Long-Term Outcomes of Reverse Total Shoulder Arthroplasty

A Follow-up of a Previous Study

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Background: Despite the increasing numbers of reverse total shoulder arthroplasty (RTSA) procedures, the long-term results have been rarely reported. We previously reported early outcomes of a cohort of patients treated with a Grammont-style RTSA. The purpose of this study was to evaluate the outcomes after a minimum of 10 years, and to document prosthetic survival and complications.

Methods: Clinical outcome assessment was based on the absolute and relative Constant scores and the active range of motion. Radiographic evaluations of scapular notching, tuberosity osteolysis, and periprosthetic radiolucent lines were done as well. Complications and revisions were compiled, and a Kaplan-Meier survival analysis was performed.

Results: The original report included the outcomes for 186 patients (191 RTSAs) who had been followed for a mean of 40 months. In the present study, in which the mean duration of follow-up was 150 months, follow-up clinical evaluations were available for 84 patients (87 prostheses) and radiographic assessments were available for 64 patients (67 prostheses). Seventy-seven patients (79 prostheses) had died before the 10-year follow-up, and 17 patients (17 prostheses) had been lost to follow-up. The mean absolute and relative Constant scores (and standard deviations) were 55 ± 16 points and 86 ± 26 points, respectively, with both having decreased significantly compared with the scores at the medium-term follow-up evaluation (at a minimum of 2 years) ($p < 0.001$ and $p = 0.025$, respectively). Forty-nine shoulders (73%) exhibited scapular notching. Forty-seven complications (29%) were recorded, with 10 cases (10%) occurring after 2 years. Sixteen (12%) of the original patients underwent revision surgery. The 10-year overall prosthetic survival rate using revision as the end point was 93%.

Conclusions: Despite a high arthroplasty survival rate and good long-term clinical results, RTSA outcomes showed deterioration when compared with medium-term results. The cause of this decrease is probably related to patient aging coupled with bone erosion and/or deltoid impairment over time.

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

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Reverse total shoulder arthroplasty (RTSA) has demonstrated promising medium-term outcomes[1-11]. Those results as well as the expansion of indications have been reported to explain the growth in the use of RTSA worldwide[12-17], but the long-term results of RTSA have rarely been reported. Although the long-term studies that have been published have highlighted high prosthetic survivorship[2,6,18,19], the loss of shoulder function and increase in radiographic findings of complications over time are concerning. In 2007, we reported the medium-term outcomes of 186 patients treated with a total of 191 RTSAs for

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etiologies associated with rotator cuff deficiency[8]. The average Constant score and anterior active elevation were significantly increased at the time of that medium-term follow-up. The aim of the current study was to evaluate the clinical and radiographic outcomes of the same cohort after a minimum of 10 years and to document rates of prosthetic survival and complications.

Materials and Methods

Study Group

The original report included a consecutive series of 186 patients (191 procedures) followed for a mean of 40 months (range, 24 to 118 months) after RTSAs performed by one of two shoulder surgeons (G.W. or L.N.-J.)[8]. The mean age at the time of surgery was 72.7 years (range, 23 to 86 years). The patients were grouped according to the surgical indications, all of which involved a deficient rotator cuff: (1) rotator cuff tear arthropathy, (2) a failed previous arthroplasty (i.e., the RTSA was a revision arthroplasty), (3) a massive rotator cuff tear without arthritis, (4) posttraumatic glenohumeral arthritis with rotator cuff compromise, or (5) primary osteoarthritis with rotator cuff compromise and with or without severe glenoid bone erosion.

Grammont-design prostheses were used, including 164 Delta-III (DePuy France) and 27 Aequalis (Tornier) systems. All but 3 were implanted through a deltopectoral approach. Six shoulders required a custom glenoid implant, allowing acromial fixation with an upper bar and screws because of glenoid bone loss. All but 1 of the humeral stems were cemented.

Clinical and Radiographic Assessments

This study was approved by our institutional ethics committee, and all patients provided written informed consent to allow their data to be used in the study. Patients were evaluated by an independent examiner (G.B.) at a minimum of 10 years after surgery. The surgical techniques and rehabilitation protocol have been described[8].

All 186 patients from the medium-term outcome study were asked to attend a consultation at our institution. Long-term assessments were performed for patients who had not undergone a prosthetic explantation. Patients who could not return for an on-site consultation because of poor health completed a self-administered questionnaire with the assistance of his/her general practitioner, and the responses were finalized via a telephone interview. Radiographs were made at a center close to the patient's home and sent to our institution. When a patient had died during the follow-up period, his/her general practitioner was asked for the date of death along with data on any prosthetic revisions or removals carried out in other centers.

Clinical assessment was based on the absolute and relative Constant scores[20,21] and the active range of motion of the shoulder. The range of motion (elevation and external and internal rotation) was measured using a goniometer. Strength measurements were carried out using a handheld dynamometer. Radiographic studies included anteroposterior views of the glenohumeral joint in neutral rotation and axillary views obtained under fluoroscopic control for all patients reassessed at our institution. Scapular notching was evaluated according to the Sirveaux classification[2]. Humeral radiolucent lines were classified according to the Sperling system[22] modified by Lévigne et al.[23]. Loosening of implants was defined as described by Melis et al.[19]. Osteolysis of the humeral tuberosities was assessed by comparing immediate postoperative radiographs with those obtained at the time of final follow-up. The preoperative condition of the humeral tuberosities as well as any intraoperative fractures, nonunions, or excisions of the humeral tuberosities were identified by reviewing the operative reports and analyzed by comparing preoperative and immediate postoperative radiographs.

Postoperative complications were classified as *early* when they had occurred in the first 2 years following surgery and as *delayed* when they had occurred afterward.

Statistical Analysis

A Kaplan-Meier survival analysis was performed with revision (i.e., removal or replacement of the prosthesis) for any reason as the end point. All revisions after the initial procedure were included in the survivorship analysis. Log-rank (Mantel-Cox) tests were performed to determine statistical differences in prosthetic survival among etiologies. Given that the paired data are from the same population, clinical outcomes were compared using nonparametric Wilcoxon signed-rank tests. The significance level was set at $p < 0.05$.

Results

Of the 186 patients (191 prostheses) assessed in the earlier study[8], 77 (79 prostheses) died before the long-term assessment, at a mean age of 82 years (range, 64 to 94 years) and at a mean of 6 years (range, 2 to 9 years) after the initial procedure.

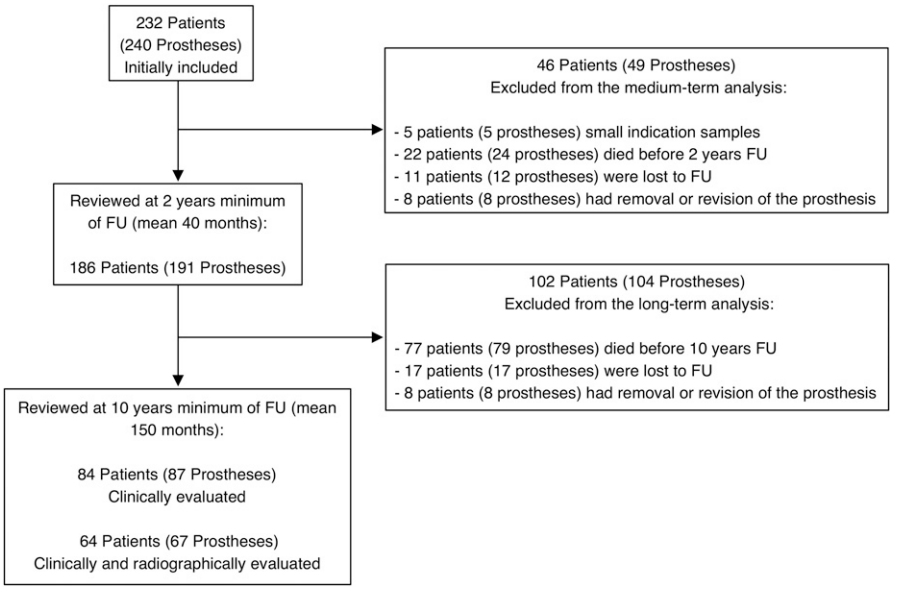

Fig. 1

Patient disposition. FU = follow-up.

Of the remaining 109 patients (112 prostheses), 17 (17 prostheses) were lost to follow-up and 8 (8 prostheses) developed a complication that led to removal or revision of the prosthesis before the 10-year follow-up assessment. Long-term clinical data were thus obtained for 84 (77%) of the living patients and 87 (78%) of the prostheses in living patients. Both clinical and valid radiographic assessments were obtained for 64 (59%) of the living patients and 67 (60%) of the prostheses in living patients (Fig. 1). Eight patients (8 prostheses) were unable to return to our clinic and their cases were reviewed at an external institution. Only 2 of the 8 had interpretable radiographs. We also encountered difficulties assessing the grade of scapular notching on radiographs of 14 patients (14 prostheses), which were excluded from the radiographic analysis. We did not find significant differences in the Constant score preoperatively or at the follow-up time points, the sex ratio, or the age at the procedure between the patients evaluated outside and those examined at our center ($p > 0.05$).

The mean duration of follow-up was 150 months (range, 121 to 241 months), and the average patient age was 83 years (range, 45 to 95 years). The preoperative etiologies included rotator cuff tear arthropathy in 27 of the shoulders, failed arthroplasty in 21, a massive rotator cuff tear in 20, posttraumatic arthritis in 10, and primary osteoarthritis in 9.

Constant Scores and Range of Motion

The mean absolute Constant score at the last follow-up was 55 ± 16 points, which was a significant improvement relative to the preoperative score (Table I). Nonetheless, there was a significant decrease in the absolute Constant scores between the medium and late follow-up evaluations both overall ($p < 0.001$) and in every etiology group ($p < 0.020$). Except for the pain score ($p = 0.051$), all of the components of the Constant score significantly decreased between the medium and long-term follow-up evaluations ($p < 0.001$). There was also a significant reduction in the relative Constant score ($p = 0.025$). Similarly, anterior active elevation improved significantly after implantation of the prosthesis but decreased significantly between the medium and long-term follow-up evaluations ($p < 0.001$). Rotational range of motion did not diminish between the medium and long-term follow-up assessments.

Rotator cuff tear arthropathy and primary osteoarthritis (as the indication for the RTSA) were associated with the highest absolute Constant scores at the time of the long-term follow-up (63 ± 13 points and 62 ± 8 points, respectively). RTSAs due to a failed previous arthroplasty or to posttraumatic arthritis were associated with the lowest Constant scores (45 points for both) and with less anterior active elevation after 10 years of follow-up (Table II). Patients who had had the

TABLE I Preoperative and Postoperative Functional Parameters for 87 RTSAs

Parameter	Preoperative*	Medium-Term Follow-up*	Long-Term Follow-up*	P Value†
Follow-up *(mo)*	—	39 (24 to 116)	150 (121 to 241)	—
Absolute Constant score† *(points)*				
All patients				
Overall score	23 ± 12	63 ± 14	55 ± 16	<0.001
Pain	4 ± 4	12 ± 3	11 ± 4	0.051
Activity	6 ± 3	16 ± 3	15 ± 4	<0.001
Mobility	12 ± 8	27 ± 8	25 ± 8	<0.001
Strength	1 ± 4	8 ± 4	5 ± 3	<0.001
According to etiology				
Cuff tear arthropathy	22 ± 11	70 ± 11	63 ± 13	0.005
Revision arthroplasty	21 ± 13	55 ± 16	45 ± 17	<0.001
Massive cuff tear	24 ± 14	63 ± 11	55 ± 12	0.004
Posttraumatic arthritis	27 ± 8	55 ± 20	45 ± 22	0.016
Primary osteoarthritis	26 ± 11	70 ± 6	62 ± 8	0.014
Relative Constant score† *(points)*	33 ± 17	90 ± 21	86 ± 26	0.025
Range of motion§				
AAE† *(deg)*	81 ± 43	138 ± 26	131 ± 29	<0.001
AER1 *(deg)*	9 ± 14	10 ± 16	9 ± 14	0.490
AER2 *(deg)*	39 ± 21	44 ± 25	43 ± 30	0.987
AIR	L5	L3	Sacrum	0.850

*The values are given as the average and standard deviation except for follow-up, which is given as the average and the range. †For comparisons between medium and long-term follow-up values performed with the Wilcoxon signed rank test. ‡The changes between preoperative and medium-term or long-term postoperative values were significant ($p < 0.05$, Wilcoxon signed rank test). §AAE = active anterior elevation, AER1 = active external rotation with the elbow at the side, AER2 = active external rotation at 90° of abduction, and AIR = active internal rotation.

TABLE II Changes in Constant Mobility and Strength Scores and Active Anterior Elevation Between Medium and Long-Term Follow-up Evaluations According to Diagnosis*

	Constant Score *(points)*								
	Mobility			Strength			Active Anterior Elevation *(deg)*		
Etiology	Medium-Term Follow-up*	Long-Term Follow-up*	P Value†	Medium-Term Follow-up*	Long-Term Follow-up*	P Value†	Medium-Term Follow-up*	Long-Term Follow-up*	P Value†
Rotator cuff tear arthropathy	29 ± 6	29 ± 6	0.548	10 ± 4	6 ± 4	<0.001	147 ± 17	146 ± 26	1.00
Revision arthroplasty	22 ± 8	19 ± 8	0.037	6 ± 4	3 ± 2	<0.001	128 ± 32	116 ± 30	0.010
Massive rotator cuff tear	29 ± 6	26 ± 7	0.011	7 ± 3	5 ± 2	0.003	142 ± 18	125 ± 25	0.002
Posttraumatic arthritis	23 ± 10	20 ± 11	0.120	7 ± 4	4 ± 3	0.035	121 ± 32	119 ± 31	0.586
Primary osteoarthritis	30 ± 5	27 ± 6	0.248	8 ± 3	5 ± 2	0.020	146 ± 24	140 ± 27	0.792

*The values are given as the average and standard deviation. †Wilcoxon signed rank test.

RTSA because of a failed previous arthroplasty were the only etiological group in which the pain and activity values of the Constant score significantly decreased between the medium and long-term follow-up evaluations ($p = 0.012$ and $p = 0.006$, respectively). A failed previous arthroplasty and a massive rotator cuff tear were the only 2 RTSA indications associated with a significant decrease in the Constant score for mobility and in anterior active elevation between the medium and long-term follow-up evaluations. The Constant score for strength decreased significantly between the 2 assessments in all of the etiological groups (Table II).

Radiographic Assessment

Radiographic analyses showed a radiolucent line around the glenoid implant in 3 shoulders. The radiolucency was ≥2 mm wide and was located around the glenoid screws and below the baseplate, with implant migration associated with the glenoid loosening.

Preoperative radiographs showed the absence of 1 humeral tuberosity in 5 shoulders and the absence of both tuberosities in 1. In addition, a fracture or confirmed nonunion during RTSA led to excision of both tuberosities in 5 cases and excision of only 1 tuberosity in 7 cases. The combination of preoperative tuberosity absence and intraoperative tuberosity excision resulted in 8 cases with absence of both tuberosities and 8 other cases with absence of only the lesser tuberosity. Postoperative absence of at least 1 tuberosity was significantly associated with a failed previous arthroplasty as the indication for the RTSA ($p < 0.001$). All except 3 cases of tuberosity absence were related to revision of an arthroplasty that had been carried out for the treatment of a displaced 4-part proximal humeral fracture.

TABLE III Complications and Revisions According to Duration of Follow-up

	No. of Complications		No. of Revisions	
Type of Complication	Up to 2 Years	After 2 Years	Up to 2 Years	After 2 Years
Dislocation	15	0	1	—
Infection	8	2	6	2
Nerve palsy	3	0	0	—
Glenoid loosening	2	4	1	3
Humeral loosening	2	3	0	2
Glenosphere not seated	6	0	0	—
Glenoid fracture	1	0	0	—
Polyethylene wear and humeral osteolysis	0	1	—	1
Total	37	10	8	8

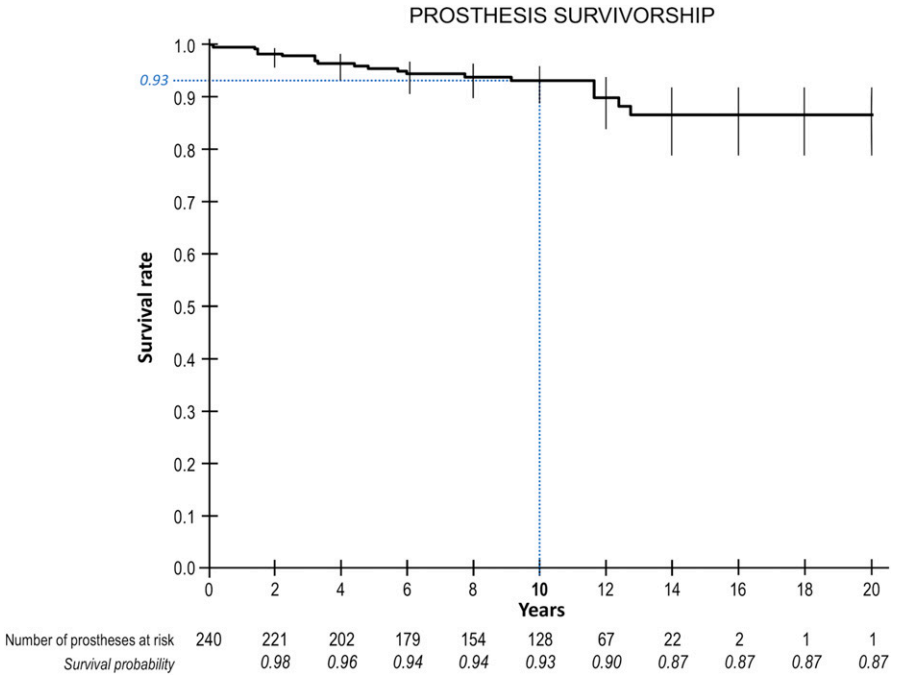

Fig. 2

Kaplan-Meier survival curve, with 95% confidence interval, with revision for any reason as the end point.

Humeral radiolucent lines in at least 3 zones were seen in 8 shoulders (12%), including 1 with asymptomatic loosening. In 5 of these cases, a failed previous arthroplasty was the original indication for the RTSA ($p = 0.016$). Postoperative absence of the greater tuberosity was significantly associated with humeral radiolucent lines at the final follow-up evaluation ($p < 0.001$).

Forty-nine shoulders (73%) had scapular notching; 30 (61%) of these cases were classified as Sirveaux stage 1 or 2 and the other 19, as stage 3 or 4. Since the time of the medium-term follow-up[8], 26 new cases of scapular notching (20 of which were Sirveaux stage 1 or 2) had developed (a 39% increase in the rate of scapular notching). Of the 23 cases that were apparent at the earlier follow-up evaluation, 11 progressed. There were no statistically significant differences in long-term Constant scores between patients without notching or with a lower stage of scapular notching (0, 1, or 2) and those with a higher stage of scapular notching (3 or 4) ($p = 0.746$).

Partial or complete osteolysis of at least 1 tuberosity was seen in 88% of the shoulders. We did not find osteolysis of the greater tuberosity ($p = 0.064$) or lesser tuberosity ($p = 0.702$) to have any impact on the long-term Constant score.

Complications

A total of 37 complications in 35 patients occurred during the first 2 postoperative years, and 10 in 10 patients occurred afterward (Table III). The 10 delayed complications were identified at a mean of 100 months (range, 37 to 139 months) after the RTSA, and they included 7 cases of unipolar prosthetic aseptic loosening: 4 on the glenoid side and 3 on the humeral side. There were no cases of glenoid loosening secondary to progression of scapular notching. The 4 cases of glenoid loosening were related to the use of a custom-made glenoid implant without a central peg but with acromial screw fixation (3 cases) and/or to technical error (1 case).

Revisions and Prosthetic Survivorship

There were 8 revisions in the first 2 years and 8 after 2 years (Table III). Six of the delayed revisions were secondary to aseptic implant loosening, and 2 were secondary to late infection.

Kaplan-Meier analysis showed a mean implant survival time of 110.3 months (95% confidence interval [CI], 103.9 to 116.7 months), with a 93% survival probability at 120 months and 128 cases at risk (Fig. 2). There was no difference in survival according to etiology ($p = 0.30$).

Discussion

The long-term results of RTSA have rarely been reported[2,6,18,19], and the average duration of follow-up in the long-term studies that have been published is <120 months (Table IV). In the present study, we evaluated the outcomes, complications, and implant survivorship in a consecutive series of Grammont-style RTSAs followed for a minimum of 10 years. While we found that the overall absolute and the relative Constant scores remained acceptable, both decreased significantly between the 2 evaluations.

Our findings are consistent with the Constant score of 57 points reported by Favard et al.[18]. The survival rate of 93% at 10 years that we reported confirms that the Grammont-style prosthesis is reliable. Other studies that analyzed the long-term survival of this type of prosthesis demonstrated similar results[6,18]. In 2004, Sirveaux et al.[2] reported better functional

TABLE IV Long-Term Results in Series of Grammont-Style RTSAs

Study	Mean Follow-up *(mo)*	Mean Constant Score *(points)*		Mean Active Anterior Elevation *(deg)*	Rate of Stage-3 and 4 Notches *(%)*	Complication Rate *(%)*	Revision Rate *(%)*	Survivorship *(%)*
		Absolute	Relative					
Sirveaux et al.[2]	44.5	65	—	138	17	19	4	95 at 8 yr
Guery et al.[6]	70	—	—	—	—	15	10	91 at 10 yr
Favard et al.[18]	91	57	85	129	35	21	5	89 at 10 yr
Melis et al.[19]	115	60	—	132	62	19	14	—
Present series	150	55	86	131	28	29	12	93 at 10 yr

outcomes and a higher implant survival rate after a shorter follow-up (mean, 44.5 months) in a study limited to RTSA performed for rotator cuff tear arthropathy. Rotator cuff tear arthropathy has been associated with the best results and long-term survival rates in several studies[6,8,18,24]. The present study confirms long-term high functional outcome scores in association with this etiology.

In contrast, we previously reported that RTSA for a failed previous arthroplasty or posttraumatic arthritis was associated with limited functional outcomes[8]. Our 10-year results are in agreement with those findings. Those 2 operative indications were each associated with a mean absolute Constant score of 45 points and mean active anterior elevation of <120°. Previous studies have shown that RTSAs performed for these indications provided less predictable results because of high rates of complications and revisions[5,24]. In the present study, shoulders that underwent the RTSA because of a failed previous arthroplasty had the lowest mean preoperative Constant score (21 ± 13 points), and each component of the score showed deterioration at the time of the long-term follow-up. It is most likely that a previous shoulder arthroplasty permanently alters shoulder function, as a result of fracture sequelae and/or of the arthroplasty itself.

The decrease in the overall absolute and relative Constant scores between the 2 evaluations is concerning. This degradation was described in 2004 by Sirveaux et al.[2], in a study with 8 years of follow-up, and then by Guery et al.[6] and Favard et al.[18], who reported functional deterioration after 6 and 8 years of follow-up, respectively. Because annual Constant scores were not available in our study, we were unable to determine the pattern of the decrease that we observed. However, as found by Favard et al.[18], aging is not the only cause of decreases in the relative Constant score. The reasons are not known. Authors have suggested the influence of occult loosening to explain the deterioration of shoulder function[6,18]. However, this hypothesis was not confirmed by our study, as the components of the Constant score that decreased most were strength and anterior active elevation, suggesting an impairment of active deltoid power. Muscle contractions of the deltoid tensioned by a lowered and medialized center of rotation correspond to alternating nonphysiological contraction-stretching cycles. Experimental studies have shown that the aging of muscle tissue hinders its adaptation to repetitive contraction-stretching movements and decreases its motor performance[25-27]. Thus, impaired deltoid efficiency could be the result of muscle senescence coupled with nonphysiological biomechanical requirements.

Functional decline varied among the different etiologies leading to the RTSA. Rotator cuff tear arthropathy, primary osteoarthritis, and a massive rotator cuff tear were associated with the least deterioration, while failed previous arthroplasty and posttraumatic arthritis were associated with a greater decrease. As suggested by Boileau et al.[5], previous operations could impact deltoid power. Also, tuberosity malunion could interfere with prosthetic positioning, with disturbed biomechanical behavior and a faster decrease in outcomes over time[28]. Shoulders that underwent the RTSA because of a massive rotator cuff tear showed the largest decrease in anterior active elevation (17°) between assessments. Others have reported poor early functional outcomes of RTSAs done for the treatment of a massive rotator cuff tear[29], but we do not have an explanation for this decrease at the time of long-term follow-up. The destruction of the rotator cuff muscles accompanying massive rotator cuff tears could lead to greater mechanical stress on the deltoid muscle, resulting in faster degradation of its action.

In the present study, 7 of the 10 complications that occurred after the 2-year follow-up time-point were related to mechanical loosening. The 4 cases of glenoid loosening were related to custom implants or a technical error. No glenoid loosening appeared in shoulders after highly advanced scapular notching. The glenoid side, which caused short-term complications in the series reported by Sirveaux et al.[2] and Guery et al.[6], did not result in frequent issues in our long-term follow-up study. We agree with Favard et al., who specified that once the period of short-term complications was past, the fixation of the glenoid component is stable[18].

We noted 3 cases of aseptic humeral loosening and 7 cases of humeral periprosthetic radiolucent lines without loosening, totaling 15% of the prostheses assessed. In 2011, Melis et al.[19] reported a similar rate of humeral radiolucent lines (12%). We noticed an association among previous failed arthroplasty (as the indication for the RTSA), perioperative tuberosity alteration, and humeral radiolucent lines. The small number of cases precluded a statistical analysis to explore 2-by-2 the strength of correlation among the diagnosis, the condition of the tuberosities, and humeral radiolucent lines. As shown by Cuff et al.[30], the absence of a tuberosity deprives the humeral implant of an epiphyseal bone seat and could generate mechanical stresses with development of radiolucent lines. Although the number of cases with notching had increased by 39%, notching had no impact on the outcomes. The long-term development of notching and slow progression that were reported in previous series[18,19,31] was confirmed by the current study. It could be a mixed process, with mechanical damage followed by a biological response[31,32]. In agreement with Melis et al.[19], we did not find any correlation between the tuberosity resorption and the presence of a scapular notch ($p = 0.328$) and we agree with those authors that a stress-shielding mechanism may explain this tuberosity resorption.

This study has limitations. First, it was a retrospective analysis, with 94 patients (50.5%) who died or were lost to follow-up before the long-term assessment. Second, the patient age range was wide, making the results difficult to generalize to other patients. As the majority of the patients who had been operated on after 76 years of age died before the final assessment, our findings mainly concern patients who were operated on before this age. Our finding of degradation of functional results in patients who underwent the operation before 76 years of age are consistent with those of Guery et al.[6] and Favard et al.[18], who encouraged caution in using this prosthesis in younger patients.

In conclusion, while we found that RTSA remained an effective therapeutic option with long-term implant survival rates similar to those described in previous reports[6,18], it is important to acknowledge that functional outcomes may be impacted by both the etiology of the shoulder dysfunction and the time since implantation. ■

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