatus and Teres Minor Muscles by Treatment Group and CLEER and Non-CLEER Subgroups*

	Goutallier Classification†					
	Grade 0 *(no.)*	Grade 1 *(no.)*	Grade 2 *(no.)*	Grade 3 *(no.)*	Grade 4 *(no.)*	Average
Infraspinatus						
LA non-BIO group (n = 36)						
CLEER (n = 5)	0	0	0	2	3	3.6
Non-CLEER (n = 31)	0	2	9	19	1	2.6
LA BIO group (n = 40)						
CLEER (n = 6)	0	0	0	2	4	3.7
Non-CLEER (n = 34)	0	4	18	12	0	2.2
Teres minor						
LA non-BIO group (n = 36)						
CLEER (n = 5)	0	0	0	2	3	3.6
Non-CLEER (n = 31)	2	6	12	10	1	2.1
LA BIO group (n = 40)						
CLEER (n = 6)	0	0	0	1	5	3.8
Non-CLEER (n = 34)	0	5	19	10	0	2.2

*CLEER = combined loss of active elevation and external rotation. †Muscle atrophy was classified according to the Goutallier classification of fatty infiltration[11].

Restoration of Active External Rotation

The average active ER0 for all patients in the LA non-BIO group (n = 36) significantly deteriorated from preoperatively (27.1° ± 23.8°) to postoperatively (17.1° ± 14.8°) (p = 0.05) (Table III). The average active ER0 in the LA BIO group (n = 40) was maintained from preoperatively (14.9° ± 22.0°) (Fig. 6-C) to postoperatively (15.8° ± 16.9°) (p = 0.45) (Fig. 6-D, Table III).

The average active ER0 for the non-CLEER patients in the LA non-BIO group (n = 31) significantly deteriorated from preoperatively (34.2° ± 17.1°) to postoperatively (18.6° ± 13.8°)

TABLE III Comparison of Preoperative and Postoperative Active External Rotation*

	Preop.	Postop.	P Value (Preop. Vs. Postop.)
ER0 (all patients)			
LA non-BIO group (n = 36)	27.1° ± 23.8°	17.1° ± 14.8°	0.05†
LA BIO group (n = 40)	14.9° ± 22.0°	15.8° ± 16.9°	0.45
P value	0.02†	0.42	
ER0 (CLEER patients)			
LA non-BIO group (n = 5)	−15.0° ± 10.0°	11.7° ± 20.2°	0.06
LA BIO group (n = 6)	−15.8° ± 9.8°	11.0° ± 15.6°	0.0072†
P value	0.41	0.41	
ER0 (non-CLEER patients)			
LA non-BIO group (n = 31)	34.2° ± 17.1°	18.6° ± 13.8°	0.004†
LA BIO group (n = 34)	21.2° ± 18.1°	17.9° ± 24.2°	0.36
P value	0.008†	0.49	
ER90 (all patients)			
LA non-BIO group (n = 36)	34.2° ± 23.0°	53.0° ± 12.3°	0.013†
LA BIO group (n = 40)	45.8° ± 21.6°	65.9° ± 15.8°	0.012†
P value	0.067	0.026†	

*ER0 = external rotation with the arm at 0°, CLEER = combined loss of active elevation and external rotation, and ER90 = external rotation with the arm at 90° of abduction. The measurements are given as the mean and standard deviation. †Significant.

(p = 0.004). The average active ER0 for the non-CLEER patients in the LA BIO group (n = 34) was maintained from preoperatively (21.2° ± 18.1°) to postoperatively (17.9° ± 24.2°) (p = 0.36) (Table III).

The average active ER90 for all patients in the LA non-BIO group (n = 36) significantly improved from preoperatively (34.2° ± 23.0°) to postoperatively (53.0° ± 12.3°) (p = 0.013). The average active ER90 for all patients in the LA BIO group (n = 40) also significantly improved from preoperatively (45.8° ± 21.6°) to postoperatively (65.9° ± 15.8°) (p = 0.012) (Table III).

There was no difference in preoperative ER90 between the LA non-BIO group (34.2° ± 23.0°) and the LA BIO group (45.8° ± 21.6°) (p = 0.067). Most importantly, postoperative ER90 for all patients in the LA BIO group was significantly greater than in the LA non-BIO group (65.9° ± 15.8° compared with 53.0° ± 12.3°; p = 0.026) (Table III).

Complications

The postoperative acromial stress fracture rate was 2.6% (2 of 76 patients). It was 1.3% (1 of 76) for the LA non-BIO-RSA group (n = 36) and 1.3% (1 of 76) for the LA BIO-RSA group (n = 40). All fractures were managed nonoperatively. The LA BIO-RSA group had 1 intraoperative glenoid facet fracture, which was managed by drilling another peg hole into the remaining glenoid facet. Overall glenoid inclination, measured as the angle between the scapular spine line and a line perpendicular to the base of glenoid component on the postoperative radiograph, was 16.1° ± 6.1°; 15.3° ± 5.3° for LA non-BIO-RSA and 16.5° ± 7.9° for LA BIO-RSA. The glenoid inclination was similar in both groups (p = 0.69). The overall scapular notching rate was 9.2% (7 of 76 patients), with no significant difference between the 2 groups (8.3% [3 of 36] for LA non-BIO-RSA and 10.0% [4 of 40] for LA BIO-RSA). The overall neurological compromise rate was 2.6% (2 of 76 patients). It was 1.3% (1 of 76) for LA non-BIO-RSA (n = 36) and 1.3% (1 of 76) for LA BIO-RSA (n = 40). All motor weakness resolved, but 1 patient in the LA non-BIO-RSA group had residual sensory disturbance on the tips of the fingers.

Discussion

RSA provides reliable restoration of shoulder elevation, but early reports on medialized RSA demonstrated that external rotation is difficult to restore and may even deteriorate[2-4]. The significant deterioration of ER0 in the LA non-BIO-RSA group in the present study is consistent with these reports (Table III).

To address this problem and to improve external rotation, lateralization of the center of rotation has been advocated because it (1) permits greater impingement-free motion[9], (2) allows for retensioning of the posterior portion of the deltoid[8], and (3) allows for retensioning of the remaining rotator cuff muscles[6,7]. The authors of some clinical studies reported favorable improvement in external rotation with lateralized RSA[12,13], while others refuted the effects of lateralization[14,15].

Multiple activities of daily living, such as combing one's hair, tucking in a shirt, and bringing a full glass to the mouth, require active rotation in harmony with active elevation of the shoulder, i.e., ER90 in the present study[16]. Although active rotation is considered more important than full anterior elevation for elderly persons, there is no degree of ER90 that is universally considered satisfactory.

Namdari et al. evaluated the range of motion required to perform various tasks and determined that ER90 of 59° ± 10° was required[17]. Boileau et al. reported on 17 CLEER patients who experienced significant improvement in active external rotation following RSA with latissimus dorsi transfer[16].

To the best of my knowledge, this is the first study to apply BIO in association with a modified direct-lateral approach, i.e., the LA maneuver. Most importantly, this is the first to show that such an RSA can significantly restore ER90, to an average of 65.9° ± 15.8°, without the use of latissimus dorsi transfer.

The preoperative atrophy of the teres minor has been demonstrated to predict postoperative deterioration of external rotation[5,18]. The present study demonstrated that teres minor atrophy in patients with CLEER status was similar between the LA non-BIO and BIO groups. Teres minor atrophy in the patients without CLEER was also similar between the LA non-BIO and BIO groups (Table II). These findings suggest that both ER0 and ER90 for the CLEER and non-CLEER patients were maintained or restored because of the BIO associated with LA RSA, not because of an infrequency of teres minor atrophy.

One limitation of the study is that the study group was not compared with patients who underwent RSA with a latissimus dorsi transfer. Thus, it remains to be understood whether the strength of external rotation in patients without latissimus dorsi transfer is inferior to that with latissimus dorsi transfer. Another limitation is that the LA BIO-RSA group was not compared with patients who underwent prosthetically more lateralized RSA through the same lateral approach. Finally, a larger cohort of CLEER patients treated with LA non-BIO might have demonstrated a significant improvement in active ER0. The nonsignificant change (−15.0° ± 10.0° preoperatively compared with 11.7° ± 20.2° postoperatively; p = 0.06; Table III) is prone to a beta-type error due to the low sample size, and active ER0 in CLEER patients might improve, irrespective of non-BIO or BIO procedures, if they are treated using the LA maneuver.

Nevertheless, this series represents one of the larger series of patients comparing BIO-RSA with non-BIO-RSA as a negative control. In conclusion, the findings of this study suggest that LA BIO-RSA restores external rotation without latissimus dorsi transfer in patients with a preoperative insufficiency of both active elevation and external rotation subsequent to a massive rotator cuff tear. ■

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