Short-Term Outcomes of the Grammont Reverse Shoulder Arthroplasty: Comparison between First and Second Generation Delta Prosthesis

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Abstract

Purpose This article compares short-term outcomes of two series of patients, who underwent reverse total shoulder arthroplasty (RTSA) with two different implants, both based on Grammont's principles: the Delta III (D-3) and the Delta Xtend (D-XT) prostheses.

Methods The D-3 group included a consecutive series of 26 patients (mean age 75 years), that were treated between 2000 and 2006; the D-XT group included a consecutive series of 31 patients (mean age 72.5 years), for a total of 33 implants performed between 2011 and 2015. In both groups the most common diagnoses were cuff tear arthropathy (18 and 22 shoulders, respectively) and malunion of proximal humerus fractures (3 and 5). All procedures were performed by the same surgeon. Constant–Murley score (CMS) was used to assess clinical and functional outcomes. Radiographic evaluation included the true anteroposterior and axillary views.

Results Twenty-three patients of the D-3 group and 22 patients (24 shoulders) of the D-XT group were evaluated at a mean follow-up of 42 months (range 26–84) and 44 months (range 26–66), respectively. Four complications occurred in the D-3 group (1 partial deltoid detachment, 1 dislocation, and 2 glenoid component loosening), while one early postoperative infection occurred in the D-XT group. Increases in elevation and CMS between preoperative and postoperative period were observed in both groups; only the D-XT group showed a slight improvement in rotations. The incidence of scapular notching was significantly different between the two groups: 100% for D-3 and 22.2% for D-XT in patients with a minimum follow-up of 5 years.

Conclusion Prosthetic design evolution and greater acquaintance with this surgery have undoubtedly led to an improvement in short-term outcomes with second generation implants of RTSA. Future studies will have to ascertain whether newer implants, relying on biomechanical solutions alternative to Grammont's original concept, might provide additional advantages and minimize drawbacks.

Keywords

- reverse shoulder arthroplasty
- grammont prosthesis
- deltopectoral
- transdeltoid
- rotator cuff arthropathy

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Introduction

Grammont reverse total shoulder arthroplasty (RTSA) was a revolutionary solution for the surgical management of cuff tear arthropathy[1] and other difficult shoulder conditions, such as fracture sequelae of proximal humerus and failed prostheses.[2] RTSA has also shown to be effective for the treatment of proximal humeral fractures, particularly in elderly patients or in cuff-deficient shoulders.[3–7] During the last decade, the worldwide use of RTSA as well as the scientific literature related to this topic have steadily increased and several prosthetic models have been introduced on the market.

The reverse prosthesis aims to provide a fixed fulcrum for deltoid action in case of cuff failure. The original Delta design, developed by Paul Grammont in the eighties, was characterized by the medialization of the center of rotation and the 155-degree inclination of the humeral component. These features allowed to decrease shear and bending stresses at the scapular bone-prosthesis interface, and achieve joint stability by deltoid coaptation.

However, the earlier clinical experiences highlighted some biomechanical drawbacks of RTSA as well as a high incidence of complications, such as infections and instability.[8–10] Scapular notching was the main reason for concern, because it could be responsible for progressive bone loss of the scapular neck and subsequent loosening of the glenoid component, a condition with limited treatment options.

The second generation Delta prosthesis introduced some innovations to overcome this problem, but the implant still relied on Grammont medialization concept. The new design included a smaller baseplate and eccentric glenospheres to facilitate lowering of the glenoid component.[11–13] Less congruent humeral inserts were introduced for preventing polyethylene wear while improving range of motion (ROM).[14] Curved back baseplate and thinner humeral epiphysis aimed to preserve glenoid and humeral bone stock, respectively.

The purpose of this study is to present a retrospective evaluation of a single-surgeon experience with RTSA, by analyzing and comparing the short-term clinical and radiographic results achieved in two series of patients treated with the Grammont RTSA in two different time periods. The earliest series included patients treated with the first generation Delta prosthesis between 2000 and 2006, while the second series included patients treated with the second generation Delta prosthesis between 2011 and 2015.

We hypothesize that technological and surgical advances in RTSA resulted in better clinical outcomes and lower complication rates.

Methods

This retrospective study was performed on two group of patients, that underwent RTSA in two different time periods. All patients were affected by nontraumatic problems of the shoulder and had a minimum follow-up of 2 years.

The first group included a consecutive series of 26 patients (24 women, 2 men) that were treated from October 2000 to June 2006 with the Delta III prosthesis (DePuy International, Leeds, United Kingdom) (group D-3); mean age was 75 years (range, 62–84).

The second group included a consecutive series of 31 patients (28 women, 3 men) that were treated from February 2011 to March 2015 with the Delta Xtend prosthesis (DePuy International) (group D-XT); mean age was 72.5 years (range, 59–79). Two patients were treated bilaterally, for a total of 33 implants.

Preoperative clinical data of the two groups of patients are reported in ►**Table 1**.

All the surgical procedures were performed by the same surgeon. The transdeltoid approach was used in 15 patients of group D-3, while the deltopectoral approach was used in all the remaining patients. In group D-XT, the subscapularis tendon was never repaired at the end of the procedure.

The humeral component was cemented in 17 cases (65.4%) of group D-3 and in 10 cases (30.3%) of group D-XT. Retroversion of the humeral component varied among patients of group D-3: 0 degrees in 6 cases, 5 degrees in 1,

Table 1 Demographical and clinical data of the two groups of patients

	Group D-3	Group D-XT
Period	2000–2006	2011–2015
Patients (*n*)	26 (24 ♀, 2 ♂)	31 (28 ♀, 3 ♂)
Implants (*n*)	26	33
Age (y)	75 (62–84)	72.5 (59–79)
Follow-up (mo)	42 (26–84)	44 (26–66)
Diagnosis		
CTA	18	22
Malunion	3	5
Rheumatoid arthritis	1	2
Glenohumeral instability	1	–
Old unreduced dislocation	–	3
AVN humeral head	–	1
Failed hemiarthroplasty	3	–
Comorbidities		
Hypertension	8	17
Diabetes	3	4
Dyslipidemia	2	8
Atrial fibrillation	2	–
Hypothyroidism	–	4
Benign prostatic hyperplasia	1	–
Gout	1	1

Abbreviations: AVN, avascular necrosis; CTA, cuff tear arthropathy.

10 degrees in 16, and 20 degrees in 3 cases. In group D-XT, the humeral component was always implanted in 20 degrees of retroversion.

Rehabilitation protocol was influenced by the surgical approach. Active elevation of the shoulder in the scapular plane was immediately allowed after the deltopectoral approach, but it was delayed for 4 weeks after the transdeltoid approach since the deltoid was partially detached from the acromion. Assisted passive elevation was started in all patients on the first postoperative day.

Clinical evaluation with the Constant–Murley score (CMS)[15] was performed preoperatively and at follow-up. The normalized CMS score was expressed as a percentage of premeasured normal values, matched for age and sex.[16] Active ROM for anterior elevation, external, and internal rotation was also assessed.

After surgery, patients were recalled at intervals of 3, 6, and 12 months and yearly thereafter for radiographic evaluation in two orthogonal views (true anteroposterior and axillary).

Scapular notching was assessed according to the Nerot classification.[17] The presence of radiolucent lines around the humeral component, osteophytes, and heterotopic ossifications was also investigated. Radiolucent lines around the humeral component were classified according to their width (≤ 2 or > 2 mm) and zones involved, as described by Sanchez-Sotelo et al.[18,19]

Statistical analysis was performed to compare mean variations in ROM and Constant scores from baseline to follow-up between the two groups: p was obtained by comparing follow-up data using baseline score as covariate with an analysis of covariance model.

The difference in scapular notching incidence between the two groups was compared using the Fisher's exact test.

A p-value of < 0.05 was considered statistically significant.

Results

Twenty-three patients (88.4%) of group D-3 were available at an average follow-up of 42 months (range, 26–84); one patient died of lung cancer and two patients could not be evaluated due to debilitating neurological conditions unrelated to their surgery. Twenty-two patients, for a total of 24 implants (72.7%), of group D-XT were evaluated at an average follow-up 44 months (range, 26–66); three patients died from causes unrelated to the surgical procedure, three were unable to reach our institution for geographical distance, two patients were hospitalized in geriatric structures for cognitive impairment, and one patient was untraceable.

Two early postoperative complications were observed in group D-3: one partial detachment of the lateral deltoid after transdeltoid approach, that was treated conservatively and healed uneventfully, and one dislocation, that was promptly reduced and did not recur. An early deep infection occurred in one patient of group D-XT 2 weeks after surgery: it was treated with debridement, glenosphere, and humeral insert replacement and 6-week targeted antibiotic therapy. At 4-year follow-up, there were no clinical signs of infection and laboratory tests (erythrocyte sedimentation rate, polymerase chain reaction) were negative, but the patient complained of recurrent shoulder discomfort and radiograms showed progressive humeral radiolucency combined with scapular notching (►**Fig. 1**).

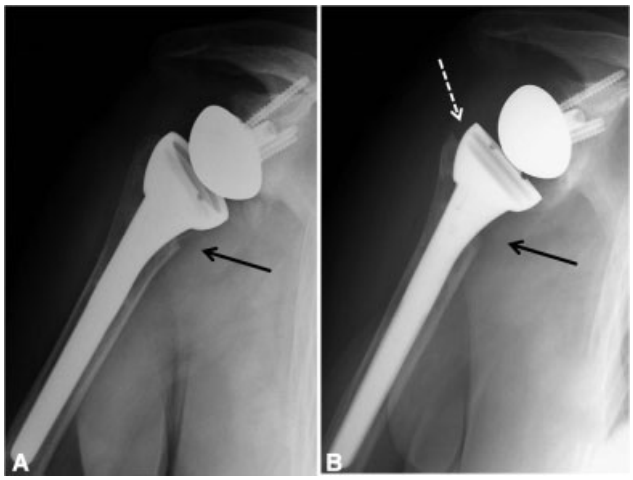

Fig. 1 Humeral radiolucency observed in the patient who suffered an early periprosthetic infection after implantation of a Delta Xtend uncemented prosthesis. (**A**) Two years after surgery, humeral radiolucency is observed in zone 7 (black arrow). (**B**) At 4 years, radiolucency progression is evident in zone 7 (black arrow) and there is initial bone resorption also in zone 1 (white dotted arrow). Grade 1 notching and an inferior heterotopic ossification are present at the scapular neck.

Two cases of glenoid component loosening, respectively at 6 months and 5 years, occurred in group D-3: both patients underwent revision surgery. In the first one, the glenoid component was replaced using a special metaglene with a plate for additional screw fixation and cancellous bone graft to fill the bone defect at the scapular neck. The second patient was treated with conversion to a hemiarthroplasty owing to the extensive bone loss and low functional demands. No late complications were observed in group D-XT.

Mean ROM and CMS of the two groups recorded preoperatively and at follow-up are shown in ►**Table 2**. The comparison of ROM changes from baseline to follow-up between the two groups did not show any significant difference (►**Table 3**). Despite the greater improvement in rotations observed in the D-XT group, significance was not reached due to the differences in baseline values.

Average absolute CMS value increased by 32.4 points (± 11.9) in the D-3 group and 38.3 points (± 10.0) in the D-XT group. The between-group difference was statistically significant ($p = 0.007$). Also for the normalized CMS, the difference of 7.1 percentage points between the two groups was significant ($p = 0.012$) (►**Table 3**).

The most relevant disparities between the two implants were noticed in radiographic findings.

Incidence, severity, and trend to progression of the scapular notch were higher in group D-3, as shown in ►**Table 4**. Differences in incidence were found to be statistically significant every year during follow-up. Among patients who were

Table 2 Mean ROM and CMS recorded in the preoperative period and at follow-up in the two groups

	Group D-3 $n = 23$		Group D-XT $n = 24$	
	Preop	Follow-up	Preop	Follow-up
Forward elevation	66.1 (±28.2)	132.6 (±26.7)	63.1 (±33.9)	140.6 (±21.1)
External rotation	17.0 (±13.4)	15.4 (±10.5)	8.1 (±19.1)	20.8 (±11.8)
Internal rotation	L3	L4	Sacrum	L4
Absolute CMS	23.2 (±9.8)	55.6 (±9.2)	26.4 (±7.8)	64.7 (±10.7)
Pain	3.9 (±3.0)	12.4 (±3.0)	2.5 (±2.9)	12.7 (±3.6)
ADL	8.6 (±3.5)	15.0 (±2.9)	9.6 (±2.9)	18.5 (±2.2)
ROM	10.1 (±5.2)	25.1 (±5.5)	12.5 (±6.2)	28.2 (±6.8)
Strength	0.7 (±0.9)	3.1 (±1.4)	1.8 (±2.3)	5.3 (±2.9)
Normalized CMS	29.0% (±12.3%)	69.6% (±12.0%)	32.8% (±9.6%)	80.5% (±13.5%)

Abbreviations: ADL, activities of daily living; CMS, Constant–Murley score; ROM, range of motion.

Table 3 Comparison of differences in ROM and CMS from preoperative period to follow-up between the two groups

	Group D-3 $n = 23$	Group D-XT $n = 24$	*p*-Value
Forward elevation	+66.5° (±29+.5°)	+77.5° (±28.8°)	0.154
External rotation	−1.6° (±14.6°)	+12.7° (±21.2°)	0.06
Internal rotation	L3 → L4	Sacrum → L4	0.056
Absolute CMS	+32.4 (±11.9)	+38.3 (±10.0)	0.007[a]
Pain	+8.5 (±4.1)	+10.2 (±5.2)	0.897
ADL	+6.4 (±3.5)	+8.9 (±3.8)	< 0.001[a]
ROM	+15.0 (±6.8)	+15.7 (±4.9)	0.295
Strength	+2.4 (±1.4)	+3.5 (±2.9)	0.014[a]
Normalized CMS	+40.5% (±15.1%)	+48.9% (±13.2%)	0.012[a]

Abbreviations: ADL, activities of daily living; CMS, Constant–Murley score; ROM, range of motion.
[a]$p < 0.05$.

Table 4 Comparison of incidence and severity of scapular notching during the study period between the two groups

Group D-3				Group D-XT			
Nerot grade[a]	Incidence	*n*	F/U	*n*	Incidence	Nerot grade[a]	*p*-Value
	43.5%	23	1 year	24	8.5%		0.008
	69.5%	23	2 years	24	12.5%		< 0.001
	88.9%	18	3 years	20	25%		< 0.001
	92.3%	13	4 years	13	23%		0.001
	100%	10	5 years	9	22.2%		0.001

[a]Shades of gray indicate different severity of the Nerot scale (light gray = grade 1, dark gray = grade 4).

followed up for 5 years, the incidence of scapular notching was 100% (10/10) for group D-3 and 22.2% (2/9) for group D-XT. Moreover, Nerot grades 3 and 4 were only observed in 5 patients of group D-3 (►**Fig. 2**).

Humeral radiolucencies ≥ 2 mm were observed in three patients of group D-3 and in one of group D-XT. All the components were uncemented and only metaphyseal zones were involved (zones 1 and 7). In group D-3, radiolucencies came into view 5 years after surgery and were always associated with scapular notching (grade 2 or higher). In group D-XT, there was only one case of progressive humeral radiolucency combined with grade 1 scapular notching: this

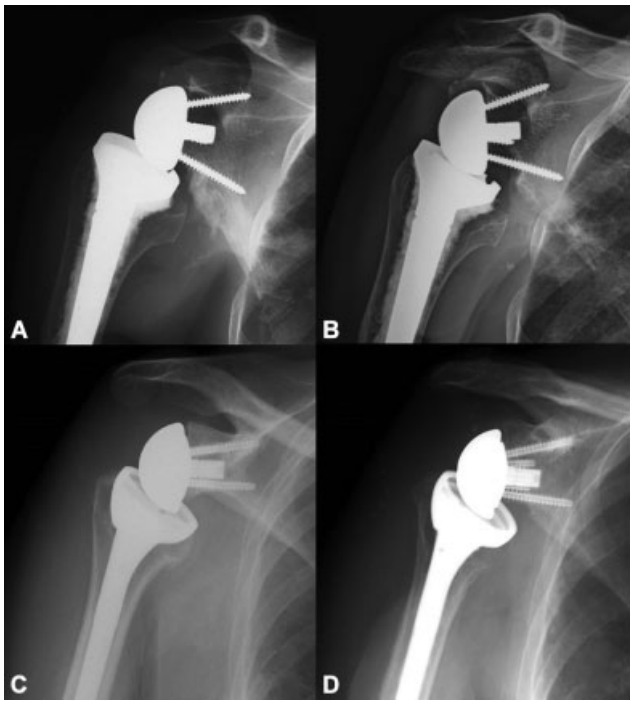

Fig. 2 Comparison between scapular notching progression between first and second generation implants. (**A**, **B**) Delta III: progression from Nerot grade 2 at 1-year follow-up (**A**) to Nerot grade 4 at 4-year follow-up (**B**). (**C**, **D**) Delta Xtend: progression from Nerot grade 1 at 1-year follow-up (**C**) to Nerot grade 2 at 4-year follow-up (**D**).

finding was observed in the patient with the early postoperative infection (►**Fig. 1**).

Heterotopic ossifications in the axillary pouch were found in 4 patients of group D-3 and in 3 of group D-XT.

Discussion

Grammont prosthesis was the first model of RTSA extensively used by orthopaedic surgeons to treat cuff tear arthropathy and other shoulder pathologies with rotator cuff deficiency. Past experiences with the Delta 3 prosthesis proved its clinical effectiveness, but at the same time highlighted some drawbacks of this implant, the main one being the high incidence of scapular notching.[2,20–28] During the last two decades, several design innovations and different biomechanical solutions were adopted in newer RTSA to overcome these problems.[8–14] Greater acquaintance with this surgery was also crucial to prevent mistakes in the implant technique, another cause of the high rate of failures and complications initially reported.[22,23,26,27,29–33]

In this study, we retrospectively reviewed the short-term results achieved in two series of patients, who were treated in two different time periods by a single experienced shoulder surgeon. In the earlier series, the first generation Delta prosthesis (Delta 3) was used, while the second generation Delta prosthesis (Delta Xtend) was implanted in the more recent series of patients. Both implants rely on the original Grammont's biomechanical principles for RTSA, but some improvement in design and instrumentation were adopted in the Delta Xtend prosthesis, with the aim to improve clinical and radiographic outcomes as well as to facilitate the surgical procedure.[24,27,34]

Both prostheses showed to be very effective in recovering active elevation in patients with pseudoparalytic shoulders, but improvements in internal and external rotation were more pronounced with the Delta Xtend. This observation does not find a univocal explanation.

An improved external rotation might be related to the different retroversion of the humeral component chosen in the two series of patients. According to Grammont's indication, most of the Delta 3 prostheses were implanted between 0 and 10 degrees of retroversion. Conversely, a 20-degree retroversion angle was adopted for all the humeral components of the Delta Xtend. This different orientation was probably useful for gaining external rotation and did not have any repercussion on internal rotation.

It has been reported that integrity of teres minor is a critical factor for the recovery of external rotation after RTSA,[35] but we do not have sufficient data—namely magnetic resonance imaging findings—to assert that this factor influenced the ROM differences between the two groups of patients.

The role of the subscapularis in hindering external rotation is still debated, but its repair in undue tension, particularly with the deltopectoral approach and lateralized RTSA, should be avoided. In our experience, the subscapularis was never repaired in the patients treated more recently and this choice might have contributed to improve recovery of external rotation. At the same time, the absence of the subscapularis did not impair either internal rotation or implant stability, since no dislocation occurred in group D-XT.

Finally, the availability and the more extensive use of less congruent humeral inserts[14] and larger glenospheres are implant-related factors that potentially played a role in achieving wider ROM with the second generation prosthesis.

The increase in CMS from baseline to follow-up was significantly greater for the D-XT group, but the improvements achieved in both groups are in accordance with the data reported in the main clinical series found in literature.[2,22,32,36–38] Our analysis showed that clinical results might be improved by newer RTSA designs, even though we could not demonstrate significant differences in ROM changes in the comparison between the two groups. The complication rate was higher in the earlier series of patients: 18.2% versus 4.2%. This trend is mainly influenced by the learning curve of RTSA and the refinement in surgical technique and patient selection, as reported by other authors.[30–32] However, loosening of the glenoid component occurred exclusively in two patients with the Delta 3 prosthesis. The absence of mechanical failures in group D-XT leads us to suppose that inherent features of second generation implants also played a role in decreasing the complication rate.

Radiographic analysis showed a significant difference in the incidence of scapular notching between the two series of patients throughout the whole study period. A large amount of research has been devoted to this topic, probably the most debated in RTSA. In previous clinical studies, reported rates

of scapular notching in the short-term ranged from 10 to 96%.[2,20,22–27,35,39,40]

Osteolysis at the scapular neck can derive either from impingement of the medial border of the humeral implant against the inferior rim of the glenoid or as a result of an inflammatory response to polyethylene debris. The former mechanism is thought to be responsible for low-grade notching and the latter for high-grade notching with severe bone loss, eventually involving the proximal humerus.[22,26,27,39]

Several factors can influence ROM and impingement in RTSA, contributing to onset and progression of scapular notching. Patient-related factors include body mass index, scapular neck angle, scapular neck length, and individual biological reactivity to implant debris.[11,23,26,27,41,42] Some factors related to the surgical technique are critical: glenosphere height and tilt above all, but also the version angles of the components.[11,23,24,26,27,34,40–43] Finally, implant design features such as the position of the center of rotation, glenosphere size and overhang, humeral neck angle, and humeral insert constraint play a role.[34,44,45] Efforts by surgeons and manufacturing companies have been addressed to improve surgical techniques and implant designs with the aim to decrease the rate of scapular notching.[23,24,34,40]

The effect of scapular notching on clinical outcome is controversial. Some authors reported a relationship between scapular notching and poorer clinical results,[22,27,35,46–48] but others pointed out that severe scapular erosions might be totally asymptomatic.[2,25,26,28,39,49] In this study, we could not find a correlation between notching and poorer clinical outcomes in both series of patients.

An even more important issue is the potential progression of scapular notching with time.[20,26,27,39] Our experience shows that the incidence of scapular notching with the first generation prosthesis (100%) was five times higher than that of the second generation implant (22.2%) at the 5-year follow-up. Moreover, the severity of notching was also greater in the earlier series of patients and caused loosening of two glenoid components.

There are some limitations of this study that temper our analysis and results interpretation, such as the retrospective design and the short-term follow-up. Another important limitation is the high drop-out rate (27.3%) observed at follow-up in the D-XT group. The risk of losing patients at follow-up in RTSA clinical studies is mainly related to the age: death or deterioration of general condition are common reasons of drop-out among elderly patients. However, the clinical experience of a single surgeon with two different implants provides some food for reflection on recent history of RTSA.

Grammont's intuitions revolutionized the world of shoulder arthroplasty: despite the initial skepticism, his Delta prosthesis conquered the market thanks to the outstanding effectiveness in treating cuff-deficient shoulders. The early clinical experience predictably highlighted the biomechanical limits of the reverse configuration and their potential consequences. Moreover, the incidence of major complications, such as infection, instability, or implant failure, was generally high, even if appreciably influenced by preoperative diagnosis.

For two decades, much research has been devoted to develop new design solutions and refine implantation techniques, to overcome drawbacks of the first generation prosthesis and improve clinical outcomes, particularly in the medium and long term. In our experience, the short-term results achieved with two different generations of Delta prosthesis exhibited subtle clinical differences in terms of shoulder functional recovery. Conversely, radiographic findings of the second generation implant showed a clear decrease in scapular notching, which might be important in the perspective of improving long-term results and survival rates.

RTSA is still an evolving field of study. Alternative solutions to the original biomechanical principles of Grammont have been adopted in some reverse prostheses. Hopefully, ongoing research and long-term clinical experiences will show us which is the best way to go for further improving outcomes and reliability of RTSA.

Conflict of Interest

F.A.G. reports personal fees from null, outside the submitted work.

References

1 Neer CS II, Craig EV, Fukuda H. Cuff-tear arthropathy. J Bone Joint Surg Am 1983;65(09):1232–1244
2 Boileau P, Watkinson D, Hatzidakis AM, Hovorka I. Neer Award 2005: the Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elbow Surg 2006;15(05):527–540
3 Bufquin T, Hersan A, Hubert L, Massin P. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 2007;89 (04):516–520
4 Grassi FA, Zorzolo I. Reverse shoulder arthroplasty without subscapularis repair for the treatment of proximal humeral fractures in the elderly. Musculoskelet Surg 2014;98(Suppl 1):5–13
5 Chalmers PN, Slikker W III, Mall NA, et al. Reverse total shoulder arthroplasty for acute proximal humeral fracture: comparison to open reduction-internal fixation and hemiarthroplasty. J Shoulder Elbow Surg 2014;23(02):197–204
6 Iacobellis C, Berizzi A, Biz C, Camporese A. Treatment of proximal humeral fractures with reverse shoulder arthroplasty in elderly patients. Musculoskelet Surg 2015;99(01):39–44
7 Reitman RD, Kerzhner E. Reverse shoulder arthroplasty as treatment for comminuted proximal humeral fractures in elderly patients. Am J Orthop 2011;40(09):458–461
8 Grassi FA, Murena L, Valli F, Alberio R. Six-year experience with the Delta III reverse shoulder prosthesis. J Orthop Surg (Hong Kong) 2009;17(02):151–156
9 Cazeneuve JF, Cristofari DJ. Long term functional outcome following reverse shoulder arthroplasty in the elderly. Orthop Traumatol Surg Res 2011;97(06):583–589
10 Walch G, Wall B, Mottier F. Complications and revision of the reverse prosthesis: a multicenter study of 457 cases. Reverse Shoulder Arthroplasty Montpellier, France: Sauramps Médical; 2006:335–352
11 Nyffeler RW, Werner CM, Gerber C. Biomechanical relevance of glenoid component positioning in the reverse Delta III total shoulder prosthesis. J Shoulder Elbow Surg 2005;14(05):524–528
12 de Wilde LF, Poncet D, Middernacht B, Ekelund A. Prosthetic overhang is the most effective way to prevent scapular conflict

in a reverse total shoulder prosthesis. Acta Orthop 2010;81(06): 719–726
13 Wirth M, Collins D, De Wilde L, et al. Inferior scapular notching in reverse shoulder arthroplasty is reduced with a novel glenoid component design. . Paper presentation at: Annual Meeting of Texas Orthopaedic Assocation; April 2010; Texas
14 Gutiérrez S, Luo Z-P, Levy J, Frankle MA. Arc of motion and socket depth in reverse shoulder implants. Clin Biomech (Bristol, Avon) 2009;24(06):473–479
15 Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987;(214):160–164
16 Grassi FA, Tajana MS. The normalization of data in the Constant-Murley score for the shoulder. A study conducted on 563 healthy subjects. Chir Organi Mov 2003;88(01):65–73
17 Valenti PH, Boutens D, Nerot C. Delta 3 reverse prosthesis for osteoarthritis with massive rotator cuff tear: long term results. In: Walch G, Boileau P, Mole D, eds. 2000 Protheses d'epaule... recul de 2 a 10 ans. Montpellier, France: Sauramps Medical; 2001:253–259
18 Sanchez-Sotelo J, O'Driscoll SW, Torchia ME, Cofield RH, Rowland CM. Radiographic assessment of cemented humeral components in shoulder arthroplasty. J Shoulder Elbow Surg 2001;10(06): 526–531
19 Sanchez-Sotelo J, Wright TW, O'Driscoll SW, Cofield RH, Rowland CM. Radiographic assessment of uncemented humeral components in total shoulder arthroplasty. J Arthroplasty 2001;16(02): 180–187
20 Bacle G, Nové-Josserand L, Garaud P, Walch G. Long term outcomes of reverse total shoulder arthroplasty: a follow-up of a previous study. J Bone Joint Surg Am 2017;99(06):454–461
21 Cheung E, Willis M, Walker M, Clark R, Frankle MA. Complications in reverse total shoulder arthroplasty. J Am Acad Orthop Surg 2011;19(07):439–449
22 Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br 2004;86(03):388–395
23 Roche CP, Marczuk Y, Wright TW, et al. Scapular notching and osteophyte formation after reverse shoulder replacement: radiological analysis of implant position in male and female patients. Bone Joint J 2013;95-B(04):530–535
24 Roche CP, Marczuk Y, Wright TW, et al. Scapular notching in reverse shoulder arthroplasty: validation of a computer impingement model. Bull Hosp Jt Dis (2013) 2013;71(04):278–283
25 Boileau P, Gonzalez JF, Chuinard C, Bicknell R, Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. J Shoulder Elbow Surg 2009;18(04):600–606
26 Lévigne C, Boileau P, Favard L, et al. Scapular notching in reverse shoulder arthroplasty. J Shoulder Elbow Surg 2008;17(06): 925–935
27 Lévigne C, Garret J, Boileau P, Alami G, Favard L, Walch G. Scapular notching in reverse shoulder arthroplasty: is it important to avoid it and how? Clin Orthop Relat Res 2011;469(09):2512–2520
28 Nicholson GP, Strauss EJ, Sherman SL. Scapular notching: recognition and strategies to minimize clinical impact. Clin Orthop Relat Res 2011;469(09):2521–2530
29 Gerber C, Pennington SD, Nyffeler RW. Reverse total shoulder arthroplasty. J Am Acad Orthop Surg 2009;17(05):284–295
30 Hattrup S. Early complications with the delta reverse shoulder arthroplasty: influence of the learning curve. J Shoulder Elbow Surg 2007;16:e55
31 Riedel BB, Mildren ME, Jobe CM, Wongworawat MD, Phipatanakul WP. Evaluation of the learning curve for reverse shoulder arthroplasty. Orthopedics 2010;33(04):237–241
32 Walch G, Bacle G, Lädermann A, Nové-Josserand L, Smithers CJ. Do the indications, results, and complications of reverse shoulder arthroplasty change with surgeon's experience? J Shoulder Elbow Surg 2012;21(11):1470–1477
33 Wierks C, Skolasky RL, Ji JH, McFarland EG. Reverse total shoulder replacement: intraoperative and early postoperative complications. Clin Orthop Relat Res 2009;467(01):225–234
34 Roche C, Flurin PH, Wright T, Crosby LA, Mauldin M, Zuckerman JD. An evaluation of the relationships between reverse shoulder design parameters and range of motion, impingement, and stability. J Shoulder Elbow Surg 2009;18(05):734–741
35 Simovitch RW, Helmy N, Zumstein MA, Gerber C. Impact of fatty infiltration of the teres minor muscle on the outcome of reverse total shoulder arthroplasty. J Bone Joint Surg Am 2007;89(05): 934–939
36 Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am 2007;89(07):1476–1485
37 Jacobs R, Debeer P, De Smet L. Treatment of rotator cuff arthropathy with a reversed Delta shoulder prosthesis. Acta Orthop Belg 2001;67(04):344–347
38 Cuff D, Pupello D, Virani N, Levy J, Frankle M. Reverse shoulder arthroplasty for the treatment of rotator cuff deficiency. J Bone Joint Surg Am 2008;90(06):1244–1251
39 Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. J Bone Joint Surg Am 2005;87(07):1476–1486
40 King JJ, Farmer KW, Struk AM, Wright TW. Uncemented versus cemented humeral stem fixation in reverse shoulder arthroplasty. Int Orthop 2015;39(02):291–298
41 Mau EM, Roche CP, Zuckerman JD. Effects of body mass index on outcomes in total shoulder arthroplasty. Bull Hosp Jt Dis (2013) 2015;73(Suppl 1):S99–S106
42 Nolan BM, Ankerson E, Wiater JM. Reverse total shoulder arthroplasty improves function in cuff tear arthropathy. Clin Orthop Relat Res 2011;469(09):2476–2482
43 Nam D, Kepler CK, Nho SJ, Craig EV, Warren RF, Wright TM. Observations on retrieved humeral polyethylene components from reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19(07):1003–1012
44 Karelse AT, Bhatia DN, De Wilde LF. Prosthetic component relationship of the reverse Delta III total shoulder prosthesis in the transverse plane of the body. J Shoulder Elbow Surg 2008;17(04): 602–607
45 Kempton LB, Balasubramaniam M, Ankerson E, Wiater JM. A radiographic analysis of the effects of glenosphere position on scapular notching following reverse total shoulder arthroplasty. J Shoulder Elbow Surg 2011;20(06):968–974
46 Sadoghi P, Leithner A, Vavken P, et al. Infraglenoidal scapular notching in reverse total shoulder replacement: a prospective series of 60 cases and systematic review of the literature. BMC Musculoskelet Disord 2011;12:101
47 Torrens C, Santana F, Picazo B, Cáceres E. Retrospective study of scapular notches in reverse shoulder arthroplasties. Am J Orthop 2013;42(08):362–365
48 Mollon B, Mahure SA, Roche CP, Zuckerman JD. Impact of scapular notching on clinical outcomes after reverse total shoulder arthroplasty: an analysis of 476 shoulders. J Shoulder Elbow Surg 2017; 26(07):1253–1261
49 Stechel A, Fuhrmann U, Irlenbusch L, Rott O, Irlenbusch U. Reversed shoulder arthroplasty in cuff tear arthritis, fracture sequelae, and revision arthroplasty. Acta Orthop 2010;81(03): 367–372