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

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We reviewed 80 shoulders (77 patients) at a mean follow-up of 44 months after insertion of a Grammont inverted shoulder prosthesis. Three implants had failed and had been revised. The mean Constant score had increased from 22.6 points pre-operatively to 65.6 points at review. In 96% of these shoulders there was no or only minimal pain. The mean active forward elevation increased from 73° to 138°. The integrity of teres minor is essential for the recovery of external rotation and significantly influenced the Constant score. Five cases of aseptic loosening of the glenoid and seven of dissociation of the glenoid component were noted.

This study confirms the promising early results obtained with the inverted prosthesis in the treatment of a cuff-tear arthropathy. It should be considered in the treatment of osteoarthritis with a massive tear of the cuff but should be reserved for elderly patients.

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The glenohumeral joint is characterised by articular surfaces which allow an extended range of movement and function in a complex musculotendinous environment. When the rotator cuff is ruptured or non-functioning the shoulder is deprived of its main stabilising elements. Under the action of the deltoid muscle, the head of the humerus will then ride upwards and contact the coracoacromial arch to create a non-physiological articulation. This can cause progressive wear of the proximal humerus. Proximal migration of the head is associated with both anteroposterior instability and nutritional changes which result in the bone lysis which is characteristic of the cuff-tear arthropathy described by Neer, Watson and Stanton[1] and Neer, Craig and Fukuda.[2]

Historically, the entity of cuff-tear arthropathy was first recorded by Adams[3] in his treatise on rheumatic gout, and then by Codman.[4] Later, several French authors[5-7] described other clinical entities as senile haemorrhagic caries of the shoulder, senile joint haemorrhage and fast destructive arthropathy. MacCarthy et al[8] and, recently, Antoniou et al[9] noted the presence of intra-articular microcrystals and proteolytic enzymes and assumed that these were responsible for the articular destruction.

While an unconstrained total shoulder arthroplasty has been successful in the treatment of shoulder arthropathy in the presence of an intact rotator cuff, poor results have been

Table I. Classification of constrained shoulder prostheses according to Huten[47]

Two-piece prosthesis		Three-piece prosthesis
Anatomic	**Inverted**	
Bickel[48]	Neer-Averill[49]	Gristina[50]
Stanmore[51,52]	Reeves[53]	Buechel[54]
Reese[55]	Kolbel[56]	
Zippel[57]	Kessel[58,59]	
Laurence[60]	Fenlin[61]	
Neer-Averill[49]	Gerard[62]	
	Grammont[59,60]	

obtained with this type of implant when the rotator cuff is torn or non-functioning. This led Neer et al[1] to propose a specific rehabilitation programme with limited goals. Franklin et al[10] have emphasised the rocking-horse phenomenon of the glenoid which is responsible for a high rate of loosening of the glenoid component. Similarly, semiconstrained implants, which offer greater cover,[1,11-17] result in increased compressive loads superiorly and increased pull-out forces inferiorly, as has been demonstrated by Orr, Carter and Schurman.[18]

In the 1970s, some surgeons believed that a constrained prosthesis (Table I) was the appropriate solution. This required a fixed centre of rotation and restored movement under the sole action of the deltoid, but high rates of loosening and mechanical complications led them to discontinue the use of such implants.
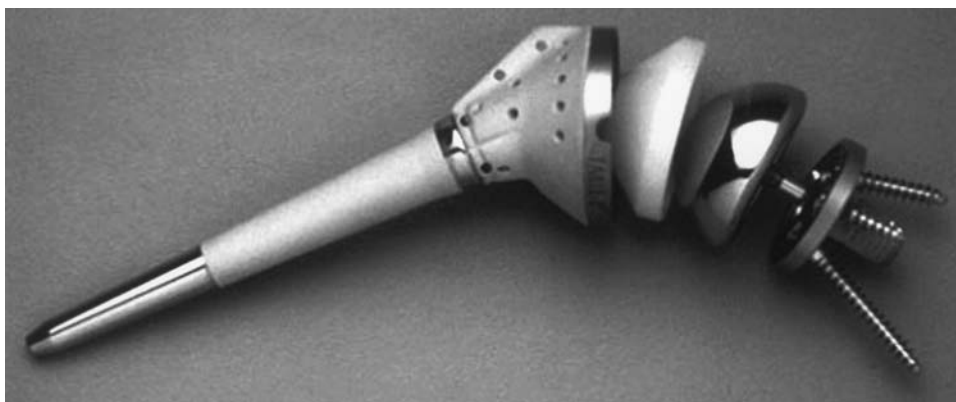
Fig. 1

Photograph showing components of the Grammont inverted prosthesis.

The Delta (DePuy, France) shoulder prosthesis, which was developed by Grammont et al[19] in 1985, is the inverted version of the constrained designs which were introduced in the 1970s (Fig. 1). Its unique feature is a lowered, medialised centre of rotation which increases the moment arm of the deltoid. In this inverted design, the resultant force applied to the neck of the scapula limits the shear forces which are responsible for loosening of the glenoid.

We have analysed the mid-term results of the use of the inverted prosthesis in the treatment of glenohumeral osteo-arthritis in the presence of a massive rupture of the cuff and compared them with those previously published for other techniques.

Patients and Methods

We collected 92 consecutive cases from eight orthopaedic centres. The patients had undergone surgery between December 1991 and March 1999. All had osteoarthritis with a massive and irreparable rupture of the complete cuff. They had undergone full pre-operative clinical and radiological assessments including the Constant score, active and passive mobility and subjective evaluation and similar observations over a minimum follow-up of two years. Six patients were lost to clinical and radiological review and six had died with the prosthesis in place.

We were therefore able to follow-up 80 prosthetic replacements in 77 patients over a mean period of 44.5 months (24 to 97). There were 14 men and 63 women with a mean age of 72.8 years (60 to 86) at the time of surgery and there were 63 right and nine left shoulders. Three patients had bilateral procedures. In 25 patients, the contralateral shoulder was considered to be healthy and in 52 it was diseased. All patients had received earlier conservative management with medication and 12 shoulders had undergone previous surgery. Eleven had acromioplasties with a cuff repair in two and a deltoid flap in one, and the other had a biceps tenotomy.

Operative technique. The superolateral approach with an anterior deltoid release was used in 58 shoulders (72%), the deltopectoral approach in 16 (19%) and the transacromial approach in three (3.7%). The surgical approach was mixed (superior and deltopectoral) in three. Associated procedures were an acromioplasty in 29 shoulders, repair of subscapularis in the cuff in eight, a biceps tenodesis in eight, a biceps tenotomy in one and a glenoid bone graft in two.

In the first 11 cases the humeral implants were of monobloc design. All the humeral stems were of standard length (100 mm); 38 were fixed with cement and 42 were uncemented. A lateralised humeral cup (+ 6 mm) was used in 37 shoulders and the cup was retentive in three. On the glenoid side a threaded component, which was recommended until 1994, was used in 11 shoulders, and a version which featured a safety-catch system was used in eight during 1995. The glenosphere was attached to the metaglene by a morse taper in 61 shoulders. A 42 mm glenosphere was only used eight times, always in men.

Assessment. Clinical and radiological measurements were performed in all patients before operation and at the post-operative follow-up, using the 100-point rating system of Constant and Murley.[20] The weighted Constant score was calculated as a percentage of normal values relative to gender and age. Ranges of active and passive movement were recorded for forward elevation and abduction, external rotation with the arm at the side (ER 1), external rotation in 90° of abduction (ER 2) and for internal rotation.

Based upon the pre-operative radiological appearance, four types of glenoid erosion were defined. In type E0, the head of the humerus migrated upwards without erosion of the glenoid. Type E1 was defined by a concentric erosion of the glenoid. In type E2 there was an erosion of the superior part of the glenoid and in type E3 the erosion extended to the inferior part of the glenoid (Fig. 2).

The tendons of the rotator cuff were assessed from additional imaging techniques or observations noted in the
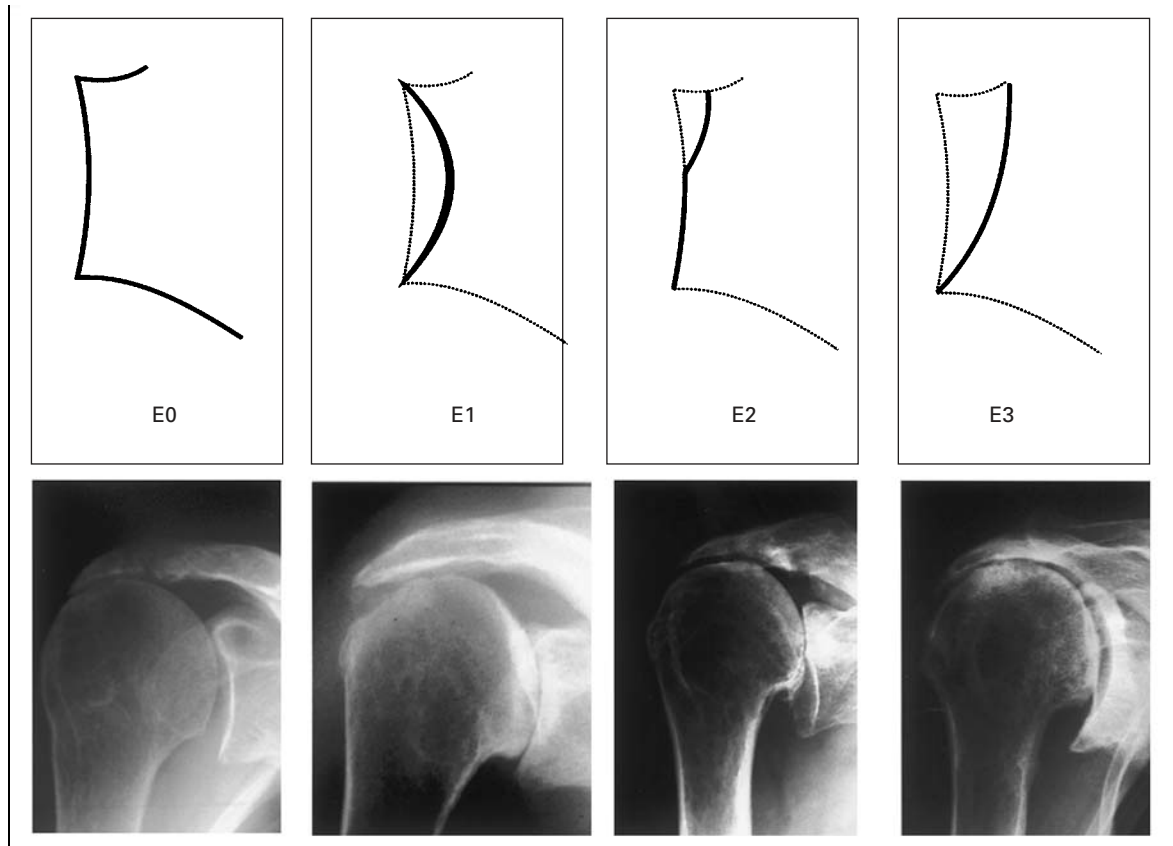
Fig. 2

Diagrams and radiographs showing classification of glenoid erosion in osteoarthritis with massive rupture of the cuff.

operation notes. The tendon of supraspinatus was always ruptured and retracted and was associated with a total rupture of infraspinatus in 90% of cases. The status of the tendon of subscapularis was assessed in 65 cases. It was intact in 24, torn in the superior one-third in 19, torn in the two superior two-thirds in 11 and completely torn in 11. The tendon of teres minor was ruptured in 15 cases.

Radiological assessment at follow-up included an anteroposterior (AP) view tangential to the baseplate and a lateral view. Analysis of the space between the baseplate and the bone was not feasible when the view was not strictly tangential or when there were superimpositions on imaging. The presence of radiolucency was noted under the baseplate and around the screw and peg. Loosening of the implant was considered to be present when either the baseplate or the stem of the humerus was displaced. Radiologically, dissociation of the glenosphere can be diagnosed when there is clear visualisation of the baseplate as this is normally masked by the glenosphere and is not visible on the radiograph. The scapular notch, which is a defect of the bone in the inferior part of the glenoid component, was noted and was classified according to the size of the defect as seen on the radiograph (Fig. 3). A defect which was con-fined to the pillar corresponded to grade 1. It was considered to be grade 2 when it was in contact with the lower screw, grade 3 when it was over the lower screw and grade 4 when it extended under the baseplate.

Peri-prosthetic calcification was graded into four using the rating system of Sneppen et al.[21] Patients were also asked to rate their satisfaction with the operation as very satisfied, satisfied, disappointed or dissatisfied.

Statistical analysis. All patients were reviewed and examined post-operatively in compliance with a specific protocol in order to allow for computerisation of the data and statistical analysis (SAS-software, SAS Institute, Cary, North Carolina). The chi-squared test, Student's t-test and the Kruskal-Wallis test were used as appropriate. A Kaplan-Meier[22] analysis, with a 95% confidence interval (CI), was used to estimate the cumulative probability of survivorship for the entire series of 92 prostheses (Fig. 4). P values of less than 0.05 were regarded to be significant.

Results

Clinical. Of the 80 shoulders, three had failed and had been revised. These cases are not included in the analysis because the initial implants were not in place at revision.
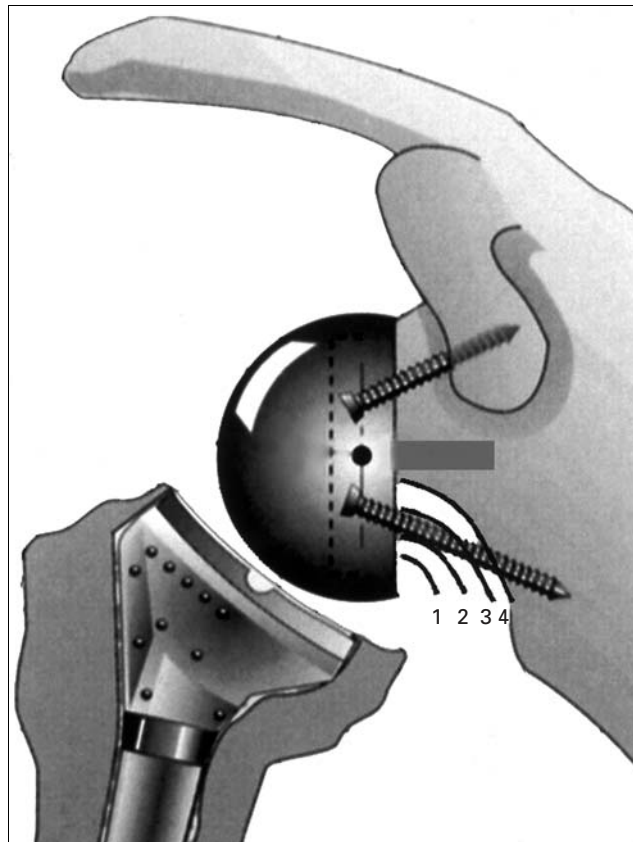
Fig. 3

Diagram showing classification of bone defects of the scapular notch.

Table II. Clinical results according to the Constant score (mean, range) in 77 patients*

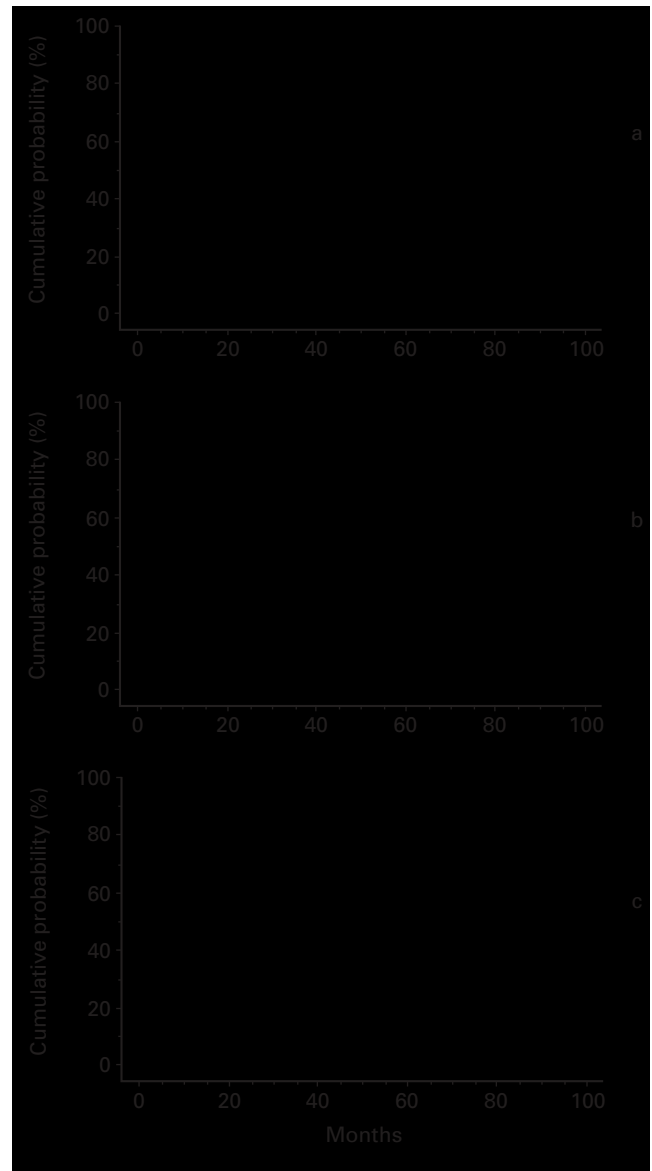|	Pre-operative	Follow-up	Improvement
Pain (15 points)	2.7 (0 to 10)	13.4 (5 to 15)*	10.7
Activity (20 points)	6 (0 to 12)	16.9 (8 to 20)*	10.7
Mobility (40 points)	12.3 (2 to 34)	27.8 (10 to 40)*	15.1
Strength (25 points)	1.9 (0 to 10)	7.4 (0 to 20)*	5.4
Constant score	22.6 (4 to 50)	65.5 (34 to 85)*	42.3

* $p < 0.001$

Fig. 4

Kaplan-Meier survivorship (95% confidence interval) curves to show the probability of failure as defined by revision of the prosthesis (a), revision or failure of the component (b), glenoid or humeral loosening, glenosphere dissociation, and revision or failure of the component or significant pain (< 10 points on the Constant score) (c).

One woman who underwent surgery in 1991, was operated on again in 1993 because of unscrewing of the glenosphere with loosening of the glenoid. She presented with further aseptic loosening of the glenoid in 2000 and needed revision of both the humerus and glenoid. One man, aged 69 years who had undergone surgery in 1996, was reoperated upon in 1999 for loosening of the glenoid. One woman, aged 66 years had undergone surgery in 1996 but required further surgery three months later for infection. The prosthesis was changed in a two-stage procedure. In one case, the glenosphere was revised in order to be screwed on to the baseplate again. This prosthesis was in place at the time of the revision and was included in our clinical and radiological results. The mean follow-up was 44.5 months (24 to 97). Follow-up was from 24 to 36 months in 30 patients, from 36 to 60 months in 30 and over 60 months in 17. The clinical results are summarised in Table II.

At follow-up, 74 patients (96%) had no or only minimal pain. Both activity and mobility had improved. Active mobility was significantly improved in forward elevation and external rotation in abduction (Table III).

The Constant scores were not significantly influenced by age, gender, surgical approach, initial radiological findings

Table III. Range of movement pre-operatively and at follow-up (AFE, active forward elevation; PFE, passive forward elevation; AER 1, active external rotation with the arm at the side; PER 1, passive external rotation with the arm at the side; AER 2, active external rotation in 90° of abduction; PER 2, passive 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)

	AFE	PFE	AER 1	PER 1	AER 2	PER 2	IR
Pre-operative range of movement in degrees	73	121	3.5	23	17	49	4
Follow-up range of movement in degrees	138	146	11.2	32	40	67	4.8
p value	<0.001	0.01	NS*	NS	<0.001	0.02	NS

* not significant

or previous surgery. However, the only patient who had received a previous deltoid flap continued to experience pain in the shoulder and had a worse result than the others (Constant score = 44 points). The status of teres minor affected the Constant score significantly. The score improved to 67 points when teres minor was intact but was a mean of 58 points when the muscle was torn (p = 0.01). A rupture of teres minor was responsible for loss of external rotation in abduction and a 'hornblower sign' in 18 patients at follow-up. The Constant score was not significantly affected by the length of follow-up. There was a mean value of 67.4 points for the 17 patients who had had more than five years of follow-up. Subjectively, 43 patients were very satisfied, 31 were satisfied, and six were disappointed.

Radiological results. Of the 77 prostheses included in our study, three glenoid components showed a progressive radiolucency with displacement of the implant and were thus considered to demonstrate loosening of the glenoid (Fig. 5). If the two failed prostheses which were revised for loosening are included, the rate of loosening was 6.25% (5/80). A stable radiolucency was noted in 20 shoulders (25%) without migration of the implant.

In five cases, the metaglene and the glenosphere were dissociated on the radiographs taken at follow-up. Of these five, there was stable unscrewing of the implants in three and progressive unscrewing of the implant, with migration in two (Fig. 5). Including the case of unscrewing of the glenosphere which was revised, this problem occurred in

seven cases, six on the right and one on the left. Four occurred with the first design of the implant and three in the modified version which featured a safety-catch system.

In 49 cases (63.6%), we noted a scapular notch which corresponded to impingement of the superomedial part of the humeral implant against the pillar of the scapula. This notch was limited to the pillar in 26 cases (grade 1), was in contact with the lower screw in ten (grade 2), was over the lower screw in seven (grade 3) and extended under the baseplate in six (grade 4). The presence of the notch was not influenced by the length of follow-up, but its size was affected by the initial radiological appearance of the glenoid (Table IV). The presence of the notch significantly affected the Constant score when the notch was either over the screw or extensive (p < 0.05). In one case an uncemented humeral stem was associated with a large radiolucency and migration.

Survivorship analysis (Fig. 4). The cumulative probability of not having a revision of the prosthesis was 95.1% (92 to 97) at 97 months. With failure defined as revision of the prosthesis or failure of the implant due to dissociation of the glenosphere or loosening of the glenoid or humeral component, the survivorship of the inverted prosthesis was 91.3% (87 to 95) at five years, 74.6% (65 to 84) at seven years and 29.8% (7 to 52) at eight years. With failure defined as revision or failure of the component or significant pain, the survivorship of the prosthesis was 88% (84 to 92) at five years, 71.9% (63 to 81) at seven years and 28.8% (7 to 50) at eight years.

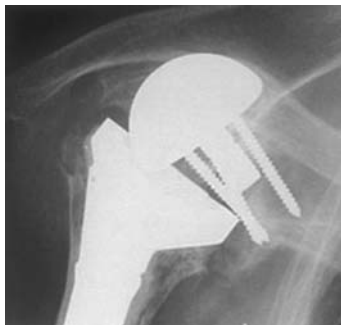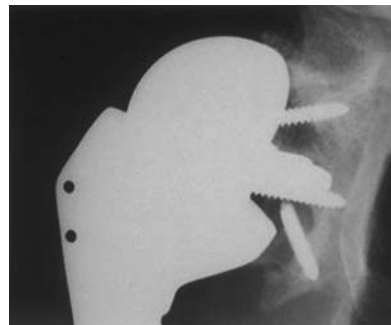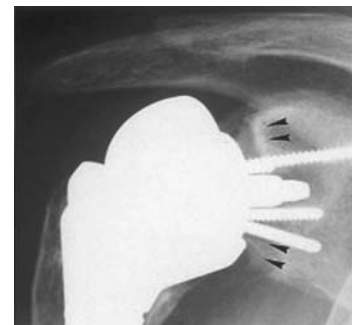Fig. 5a   Fig. 5b   Fig. 5c

Anteroposterior radiographs of three cases of glenoid loosening showing progressive unscrewing of the glenosphere associated with loosening of the baseplate.

Table IV. Distribution and size of the scapular notch according to the type of glenoid (p < 0.05)

Glenoid type	No notch or limited to the pillar	Notch in contact with the lower screw	Notch over the lower screw or extensive
E0	27	6	5
E1	23	1	3
E2	4	1	3
E3	0	2	2

Discussion

Our study confirms the promising functional results which were obtained by Grammont et al[19] and Baulot, Chabernaud and Grammont[23] with the inverted prosthesis in the treatment of cuff-tear arthropathy.

The natural history of tears of the rotator cuff is not well known and the development of a cuff-tear arthropathy is extremely rare. It occurred in 4% of the cases of Neer et al[1] and in 20% according to Worland et al.[24] Our series confirms the epidemiological data presented in other studies[1,8,24-26] with a marked female preponderance and a more frequent occurrence in the dominant shoulder. The initial symptoms are mainly those of pain and loss of movement which results in a major functional deficit.

What are the therapeutic alternatives to failed conservative treatment? Although arthroscopic debridement appears to provide acceptable relief from pain in irreparable tears of the rotator cuff,[27,28] its success has not been demonstrated in osteoarthritis of the shoulder with a massive deficit of the cuff. In a retrospective study, Guyette et al[29] showed that arthroscopic subacromial decompression was effective for impingement which was associated with moderate or mild glenohumeral degenerative disease. However, in their study patients with full-thickness tears of the rotator cuff were not included.

Glenohumeral arthrodesis may be used as palliative surgery in patients with nerve injuries. It is an alternative solution in cases in which shoulder arthroplasty has failed or is contraindicated. In osteoarthritis with a massive tear of the rotator cuff, arthrodesis is indicated in cases in which the deltoid is no longer functioning because of either an injury to the axillary nerve or after previous surgery.[30-32]

However, in these often elderly patients, problems may be encountered because of osteoporosis. Prolonged immobilisation is also required although not always well tolerated. Furthermore, according to Cofield and Briggs,[31] 55% of patients with a cuff-tear arthropathy who had been treated by arthrodesis, still complained of moderate to severe pain. Only 64% showed improvement after the operation. Duparc et al[33] suggested a Benjamin osteotomy as a therapeutic alternative. They demonstrated the effect of this double osteotomy on relief from pain in 22 patients of whom 11 had osteoarthritis of the shoulder and 11 advanced rheumatoid arthritis associated with a tear of the rotator cuff, with a mean follow-up of 4.1 years. The Constant pain score improved from 1.3/15 to 11.6/15 but the scores obtained for range of movement and level of activity remained very low. Sixteen of the 22 patients were satisfied with their operation.

Hawkins, Bell and Jallay,[34] Barrett et al[35] and Franklin et al[10] showed that the main complication associated with an unconstrained total shoulder arthroplasty in the presence of a cuff-tear arthropathy was loosening of the glenoid component. Some authors[25,26,36-41] consider hemiarthroplasty to be the best therapeutic option. Sanchez-Sotelo et al[41] showed that hemiarthroplasty provided satisfactory relief from pain in 75% of patients but only a moderate gain in movement after five years of follow-up. Worland et al[24] suggested the use of a bipolar prosthesis for an increased range of movement. In this study, 96% of the patients with the prosthesis still in place had no or only minimal pain. The antalgic effect was similar to that obtained with a hemiarthroplasty. By contrast, the gain in active forward elevation and abduction was better with the Grammont prosthesis than with hemiarthroplasties and bipolar prostheses. Specifically the mean active forward elevation obtained by Worland et al[24] in his series of 33 shoulders was 67°. At revision, the mean active forward elevation was 88° in the study of Sarris, Papadimitriou and Sotereanos,[42] 69° in that of Duranthon et al[43] and 84° in that of Petroff et al,[44] with a bipolar prosthesis. The best results of hemiarthroplasty were obtained by Pollock et al[26] with only 112°, compared with a mean of 138° in our series. With the inverted prosthesis, the range of active forward elevation was over 120° at follow-up in 70% of the patients. In the study by Sanchez-Sotelo et al,[41] 18% of the patients had active elevation of over 120° with a hemiarthroplasty. With a hemiarthroplasty, the mean range of active external rotation was 36° in the study of Arntz et al,[25] 46° in that of Williams and Rockwood,[36] 30° in that of Field et al,[37] 29° in that of Zuckerman et al[40] and 41° in that of Sanchez-Sotelo et al.[41] Worland et al[24] reported better results with a bipolar prosthesis, with a mean of 51° of active external rotation at follow-up. These authors did not specify whether their measurements refer to ER 1 (external rotation with the arm at the side) or ER 2 (external rotation in 90° of abduction).

In our study, the state of teres minor was vital. Its integrity was necessary in order to obtain a good Constant score and its disappearance led to a loss of external rotation and the 'hornblower sign'. According to Grammont et al,[19] and Baulot et al[23] in the absence of the rotator cuff, the deltoid allows recovery of external rotation synchronous with abduction. This accounts for the discrepancy between the

gain in external rotation with the elbow by the side and external rotation in 90° of abduction. Assessment of the level of activity by the Constant criteria showed that most patients were able to raise their affected arms to their heads (mean activity score 8/10), that 50% of patients could use their affected arms above their heads and that 90% of patients did not feel any discomfort at night. These results cannot be compared with those of other series which did not use the same assessment criteria. According to Pollock et al,[26] 100% of patients with a hemiarthroplasty are able to dress, 96% can place their hand to their mouth for eating, 88% can lie on the affected side and 80% are able to comb their hair.

Our statistical analysis showed that the Constant score was not significantly influenced by the age of the patient or by previous surgery. The patient who underwent surgery for a deltoid flap had a bad result which showed the importance of deltoid function for the success of this type of prosthesis. The Constant score did not correlate with the status of the tendon of subscapularis or with the positioning of the implant.

The transacromial approach was used in only three cases. This group was too small to be compared statistically with the other surgical approaches. Rittmeister and Kerschbaumer[45] have recently shown a high rate of poor bone healing after osteotomy of the acromion. The superolateral approach provides an adequate exposure of the glenoid, thus facilitating insertion of the metaglene. Performing a concomitant acromioplasty does not significantly compromise function, provided that the deltoid is carefully repaired. Unlike the situation for a hemiarthroplasty, the status of the coracoacromial arch does not influence the outcome. Anterosuperior subluxation of a hemiarthroplasty, in cases in which a previous acromioplasty had been performed, has been responsible for half of the failures reported by Field et al[37] and for three stress fractures of the acromion seen by Fenlin et al.[38] Sanchez-Sotelo et al[41] reported that an earlier acromioplasty was associated with anterosuperior instability and less active elevation. Moreover, the proximal migration of a hemiarthroplasty was associated with progressive bone erosion on both the glenoid and acromion sides as well as the medial aspect of the proximal humerus.[41] The same effect can be found on the glenoid with a bipolar prosthesis.[43]

In our study, there was only one example of humeral loosening. However, taking into account the age of such patients, we recommend the use of a cemented humeral component and use of a lateralised plastic insert in order to restore appropriate tension to the deltoid.

Despite our good results, various complications can occur. In our three failed cases, there was one infection. Further complications were linked to loosening of the glenoid (6.25%), unscrewing of the glenosphere (8.75%) and the development of a scapular notch (grade 3 or 4 in 16.25%). Scapular notches can affect the Constant score when they are extensive and are worrying for the future.[46]

Loss of bone from the superior part of the glenoid leads the surgeon to position the baseplate on the top which increases the risk of impingement. It is important to be careful in such cases, especially for glenoid types E2 or E3. It is better to position the baseplate on the lower part of the glenoid, with a slight tilt. Radiological analysis of polyethylene wear is not reliable but it seems not to be an important complication.

There is no survivorship analysis in the literature of a shoulder prosthesis in association with the specific problem of a cuff-tear arthropathy. Our study shows that the probability of failure of the inverted prosthesis with follow-up of more than seven years is high. However, the implants used during this period were the first designs of this implant. Delloye et al[46] suggest that modification of the glenoid component will not decrease the high risk of loosening because of the progression of the scapular notch. This must be further assessed by a long-term follow-up study.

Our study therefore confirms the promising early results obtained by Grammont et al[19] and Baulot et al[23] with the inverted prosthesis in the treatment of a cuff-tear arthropathy. Because of the lack of sufficient follow-up and uncertainty about the long-term fixation of the glenoid component, the Delta 3 prosthesis should be reserved for elderly patients with shoulder arthropathy who have failed to respond to conservative therapy and who have adequate bone support for firm anchorage of the glenoid component.

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