Acta Orthop. Belg., 2009, **75**, 158-166

ORIGINAL STUDY

Reverse shoulder arthroplasty : Does reduced medialisation improve radiological and clinical results ?

Ibrahim KALOUCHE, Nuno SEVIVAS, Abhijeet WAHEGAONKER, Philippe SAUZIERES, Denis KATZ, Philippe VALENTI

From the Institut de la Main, Paris, and Ter Clinic, Ploemeur, France

The purpose of this retrospective study was to assess the effect of the reduced medialisation of the Arrow^{R} reverse shoulder prosthesis on short-term clinical and radiological results.

The clinical and radiological results of 47 Delta III^{R} reverse prostheses and 49 Arrow^{R} reverse prostheses were retrospectively compared at a minimum of twelve months follow-up.

There was a significant increase ($p < 1.10^{-4}$) in range of motion from the preoperative range in the two groups except for internal rotation in the Delta III group ($p = 0.1$). Radiological analysis on antero-posterior view in neutral position showed greater lateralisation ($p < 0.001$) with the Arrow prosthesis. Scapular notching was noted in 32 patients with a Delta III prosthesis, and in no instance with an Arrow prosthesis. Complication rates were 14.9% for the Delta group and 10.2% for the Arrow group.

The design features of the Arrow prosthesis – reduced medialisation of the center of rotation with lateralisation of the humerus – were found to be associated with slight improvement in range of motion and absence of scapular notching.

Keywords : reverse shoulder arthroplasty ; scapular notching.

INTRODUCTION

Reverse shoulder arthrosplaty can yield satisfactory results in patients with pseudoparalysis of the shoulder due to glenohumeral osteoarthritis associated with an irreparable rotator cuff tear (*5,25,26, 28,30*). Medialising and lowering the center of rotation improves the lever arm of the deltoid, particularly when the rotator cuff is deficient. This design of reverse prostheses decreases shearing forces at the glenoid component bone interface, and results in improved survival rate of the glenoid component compared with other constrained and semiconstrained designs (*5,26,28,30*). However medialisation of the center of rotation and of the humerus stem encourages impingement of the humeral polyethylene insert on the scapular neck, resulting in inferior scapular notching. The high rates of scapular notching reported (*28,30*) adversely affect the mid-term clinical outcome (*27*) and represent a potential risk of glenoid loosening on the long term (*9*).

As reported by Nyfeller *et al* (*23*) mechanical failure of the baseplate has been associated with polyethylene wear, chronic inflammation of the

■ Ibrahim Kalouche, MD, Fellow.
■ Nuno Sevivas, MD, Fellow.
■ Abhijeet Wahegaonker, MD, Fellow.
■ Philippe Sauzières, MD, Orthopaedic surgeon.
■ Philippe Valenti, MD, Orthopaedic surgeon.
Institut de la Main, 6 Square Jouvenet, 75016 Paris, France.
■ Denis Katz, MD, Orthopaedic surgeon.
Ter Clinic, 56270 Ploemeur, France.
Correspondence : Philippe Valenti, M.D., Institut de la main, 6 Square Jouvenet, 75016 Paris, France.
E-mail : philippe.valenti@wanadoo.fr

No benefits or funds were received in support of this study

joint capsule and local osteolysis. Although good short- and mid-term clinical results were observed with the Delta III reverse prosthesis (Depuy, Warsaw, USA), scapular notching has been a frequent complication (*28-30*). Frankle *et al* (*11*) proposed a more lateralised center of rotation to avoid scapular notching, with better rotations compared to the results of Sirveaux *et al* (*28*) but with a high rate of complications (17%). Excessive lateralization of the center of rotation results in increased torque and shear forces at the glenoid component-bone interface, as previously reported for constrained and semi-constrained designs (*5,26,28,30*). Improvement in the fixation of the baseplate in semi-constrained prostheses can allow for a moderate lateralisation of the center of rotation. In the Arrow reverse prosthesis (FH Orthopedics, France), the convex design of the baseplate backside, combined with press fit fixation (central keel and anterior extension) allows lateralisation of the center of rotation with a good primary fixation.

The purpose of this study was to compare the clinical and radiological results of the more lateralized Arrow reverse shoulder prosthesis with those of the Delta III reverse prosthesis.

MATERIALS AND METHODS

Patient Selection

The study included all patients who received a Delta III reverse shoulder prosthesis (*36 mm*) or an Arrow reverse shoulder prosthesis implanted by one of the senior authors and who had a minimum follow-up of 12 months. All patients included in this study were treated for irreparable rotator cuff tears with pseudoparalysis of the shoulder defined as the inability to actively elevate the arm > 90° in the presence of free passive anterior elevation. The patients did not display a hornblower's sign preoperatively. Gerber' test was not performed in all patients.

Patients with rheumatoid arthritis, revision surgery (failed hemi or total arthroplasties) and post-traumatic osteoarthritis were not included.

The first group included patients operated with the Delta III prosthesis between December 1993 and March 2003. There were 51 patients with 51 prostheses implanted. Follow-up was available for 47 patients. The mean age was 73.3 years (58-88) ; there were 36 women and 11 men. Eight shoulders had undergone previous surgery : four had a prior cuff repair ; two had a deltoid flap and two had a tenodesis of the long head of the biceps. The mean follow-up for this group was 42.8 months (min 12, max 120, SD 22.2).

The second group included 50 patients with 50 Arrow prostheses implanted by the same surgeons between April 2003 and January 2006. Follow-up was available for 49 patients. The mean age was 74.9 years (52-89) ; there were 38 women and 11 men. Nine shoulders had undergone previous surgeries : cuff repair in four, tenotomy of the long head of the biceps in three, acromioplasty and deltoid flap in one each. The mean follow-up for this group was 19.1 months (min 12, max 40, SD 7.3).

Surgical technique

We mostly used the superolateral approach with an anterior deltoid split (in 44 cases in the first group, in 41 cases in the second group). In stiff shoulders, when the approach to the joint was expected to be difficult, we used a deltopectoral approach (3 cases in the first group, 8 cases in the second group). Supra- and infraspinatus tendons were irreparable in all cases, with retraction to the level of the glenohumeral joint or thin with an atrophic muscle and advanced fatty infiltration.

Differences in surgical technique between the two groups were related with the designs of the glenoid and humeral components of the two prostheses. With the Delta III prosthesis, implantation of the humeral stem requires a large metaphyseal bone resection, and the proximal part of subscapularis is frequently detached. The metaphyseal reamers remove all the cancellous bone, and cement fixation of the stem is recommended. The back surface of the baseplate is flat and comes in one size only. The quality of the fixation depends on the diverging positions of the screws into the coracoid and the pillar of the scapula. With the Arrow prosthesis, the shape of the humeral stem is similar to the anatomical prosthesis ; the metaphyseal bone resection preserves enough metaphyseal cancellous bone to obtain good press fit fixation, so that cement was used in the diaphysis only in osteoporotic bone. The back side of the baseplate is convex, with three sizes to achieve optimal glenoid adaptation.

Postoperative rehabilitation

All patients were managed with a simple sling postoperatively, with the arm at the side and the shoulder in

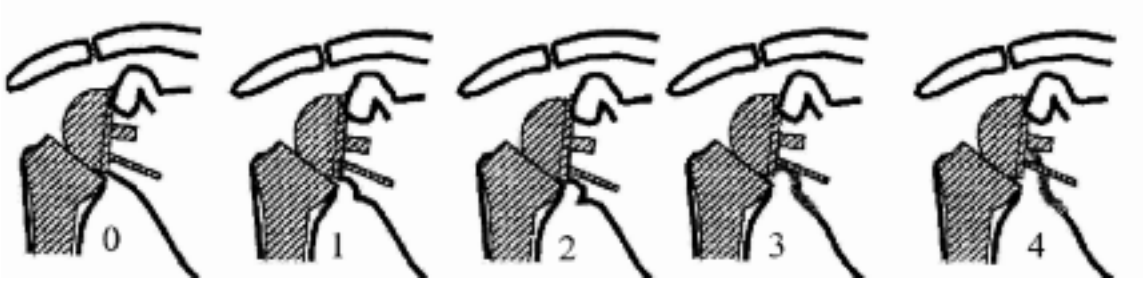

Fig. 1. — Classification of glenoid notching. Grade 0 : no notch ; Grade 1 : small notch ; Grade 2 : notch with condensation (stable) ; Grade 3 : progressing notch (erosion of the inferior screw) ; Grade 4 : incipient glenoid loosening (extension of the notch under the baseplate).
With permission from : Valenti Ph, Boutens D, Nerot C. Delta 3 reversed prosthesis for osteoarthritis with massive rotator cuff tear : Long term results (> 5 years). In : Walch G. (ed). *2000 Shoulders Prostheses. Two to Ten years follow-up*, Sauramps Médical, Montpellier, 2001, pp 253-259.

internal rotation ; the sling was worn for four weeks to allow healing of the anterior deltoid, and passive range-of-motion exercises were started the day after surgery. Active assisted activities and active range of motion were initiated after four weeks.

Assessment

Clinical evaluation was performed in all patients before operation and at last follow-up, using the 100-point rating system of Constant and Murley *(7)* (pain on a scale of 15 points, activity of daily living : 20 points and strength : 25 points). Ranges of active and passive movement were assessed visually for forward elevation and abduction, external rotation with the arm at the side (ER1), external rotation at 90° of abduction (ER2) and for internal rotation. The mean follow-up was 42.8 months (min 12, max 120, SD 22.2) for the first group with the Delta Prosthesis and 19.1 months (min 12, max 40, SD 7.3) for the second group with the Arrow prosthesis.

Radiological evaluation at one year follow-up included a true anteroposterior view of the glenohumeral joint in neutral rotation, made under fluoroscopic control. We looked for signs of glenoid component loosening (radiolucent lines around the base plate, hardware breakage, change in base plate position) and for the presence of scapular notching, using the classification of Nerot (fig 1) with five grades according to the size of the defect as seen on the radiograph *(29)*.

Positioning of the prosthesis was also evaluated on this film by measuring distances between the center of rotation and the greater tuberosity (lateral offset), between the acromion and the greater tuberosity, and between the acromion and the humerus (fig 2). The radiologic measurements are limited by the difficulties to reproduce the same positioning of the arm in neutral position. Radiographs were obtained under fluoroscopic control to minimise the influence of the position of the shoulder during x-ray exposure.

All measurements were made by the same surgeon.

The center of rotation of the Delta prosthesis is at the level of the glenoid bone because the glenosphere covers the baseplate. In the Arrow prosthesis, the increased thickness of the baseplate and the apposition of the glenosphere result in 3.5 mm lateralisation of the center of rotation.

Statistical analysis

Univariate linear models were fitted to assess the effect of the type of prosthesis on the postoperative clinical outcome. Multiple linear models were constructed with the type of prosthesis, the preoperative relevant covariate and the covariates that reached the 0.2 significance level in the univariate model as independent predictors. All tests were two-sided at the 0.05 significance level, and all analyses were performed on R software (R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License).

RESULTS

The preoperative clinical evaluation of pain, function in daily activities, strength and mobility in the two groups are summarised in table I and the

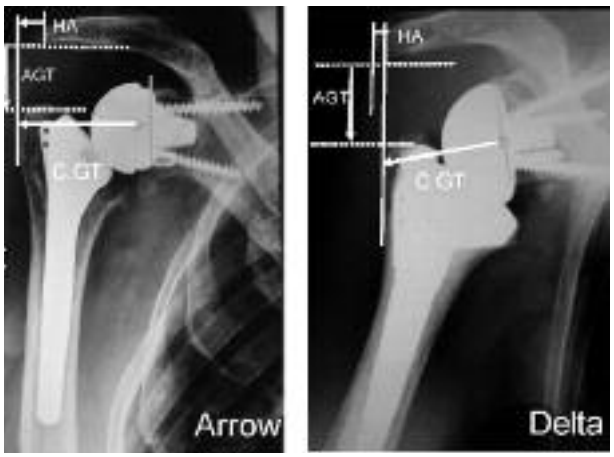

Fig. 2. — Antero-posterior radiograph of the Arrow and Delta prostheses. HA : Distance between acromion and humerus ; AGT : distance between acromion and greater tuberosity ; CGT : distance between center of rotation and greater tuberosity.

Table I. — Pre-operative clinical evaluation. Mean values and range

	Delta III	Arrow
Pain / 15 points	3.8 (0 to 10)	4.2 (0 to 13)
Daily Activity / 20 points	5.2 (2 to 13)	5.2 (2 to 8)
Strength / 25 points	2.2 (0 to 8)	1.4 (0 to 8)
Mobility / 40 points	17.4 (4 to 42)	15 (3 to 35)
Constant / 100 points	28.6 (14 to 45)	24.6 (11 to 40)

Table II. — Clinical results at final follow-up. Mean values and range

	Delta III	Arrow
Pain / 15 points	13.8 (10 to 15)	13.4 (10 to 15)
Daily Activity / 20 points	14.8 (10 to 20)	14.4 (8 to 20)
Strength / 25 points	7.6 (3 to 15)	6 (3 to 12)
Mobility / 40 points	29.8 (18 to 40)	28.5 (18 to 40)
Constant / 100 points	66.0 (50 to 86)	62.3 (49 to 75)

postoperative results in table II. The difference between the preoperative and postoperative status was significant in the two groups ($p < 1.10\text{-}4$). The Delta III prosthesis ended up with a superior postoperative Constant score and more postoperative strength ($p = 0.01$).

Table III. — Mean pre-operative range of motion (* in degrees) AFE : active forward elevation, AER1 : active external rotation with the arm at the side, AER2 : active external rotation in 90° of abduction, IR : internal rotation out of a score of 10 points (buttock : 2, sacrum : 4, L3 : 6, T12 : 8, T7 to T8 :10) ; mean values are given, with range

	Delta III	Arrow
AFE*	70.3 (20 to 140)	61.5 (10 to 120)
AER1*	16.0 (-20 to 40)	14.8 (-20 to 70)
AER2*	25.6 (0 to 60)	18.7 (-20 to 60)
IR	5.2 (0 to 10)	4.5 (0 to 10)

Table IV. — Mean range of motion at final follow-up (* in degrees)

	Delta III	Arrow
AFE*	140.8 (95 to 180)	134.7 (95 to 180)
AER1*	24.8 (-10 to 60)	28.6 (0 to 60)
AER2*	48.0 (0 to 90)	51.5 (10 to 95)
IR	6.0 (2 to 10)	6.4 (2 to 10)

Table V. — Mean improvement in range of motion (* in degrees)

	Delta III	Arrow
AFE*	70.5	73.2
AER1*	8.8	13.8
AER2*	22.4	32.8
IR	0.8	1.9

Preoperative range of motion is summarised in table III, and in table IV at follow-up. Table V summarizes the mean improvement. There was a significant postoperative increase ($p < 1.10^{-4}$) in range of motion in the two groups, except for internal rotation in the Delta group ($p = 0.1$). This improvement in range of motion was more important in the Arrow group compared to the Delta group but the difference was not significant ($p = 0.12$ for ER1, $p = 0.52$ for ER2 and $p = 0.31$ for IR).

The radiological measurements of the lateral offset, the acromion-greater tuberosity distance and the acromion-humerus distance are summarised in table VI

Table VI. — Radiological results. Mean values (* in cm) and range

	Delta	Arrow
Lateral offset*	4.2 (3.4 to 5)	5.4 (4 to 6.2)
Acromion-greater tuberosity distance*	3.8 (2.5 to 5)	3.6 (0.6 to 6.2)
Acromion-humerus distance*	-0.3 (-1.2 to 0.9)	1.7 (0 to 3.6)

Scapular notching was noted in 32 patients in the Delta III prosthesis group. All scapular notchings were present at one year follow-up. At the last follow-up there were 11 grade 1, 11 grade 2, 9 grade 3 and 1 grade 4.

There was no scapular notching in the Arrow group, neither at one year nor at last follow-up.

Complications

There were seven complications in the Delta group. These included five cases of deep infection : three chronic infections were treated with removal of the prosthesis, placement of a bone spacer and revision after 3 months with a reverse prosthesis in two cases and hemiarthroplasty in one case. One other case was an acute post-operative infection, which was treated by arthrotomy and lavage without replacement of the prosthesis ; the fifth case was treated by resection arthroplasty. Two cases of intra-operative glenoid fracture were treated by stabilisation with the metaglene.

In the Arrow group there were four early mechanical complications, all within the first year : disassembly of the glenosphere in three cases and dislocation of the humeral cup in one case. We revised three patients with a new glenosphere with a Morse taper and screw fixation (second generation) and one patient with a hemiarthroplasty. One of the revised patients developed an infection and was treated with a bone spacer after removing the implant, without further revision.

DISCUSSION

Modern shoulder arthroplasty introduced by Neer in the 1950s has demonstrated its clinical efficacy when used for the treatment of primary and secondary degenerative conditions of the shoulder with a functional rotator cuff.

In patients with a pseudoparalytic shoulder caused by a functionally ineffective or anatomically deficient rotator cuff and a deficiency of the coracoacromial arch, a condition initially described by Neer *et al* as "cuff tear arthropathy" (*22*), traditional designs of total shoulder arthroplasty components have lead to early failures. With these designs, the changing instant center of rotation and eccentric loading of the glenoid component (*12,13,21*), resulted in instability and unsatisfactory active mobility with early glenoid component loosening.

Since the 1970s, constrained and semiconstrained shoulder prostheses, such as the so-called reverse ball-and-socket design (*31*), have been used in the treatment of cuff tear arthropathies, but these prostheses were associated with high complication and revision rates (*2,33*). Early reverse shoulder prostheses (Gerard and Lannelongue, Kolbel, Kessel, Fenlin) (*10,14,19,20*) had a center of rotation outside the scapula ; their functional results were poor, with high rates of failure due to glenoid loosening.

In the 1980s Grammont (*15*) introduced the Delta reverse shoulder prosthesis with satisfactory results in elderly patients with persistent shoulder pseudoparalysis due to an irreparable rotator cuff tear. In this prosthesis, the center of rotation is medialised, which increases the lever arm of the deltoid, and the humerus is distalised which increases the tension of the deltoid. Alltogether, tensioning the deltoid and recruiting its anterior and posterior fibers can restore active anterior elevation and abduction when the rotator cuff is deficient. The design of this new semi-constrained prosthesis results in biomechanical conditions that decrease the incidence of the complications noted previously : absence of a glenoid neck and coverage of the baseplate by the glenosphere allow moving the center of rotation to the level of the glenoid and minimizing the shearing forces at the junction between the baseplate and the glenoid bone, which were mainly responsible for glenoid loosening.

Medialisation of the glenoid component with a fixed center of rotation allows restoration of active

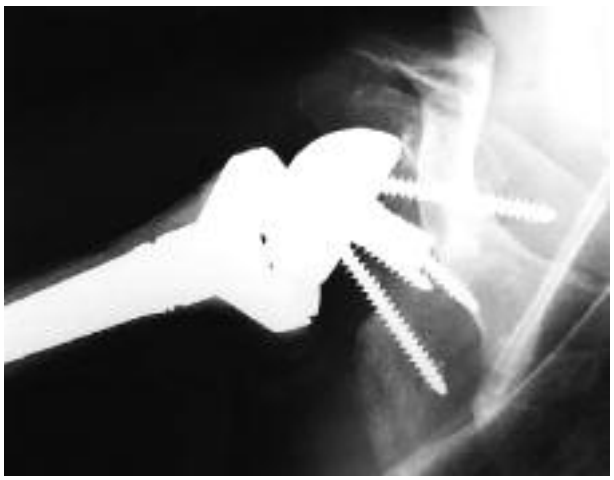

Fig. 3. — Scapular notching type IV (Nerot classification) with potential risk of glenoid loosening at mid or long term.

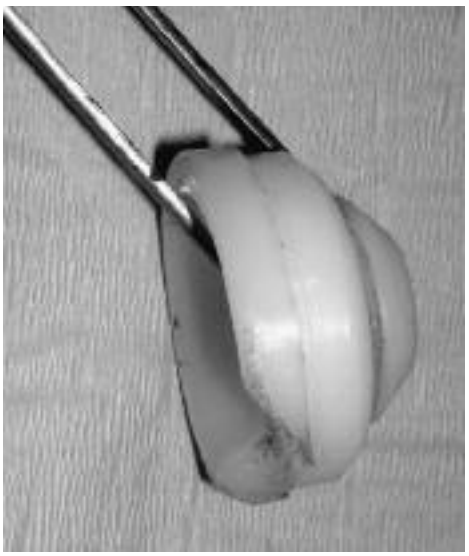

Fig. 4. — Medial polyethylene wear (Delta III)

anterior elevation but results in medialisation of the humerus and a potential impingement of the medial part of the humeral stem against the lateral pillar of the scapula. Medialisation of the humerus is also accentuated by the orientation of the humeral cup (155°). This orientation improves the stability of the reverse prosthesis as compared to the anatomical neck (135°), lengthens the fibers of the deltoid and improves deltoid strength. However, with this design, scapular notching appears soon after the operation and entails a potential risk of glenoid loosening on the long term (> 7 years) (*17*). Scapular notching is a frequent complication with the Delta III reverse prosthesis : it was reported in 50% of cases by Vanhove *et al* (*30*) and in 63.6% by Sirveaux *et al* (*28*) (33.7% grade 1, 12.9% grade 2, 9% grade 3 and 7.8% grade 4). Notching can affect the Constant score when extensive and is worrysome for the future (*9*). In 2001, Valenti *et al* (*29*) reported a series of 59 reverse Delta prostheses : at follow-up greater than 7 years, 60% presented with scapular notching. In this series scapular notching was classified according to Nérot (*29*). This classification is useful to appreciate the evolution and the potential risk of fracture of the screw and secondary loosening. In grade 1 and 2, scapular notching does not progress and a densification appears at the level of the lateral pillar of the scapula, but in grade 3 and 4, scapular notching is progressive with polyethylene wear, chronic inflammation of the joint capsule and local osteolysis (*23*). Fibrous tissue may stabilize the metaglene (*23*) but osteolysis progresses to the metaphysis of the humerus, leading to a difficult revision procedure (figs 3 & 4).

To prevent scapular notching with the same implants (Delta-Tornier), some authors recommended to distalise the implantation into the glenoid of an inferiorly tilted glenosphere with a large diameter (42 mm) (*8*) ; but scapular notching may still appear if the prosthesis-scapular neck angle is high (*18*). Recently, Boileau *et al* (*3*) proposed to interpose a bone graft between the glenoid bone and the baseplate to prevent this scapular notching.

There was no scapular notching in this series of 49 patients managed with the reverse Arrow prosthesis. The absence of medial impingement could be explained by two differences in the design of the Arrow prosthesis : the first is that the glenosphere does not cover the metaglene and creates a 3.5 mm lateralisation of the center of rotation ; the second difference is the shape of the Arrow humeral stem particularly of the metaphysis with an inclination of 135° which results in increased lateralisation of the humerus. In order to achieve stability similar to the

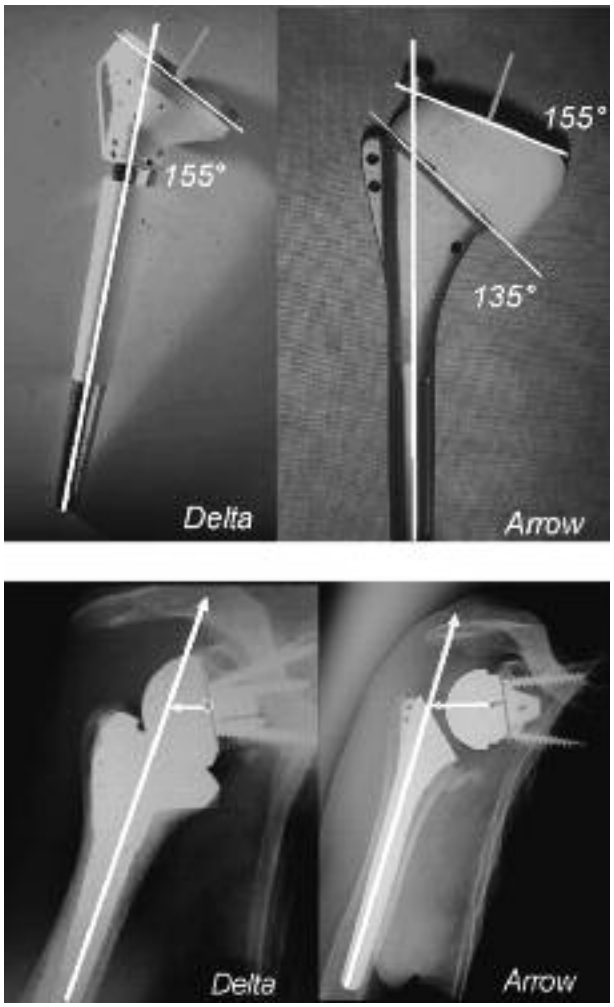

Fig. 5. — Designs of the humeral stem of Delta III and Arrow Prostheses with increased lateralisation in the Arrow design.

Fig. 6. — Lateralisation of the humerus restores the normal contour of the shoulder.

Delta III, the polyethylene cup is designed to obtain the same 155° inclination (fig 5).

Radiological analysis on the AP view in neutral position (table VI) showed that the Arrow prosthesis is more lateralised than the Delta III (5.4 versus 4.2cm) ($p < 0.001$). An important advantage of this lateralisation of the humerus is the reproduction of the anatomical contour of the shoulder on visual inspection (fig 6).

The position of the humerus on the craniocaudal axis is not significantly different between the two prostheses. The lever arm of the deltoid is similar in the two designs and respects the Grammont concepts. Frankle *et al* (*11*) made similar observations and found no scapular notching in a series of 60 patients managed with an other type of reverse prosthesis (ENCORE Medical, Austin, Texas, U.S.A.) designed with a more lateral center of rotation. Lateralisation of the center of rotation reproduces the normal lateral offset and preoperative shoulder contour ; however in the series of Frankle *et al* (*11*) seven patients (12%) required revision for glenoid loosening at a mean follow-up of 21.4 months. They noted no bony ingrowth into the baseplate and the mode of failure appeared to be metal fatigue of the screws. They reported that the first two years after operation were critical and that the quality of the fixation of the baseplate is essential.

The design of the baseplate of the reverse Arrow prosthesis may explain the reduced incidence of early glenoid loosening : the prosthesis is available

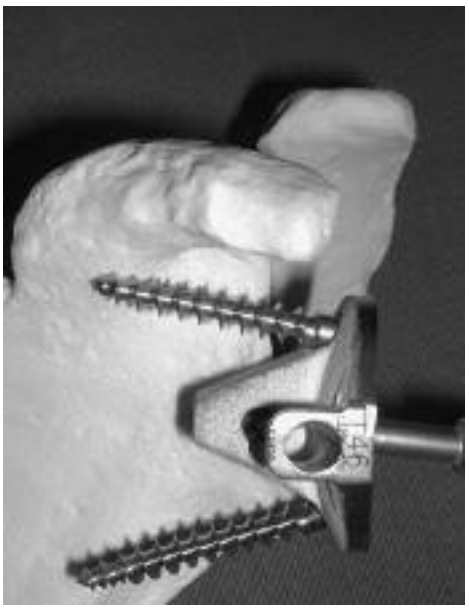

Fig. 7. — The design of the hydroxyapatite-coated baseplate of the Arrow prosthesis with a convex backside, a central keel and an anterior extension and fixation with two diverging screw allows for good press fit fixation.

in four sizes, it has a metaglene with a convex back surface that adapts perfectly to the normal curvature of the glenoid fossa. It also features a central keel and an anterior extension which ensure a primary press fit fixation to counteract shearing and torque forces during the first degrees of abduction. The metaglene is coated with hydroxyapatite on its deep surface, allowing for a better bony fixation. The two diverging screws (5.5 mm) with 15° of liberty (superior toward the foot of the coracoid and inferior toward the lateral pillar of the scapula), reproduce the initial fixation of the Grammont metaglene (*16*) to resist shearing forces (fig 7).

In a French multicentric retrospective study of 487 reverse Delta prostheses (*1*), active forward elevation, had increased by 59° (71 to 130°) external rotation by 4° and medial rotation by only one vertebral level. Sirveaux *et al* (*28*) reported on 80 reverse Delta-III prostheses and found an 65° increase in forward elevation and 7.5° in external rotation (non significant). Frankle *et al* (*11*) reported a 50° increase in forward elevation, and 29.1° in external rotation.

In this study, we found a similar postoperative improvement in range of motion in the two groups (table V). This improvement was significant ($p < 1.10\text{-}4$) except for internal rotation in the Delta group ($p = 0.1$). Improvement in range of motion was more important in the Arrow group compared to the Delta group but this difference was not significant ($p = 0.12$ for ER1, $p = 0.52$ for ER2 and $p = 0.31$ for IR).

The reverse shoulder prosthesis can yield satisfactory and even spectacular results when used by an experienced shoulder surgeon (*25*). Even then however, the complication rates remain high, ranging from 13% to 50% (*4,6,11,24,28,32*). In our series, complication rates were 14.9% for the Delta group and 10.2% for the Arrow group. The lower postoperative strength observed with the Arrow prosthesis compared with the Delta prosthesis could be explained by the smaller medialisation of the center of rotation.

In summary, arthroplasty with the reverse shoulder prosthesis which respects Grammont's concepts can restore active forward elevation of the arm in patients with glenohumeral osteoarthritis and severe rotator cuff deficiency (pseudoparalytic shoulder). Reduced medialisation of the center of rotation with lateralisation of the humerus and a good primary fixation of the metaglene can yield improvement in range of motion while avoiding scapular notching. Improvement in external and internal rotation is slightly better with the Arrow prosthesis, which may be more appropriate for elderly patient. While it is too early to predict the longevity of this prosthesis, absence of early scapular notching appears as a good predictive factor for absence of glenoid component loosening. A longer follow-up with more cases should confirm these early good results.

REFERENCES

1. **Baulot E, Valenti P, Garaud P *et al.*** [Results with reverse prostheses.] (in French). *Rev Chir Orthop* 2007 ; 93 (Suppl) : 63-92.
2. **Bohsali KI, Wirth MA, Rockwood CA Jr.** Complications of total shoulder arthroplasty. *J Bone Joint Surg* 2006 ; 88-A : 2279-2292.

3. **Boileau P, Chuinard Ch, Bicknell R, Pelegri C.** Bony increased offset reverse shoulder arthroplasty (BIO RSA) ; a biologic solution to scapular notching prosthetic instability and limited shoulder rotation. in *10th International Congress of Shoulder and Elbow Surgery*, Brazil, 2007.
4. **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 : 527-540.
5. **Boileau P, Watkinson DJ, Hatzidakis AM, Balg F.** Grammont reverse prostheses : design, rationale, and biomechanics. *J Shoulder Elbow Surg* 2005 ; 14 Suppl S : 147S-161S.
6. **Boulahia A, Edwards TB, Walch G, Baratta RV.** Early results of a reverse design prosthesis in the treatment of arthritis of the shoulder in elderly patients with a large rotator cuff tear. *Orthopedics* 2002 ; 25 : 129-133.
7. **Constant CR, Murley AH.** A clinical method of functional assessment of the shoulder. *Clin Orthop* 1987 ; 214 : 160-164.
8. **De Wilde LF, Audenaert EA, Berghs BM.** Shoulder prostheses treating cuff tear arthropathy : a comparative biomechanical study. *J Orthop Res* 2004 ; 22 : 1222-1230.
9. **Delloye C, Joris D, Colette A, Eudier A, Dubuc JE.** [Mechanical complications of total shoulder inverted prosthesis.] (in French). *Rev Chir Orthop* 2002 ; 88 : 410-414.
10. **Fenlin JM Jr.** Total glenohumeral joint replacement. *Orthop Clin North Am* 1975 ; 6 : 565-583.
11. **Frankle M, Siegal S, Pupello D *et al.*** The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients. *J Bone Joint Surg* 2005 ; 87-A : 1697-1705.
12. **Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd.** Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. *J Arthroplasty* 1988 ; 3 : 39-46.
13. **Fukuda K, Chen CM, Cofield RH, Chao EY.** Biomechanical analysis of stability and fixation strength of total shoulder prostheses. *Orthopedics* 1988 ; 11 : 141-149.
14. **Gerard Y, Leblanc JP, Rousseau B.** [A complete shoulder prosthesis.] (in French). *Chirurgie* 1973 ; 99 : 655-663.
15. **Grammont P, Trouilloud P, Laffay JP, Deries X.** [Design and development of a novel shoulder prosthesis.] (in French). *Rhumatologie* 1987 ; 39 : 407-418.
16. **Grammont PM, Baulot E.** Delta shoulder prosthesis for rotator cuff rupture. *Orthopedics* 1993 ; 16 : 65-68.
17. **Guery J, Favard L, Sirveaux F *et al.*** Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. *J Bone Joint Surg* 2006 ; 88-A : 1742-1747.
18. **Gutierrez S, Greiwe RM, Frankle MA, Siegal S, Lee WE 3rd.** Biomechanical comparison of component position and hardware failure in the reverse shoulder prosthesis. *J Shoulder Elbow Surg* 2007 ; 16 : S9-S12.
19. **Kessel L, Bayley I.** Prosthetic replacement of shoulder joint : preliminary communication. *J R Soc Med* 1979 ; 72 : 748-752.
20. **Kolbel R, Friedebold G.** [Shoulder joint replacement.] (in German). *Arch Orthop Unfallchir* 1973 ; 76 : 31-39.
21. **Laurence M.** Replacement arthroplasty of the rotator cuff deficient shoulder. *J Bone Joint Surg* 1991 ; 73-B : 916-919.
22. **Neer CS 2nd, Craig EV, Fukuda H.** Cuff-tear arthropathy. *J Bone Joint Surg* 1983 ; 65-A : 1232-1244.
23. **Nyffeler RW, Werner CM, Simmen BR, Gerber C.** Analysis of a retrieved delta III total shoulder prosthesis. *J Bone Joint Surg* 2004 ; 86-B : 1187-1191.
24. **Rittmeister M, Kerschbaumer F.** Grammont reverse total shoulder arthroplasty in patients with rheumatoid arthritis and nonreconstructible rotator cuff lesions. *J Shoulder Elbow Surg* 2001 ; 10 : 17-22.
25. **Rockwood CA Jr.** The reverse total shoulder prosthesis. The new kid on the block. *J Bone Joint Surg* 2007 ; 89-A : 233-235.
26. **Seebauer L, Walter W, Keyl W.** Reverse total shoulder arthroplasty for the treatment of defect arthropathy. *Oper Orthop Traumatol* 2005 ; 17 : 1-24.
27. **Simovitch RW, Zumstein MA, Lohri E, Helmy N, Gerber C.** Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. *J Bone Joint Surg* 2007 ; 89-A : 588-600.
28. **Sirveaux F, Favard L, Oudet D *et al*.** 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* 2004 ; 86-B : 388-395.
29. **Valenti Ph, Boutens D, Nerot C.** Delta 3 reversed prosthesis for osteoarthritis with massive rotator cuff tear : long term results (> 5 years). In : Walch G. (ed). *2000 Shoulders Prostheses. Two to Ten years Follow-Up*, Sauramps Médical, Montpellier, 2001, pp 253-259.
30. **Vanhove B, Beugnies A.** Grammont's reverse shoulder prosthesis for rotator cuff arthropathy. A retrospective study of 32 cases. *Acta Orthop Belg* 2004 ; 70 : 219-225.
31. **Visotsky JL, Basamania C, Seebauer L, Rockwood CA, Jensen KL.** Cuff tear arthropathy : pathogenesis, classification, and algorithm for treatment. *J Bone Joint Surg* 2004 ; 86-A Suppl 2 : 35-40.
32. **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* 2005 ; 87-A : 1476-1486.
33. **Wirth MA, Rockwood CA Jr.** Complications of total shoulder-replacement arthroplasty. *J Bone Joint Surg* 1996 ; 78-A : 603-616.