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Grammont Award 2018: Scapular fractures in reverse shoulder arthroplasty (Grammont style): prevalence, functional, and radiographic results with minimum 5-year follow-up

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Background: Scapular fractures after reverse shoulder arthroplasty (RSA) are an increasingly reported complication. Information is missing regarding midterm to long-term follow-up consequences. The aim of this study was to determine the rate of scapular fracture (acromial base and spine) after Grammont-style RSA and to report functional and radiographic results of patients with a minimum 5-year follow-up.
Materials and methods: We retrospectively reviewed 1953 Grammont-style RSAs in 1745 patients in a multicenter study. Of these, 953 patients (1035 RSAs) had minimum 5-year follow-up for functional and radiographic assessment (anteroposterior and scapular Y views.
Results: Twenty-six patients (1.3%) had sustained a scapular fracture; of these, 19 (10 acromial base and 9 spine fractures) had minimum 5-year follow-up and were reviewed at a mean follow-up of 97 months. Three patients (15.8%) were diagnosed at the last follow-up after an undiagnosed fracture. There were 3 traumatic cases (15.8%) and 13 (68.4%) without antecedent trauma. These 16 patients underwent nonoperative treatment. The fracture was healed in 8 (4 acromion and 4 spine). The average active forward elevation was 109° (range, 50°-170°), and the Constant score was 47.0 points (range, 8-81 points).
Conclusions: Scapular fractures after Grammont-style RSAs are rare (1.3%) but remain a concern. These fractures occur mainly in the early postoperative 6 months. Immobilization with an abduction splint frequently resulted in nonunion or malunion. Final functional outcomes are poor regardless of acromial or spine fracture compared with primary RSA without fracture.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Scapular fracture; acromion; spine; nonoperative treatment; outcomes; postoperative complication; reverse shoulder arthroplasty; multicenter study

Reverse shoulder arthroplasty (RSA) using a Grammont-style prosthesis relies on medializing and lowering the center of rotation of the shoulder. Both have a significant effect on the deltoid muscle, with recruitment of more muscle fibers and increasing muscle tension.[15,21] The deltoid muscle, which originates from clavicle, acromion, and spine of the scapula,

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may observe increased constraint after reverse arthroplasty, potentially increasing the fracture risk in these areas. Fracture of the acromion or spine of the scapula are reported complications after RSA.[3,4,6,9,10,13,20,22,24]

In patients without preoperative acromial insufficiency, a fracture line through the posterior acromion (acromial base fracture) or through the spine of the scapula can be observed after a clear trauma or in the setting of sudden pain without trauma after RSA. In a review of postoperative events after RSA, Zumstein et al[24] reported scapular fracture as the fourth most common complication (1.5%) behind instability, infection, and aseptic glenoid loosening. The reported prevalences of scapular fracture after RSA vary from 1% to 10.2%.[3,4,6,9,10,13,22]

The first aim of this study was to report the rate of scapular fracture after a Grammont-style RSA in a large cohort of patients using data from a retrospective multicenter study. The second goal was to report the functional and radiographic results of patients who sustained a scapular fracture with minimum 5-year follow-up.

Materials and methods

Identification of study groups

Entire cohort

Between April 1993 and December 2010, 1953 Grammont-style RSAs were implanted in 1745 patients in 7 regional centers and were retrospectively included in a specific database (EasyMedStat; Easy Made Stat, Neuilly-sur-Seine, France). The database was searched to identify patients with postoperative complication "acromial base fracture = yes" and "spine fracture = yes". This cohort was used to calculate the rate of scapular fracture after Grammont-style RSA.

Minimum 5-year follow-up subgroup

For functional and radiographic assessment, a minimum of 5-year follow-up was required for inclusion. Among the 1745 patients, 307 patients (17.6%; 324 RSAs) died, and 485 patients (28%; 585 RSAs) had less than 5-year follow-up. Subsequently, a subgroup of 953 patients (1035 RSAs) with minimum 5-year follow-up was identified. There were 19 patients (19 RSAs) with a postoperative scapular fracture (10 acromion base fractures and 9 spine fractures) who reached the 5-year follow-up and were functionally and radiographically assessed.

Patients demographics

There were 16 women (84%) and 3 men (16%). The average age at surgery was 74 years (range, 65-83 years). The average duration of follow-up after surgery was 98 months (range, 60-167 months). The dominant side was affected in 69%.

The initial diagnosis was massive rotator cuff tear (Hamada 1, 2, 3) in 5 patients, cuff tear arthropathy (Hamada 4, 5) in 4, fracture sequelae in 3, revision of a hemiarthroplasty in 2, primary osteoarthritis in 2, previous cuff surgery in 2, and previous instability surgery in 1 (Table I).

Radiographic analysis

Radiographic evaluation of each patient of the entire cohort included preoperative radiographs in anteroposterior and scapular Y

Table I Baseline demographic and scapular fracture characteristics

Patient	Sex	Age at surgery (yr)	Indication index RSA	Interval RSA→diagnosis (mo)	Fracture type	Circumstance of event
1	Male	74	Massive cuff tear	4	Acromion base	Sudden pain without trauma
2	Female	70	Primary OA	4	Acromion base	Sudden pain without trauma
3	Female	77	Massive cuff tear	2	Acromion base	Sudden pain without trauma
4	Female	71	Fracture sequelae	1	Acromion base	Sudden pain without trauma
5	Female	83	Fracture sequelae	2	Acromion base	Sudden pain without trauma
6	Female	77	CTA	1	Acromion base	Sudden pain without trauma
7	Female	68	Revision hemi	1.5	Acromion base	Sudden pain without trauma
8	Female	79	Massive cuff tear	1.5	Acromion base	Sudden pain without trauma
9	Female	73	Massive cuff tear	2	Acromion base	Sudden pain without trauma
10	Male	72	CTA	2	Acromion base	Sudden pain without trauma
11	Female	81	CTA	2.5	Spine	Traumatic (fall)
12	Female	70	Fracture sequelae	36	Spine	Traumatic (fall)
13	Female	73	Revision hemi	15	Spine	Sudden pain without trauma
14	Female	77	Massive cuff tear	7	Spine	Sudden pain without trauma
15	Female	78	Failed cuff surgery	112	Spine	Last FU x-ray control
16	Female	78	Primary OA	136	Spine	Last FU x-ray control
17	Male	78	Prev. Instab. surgery	2	Spine	Traumatic (fall)
18	Female	72	CTA	2	Spine	Sudden pain without trauma
19	Female	65	CTA	167	Spine	Last FU x-ray control
Total		74.6				

RSA, reverse shoulder arthroplasty; *OA*, osteoarthritis; *CTA*, cuff tear arthropathy; *FU*, follow-up.

views and postoperative radiographs at regular follow-up intervals and at the final follow-up for the present study. If a fracture was not visualized on plain routine radiographs and a fracture was suspected, then additional radiographic views or computed tomography (CT) scans were obtained per each surgeon's preference.

In this study, the presence and location of each scapular fracture was confirmed by senior surgeons (G.W. and L.N.) and 2 shoulder fellows (F.A. and G.B.). When observers disagreed, a collegial discussion was held to obtain agreement.

Fracture healing was assessed on radiographic evidence of bone callus or persistence of a visible gap at the fracture site on plain radiographs or CT when available. The relationship between tip of the screw fixation of the baseplate and the fracture line was also assessed.

Surgical technique

The deltopectoral approach was used in 17 patients, anterosuperior approach in 1, and transdeltoid approach in 1.

The prosthesis was an Aequalis reversed (Tornier, Bloomington, MN, USA) in 12 patients, Delta (DePuy, Warsaw, IN, USA) in 4, and Aequalis fracture long stem in 1 (Tornier).[8] All implants were Grammont style with 155° neck-shaft angle. The glenosphere size was 36 mm in 15 patients and 42 mm in 2. Four fixation screws were used in all cases.

Outcomes measured

Preoperative and final follow-up active ranges of motion assessed were active forward elevation (AFE), external rotation (ER) with the elbow at side, and internal rotation (IR). These were measured by an independent observer with a manual goniometer. Constant scores (CS) were also obtained. The CS is broken into 4 sections (pain, 15 points; activities of daily living, 20 points; movement, 40 points; strength, 25 points) for a total of 100 points.[2] Higher scores indicate better function.

Statistical analysis

The Student *t* test for paired data was used to compare differences between the last follow-up and preoperative values, and the Fisher test or the χ^2 test were used to find relationships between variables. The Student *t* test was used for unpaired, normally distributed variables. If the data were not normally distributed, the Mann-Whitney *U* test was used. The tests used were 2-tailed, and the α value was set to 0.05.

Results

Rate of scapular fracture after Grammont-style RSA

Among the 1953 Grammont style prostheses in the entire cohort, 26 RSAs (1.3%) were identified to have a postoperative scapular fracture. Thirteen fractures (0.67%) were fractures through the acromion just posterior to acromioclavicular joint (Crosby type II, Levy type I).[3,13] Thirteen RSAs (0.67%) had a spine fracture (Crosby type III, Levy type II).

Minimum 5-year follow-up cohort

Nineteen patients had 5-year follow-up. The fracture occurred atraumatically with sudden onset of pain in 13 patients (10 acromial fractures and 3 spine fractures) at a mean 3.3 months postoperatively (range, 1-15 months). The fracture occurred within the first 6 months in 11 of the 13 patients (84.6%). Among these patients, 5 had no evidence of a fracture on plain radiographs and were further investigated with a CT scan that confirmed the diagnosis (3 acromial fractures and 2 spine fractures; Fig. 1).

The fracture occurred after a documented traumatic event in 3 patients at 2, 2.5, and 36 months, respectively (mean, 5.2 months). The fractures that occurred after these falls were all scapular spine fractures. The fracture was displaced in 2 patients and nondisplaced in 1.

A spine fracture was diagnosed in 3 patients at the time of their final radiographic follow-up for the present study. They were asymptomatic, and the fracture had healed in 2 patients and resulted in a nonunion in 1 (112, 136, and 167 months, respectively). Careful review of clinical records and patient interview could not find a specific event to estimate the time of fracture occurrence.

The 3 patients who had asymptomatic fractures received no specific treatment. In the 16 other patients, immobilization with an abduction splint was used for 6 weeks for pain relief. Patients were asked to resume daily activities as tolerated after the period of immobilization.

Radiographic results at final follow-up

Overall, nonunion was observed in 11 patients, and the fracture healed in 8 (Table II). In the acromion group, 6 patients had nonunion and 4 healed. In the spine group, 5 patients had nonunion and 4 healed.

Of the 19 fractures of this cohort, 16 were identified before the patient's final follow-up visit and were treated in an abduction splint, and 6 (37.5%) of these fractures healed. All fractures healed with some downward tilt, resulting in decreasing of acromion-greater tuberosity distance from prefracture status. Of the 16 fractures treated with an abduction splint, 4 of 10 acromial fractures (40%) healed, and 2 of 6 spine fractures (33%) healed. Among the 3 unnoticed and untreated fractures, 2 were healed and 1 was not healed at the last follow-up.

Outcomes

Outcomes are listed in Table III. Overall, the average AFE at last follow-up was 109° (range, 50°-170°), with significant improvement from the preoperative evaluation ($P = .002$). The average CS was 47.0 points (range, 8-81 points), with significant improvement from the preoperative scores ($P = .001$).

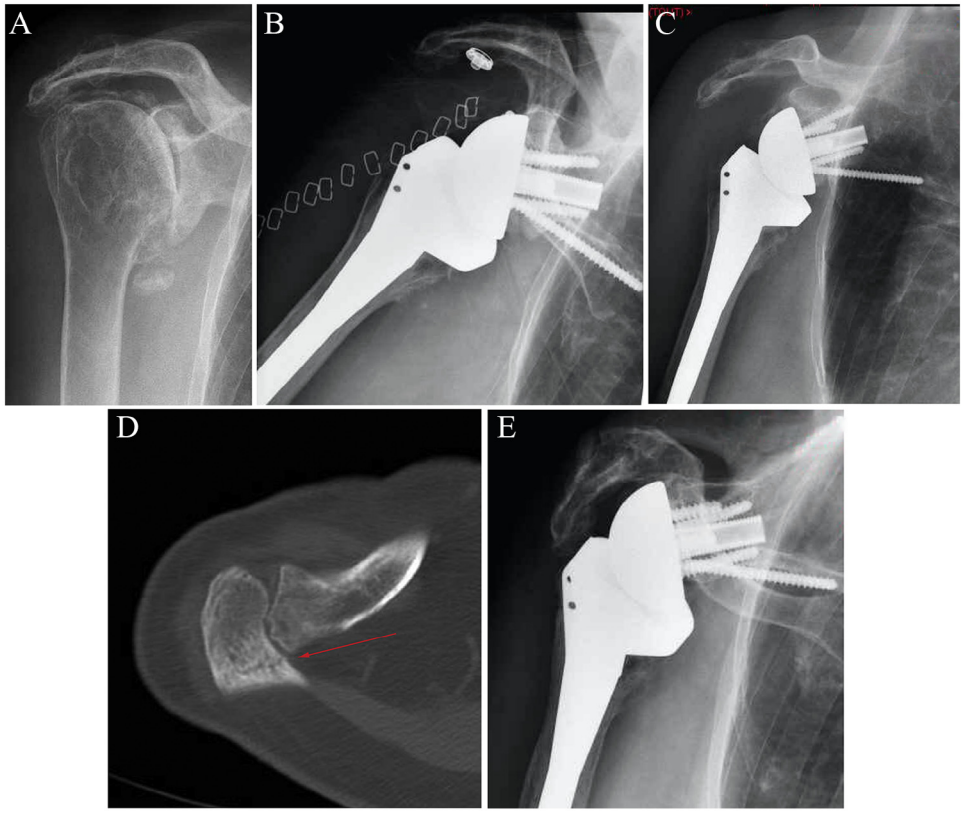

Figure 1 (**A**) An 83-year-old woman with post-traumatic osteoarthritis underwent reverse shoulder arthroplasty on her right shoulder with intact preoperative acromion and spine. (**B**) Immediate postoperative radiographs. Two months after the procedure, acromion base fracture was not seen on (**C**) x-ray images but was diagnosed with a (**D**) computed tomography scan (*arrow*) and treated conservatively with an abduction splint. (**E**) At the 6-year-follow-up, healing was achieved with malunion and acromial tilt.

Table II Radiographic and clinical results

Patient	Last follow-up (mo)	Screw relationship	Rx evolution	Pain score (points)	AFE (°)	CS (points)
1	97	No	Nonunion	6	120	48
2	56	No	Nonunion	15	170	77
3	60	No	Nonunion	14	150	74
4	95	No	Nonunion	15	90	49
5	74	No	Nonunion	15	90	39
6	57	No	Nonunion	15	170	81
7	82	No	Healed	9	90	32
8	111	No	Healed	10	110	52
9	117	No	Healed	10	130	52
10	109	No	Healed	5	60	17
11	88	Yes	Nonunion	5	90	27
12	74	No	Nonunion	15	60	37
13	147	Yes	Nonunion	0	50	8
14	94	No	Nonunion	5	90	28
15	112	Yes	Nonunion	7	60	27
16	136	No	Healed	15	160	79
17	120	No	Healed	14	140	72
18	59	No	Healed	14	150	58
19	167	Yes	Healed	13	100	36
Total	97.6			10.6	109.4	47

AFE, active forward elevation; *CS*, Constant score.

Table III Clinical results according to scapular fracture type

Variable	Series (n = 19)			Acromial fracture (n = 10)			Spine fracture (n = 9)		
	Pre-op	FU	*P*	Pre-op	FU	*P*	Pre-op	FU	*P*
AFE, °	60 ± 30 (20-120)	109 ± 39 (50-170)	.002	60 ± 31.2 (20-120)	118 ± 37 (60-170)	.019	61 ± 30.5 (20-100)	100 ± 41.2 (50-160)	.058
Pain, pts	4.3 ± 2.6 (0-10)	10.6 ± 4.7 (0-15)	<.001	4.3 ± 2.7 (0-9)	11.4 ± 3.9 (5-15)	.009	4.4 ± 2.8 (0-10)	9.8 ± 5.6 (0-15)	.014
Constant score, pts	25.6 ± 10.6 (2-50)	47 ± 21.9 (8-81)	.001	26.8 ± 10.5 (14-50)	52.1 ± 20.4 (17-81)	.027	24.3 ± 11.2 (2-40)	41.3 ± 23.4 (8-79)	.021

FU, follow-up; *AFE*, active forward elevation; *pts*, points.
Data are presented as the mean ± standard deviation (range).

The average pain score was 10.6 points (range, 0-15 points), with significant improvement from the preoperative scores ($P < .001$). Pain score distribution at the final follow-up showed that 10 patients reported minimal or no pain with a score of 12 points or higher of 15.

We found no relationship between screw placement in the baseplate and acromial base fractures. Four scapular spine fractures (44%) demonstrated a fracture line in relationship with the tip of the superior screw (Fig. 2).

Complications and reoperations

One patient underwent a reoperation because of a glenosphere disassembly. Immediate postoperative x-ray images showed incomplete engagement of the sphere on the baseplate Morse taper leading to complete disassembly. During revision, the glenosphere was changed, and no attempt at fixation of the acromial nonunion was made. The AFE at last follow-up was 90°, and the CS was 49 points.

Two patients underwent open reduction and internal fixation (ORIF) of a scapular spine nonunion. An RSA was implanted for cuff tear arthropathy in 1 patient (Hamada 5). The spine fracture was diagnosed 2.5 months after the RSA and treated conservatively. There was no evidence of fracture healing, with a painful shoulder 8 months later, and ORIF was performed with 2 perpendicular Arbeitsgemeinschaft für Osteosynthesefragen (AO) plates. The nonunion remained, and the hardware was removed 21 months after the reoperation. At the last follow-up (5 years after hardware removal), the patient was 89 years old, still painful (pain score of 5 points of 15 possible), AFE was 90°, and CS was 27 points.

An RSA was implanted in another patient for a massive cuff tear (Hamada 3), and the fracture was diagnosed 7 months postoperatively. After a period of nonsurgical treatment, a CT scan demonstrated a nonunion of the index fracture. ORIF was performed (plating and tension band) with bone grafting. The hardware was removed 10 years later due to local irritation, but the nonunion was healed. At the last follow-up (5 years after the last procedure), the patient was 85 years old, still painful (pain score of 5 points of 15 possible), AFE was 90°, and CS was 28 points.

Discussion

The primary objective of this study was to determine the prevalence of scapular fractures after implantation of Grammont style prostheses. The prevalence of scapular fracture (acromial or spine fracture) in our study of 1953 Grammont style RSAs was 1.3%.Scapular fractures after RSA are a well-identified complication in the literature. However, inhomogeneous prevalence rates of 1% to 10% have been reported because of confusing factors such as small sample sizes, use of different prostheses in the same series, use of different classification, or inclusion of preoperative acromial insufficiencies.[3,5,9,10,13,22]

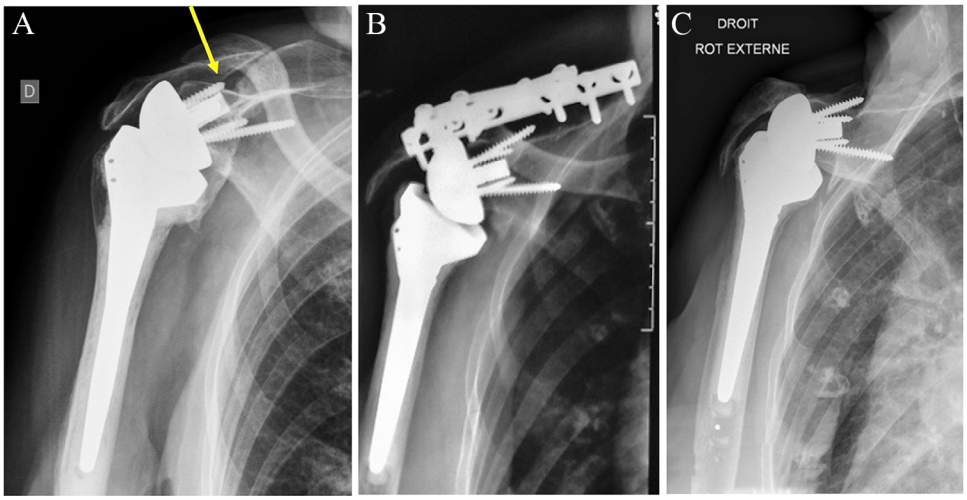

Figure 2 (**A**) An 81-year-old woman underwent reverse shoulder arthroplasty for cuff tear arthropathy on her right shoulder. Radiographs 8 months after the procedure demonstrate a fracture line in relationship with the tip of the superior screw (*arrow*). (**B**) Open reduction and internal fixation was performed with 2 perpendicular AO (Arbeitsgemeinschaft für Osteosynthesefragen) plates. The nonunion remained, and the hardware was removed 21 months after the reoperation. (**C**) At 7 years of follow-up, nonunion is present with downward tilt and decrease acromion-greater tuberosity distance.

Few series are comparable to ours. The largest series with a single implant (Reverse Shoulder Prosthesis; DJO Surgical, Austin, TX, USA) was reported by Teusink et al[19] with a prevalence of scapular fracture of 3.1% in 1018 RSAs. Interestingly, Levy et al[13] reported a prevalence of 10% with the use of the same implant but in a smaller series of 157 RSAs and using a different classification system.

In the literature, 2 classification systems for scapular fractures after RSA are used, adding to the confusion.[3,13] We did not focus on these classification systems because we felt that most readers might be unfamiliar with these systems and better served by an anatomic description of the fracture. Patients with preoperative scapular insufficiency (os acromiale, acromion erosion or fragmentation) were not included because this is a completely different entity from postoperative scapular fractures and is known to have little clinical influence on RSA functional results.[1,14,20] These patients were excluded because scapular insufficiency had the potential to falsely improve the functional outcomes if they were grouped with the postoperative fracture population.

Conventional radiographs were unreliable in diagnosing scapular fracture. A CT scan was required to confirm the fracture in 5 patients. Unless tilting of the fractured part of the scapula is obvious on plain radiographs, the fracture line identification and localization can be challenging because of the superposition with the clavicle on anteroposterior radiography. In addition, initial pain can be related to a nondisplaced fracture before secondary displacement. The diagnosis can even be more challenging when a spine fracture occurs in the presence of a meso os acromiale. We observed 1 patient in our series, without tilting in the os acromiale area, that could not have been clearly identified without CT scan.

The secondary goal of our study was to report the 5-year functional and radiographic results of patients who sustained a scapular fracture after RSA.

Many authors have emphasized the detrimental effect of postoperative scapular fracture on the functional result.[3,9,10,19] The average preoperative CS in our study was 25.6, which is consistent with many prior studies.[7,18] Our postoperative results show an average AFE of 109° and average CS of 47 points at a minimum 5-year follow-up. This is a statistically significant improvement compared with the preoperative evaluation. It also is likely still a clinically significant improvement, because some research has indicated that 10 is approximately the minimal clinically significant difference in the CS in the setting of rotator cuff tears.[12] However, prior studies have demonstrated that patients with scapular fractures have inferior outcomes compared with controls without fracture, in which the postoperative CS is closer to 70[7,18,19] In addition, although this average score of 47 points represents a statistically significant improvement from the preoperative evaluation, CSs from healthy individuals in the same age group as our average age are generally between 80 and 90.[23]

Why these fractures occur remains undetermined. The retrospective nature of our study and small sample size did not permit the appropriate multivariate statistical analysis to identify a predictive factor for scapular fracture.

Prior studies have identified some factors that may play a role in scapular fracture, such as arm lengthening with excessive deltoid tension, acromioclavicular joint osteoarthritis, bone quality (osteopenia/osteoporosis), and the baseplate screw fixation tip acting as a stress riser. Otto et al[16] evaluated the risk factors in a comparative study and found osteoporosis was significantly associated with a risk of fracture.

The type of arthroplasty is also likely to play a role. We observed a 1.3% rate of scapular fracture with inlay

Grammont-style humeral implants. Onlay humeral implants have been introduced on the market and represent a substantial modification of the initial design with induction of humeral lateralization. Scapular fractures rates have been reported with these implants from 4.4% with Equinoxe Reverse Total Shoulder Arthroplasty (Exactech, Gainesville, FL, USA)[11] to 5.3% with Aequalis Ascend Flex prosthesis (Tornier).[22] The exact role of humeral onlay implant design on scapular fracture occurrence has yet to be determined, but 4- to 5-times higher rates compared with the Grammont design may be a concern.

The length and orientation of screw for fixation of the baseplate have been identified as a potential stress riser if the tip of the screw reaches or crosses through the scapular spine.[3,11,16] In their study with CT evaluation, Kennon et al[11] determined that removal of the superior baseplate screw decreased their rate of scapular spine fracture from 4.4% to 0%. Assessing the screw tip/fracture line relationship on plain radiographs with any certainty is difficult. In the present study, we estimated a potential link with a screw in 44% (4 of 9) of the scapular spine fractures. The significance of this correlation between screw tip and spine fracture remains uncertain and does not elucidate why the vast majority of the patients do not experience any scapular fracture despite the use of the same implant with superior screw fixation.

The benefit of abduction splint treatment in this study is questionable. The rationale for the use of an abduction splint was to reduce the initial pain after the fracture by placing the upper limb in a resting position with decrease of the traction of the deltoid on the fracture line. However, the treatment with abduction splint for 6 weeks failed to obtain healing in 62.5%. Only 40% of the treated acromial fractures and 33% of the spine fractures radiographically healed, all with some degree of downward tilt of the most lateral scapula fragment. This is consistent with the available data showing a global rate of 66% nonunion after immobilization.[17] Subsequently, it could be hypothesized that obtaining a healed fracture in an anatomic position would result in the best outcome.

ORIF is a described treatment,[3,17] but fixation of these fractures is challenging because of mechanical conditions due to deltoid muscle distraction forces combined with thin and osteoporotic bone. Various techniques of fixation have provided inconsistent results, and even with updated data, there is no strong evidence that surgical fixation provides superior results compared with conservative treatment, and further studies are required.

We acknowledge this study is not free of limitations. This is a retrospective multicenter series with a relatively small sample size of scapular fractures, which limited the statistical analysis and precluded identification of significant differences between subgroups or prognostic factors. In addition, it is difficult to ensure that we have not missed any fractures, because they are relatively rare by most estimates, are challenging to diagnosis with plain radiographs, and occasionally are minimally symptomatic.

However, even if our study has slightly underestimated the overall percentage of these events, we do not feel this outweighs the potential strengths of our study, which include the up-to-date largest number of RSA with a single prosthetic design (Grammont style) studied with an average of 97 months of follow-up. This allowed us to calculate the prevalence of scapular fractures with this RSA design. Lastly, we highlighted the methodologic flaws observed in the literature about scapular fractures that preclude comparison between the series.

Conclusions

Our data show a rate of 1.3% scapular fractures after Grammont-style RSA. This study indicates that acquired scapular fractures (acromion, spine) are a turning point in the postoperative course after RSA. Three diagnostic patterns occur: traumatic, atraumatic with sudden onset of pain, and the fracture unrecognized until appropriate imaging is performed. The fracture can be recognized radiographically when immediate acromial/spine tilt occurs or in case of obvious fracture line. When no obvious fracture line is present, a CT scan is recommended. Immobilization with an abduction splint frequently resulted in nonunion or healing with malunion of the fracture. Final functional outcome is poor, regardless of acromial or spine fracture.

Disclaimer

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