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REVIEW ARTICLES

Mid-term results of reverse shoulder arthroplasty for glenohumeral osteoarthritis with posterior glenoid deficiency and humeral subluxation

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Background: Results of anatomic shoulder arthroplasty for glenohumeral osteoarthritis with severe glenoid retroversion are unpredictable with a high rate of glenoid loosening. Reverse shoulder arthroplasty (RSA) has been suggested as an alternative, with good early results. We sought to confirm this at longer follow-up (minimum 5 years). The study hypothesis was that early results would endure over time.
Methods: We retrospectively reviewed all RSAs performed in 7 centers from 1998 to 2010. The inclusion criteria were primary glenohumeral osteoarthritis with B1, B2, B3, or C glenoid. Forty-nine shoulders in 45 patients fulfilled the criteria. Bone grafting was performed in 16 cases. Clinical outcomes were evaluated with the Constant score (CS) and shoulder range of motion.
Results: The mean total CS increased from 30 preoperatively to 68 points ($P < .001$) with significant improvements in all the subsections of the CS and range of motion. Scapular notching was observed in 20 shoulders (43%), grade 1 in 5 (11%), grade 2 in 7 (15%), grade 3 in 5 (11%), and grade 4 in 3 (6%). The glenoid bone graft healed in all the shoulders. Partial inferior lysis of the bone graft was present in 8 cases (50%). Scapular notching and glenoid bone graft resorption had no influence on the CS ($P = .147$ and $P = .798$).
Conclusion: RSA for the treatment of primary glenohumeral osteoarthritis in patients with posterior glenoid deficiency and humeral subluxation without rotator cuff insufficiency resulted in excellent clinical outcomes at a minimum of 5 years of follow-up.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Mid-term results; reverse shoulder arthroplasty; glenohumeral osteoarthritis; posterior glenoid deficiency; posterior glenoid defect; humeral subluxation

The study was approved by IRB Institut Locomoteur de l'Ouest (IULS 2015-01).

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When total shoulder arthroplasty was first introduced as a treatment for glenohumeral osteoarthritis, Charles Neer warned about certain cases with severe glenoid retroversion and posterior humeral subluxation.[25] To facilitate analysis of results, Gilles Walch introduced a classification system to identify patients with glenoid retroversion and/or posterior wear (types B and C). The classification system was based on 3 distinct parameters: glenoid retroversion, posterior glenoid wear, and posterior subluxation of the humeral head.[34] This classification was widely adopted, enabling more precise analysis of results. However, treating glenohumeral osteoarthritis with severe glenoid retroversion or posterior humeral head subluxation using anatomic total shoulder arthroplasty (TSA) remains difficult. Several options have been proposed to deal with this problem, which include asymmetric reaming,[9,35,36] reconstruction of the glenoid defect using bone graft,[24,33,35] and augmented glenoid implants,[25,27] all with variable outcomes. The complication rate after TSA for glenoid deficiency and humeral subluxation is higher because of recurrence of posterior humeral subluxation, leading to polyethylene (PE) wear and glenoid loosening.[2,5,9,14,35]

Reverse total shoulder arthroplasty (RSA) was initially intended for eccentric osteoarthritis, but in 2013, Mizuno et al[22] reported good clinical and radiological results at a minimum 2-year follow-up (mean follow-up: 44 months) in type B and C primary osteoarthritis using RSA.

Insufficient central peg length was highlighted as a cause of failure. The present study sought to confirm Mizuno et al's preliminary results at longer follow-up (minimum 5 years), taking into account the risk factors for failure. The study hypothesis was that the good early results would endure over time.

Materials and methods

Study group

We retrospectively reviewed all RSA performed in 7 centers (multicentric study) from 1998 to 2010 with at least 5-year follow-up (FU) with complete functional outcome and radiographic data. The study protocol was approved by the Hospital Ethics Committee. The inclusion criteria were primary glenohumeral osteoarthritis with B1, B2, B3, and C glenoid.[1,34] The exclusion criteria based on plain radiographs and computed tomography (CT) arthrograms were rotator cuff tear arthropathy, primary glenohumeral osteoarthritis with massive rotator cuff tear (isolated supraspinatus tear has been included) posttraumatic glenohumeral arthritis, inflammatory disease or aseptic osteonecrosis, and previous shoulder replacement. We also excluded patients who had undergone 2-stage procedures.

Between 1998 and 2010, 71 shoulders with primary osteoarthritis and a type B or type C glenoid were implanted with RSA. Of these, 7 died before 5-year FU, 5 were bedridden and could not return for follow-up, and 10 were lost to follow-up. The remaining 49 shoulders of 45 patients who fulfilled the criteria formed the cohort of this study. RSA was indicated when posterior subluxation of the humeral head was >55% and when glenoid retroversion could not be corrected with an asymmetric reaming. There were 12 cases with a B1 glenoid, 16 B2, 12 B3, and 9 type C glenoids. The mean age at surgery was 74.5 years (range, 61-86 years).

Thirty-three patients (73%) were women, 25 (51%) involved the right shoulders, and 25 (51%) involved the dominant arm. Twelve patients had an RSA and 6 had an anatomic prosthesis implanted on the contralateral side.

Clinical assessment

Active and passive range of motion were measured preoperatively and postoperatively by independent observers. Constant[7] score was assessed, and its normalized value was calculated.[15] In addition, patients were asked to grade the subjective shoulder value[10] out of 100% representing a normal shoulder.

Radiographic evaluation

Preoperative and postoperative radiographic evaluation consisted of plain radiographs of true anteroposterior view (with the humerus in neutral, internal rotation, and external rotation) and an axillary view of the glenohumeral joint. All radiographs were performed under fluoroscopic control using a standardized protocol in all the centers. All patients had a preoperative CT arthrogram. Preoperative fatty infiltration of *supraspinatus*, *infraspinatus*, and *subscapularis* muscles was classified according to Goutallier et al.[11] The *teres minor* muscle was staged as normal, atrophic, hypertrophic, or missing.[20]

The axial slice immediately inferior to the tip of the coracoid process was used to quantify glenoid version and humeral head subluxation[17,28] (Fig. 1, *A*). Measurement of glenoid retroversion was made according to Friedman's technique, adapted to the biconcave glenoid.[8,28] For B2 glenoids, 3 retroversion angles (RV) were measured, including RV1 (retroversion of the native glenoid or paleoglenoid), RV2 (retroversion of the intermediate glenoid), and RV3 (retroversion of the posterior eroded glenoid or neoglenoid) (Fig. 1, *B*). For other types of glenoid, we measured only the global retroversion angle on the same CT-scan slice. Subluxation of the humeral head was measured relative to the axis of the scapula (Fig. 1, *C*). Posterior subluxation of the humeral head was defined as a posterior displacement of 55% or more of the diameter of the humeral head relative to Friedman's line. Postoperative radiographs were reviewed, and radiolucent lines around the glenoid and humeral components were evaluated.[30] Postoperative graft incorporation

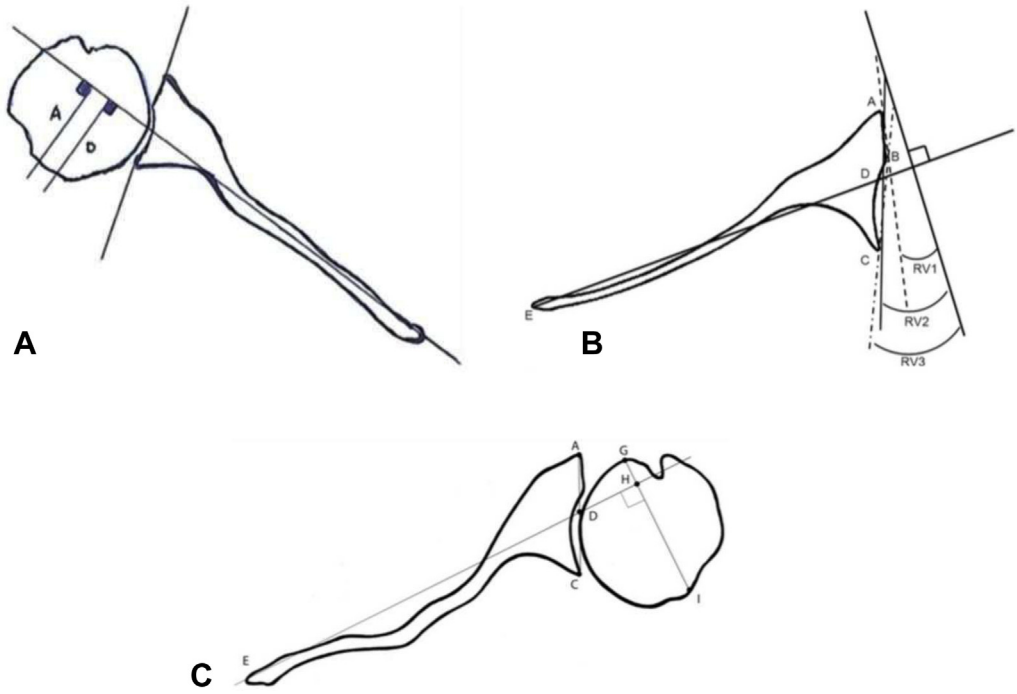

Figure 1 (**A**) Preoperative computed tomography–scan measurements, on the axial slice just inferior to the tip of the coracoid. A line is first drawn from the most medial point of the scapula to the middle of the glenoid surface (Friedman's line). (**B**) Measurement of retroversion angles of the glenoid, relative to the axis of the scapula (Friedman's line). RV1, paleoglenoid angle; RV2, intermediate glenoid angle; RV3, neoglenoid angle. The retroversion of a biconcave glenoid can be measured 3 different ways relative to the Friedman line (ED). Line AB represents the native glenoid or paleoglenoid; the retroversion of the paleoglenoid (RV1 angle) is the angle between line AB and a line perpendicular to the Friedman line. Line AC represents the intermediate glenoid; the retroversion of the intermediate glenoid (RV2 angle) is the angle between line AC and a line perpendicular to the Friedman line. Line BC represents the posterior eroded surface or neoglenoid; the retroversion of the neoglenoid (RV3 angle) is the angle between line BC and a line perpendicular to the Friedman line. (Reproduced from Mizuno et al.[22]) (**C**) Humeral head subluxation according to Friedman's technique. Humeral head subluxation can be assessed with regard to the scapular axis. A line is drawn from the medial tip of the scapula through the center of the glenoid, also called the Friedman line (line ED). Another line is drawn perpendicular to the Friedman line such that it passes through the widest portion of the humeral head. Humeral head subluxation is then estimated at the percentage of the humeral head that lies posterior to the Friedman line. In this example, the subluxation (HI/GI) is 80.2%. Note that the center of the humeral head (J) is not required in this measurement. (Reproduced from Mizuno et al.[22]).

was evaluated in the 16 patients (33%) who received glenoid bone graft at the time of surgery. Scapular notching was graded according to the classification system of Sirveaux et al.[32] Osteophytes and inferior scapular neck ossification in the scapulohumeral space were noted in the anteroposterior radiograph. Resorption of the greater and lesser tuberosities, when present, was classified as partial or complete.[21]

Operative technique

All the prostheses used were based on the Grammont design. A Delta III prosthesis (DePuy Orthopaedics, Warsaw, IN, USA) was implanted in 3 shoulders, and an Aequalis Reversed prosthesis (Tornier, Edina, MN, USA) was implanted in 46 shoulders. In 44 cases (90%), a deltopectoral approach was used: 2 cm of the pectoralis major tendon was released, and the subscapularis tendon was tenotomized at the level of the anatomical neck or peeled from the lesser tuberosity. In 5 cases (10%), a superior transdeltoid approach was used, with a preservation of the subscapularis tendon. The humeral head was cut in 0° to 20°of retroversion. The glenoid was clearly exposed and was reamed asymmetrically with the goal to correct glenoid retroversion. The orientation of reaming was determined by palpating the glenoid centering point on the anterior scapular neck as described by Matsen et al[19] without any additional tool or guide being used to control the reaming. Before 2005, reaming was performed with a freehand technique; thereafter, a cannulated system became available and was used for reaming. Sixteen patients (33%) required bone grafting of the glenoid because asymmetrical reaming of the anterior aspect of the glenoid was not sufficient to eliminate the posterior defect and to provide a reasonably flat surface for glenoid implantation. The cancellous graft was contoured to fit the posterior glenoid defect and was secured to the native glenoid with standard screws that were placed through the baseplate. The central post of the baseplate was implanted into the native scapula to secure its fixation. In all 16 cases,

an autogenous bone graft disc was obtained from the humeral head and secured on a long baseplate peg of 25 mm. In the 33 nongrafted glenoids, a 15 mm peg was used in 31 cases and a long peg in 2 cases. A 36-mm-diameter glenosphere was inserted in 45 shoulders, and a 42- mm-diameter glenosphere was inserted in 4 shoulders (4 males), based on the surgeon preference and operative findings. A humeral component was implanted in the standard fashion with retroversion between 0° and 25° to fit the humeral anatomy, with cement in 40 cases and without in 9 cases. In 43 cases, a 6 mm lateralized PE was used, whereas a 9 mm PE was used in 5 cases and a 12 mm PE in 1 case. In the case of deltopectoral approach, the subscapularis tendon was repaired with transosseous nonabsorbable sutures. A soft-tissue biceps tenodesis was performed when the tendon was still present. The attachment of the supraspinatus tendon was either preserved or detached.

Postoperative rehabilitation

Postoperatively, the shoulder was immobilized with a simple sling in internal rotation, or with a neutral rotation sling for 4 weeks to protect the subscapularis repair. During this period, the sling was removed for hygiene and the patient was allowed to use the hand and elbow for simple daily activities. No lifting was allowed. Pendulum exercises were initiated 3 days after surgery. After 4 weeks, the sling was discontinued, and activities were allowed as tolerated.

Statistical analysis

Numerical outcomes were described as mean and standard deviation or range (minimum–maximum). Discrete outcomes were described as absolute and relative frequencies. For numerical data, Wilcoxon's test was used to compare preoperative and postoperative results, and the Mann-Whitney or the Kruskal-Wallis test was used to compare outcomes between groups. For discrete outcomes, Fisher's test or the chi-square test was used. The alpha risk was set at 5%. Survival analysis was performed according to the Kaplan-Meier method, and 95% confidence interval (95% CI) of the survival estimate was calculated according to the log-log method. Data were analyzed using the online software Easy Med Stat (www.easymedstat.com; Neuilly-Sur-Seine, France).

Results

The mean duration of follow-up was 7.7 years (5-16 years).

Complications and revisions

Complications occurred in 3 patients (6%): 1 patient suffered a transient radial nerve palsy, 2 male patients had postoperative infections that required revision. The first patient who was 78 years old at surgery was diagnosed with an infection due to *Cutibacterium acnes* infection 6 years after surgery, which was first treated with an unsuccessful washout. Eleven months later, explantation of the RSA was performed and a cement spacer was left in situ. At the last follow-up, his result was poor (Constant score = 20). The other patient was 67 years old at surgery and was diagnosed with a postoperative infection due to *Staphylococcus epidermis* infection, which required a 2-stage RSA exchange 1 year and 9 months after the index surgery.

At the last follow-up, the Constant score was 61. These 2 revised patients were excluded from the functional analysis. The survival rate without revision was 98% at 5 years (95% CI, 86.4%-99.7%) and 94% at 10 years (95% CI, 78%-99%).

Table I Evolution of constant score

	Preoperative	Last follow-up	*P* value
Pain (/15)	4 (± 2)	13 (± 3)	<.001
Activity (/20)	7 (± 3)	16 (± 5)	<.001
Mobility (/40)	15 (± 7)	31 (± 7)	<.001
Strength (/25)	4 (± 4)	7 (± 4)	<.001
Total (/100)	30 (± 12)	68 (± 13)	<.001
Adjusted (%)	43 (± 19)	105 (± 19)	<.001

Clinical results

The mean total Constant score increased from 30 preoperatively to 68 points at the last FU ($P < .001$) with significant improvements in all the subsections of the Constant score (Table I). There were also significant postoperative improvements in terms of active forward flexion. Results of range of motion are in Table II.

Radiological analysis

At the final FU, scapular notching was observed in 20 shoulders (43%). The notching was classified as grade 1 in 5 shoulders (11%), grade 2 in 7 (15%), grade 3 in 5 (11%), and grade 4 in 3 (6%). All shoulders showed healing of the glenoid bone graft on radiographs. Partial inferior lysis of the bone graft was present in 8 cases (50%) (Fig. 2). Partial

Table II Evolution of range of motion

	Preoperative	Last follow-up	*P* value
Active elevation (°)	89 (± 26)	145 (± 26)	<.001
Passive elevation (°)	107 (± 23)	147 (± 29)	<.001
Active ER1 (°)	3 (± 20)	18 (± 14)	<.001
Passive ER1 (°)	6 (± 21)	23 (± 13)	<.001
Active ER2 (°)	27 (± 24)	64 (± 19)	<.001
Active IR1 (/10)	3.6 (± 2.4)	6.5 (± 2.9)	<.001

ER1, external rotation 1; *IR1*, internal rotation 1.

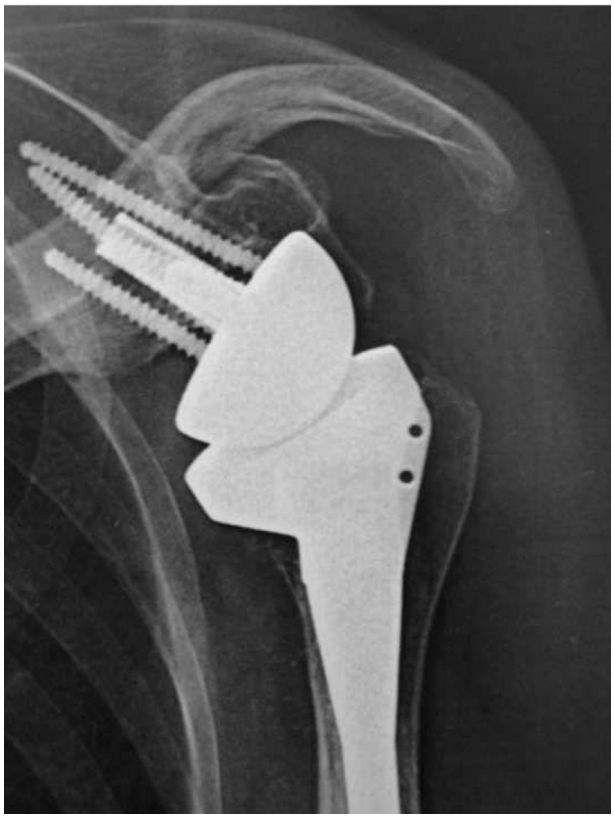

Figure 2 Resorption of a glenoid graft at 5 years postoperatively.

radiolucent lines were observed around the humeral implant in 3 shoulders (6%). No radiolucent lines were observed around the central peg but were found in 2 cases (4%) behind the base plate and in 1 case (2%) around the screws of the glenoid component. Partial resorption of the greater tuberosity was observed in 4 cases (9%) and was complete in 2 cases (4%). For the lesser tuberosity, we observed 8 partial (17%) and 3 complete (6%) resorptions. Ossifications in the glenohumeral space were found in 11 shoulders (23%). Scapular notching and glenoid bone graft resorption had no influence on the adjusted CS ($P = .147$ and $P = .798$). Greater tuberosity resorption was associated with lower adjusted CS (100% vs. 119%; $P = .0174$) but had no significant influence on active forward elevation (AFE) or external rotation 1 (ER1). Ossifications in the glenohumeral space were associated with the lower adjusted Constant score (88% vs. 108%; $P = .029$), active anterior elevation (119° vs. 153°; $P = .032$), active ER1 (9° vs. 21°; $P = .038$), and active internal rotation (3.8 vs. 7.3; $P < .001$).

Table III Clinical outcomes according to the preoperative glenoid type

	B1	B2	B3	C	*P* value
	n = 11	n = 15	n = 12	n = 9	
Female (%)	86	64	100	71	.498
Age at surgery	78	72	77	73	.023
AFE (°)	151	147	137	145	.910
AER1 (°)	19	18	19	18	.920
AIR1 (/10)	5.8	6.4	6.5	7.1	.771
CS (/100)	63	73	66	68	.190
Adjusted CS (%)	100	107	100	105	.833
SSV (%)	78	79	78	76	.907

AFE, active forward elevation; *AER1*, active external rotation 1; *CS*, Constant score; *SSV*, subjective shoulder value.

Table IV Comparison of patients with or without glenoid graft

	Glenoid grafting	No graft	*P* value
	N = 16	N = 33	
Female (%)	53	84	.034
Age at surgery (yr)	73	75	.169
Year of surgery (median year)	2010	2007	<.001
Follow-up (yr)	6.2	8.4	<.001
Revision (n)	1/16	1/33	1
Adjusted CS (%)	107	101	.613

CS, Constant score

Influence of preoperative glenoid type

We found no difference in terms of AFE, active ER1, active internal rotation 1 (IR1), CS, adjusted CS or subjective shoulder value, and the type of glenoid at the last follow-up (Table III).

Influence of preoperative humeral head subluxation

Preoperatively, the mean humeral head subluxation was 74% of the humeral head diameter, relative to Friedman's line (Min. 57%-Max. 99%). Therefore, we compared patients with less or more than 75% of preoperative subluxation and did not find any difference in the adjusted Constant score (106% vs. 105%; $P = .828$) at the last FU.

Influence of the operative technique

We found no significant difference in terms of adjusted CS or range of motion in terms of the surgical approach, glenoid size, Bio-RSA, and humeral cementation (data not provided). Glenoid grafting had no influence on the last FU adjusted CS, but the groups were hardly comparable preoperatively and for follow-up duration (Table IV).

Discussion

Primary osteoarthritis of the shoulder with intact rotator cuff and posterior humeral head subluxation and/or

excessive retroversion is now a recognized distinct pathological entity. When treated with anatomic total shoulder arthroplasty, ''biconcave'' glenoids may lead to a revision rate of 16% at a mean 6-year FU,[35] leading Gilles Walch to recommend reverse shoulder arthroplasty even in the case of healthy cuff, simply aiming to correct the posterior humeral head subluxation by means of semiconstrained arthroplasty. Preliminary results at a minimum 2-year follow-up were encouraging,[22] but the authors stressed that reverse shoulder arthroplasty in primary osteoarthritis is off-label, and that longer follow-up was needed to justify its indication.

Our current study at 5-year minimum follow-up confirmed that these results remained stable over time: revision rate (2/49 in our series vs. 1/27 in the study of Mizuno et al in 2013[22]), Constant score (68 vs. 76), and active forward elevation (145° vs. 152°) were comparable. The preoperative type of glenoid had no influence on clinical results in our series, and our revision rate was too low to draw any conclusion on the risk factors for revision. Our midterm results suggest that RSA is a valuable option in elderly arthritic patients (mean age 74 years, in our series) with severe glenoid posterior deficiency. Correction of severe glenoid deformity can be done with the use of bone graft harvested from the humeral head (BIORSA technique,[3] performed in one-third of our cases). Another advantage of this technique is that it allows fixing the bone graft with the long central post and screws inserted through the baseplate. At the mean follow-up of 7.7 years (5-16 years), all but one bone graft healed, and no revision for glenoid loosening was required. Until recently, anatomical TSA was the only option in OA with severe posterior glenoid deficiency.

There are currently 3 ways to manage these posteriorly-worn glenoids: asymmetric reaming, posterior-augmented glenoid implant, and posterior bone graft with anatomical TSA. In the past, surgeons first sought to correct excess retroversion by asymmetric reaming, to treat posterior humeral subluxation. Habermeyer et al[18] reported good short-term results (2 years minimum) in 49 shoulders, with systematic correction of posterior subluxation. Gerber et al[9] also reported good correction of posterior subluxation in 21 of 23 cases at a minimum 2-year follow-up. However, comparison with that series is limited by the fact that there were only 12 cases of primary osteoarthritis, and only 5 type B glenoids. Chin et al[5] obtained good clinical results in 37 B2 glenoids treated with TSA at 5-year mean FU, when correcting retroversion to less than 10° while removing less than 5 mm of glenoid bone. However, eccentric reaming with anatomical TSA poses its own technical problems: when retroversion exceeds 10°,[4] ablation of cortical bone may prevent the use of a cemented glenoid implant and increase the risk of glenoid loosening.[18,23] Ho et al[13] recently showed that postoperative retroversion greater than 15° was associated with increased osteolysis around the cemented glenoid component.

Some authors therefore recently suggested using anatomical TSA with a posterior-augmented glenoid implant.[16,37] Rice et al[27] reported a case series of 14 shoulders in which a keeled cemented all-polyethylene component with posterior augmentation (Cofield 2; Smith & Nephew, Memphis, TN, USA) was implanted. The implant had 3 different sizes, with a difference in height between the anterior and posterior aspects of the component providing approximately 4° correction of version. At a minimum 2 years and mean 5 years of follow-up, no shoulders required revision surgery. However, 2 patients had unsatisfactory results, and preoperative instability was not always corrected with this prosthesis: 3 patients still had posterior subluxation after the procedure, and another 2 had anterior subluxation. The authors attributed these cases of subluxation to a weakened subscapularis muscle. Sandow and Schutz[31] reported good clinical and radiological results with trabecular metal augmented implants at 2 years of follow-up; however, long-term results for the arthroplasty and for bone stock in case of revision are unknown.

The third option is to compensate the glenoid retroversion with an autologous bone graft and a metalback glenoid implant. Neer and Morison[24] were the first to report on TSA with bone grafting for severe glenoid deficiency. Steinmann and Cofield[33] reported excellent results in 29 cases (with 10% glenoid loosening), but once again type B and C glenoids were not clearly identified, making it difficult to know whether comparison is justified. Hill and Norris[12] reported unsatisfactory graft results, with almost half of 18 patients dissatisfied. Sabesan et al[29] reported clinical and radiographic outcome in 12 patients (9 type B2, 3 type C) who underwent total shoulder arthroplasty with glenoid bone grafting using autologous humeral head graft. Ten patients had good or excellent clinical results at a minimum 2 years of follow-up, and 9 patients showed graft integration without resorption. Revision surgery was required in 2 cases because of glenoid component failure. Infection was found in 1 case. Recently, Nicholson et al[26] reported good clinical and radiological results with posterior glenoid bone graft from the humeral head. The graft could correct glenoid retroversion from −28° to −4° postoperatively, with all grafts healed on radiographs, and no revision needed at a mean 4 years of follow-up.

The problem with anatomical total shoulder arthroplasty in arthritic shoulder with biconcave/dysplastic glenoids is recurrence of humeral head subluxation that can result in early polyethylene wear and glenoid component loosening. Being semiconstrained, reverse shoulder arthroplasty seems an appropriate choice to treat posterior humeral head subluxation. The first results were reported by Mizuno et al[22] in 2013, in 27 cases with a mean follow-up of 54 months. There was only 1 glenoid failure in the short term, due to a technical error: use of a short peg that was not completely anchored in the native glenoid. The authors concluded that,

whatever the size and type of graft, the baseplate peg should anchor at least 10 mm length into the native glenoid. Thus, in all grafted cases, we used a long peg. This had improved primary fixation and prevented any early loosening. In addition, there were no dislocations, despite retroversion averaging 27°. Like in Mizuno et al's study,[22] we had a female predominance with 73% of patients being women (vs. 81%), which may limit the extrapolation of these results to men.

In our series, scapular notching was observed in 44% of cases, and inferior graft lysis in 50%, as reported by Collin et al.[6] These radiological findings that could be a source of long-term glenoid complications were not more frequent in the present series than in reverse total shoulder arthroplasty performed for other conditions. All grafts were well integrated. Clinical and radiological results were the same in patients with and without bone graft: this can be explained by the fact that bone grafting was used in the more severe cases of glenoid erosion and allowed lateralization while restoring the joint line.

The present study had several limitations. It was retrospective, noncomparative, and multicenter study with involvement of several surgeons. Retroversion was analyzed 2-dimensionally, whereas 3D analysis would have been more precise and reproducible. We did not analyze postoperative correction of retroversion and subluxation using CT-scans, because there was no clinical indication for such imaging in patients with no complications.

Nevertheless, this is the largest series of patients with primary osteoarthritis and type B or C glenoid treated with an RSA. Our minimum FU of 5 years allowed us a mid-term assessment of glenoid complications, which was a concern in these patients.

Conclusions

The study hypothesis confirmed that the good early results endure over time for patients with posterior glenoid deficiency and humeral subluxation without rotator cuff insufficiency. Clinical outcomes remain excellent at a minimum of 5 years of follow-up, despite a high rate of glenoid notching.

Disclaimer

Philippe Collin, Gilles Walch, and Pascal Boileau declare royalties for consulting from Wright Tornier in outside submitted work. The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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