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Original article

Does ORIF of rare scapular spine fractures sustained after reverse shoulder arthroplasty benefit elderly patients? A case-series appraisal

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ABSTRACT

Purpose: Scapular spine fractures sustained after reverse shoulder arthroplasty (RSA) are debilitating for elderly patients with osteoporosis. We examined the 1-year postoperative outcomes of open reduction and internal fixation (ORIF) in a small case-series, and hypothesised that patients undergoing surgical treatment for post-RSA scapular spine fractures would improve in function and pain.
Methods: Five consecutive RSA patients within our shoulder arthroplasty register who sustained a scapular spine fracture underwent ORIF using a double plating technique. Standard radiographs and clinical/patient-rated assessments of Constant–Murley (CS), Shoulder Pain And Disability Index (SPADI), Subjective Shoulder Value (SSV) and visual analogue scale (VAS) pain were made up to 12 months post-ORIF. Patients were also asked to rate their satisfaction since the surgery. Post-ORIF complications were documented. All post-RSA data were used as a baseline measure for comparison with post-fracture outcomes.
Results: Mean CS, SPADI and SSV scores as well as pain were similar to pre-fracture scores. All patients improved in function and pain, and would undergo the same procedure again. Individual cases of iatrogenic pneumothorax and screw loosening were reported.
Conclusions: ORIF is a viable option with adequate improvements in function and pain for elderly patients with debilitating scapular spine fractures after RSA.

1. Introduction

The incidence of acromion or scapular spine fractures after reverse shoulder arthroplasty (RSA) is reported to be up to 11.2% [1]. These injuries contribute to inferior clinical outcomes, especially if the acromial base or scapular spine is involved [2]. Yet conservative management is the apparent treatment of choice for this particular cohort [3].

There is, in fact, a lack of evidence advocating the best treatment for patients who sustain a scapular spine fracture after RSA [2]. Only one report recommends open reduction and internal fixation (ORIF) of type III fractures according to the Crosby classification without proving its superiority over conservative treatment [4]. In addition, the few studies on ORIF disclose neither any detail regarding the surgical technique used nor the rationale behind the choice of implant or fracture fixation method, and postoperative clinical outcome data is sparse [2,5–7].

Our aim was to examine the 1-year postoperative clinical and radiological outcomes of ORIF in treating post-RSA scapular spine fractures. We also provide a detailed account of our rationale for and experiences with the chosen surgical method. Our hypothesis was that elderly patients with osteoporosis and an ORIF-treated post-RSA scapular spine fracture would greatly improve in function and pain.

2. Patients and methods

Since 2006, patients who underwent RSA at our clinic were consecutively documented in a local shoulder prosthesis register [8]. Up to January 2015, all RSA patients and particularly comorbid elderly patients with osteoporosis (confirmed by dual energy X-ray absorptiometry [DEXA]), who presented with either an acromial or scapular spine fracture were treated conservatively; these fractures were defined as laterally or medially located to the acromial base, respectively. Based on our observations, patients with scapular spine fractures are generally unable to achieve adequate upper

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extremity function, which motivated the senior author to treat this uncommon, yet largely debilitating injury with ORIF. Between January 2015 and January 2016, 5 consecutive RSA patients came in for an unscheduled consultation due to symptoms of pain and decreased function; this examination occurred outside the standard clinical and radiological follow-up examinations held at 2-, 5- and 10-years post-RSA. Based on standard radiographs as well as complementary computer tomography (CT) scanning, each patient was diagnosed with a scapular spine fracture. Fractures were either acute, delayed union or nonunion if the time between sustaining the injury and potential treatment was within 3 months, between 3 and 6 months or greater than 6 months, respectively. Patients were thoroughly informed about the benefits and risks of both conservative and surgical treatment options based on expert opinion and previous experience of the main treating physician (senior author). All patients opted to undergo surgery at their own discretion and provided informed consent to allow the clinical data to be used for research purposes.

2.1. Surgical technique

All patients were operated using an incision along the scapular spine in a lateral decubitus position based on the procedure of Hill et al. [9]. In order to gain visual and surgical access to the fracture site, the insertions of the trapezius and deltoid muscles were subperiosteally detached cephalad and caudal from the scapular spine, and the most cephalad portions of the infraspinatus muscle as well as the most dorsal parts of the supraspinatus muscle at the area of the fracture were detached from the bone, carefully protecting the neurovascular bundle running across the supraspinatus fossa and curving around the acromion base. In the case of delayed union or symptomatic nonunion, tissue at the fracture site was resected until vital bone was identified.

Reduction and preliminary fixation with clamps and/or K-wires was initially done to estimate the dimensions and position of the plates as well as the size of bicortical iliac crest and cancellous bone autografts when needed, respectively. Although no grafts were intended for acute fractures, patient 1 was operated on with a delay of two and a half weeks, therefore cancellous bone graft was applied to support bone healing. All fractures were fixed with one of the following implants (DuPuy Synthes, Oberdorf, Switzerland): a locking compression plate (LCP)® distal humerus; variable angle (VA)-LCP® olecranon; or VA-LCP® distal humerus plate (lateral). One or two lag screws were placed perpendicular to the fracture line through the plate heading towards the glenoid neck, where appropriate. A 5- or 6-hole quarter tubular plate (DePuy Synthes, Oberdorf, Switzerland) was then applied across the fracture to the caudal area of the scapular spine and fixed with 2.7 mm screws to keep the reduced fracture and graft material in place as well as achieve a 90° construction with the cephalad-positioned plate (Figs. 1 and 2). The latter was finally fixed to the scapular spine predominantly with 2.7 mm locking screws medially and 2.7 or 3.5 mm locking or conventional screws laterally to the fracture site. The fracture site was finally irrigated before cancellous bone graft was applied, followed by suturing the detached deltoid and trapezius muscles with their fasciae end-to-end over the plate and standard wound closure.

2.2. Postoperative rehabilitation protocol

The treated arm was kept immobilised in a Donjoy Ultrasling II® abduction orthosis (DJO Global, Vista, CA) for 6 weeks with pain-free passive mobilisation beginning 4 weeks after surgery. Free active range of motion without resistance or weightlifting was initiated at the 6-week postoperative time point and by 3 months post-ORIF, patients were allowed to increase the level of strengthening exercises in their rehabilitation program.

2.3. Clinical and radiological outcome assessment

All patients were included in our shoulder registry and attended post-RSA standardised clinical and radiographic evaluation at 2, 5, and 10 years follow-up; all available post-RSA follow-up data collected prior to sustaining the fracture represented the patient's baseline (i.e. pre-ORIF) status. Furthermore, each patient attended follow-up examinations at 2 and 6 weeks as well as 3, 6 and 12 months post-ORIF to assess functional outcome and fracture healing.

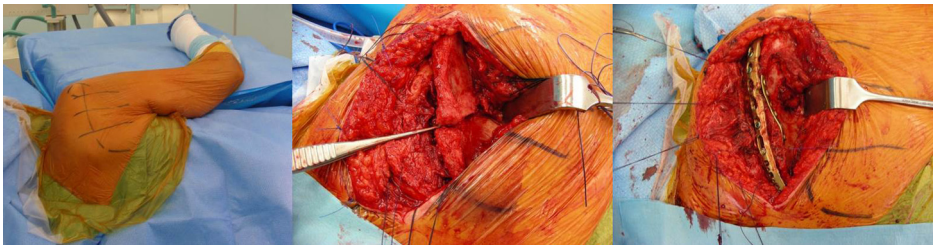

Fig. 1. Patient positioning (lateral decubitus) and incision landmarks (left), surgical forceps pointing at the spine fracture (middle) and final result with plates and graft in position (right).

Fig. 2. Detailed view of plate positioning and screw-/drill trajectory; a: medial to lateral view; b: posterior view; c: postero-inferior to medial-superior view; blue line: VA-LCP lateral distal humerus plate; black square: ¼ tubular plate; green arrows: drill trajectory for the VA-LCP; orange arrows: drill trajectory for the ¼ tubular plate.

Functional outcome was measured at the last scheduled 12-month follow-up using the Constant–Murley (CS), Shoulder Pain And Disability Index (SPADI) and Subjective Shoulder Value (SSV) questionnaires, and pain levels were determined on a 0–10 visual analogue scale (VAS) (0 = no pain; 10 = worst pain possible) [10–12]. Range of motion (ROM) and abduction strength were both measured as described by Constant et al. using a goniometer and spring balance, respectively [13].

Standard radiographs in anteroposterior, scapular y and axial views were made immediately and at 2 and 6 weeks as well as 3, 6 and 12 months post-ORIF. All radiographs were assessed by the primary and senior authors. Postoperative healing was defined as the disappearance or fading of the former fracture line, in addition to a lack of pain on palpation at the former fracture site as well as with caudal pressure on the lateral acromion.

At the 12-month follow-up, patients were asked the following questions: "Compared to before surgery, would you say you benefited from the intervention in terms of (A) pain (at rest as well as under load and during motion) and (B) shoulder function? If yes, little, noticeable or marked?" and "Based on your current postoperative status, would you undergo the same operation again?".

Local complications were documented throughout the 12-month postoperative follow-up period.

2.4. Data handling and analysis

All RSA register and post-ORIF data were managed using the REDCap Electronic Capture system and Microsoft Excel, respectively [14]. All baseline and follow-up parameters were tabulated per patient and compared using clinical judgment to assess post-fracture patient status after ORIF, where appropriate. Complications occurring within the reported postoperative period were described.

3. Results

From a total of 1475 RSA patients in our shoulder arthroplasty registry, 25 sustained a post-RSA fracture either at the acromion (n = 13 [0.9%]) or scapular spine (n = 12 [0.8%]). Between May 2006 until January 2015, 7 patients with a post-RSA scapular spine fracture (Crosby type III) were treated conservatively [4]. Thereafter, 5 patients sustained a scapular spine fracture up to January 2016, and had sufficient post-RSA follow-up data to provide a satisfactory picture of their pre-fracture (baseline) status. All patients were females with a mean age of 76 years (range: 73–81) and opted to undergo ORIF (Table 1). Surgical details concerning implants and indication for ORIF as well as RSA-related data are highlighted in Table 2.

At the final post-ORIF follow-up, each patient had a higher CS compared to that measured before RSA, and was similar to those documented at baseline (either at 2 or 5 years post-RSA) (Table 3). Baseline SPADI scores were also similar to those documented at the final post-ORIF follow-up for all patients. ROM improved after ORIF, although the same levels of mobility were not achieved when compared to the pre-fracture status for 3 of 4 patients (Table 4). Both SSV and VAS pain levels at the final post-ORIF follow-up were comparable to the patient-rated status measured before the fracture occurred.

By the final follow-up, all fractures were considered healed. Each patient stated that they experienced a marked improvement in pain and function (particularly ROM) and would definitely undergo the same procedure again.

Two complications were reported during the 1-year post-ORIF follow-up period. Two weeks after patient 1 underwent ORIF, one medial screw in the 5-hole LCP® distal humerus and another medial screw in the 5-hole quarter tubular plate displaced, although the entire ORIF construct remained stable with only one remaining

Table 1
Baseline status of all patients with a post-RSA scapular spine fracture treated with ORIF.

Patient	Comorbidities	Age	Affected shoulder (dominant side)	Time between RSA and fracture	Time between fracture and ORIF	Fracture type
1	Osteoporosis[a] Depression Kidney insufficiency Slight anaemia Hypothyroidism	76	Left (left)	4 months	17 days	Acute
2	Osteoporosis[a] Cuff tear arthropathy (right shoulder) Anaemia	81	Left (right)	97 months	7 days	Acute
3	Depression	73	Right (right)	31 months	5 months	Delayed union[b]
4	Osteoporosis[a] Depression Seropositive polyarthritis + CPPD	76	Right (left)	55 months	13 months	Nonunion[c]
5	Osteoporosis[a] Depression Asthma (treated with steroid medication) Hypoferraemia Kidney and adrenocortical insufficiency	73	Right (right)	113 months	2 months	Delayed union[d]

RSA: reverse shoulder arthroplasty; ORIF: open reduction and internal fixation; CPPD: calcium pyrophosphate deposition disease (pseudogout).

[a] Osteoporosis confirmed by dual energy X-ray absorptiometry.

[b] Patient 3 sustained their fracture after a fall with minimal fragment displacement. Conservative management over the next 3 months resulted in progressive pain and reduced function. Upon SPECT-CT confirmation of a delayed union, the patient was offered and agreed to undergo ORIF.

[c] Patient 4 sustained their fracture after a fall. Initial pain was moderate followed by inconsistently reported pain at further follow-ups. Conservative treatment was undertaken until a 6-month CT image confirmed nonunion after the patient reported consistent pain under load. By 12 months post-trauma, the patient finally agreed to undergo ORIF.

[d] Patient 5 was referred to our clinic for further treatment with some delay.

Table 2
Surgical details of all patients with a post-RSA scapular spine fracture treated with ORIF.

Patient	Surgery prior to RSA	Indication for RSA	RSA prosthesis[a]	Fracture injury	Scapular notching[b]	ORIF implant/bone graft
1	–	Avascular necrosis with massive cuff tear	Universe Revers®	Quick arm movement	0	5-hole LCP® distal humerus plate; cancellous bone graft
2	ORIF for proximal humerus fracture 2 y prior to RSA	Avascular necrosis after ORIF for proximal humerus fracture and cuff tear	PROMOS®	Fall	I	VA-LCP® olecranon plate; no graft
3	–	Cuff tear arthropathy (grade II)[c]	PROMOS®	Fall	0	VA-LCP® distal humerus plate (lateral); bicortical iliac crest + cancellous bone graft
4	Open rotator cuff repair 3 y prior to RSA (TOS)	Dislocation with massive cuff tear, instability and glenohumeral arthritis (grade I)[d]	PROMOS®	Contusion	II	VA-LCP® distal humerus plate (lateral); bicortical iliac crest + cancellous bone graft
5	2 × rotator cuff repair at 1.5 & 2 y prior to RSA	Cuff tear arthropathy (grade IV)[c]	SMR™	–	IV	VA-LCP® distal humerus plate (lateral); cancellous bone graft

RSA: reverse shoulder arthroplasty; ORIF: open reduction internal fixation; TOS: transosseous suture; LCP: locking compression plate; VA: variable angle.
[a] Universe Revers® (Arthrex Swiss AG, Belp-Bern, Switzerland); PROMOS® (Smith & Nephew Orthopedics AG, Rotkreuz, Switzerland); SMR™ Reverse Modular Shoulder System (Lima Corporate S.p.a., Udine, Italy).
[b] According to Sirveaux F, 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 Br 2004;86:388–95 at the time of fracture diagnosis.
[c] According to Hamada K, et al. Roentgenographic findings in massive rotator cuff tears: a long-term observation. Clin Orthop Relat Res 1990;(254):92–6.
[d] According to Samilson RL, Prieto V. Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 1983;65:456–60.

Table 3
Comparison of baseline and post-ORIF shoulder functional scores.

Patient	Constant–Murley				Shoulder Pain and Disability Index			
	Pre-RSA	2-year post-RSA	5-year post-RSA	1-year post-ORIF	Pre-RSA	2-year post-RSA	5-year post-RSA	1-year post-ORIF
1	18	–	–	40	6	–	–	51
2	19	47	43	49	23	53	31	55
3	28	69	–	52	39	69	–	68
4	60	73	41	55	34	65	58	75
5	19	32	–	26	11	59	–	40

Constant–Murley [12] (CS) and Shoulder Pain And Disability Index [13] (SPADI) scores both ranging from 0 = worst to 100 = best.
Baseline = post-RSA time points.

Table 4
Comparison of baseline and post-ORIF range of motion, strength and patient-rated outcomes.

Patient	Time point		Range of motion				ABD ST (kg)	VAS	SSV
			FFL (°)	ABD (°)	ER (°)	IR (level)[a]			
1	Post-RSA FU	–	–	–	–	–	–	–	–
	Pre-ORIF	Baseline	–	–	–	–	–	–	–
	Post-ORIF	12 mo	90	90	30	Sacral	1.5	5	60
2	Post-RSA FU	5 y	105	70	10	Gluteal	0	3	–
	Pre-ORIF	Baseline	10	10	–	Waist	–	–	–
	Post-ORIF	12 mo	110	100	20	L3	2.0	4	50
3	Post-RSA FU	2 y	150	85	60	L3	6.0	5	70
	Pre-ORIF	Baseline	90	70	30	Gluteal	–	–	–
	Post-ORIF	14 mo	110	90	20	L1	2.4	2	70
4	Post-RSA FU	5 y	150	150	60	Th10	0	3	60
	Pre-ORIF	Baseline	80	80	60	L3	–	–	–
	Post-ORIF	17 mo	120	90	50	Th7	1.5	1	70
5	Post-RSA FU	2 y	120	120	0	Sacral	0	1	–
	Pre-ORIF	Baseline	30	30	–	–	–	–	–
	Post-ORIF	12 mo	90	70	20	Gluteal	–	3	50

mo: month; y: year; range of motion (FFL: forward flexion; ABD: abduction; ER: external rotation; IR: internal rotation) and ABD ST = abduction strength measured according to Constant et al., 2008 [13]; VAS = 0–10 visual analogue scale where 0 = no pain and 10 = worst pain possible; SSV = subjective shoulder value according to Gilbart and Gerber, 2007 [12], where 100 = completely normal shoulder.
Post-RSA FU = data collected from either the 2- or 5-year post-RSA follow-up prior to fracture.
Baseline = time after fracture diagnosis and prior to ORIF.
Post-ORIF = last follow-up examination attended by patient.
[a] Based on the Apley scratch test.

screw in the medial fragment. Despite this early event of screw loosening, the fracture achieved union by the 12-month follow-up. During the immediate post-ORIF period, a second patient (patient 4) had iatrogenic pneumothorax (confirmed on the intermediate care postoperative radiograph) most likely as a result of the drill or K-wires used for lag screw placement and/or preliminary fixation. After a thoracostomy and drainage procedure over a 3-day period, the patient recovered without any further issues.

4. Discussion

Our series of 5 patients benefited from ORIF to treat a post-RSA scapular spine fracture. CS, SPADI, and SSV did not change between the post-RSA and post-ORIF time points. At 12-months post-ORIF, ROM improved and all fractures healed. All patients also rated a marked improvement in pain and function, and would opt for surgery again given their current shoulder status. Of note, VAS pain levels varied greatly after sustaining the fracture up to the time of fracture fixation, which impeded the determination of a reliable baseline VAS score. Nonetheless, debilitating pain was the main reason for ORIF, which decreased to pre-fracture levels.

Conservative treatment is considered standard as surgical fixation is deemed too precarious for patients with osteoporotic bone, and results of surgically-treated spine fractures are inconsistently reported [15]. Despite some successful reports, ORIF often failed or patients did not achieve functional improvement [16–20]. This belief is shared by three-quarters of surveyed American Shoulder and Elbow Surgeon members who would treat post-RSA acromion fractures conservatively [3]. Furthermore, spine and acromion fractures have not always been clearly discriminated within individual studies, which makes the interpretation of results difficult. The trend of unsuccessful conservative treatment at our clinic promoted a change of thought in our handling of scapular spine fractures; the main challenge in surgical management is obtaining adequate fixation in osteopenic/osteoporotic bone.

Fixation constructs for post-RSA acromion or scapula spine fractures vary from tension band fixation and additional mesh plating to single and double plating techniques [7,16–21]. Apart from a precontoured acromion plate with very limited medial extension, no prefabricated specific plate is available for the scapular spine. We believe fixation devices for scapular spine fractures should be designed to withstand traction, bending and torsional strain. Not only does the deltoid muscle influence the load at the scapular spine or acromion, but every muscle attached at or originating from the scapula or its processes creates distracting, bending and torsional forces that need to be counterbalanced by the chosen implant as well as an intact scapular spine [22]. Rouleau and Gaudelli successfully treated a traumatic post-RSA acromial base fracture of a 71-year old female with a double plate construct [19]. We agree with their rationale of the orthogonal double plating with locking screws because this setup is most suitable to withstand the above mentioned multidirectional forces acting at the scapular spine, and provides improved cut-out strength of the locking screws. We believe that a single plate construction is too weak to withstand these forces, particularly in osteoporotic bone.

We attribute our first experiences of early screw loosening to an “unbalanced” osteosynthesis with only two medial non-locking screws in the LCP® distal humerus plate and a single medial non-locking screw in the quarter tubular plate. In hindsight, this construction most likely gave rise to too much motion at the fracture site, despite the post-surgery immobilised shoulder. To optimise construct stability, we adapted our procedure with a low profile VA-LCP® olecranon plate in our second patient. This strategy allows plate adaption to the shape of the scapular spine and offers multiple variable angle 2.7 mm screw fixation in the medial fragment, which enhances stability in this fragile region.

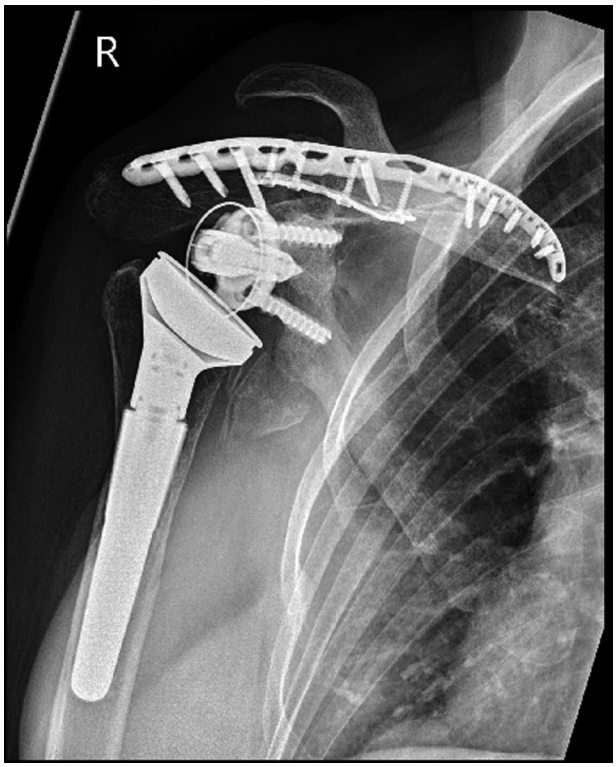

Fig. 3. One-year postoperative anteroposterior radiograph in internal rotation of patient 5 highlighting open reduction and internal fixation (ORIF) with a VA-LCP® distal humerus plate (lateral) with quarter tubular plate.

The lateral VA-distal humerus plate also provides a suitable alternative because of the lower profile medial part of the implant compared to the olecranon plate. With the same advantages, there is the possibility of multiple VA locking screw fixation medial to the fracture site as well as at the transition zone from the scapular spine to the margo medialis. At this region, bone quality is more than critical for screw purchase and fixation to achieve sufficient stability and an adequate distribution of pull-out forces across a broad area. This plate was used for all consecutive procedures. A quarter tubular plate was also applied and fixed with two screws in each fragment (Fig. 3). With the medially extended plates and optimised screw fixation, no additional implant-related complications were reported. This infers the potential feasibility of ORIF in patients with osteopenic/osteoporotic bone.

A combination of the classification systems proposed by Rouleau and Gaudelli and Levy et al. is most applicable to our own experiences with 25 post-RSA scapula fracture patients (Fig. 4a and b) [19,23], as the Crosby classification does not incorporate the deltoid anatomy. Fractures at the tip or the lateral acromion (type I fractures [Fig. 4c]) do not have major impact on functional outcome once the acute pain subsides, even if the fractured fragment fails to unite and remains displaced [1]. This fracture type is comparable with an unstable os acromiale, which did not affect patient outcome [17]. It is possible that the intact clavicle and scapular spine provide stable suspension for the remaining deltoid, so functional loss is negligible. To date, we have not observed any subsequent fractures at the spine or clavicle due to altered load distribution after this kind of acromial fracture or an os acromiale [2]. Thus, we currently do not see the necessity for surgical fixation of this fracture type. Fractures lateral to the acromial base (type II fractures [Fig. 4d]) do impair shoulder function, but tend to heal without surgery. If union does not occur, then surgical fixation is offered. The chances

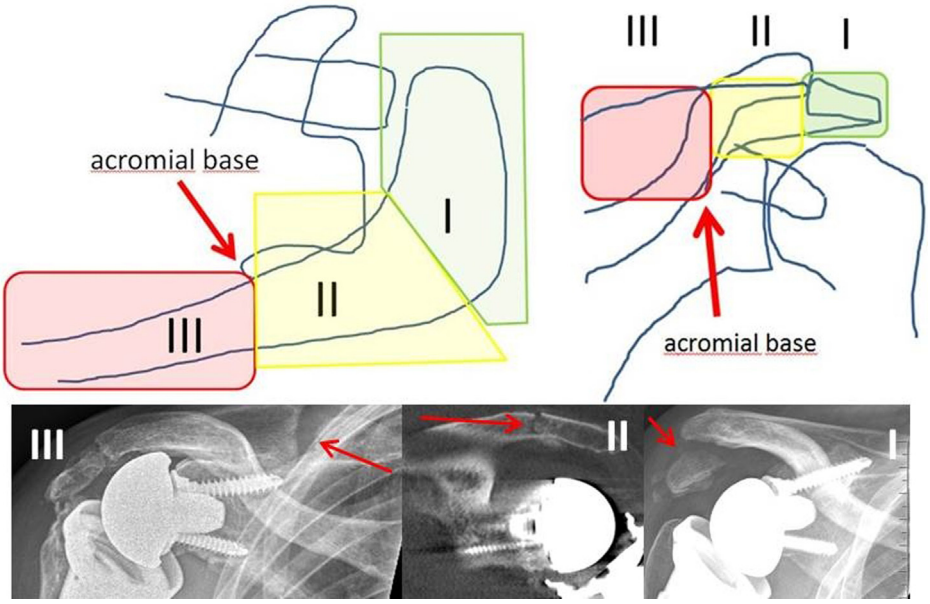

Fig. 4. Diagrammatic representation of our proposed classification of post-reverse shoulder arthroplasty (RSA) acromial and scapular spine fractures in axial (upper left) and anteroposterior view (upper right) with example radiographs/computed tomography scan in anteroposterior view showing type I (bottom right), II (bottom centre) and II (bottom left) fractures (as indicated by the red arrows).

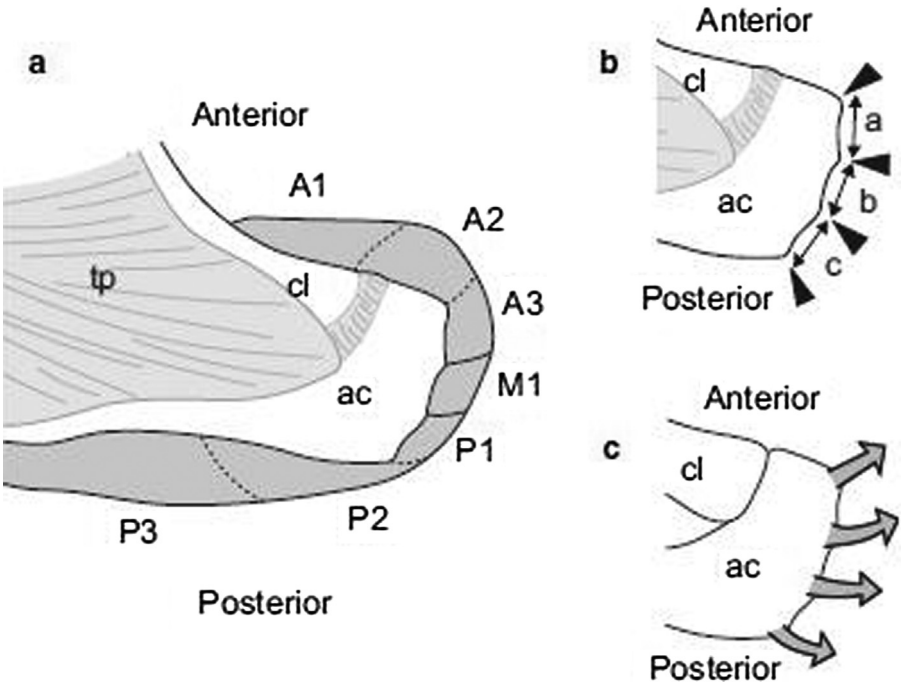

Fig. 5. Classification of deltoid segments. tp: trapezius muscle; cl: clavicle; ac: acromion.

Reproduced with permission and copyright © of John Wiley and Sons, Inc. from Sakoma Y, Sano H, Shinozaki N, Itoigawa Y, Yamamoto N, Ozaki T, et al. Anatomical and functional segments of the deltoid muscle. J Anat 2011;218:185–90 [24].

of healing at the scapular spine (type III fractures [Fig. 4e]) is quite poor and this fracture type has major negative impact on shoulder function, which, in our opinion and based on these results, justifies the surgical fixation of these fractures in both an acute as well as delayed setting [3,15,23].

There is a lack of biomechanical studies investigating the cause of the different fracture locations and the impact of RSA on loads at the acromion and scapular spine during rest as well as motion. Furthermore, it remains unknown which fixation construct is most suitable to achieve sufficient stability for fracture healing. One anatomical study characterised the deltoid muscle morphology (including humeral insertion as well as the proximal origins) into 7 segments based on the distribution of its intramuscular tendons, which represent separate functional units; tendon origins at the lateral clavicle, acromion and scapular spine were also described in detail [24]. Two bony tubercles at the lateral acromion were described in 93% of specimens, separating the anterior, middle and posterior parts of the deltoid muscle and creating 3 acromial facets where 4 intramuscular tendons originate. In 4 specimens, 4 facets with 5 originating intramuscular tendons at the lateral

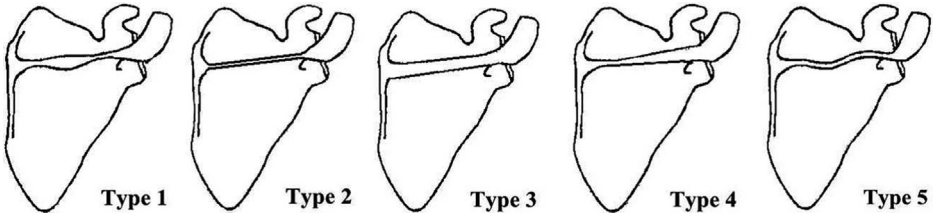

Fig. 6. Scapular spine morphology classification scheme. Type 1 = fusiform shape (tapered at both ends and wide in the middle); type 2 = slender rod shape (thin throughout); type 3 = thick rod shape (thick throughout); type 4 = wooden club shape (gradual thickening from medial to lateral edge); and type 5 = horizontal S-shape ("S" shaped spine). *Reproduced with permission and copyright © of Wolters Kluwer Health, Inc. from Wang HJ, Giambini H, Hou DB, Huan SW, Liu N, Yang J, et al. Classification and morphological parameters of the scapular spine: implications for surgery. Medicine (Baltimore) 2015;94:e1986 [25].*

acromion were observed (Fig. 5). In consideration of these findings with the previously outlined fracture types, type I fractures would involve anatomical segments A2 (partially), A3, M1 and P1 (P2 and P3 spared) corresponding to the three facets. Type II fractures would affect the aforementioned segments as well as (partially or complete) P2 lateral to the acromial base (P3 spared), and type III fractures would also include segment P3. This would also explain the gradual functional loss of the different fracture types depending on the amount of segments affected. Naturally, validation of our proposed system is necessary.

Wang et al. examined 319 Chinese cadaveric scapulae and distinguished 5 specific scapular spine morphology types, where thinner morphologies were hypothesised as more susceptible to fracturing (Fig. 6) [25]. Without three-dimensional CT scapula reconstructions, we could not define the spine type or check for correlations between certain spine morphologies and fractures. It is also unclear whether this classification can be applied to our patient cohort. Further research in this field certainly seems reasonable to determine morphologies at risk and potentially alter soft tissue tensioning in RSA surgery as a prophylactic measure.

Our patient cohort is small, yet the knowledge gained from our treatment strategy as well as the positive 1-year postoperative clinical and radiological outcomes is valuable. Our use of post-RSA follow-up data is valid given that clinical evaluation of the fracture is painful for patients and does not result in reliable baseline data for comparative purposes. In general, we cannot prove that true bony union occurred due to the lack of affirmative post-ORIF CT images. Nevertheless, the absence of local pain, improved post-fracture ROM and fading fracture lines on radiographs imply union or at least a stable, painless pseudarthrosis. Further work needs to validate ORIF as the treatment of choice for a greater number of patients. Another drawback is the lack of a conservatively treated patient control group. From the 7 conservatively treated patients between 2006 and 2015, only 4 patients were available for comparison. All patients were female, aged between 78 and 88 years, and had osteoporosis confirmed by DEXA. As these patients would not have benefitted from ORIF due to several reasons or comorbidities, respectively, this patient sample would not have been a legitimate control group because of many confounders. Consequently, we refrained from comparing the 4 conservatively treated patients with our surgically-treated cohort.

5. Conclusion

Scapular spine fractures sustained after RSA pose a rare, yet significant problem in shoulder surgery that greatly compromises clinical outcome due to a high nonunion rate. ORIF can be considered a viable option to markedly improve function and pain without major complications in elderly patients with osteoporosis. Complications can be avoided with cautious drilling and/or K-wire placement as well as aiming for a stable, counterbalanced osteosynthesis. The superiority of post-surgery outcomes over conservative treatment, however, still needs to be validated by further research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Disclosure of interest

The authors declare that they have no competing interest.

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Authors' contribution

Felix Toft: writing, editing, drafting, revision.
Fabrizio Moro: supervision, editing, drafting.

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