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SHOULDER

Open screw fixation of large anterior glenoid rim fractures: mid- and long-term results in 29 patients

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Abstract The aim of this retrospective study was to analyse the clinical, functional and radiographic outcomes of patients sustaining traumatic anterior dislocations of the shoulder in combination with large anterior glenoid rim fractures, treated by open reduction and internal screw fixation (ORIF). Twenty-nine patients with a mean follow-up of 6.5 years (2.5–12 years) were evaluated clinically using the Constant and DASH scores, radiographs in two planes and isokinetic muscle strength measurement (Biodex 3 PRO). Mean age was 41.6 years (17–68 years). There was no case of postoperative re-dislocation. Eight out of 29 patients (27.5%) underwent revision surgery to remove the screws. The mean age- and gender-adjusted Constant score was 93.3% (range 64–102%), and the mean DASH score was 10.1 points (range 0–71 points). On radiological examination, 6 patients had signs of osteoarthritis: Samilson type I ($n = 3$) and II ($n = 3$). Significant differences for maximal strength in external rotation and muscular endurance compared to the unaffected side were found ($P < 0.035$). Twenty-seven patients (93%) were satisfied or very satisfied with the result after surgery. ORIF seems to be a good treatment option in cases of large glenoid rim fractures to avoid re-dislocation in the mid-term. Prospective randomised studies are necessary to compare these findings with those after non-operative or arthroscopic treatment of these injuries.

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Introduction

Traumatic anterior dislocation of the shoulder can be associated with fractures of the acromioclavicular joint, the greater tuberosity, the coracoid and the anterior glenoid [9, 14, 15, 19, 23, 24]. Increasing numbers of fractures of the anterior glenoid correlated to patient's age are described [9]. Hovelius et al. [9] reported a rate of about 8% of associated anterior glenoid rim fractures, mostly in older patients. This injury is associated with recurrent dislocations, persistent pain, malunion and early-onset osteoarthritis. For glenoid fractures involving less than 21% of the articulating area, arthroscopic procedures using suture anchors or transcutaneous screws have been established in recent years [1–3, 19, 25, 26]. A large fracture with a glenoid defect greater than 21% is seen as a indication for open reduction and internal screw fixation (ORIF) [2, 11, 13, 15, 22, 23].

Although there are reports of good clinical and radiological outcomes after arthroscopic repair or non-operative treatment, ORIF remains the standard treatment [14, 25, 26]. Despite ORIF being a well-established procedure, there is a paucity of evidence relating to outcomes. The results are rarely reported and often difficult to interpret, due to a small number of cases or inhomogeneity of the collectives [2, 15, 22, 23].

Therefore, the aim of this retrospective study was to describe the clinical, functional and radiological outcome of 29 patients with large anterior glenoid fractures who underwent ORIF after traumatic anterior shoulder dislocation.

Patients and methods

Between May 1995 and February 2005, 35 consecutive patients (35 shoulders) with a traumatic first-time dislocation of the shoulder causing a large anterior glenoid fracture underwent open reconstruction. Inclusion criteria were: (1) an isolated traumatic anterior glenoid fracture type IIIb according to Bigliani [2] causing possibly recurrent instability due to an "inverted pear"; (2) treatment with ORIF; and (3) a minimum follow-up of 2.5 years. Exclusion criteria were: (1) concomitant fracture of the clavicle or the humeral head; (2) intraoperative application of autologous bone grafts; and (3) previous dislocation or surgical treatment of the affected shoulder. Six patients moved to an unknown address and were lost to follow-up. Twenty-nine patients (82.9%) were included in the study. The mean duration of follow-up was 6.5 years (2.5–12 years). There were 26 men and 3 women with a mean age of 41.6 years (17–68 years). Demographic data are shown in Table 1. The left shoulder was involved in 16 cases, the right in 13 cases. The dominant shoulder was affected in 13 of 29 individuals. One patient had an associated lesion of the axillary nerve. The initial injury was associated with a simple fall in 12 cases, a sports-related accident in 13 cases and a traffic accident in four cases. Six patients had a direct trauma to the shoulder; the other 23 had an impact on the outstretched arm. The mean time from trauma to surgery was 30 days (range 0–360 days, median 13 days). Fifteen patients (51.7%) were treated during the first 2 weeks after injury. The patient with 360 days between initial injury and surgery was a professional ice-hockey player who refused surgical repair for a year. After multiple re-dislocations the patient underwent ORIF. No patient had a history of prior dislocations or surgical treatment on the affected shoulder.

Table 1 Demographic data of patients

ID	Age (years)	Gender	Affected side	Fragment width (mm)	Fragment length (mm)	Screw removal	Capsule shift	Bankart lesion	Sports	Return to sports	CS (%)	DASH (points)
1	45	Male	Left	15	19	No	Yes	No	Cycling	Without limitation	93	5
2	61	Male	Right	16	18	No	No	No	Kayaking	Without limitation	99	0
3	41	Male	Left	15	23	No	Yes	Traumatic	Skiing	Without limitation	100	0
4	48	Male	Left	8	15	No	No	No	Football	Without limitation	86	7
5	49	Male	Right	8	20	Yes	Yes	No	Skiing	Without limitation	99	2
6	40	Female	Right	11	19	No	No	No	Horse riding	Without limitation	97	1
7	46	Male	Left	10	20	No	No	No	Horse riding	Without limitation	94	0
8	31	Male	Left	8	15	No	Yes	Traumatic	Athletics	Without limitation	95	2
9	34	Male	Left	15	19	No	Yes	Traumatic	Football	Without limitation	91	0
10	27	Male	Left	9	14	No	Yes	Iatrogen	Icehockey	Without limitation	100	0
11	50	Male	Right	19	21	Yes	No	No	Hiking	Without limitation	92	2
12	25	Male	Right	18	16	No	No	No	Icehockey	Without limitation	99	0
13	66	Female	Right	12	18	Yes	Yes	Iatrogen	Hiking	Without limitation	91	6
14	51	Male	Left	8	20	Yes	No	Iatrogen	Skiing	Without limitation	100	3
15	31	Male	Right	15	25	Yes	No	Traumatic	Strength training	Few limitations	91	52
16	36	Male	Right	14	17	No	No	No	Snow boarding	Without limitation	99	10
17	58	Male	Right	16	25	Yes	Yes	No	No sports	No sports	64	71
18	71	Male	Right	14	27	No	Yes	Traumatic	Hiking	Few limitations	85	37
19	65	Male	Left	18	21	Yes	Yes	No	Strength training	Without limitation	100	0
20	47	Male	Left	12	16	Yes	No	No	Motor sports	Few limitations	73	27
21	40	Male	Right	14	17	No	Yes	No	Football	Without limitation	94	0
22	71	Male	Left	16	30	No	No	No	Skiing	Without limitation	99	0
23	53	Male	Right	16	22	No	No	No	Horse riding	Few limitations	93	12
24	60	Male	Left	18	14	No	Yes	No	Skiing	Without limitation	100	3
25	40	Male	Left	10	20	No	Yes	No	Squash	Without limitation	95	1
26	35	Male	Left	20	17	No	Yes	No	Skiing	Without limitation	96	0
27	60	Male	Left	20	20	No	Yes	Iatrogen	Cycling	Without limitation	93	16
28	71	Female	Right	13	23	No	No	No	Nordic walking	Without limitation	102	0
29	45	Male	Left	18	20	No	No	No	Football	Few limitations	87	37

Clinical results were assessed by means of the DASH score [8] and the Constant score [4, 5].

Active and passive shoulder motion (flexion, abduction, rotation in neutral position) were assessed clinically. Shoulder flexion, abduction and external rotation were recorded in degrees; internal rotation was graded according to the posterior spinal region that could be reached by the thumb. Examination of anterior shoulder instability was performed using the apprehension test according to Rowe and Zarins [20]. Status of the rotator cuff was evaluated clinically and with an isokinetic muscle strength measurement. Pain was graded using the visual analogue scale (VAS) and the Constant score [0 points (severe pain) to 15 points (no pain)]. The patients rated the subjective result after surgery as "very satisfactory", "satisfactory", "somewhat disappointing" or "very disappointing". Sporting activities of the patients were recorded.

The diagnosis was established preoperatively using standardised radiographs (antero-posterior and axillary views) and 2D CT imaging in all cases (Figs. 1, 2, 3, 4 and 5). Postoperatively, only eight of the initially performed CT scans after injury were available. Therefore, fragment sizes were calculated on conventional radiographs as described by Maquieira et al. [14], who found good correlation between radiographic measurements of glenoid fragment sizes and measurements made from CT images.

Fig. 1 Antero-posterior radiograph of a 35 years old woman with a traumatic anterior glenohumeral dislocation

Osteoarthritis was rated according to Samilson and Prieto [21]. In this classification, a diameter of osteophytic annexes of the humeral head, the glenoid or both of less than 3 mm is classified as mild arthritis (type I), a diameter between 3 mm and 7 mm indicates moderate osteoarthritis (type II), and osteophytic changes with a calibre greater than 7 mm imply severe arthritis (type III). The diagnosis of humeral glenoid osteophytes was made comparing the immediate postoperative and the most recent follow-up X-rays.

Fig. 2 Antero-posterior radiograph of the shoulder shown in Fig. 1 after relocation with a large anterior glenoid rim fracture

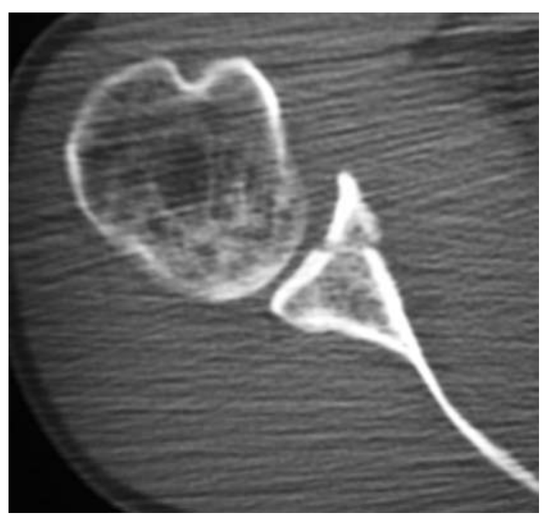

Fig. 3 CT scan of the shoulder shown in Figs. 1 and 2 with a large glenoid fragment greater than 25%

Fig. 4 Antero-posterior radiograph of the shoulder illustrated on Figs. 1, 2 and 3 after ORIF at the most recent follow-up examination 9.5 years after surgery. This patient was able to return to her preoperative sports level

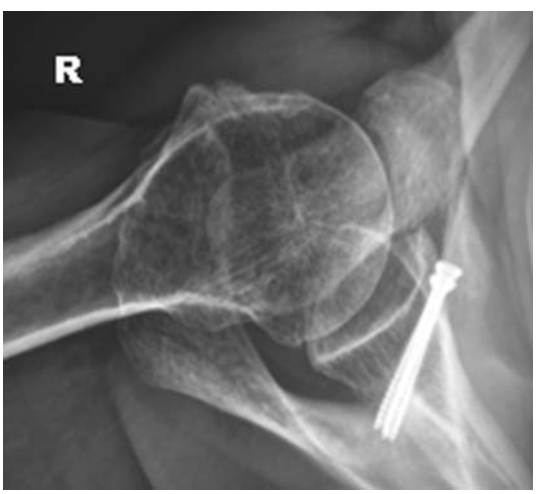

Fig. 5 Axillary radiograph of the patient shown in Figs. 1, 2, 3 and 4 postoperatively

Isokinetic muscle strength measurement

All patients were able to complete isokinetic muscle strength measurements on the Biodex 3 Pro (Biodex Medical Systems, Shirley, USA). All measurements were done according to a standardised protocol supervised by the same examiner. The patients were in a sitting position with securing bands around their chest, pelvis and contra-lateral leg. To achieve comparability of results, adjustments of the lever axis to body height and arm length, adaptation of range of motion and gravity correction were required. Prior to the measurements, the patients underwent a warm-up module of 10 sub-maximal repetitions with an angular velocity of 120°/s. Measurements of shoulder flexion/extension, abduction/adduction and internal/external rotation in 90° flexion of the elbow were performed in two cycles for the non-affected arm, then the affected arm. The first cycle quantified maximal muscle strength using five repetitions with a low angular velocity of 60°/s. After a rest period of 90 s, muscular endurance was recorded during the second cycle. This comprised 10 repetitions with a high angular velocity of 180°/s. The results of the isokinetic dynamometry were interpreted as average torsional maximum (in Nm) and as a percentage of the value of the unaffected arm. The deficit in muscular strength was expressed as the quotient of the affected shoulder over the unaffected shoulder.

Operative technique

Twenty-three surgical procedures were performed or supervised by the senior author. All patients were placed in beach-chair position. In all shoulders a delto-pectoral approach was used, as described by Neer [18]. The subscapularis tendon was detached vertical to the fibres and the joint was exposed. In all cases a glenoid defect greater than 25% of the glenoid bone stock, corresponding to Bigliani type IIIb, was found [2].

After reduction, the fragment was temporarily fixated with K-wires. The fragment was brought into anatomical alignment with the articular surface and correct positioning confirmed with intraoperative radiography. The K-wires were over-drilled and the fragment was fixated using cannulated titanium screws, ensuring extra-articular placement of the screw heads. In no case did the fragment fractured during insertion of the screws. In eight cases one screw was used, in 17 cases two, and in four cases three. The mean length of the screws was 30.75 mm (median 32 mm, range 15–40 mm).

In nine cases re-attachment of the glenoid labrum was achieved by means of suture anchors (in four cases Panalok® anchors and in three cases G2 Quick anchors® from Mitek Co., Raynham, USA, and in two cases Fastak® anchors from Arthrex Inc., Naples, USA). In two cases one anchor was used, in five cases two, and in two cases three. Detachment of the labrum was associated with the trauma in five out of nine cases. In four cases the labrum had to be detached for mobilisation and fixation of the glenoid fragment.

Redundancy of the capsule after temporary fixation was diagnosed by the surgeon in 15 patients. In these cases a T-shift according to Neer [18] was performed to improve ventral stability. In all cases a tendon-to-tendon repair of the subscapularis was performed using five or six nonabsorbable sutures. Postoperatively the patients had shoulder immobilisation for 3 weeks using a Gilchrist bandage. Subsequent limited mobilisation was permitted in the 4th and 5th weeks with shoulder flexion and abduction restricted to 90° but no external rotation permitted. Free range of motion was allowed 6 weeks after operation. High-impact sports were allowed 6 months after surgery.

Statistics

Paired data (affected and non-affected shoulders) were compared using the Wilcoxon sign rank test. Constant scores, range of motion and strength measurements by the Biodex 3 Pro System were evaluated using this analysis. The comparison of the Constant score, DASH score, range of motion and strength between the cohort with and without screw removal and the cohort with and without signs of osteoarthritis was calculated using the Mann–Whitney-*U*-test. $P \leq 0.05$ was considered significant.

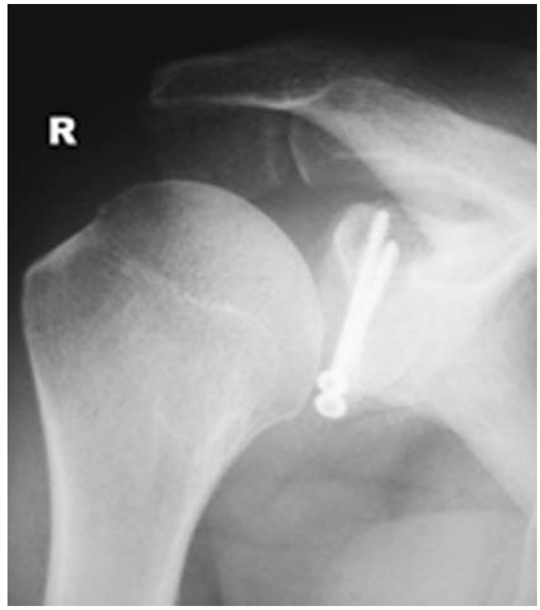

Fig. 6 Immediate postoperative antero-posterior radiograph of a 32 years' old man after surgery treated with two cannulated screws

Results

Pre-, peri- and postoperative data and revisions

One patient had a post-traumatic palsy of the axillary nerve which had resolved by 1 month.

In one case intra-articular placement of a screw head was necessary to achieve adequate stability of the fragment. Three months after surgery the screw was removed. To exclude non-union of the fragment, conventional radiographs in two planes were obtained before re-operation. Signs of cartilage damage were not found intraoperatively.

One patient sustained fracture of both screws and reported moderate pain on exertion (Figs. 6, 7 and 8). After removal of the screws his symptoms resolved. Signs of non-union of the fragment were not found intraoperatively and on postoperative radiographs (Fig. 8). Eight out of 29 patients (27.5%) underwent revision surgery to remove the screws. The time interval between ORIF and screw removal was 15 months (range 6–38 month). In no case did shoulder dislocation recur.

Fig. 7 Antero-posterior radiograph of the same patient as shown in Fig. 6, 3 years after surgery with screw breakage. At this time, the patient reported about moderate pain in the affected shoulder

Clinical results and patient satisfaction

The mean age- and gender-adjusted Constant score was 93.3% (range 64–102%) in the affected shoulders compared to 96.3% (range 73–104%) in the unaffected shoulders. The Constant score did not differ significantly between the two sides ($P \leq 0.7$). The mean DASH score was 10.1 points (range 0–71 points). Seven patients (24.1%) had a DASH score over 10 points. The mean DASH score in affected left shoulders was 6.3 points (range 0–37 points) and in right shoulders 14.9 points (range 0–71 points).

In no case was a positive result of the apprehension test found. The active range of motion was recorded for both shoulders (Table 2). Significant differences between

Fig. 8 Antero-posterior radiograph of the shoulder shown in Figs. 6 and 7 after partial removal of both screws. The intraosseous ends of the screws were left in the glenoid

affected and unaffected shoulder were found for abduction and external rotation ($P < 0.014$). Between the 15 patients who underwent a capsular shift and the 14 patients without capsular shifts a significant difference in abduction (162.1° vs. 173.6°) and external rotation (38.3° vs. 42.2°) was found ($P < 0.033$).

No significant differences were found comparing the results of the Constant score, DASH score, shoulder motion (flexion/extension; abduction/adduction; external/internal rotation) and strength (using the Biodex) between patients with and without screw removal ($P \leq 0.05$). Also no significant differences for the above mentioned parameters were found comparing patients with and without signs of osteoarthritis ($P \leq 0.05$). One patient did not follow the recommended rehabilitation programme. After surgery this patient placed the arm in a sling without mobilisation for more than 3 months. This patient still has a maximum active elevation of 130°.

The patients were able to return to their profession 6 weeks after surgery (range 0–12 weeks). Twenty-three patients (79.3%) were able to return to their preoperative sports level without limitations, including high-impact sports such as tennis and handball. Five patients (17.3%) were able to return to their preoperative sports activity level with minimal restrictions.

Mean pain on the VAS was 0.4 points (range 0–4.8 points). In 17 cases (58.6%) no pain was reported. Minimal pain was reported in a further eight (27.6%) cases, and moderate pain in four cases (13.8%).

Twenty-seven patients were satisfied ($n = 4$, 13.8%) or very satisfied ($n = 23$, 79.3%) with the procedure. Two patients (6.9%) were somewhat disappointed with the result of surgery. One of these two cases was the patient who failed to follow the rehabilitation scheme (patient 17, Table 1). The other patient's accident was covered by workers' compensation (patient 15, Table 1).

Imaging results

No case of malunion or loss of reduction of the glenoid fragment was observed. We have seen three patients with mild osteoarthritis (Samilson type I) and three patients with Samilson type II changes. No patient had severe osteoarthritic changes (Samilson type III). Mean age of patients with signs of osteoarthritis was 52 years (range 31–67 years).

Results of the isokinetic muscle strength measurements

In four patients a strength deficit of 15–20% compared to the unaffected shoulder was recorded for shoulder flexion/extension, abduction/adduction and external/internal rotation. Mean torque values and the deficit in muscular

Table 2 Averaged active range of motion

	Affected shoulder mean in degree (range)	Unaffected shoulder mean in degree (range)	Mean deficit affected/unaffected in %	Significant differences affected/unaffected shoulders (P value)
External rotation	40.2 (20–60)	43.1 (30–50)	2.9 [(−5) to 25]	$P < 0.014$
Internal rotation[a]	TH 12 (L3-TH 7)	TH 12 (L3-TH 7)	–	NS
Shoulder flexion	173.6 (90–180)	177.2 (130–180)	3.6 [(−40) to 80]	NS
Shoulder extension	43.1 (10–50)	44.0 (30–50)	0.9 (0–20)	NS
Abduction	166.9 (100–180)	172.9 (160–180)	6.0 (0–70)	$P < 0.014$
Adduction	35.6 (30–40)	36.0 (30–40)	0.2 [(−5) to 10]	NS

NS no significant difference

[a] Internal rotation was graded according to the posterior spinal region to which the thumb could reach

Table 3 Isokinetic muscle strength measurement

	Affected shoulder mean in Nm (range)	Unaffected shoulder mean in Nm (range)	Mean deficit affected/unaffected in %	Significant differences affected/unaffected shoulders (*P* value)
External rotation 60°/s angular velocity	24.3 (11–39)	27.5 (9–45)	3.2 [(−16) to 26]	$P < 0.035$
Internal rotation 60°/s angular velocity	30.5 (3–50)	34.9 (11–55)	4.4 [(−29) to 44]	NS
External rotation 180°/s angular velocity	16.4 (2–34)	20.6 (0–43)	4.2 [(−8) to 25]	$P < 0.035$
Internal rotation 180°/s angular velocity	22.1 (0–39)	26.5 (2–60)	4.4 [(−9) to 53]	NS
Shoulder extension 60°/s angular velocity	59.1 (9–91)	67.2 (22–106)	8.1 [(−11) to 52]	NS
Shoulder flexion 60°/s angular velocity	52.0 (23–81)	57.4 (15–96)	5.4 [(−16) to 95]	NS
Shoulder extension 180°/s angular velocity	44.2 (1–72)	50.9 (4–78)	6.7 [(−14) to 43]	NS
Shoulder flexion 180°/s angular velocity	39.5 (14–59)	43.8 (8–93)	4.2 [(−22) to 69]	NS
Abduction 60°/s angular velocity	49.2 (20–77)	53.2 (19–88)	4.0 ((−19) to 48)	NS
Adduction 60°/s angular velocity	57.4 (11–92)	64.5 (28–105)	6.1 [(−16) to 94]	NS
Abduction 180°/s angular velocity	32.5 (0–59)	37.0 (16–58)	4.5 [(−10) to 58]	NS
Adduction 180°/s angular velocity	37.0 (0–70)	43.6 (2–72)	6.6 [(−18) to 52]	NS

NS no significant difference

strength for all patients are shown in Table 3. Significant differences between the affected and unaffected shoulders were found for mean maximal strength in external rotation at an angular velocity of 60°/s as well as for muscular endurance (angular velocity 180°/s; $P < 0.035$). Mean maximal strength and muscular endurance for all directions of motion (flexion/extension; abduction/adduction and external/internal rotation) were higher in the unaffected shoulders, albeit not significantly so (Table 3).

Discussion

Over the past few decades there has been controversy over the management of large glenoid fractures involving more than 20% of the articulating glenoid. A major problem in comparing studies of treatment of large glenoid fractures is variability in the outcome measures. Itoi et al. [11] identified a critical point for glenohumeral stability at a glenoid defect greater than 21% in a biomechanical cadaver study. The identification and classification of this injury have been difficult. Isolated glenoid fractures were first classified by Bigliani et al. in 1998 [2]. They identified four types depending on attachment to the capsule and fragment size. A Bigliani type IIIB fracture involves more than 25% of the glenoid detached from the labrum. Maquieira et al. [14] found a strong correlation between the fragment size measured on conventional radiographs and CT scans. Although three-dimensionally reconstructed CT remains the only method of calculating the glenoid bone loss objectively, conventional radiographs may provide sufficient accuracy for clinical decision-making [4, 24].

Fujii et al. [6] stated after a histological analysis of 27 samples of bony Bankart lesions that the fragment may be viable and be used for repairing the glenoid defect even in cases of chronic instability which has been present for years. The treatment goal of all operative and non-operative techniques is the anatomic reconstruction of the glenoid joint surface. Good clinical and radiological results have been reported after non-operative treatment and minimally invasive arthroscopic repair [14, 25, 26]. Moreover, autologous bone grafting or coracoid transfers are described as viable treatment options to repair large glenoid rim fractures [10, 12, 17]. However, ORIF is seen as the gold standard for large glenoid fractures following traumatic anterior dislocation of the shoulder [2, 13, 15, 22, 23].

Maquieira et al. [14] recently published a series of 14 non-operative treated large anterior glenoid fractures. Mean fragment length was 17 mm (range 12–22 mm), and mean fragment width was 8 mm (4–14 mm). No case of re-dislocation was observed. However, the mean age of 53 years (range 32–73 years) was relatively high and may not be representative for young and active patients with high risk of re-dislocation. The radiological assessment showed complete bone consolidation in all shoulders, although a mean step-off of 3.0 mm (range 0.5–11.0 mm) remained. Maquieira et al. also found a residual loose body in seven cases. After a mean follow-up of 5.6 years, osteoarthritic changes were present in three patients: two patients with type I and one patient with type II osteoarthritis according to Samilson and Prieto [21]. The proportion of patients with signs of osteoarthritis is comparable to that in the current study although surgery was not performed. The Constant score in our cohort was slightly inferior to that of Maquieira et al. (mean 93 vs. 98%). We have to note that the mean fragment size of the anterior glenoid was higher in the current study

Table 4 Patients with signs of osteoarthritis

	Samilson Grade	Metal removed	Affected bone	Age (years)	Constant score (%)
1	I	Yes	Glenoid	31	91
2	I	No	Glenoid & Humerus	71	99
3	I	No	Humerus	45	93
4	II	No	Humerus	36	99
5	II	No	Humerus	48	86
6	II	No	Glenoid	71	85

(19.7 × 14 mm vs. 17 × 8 mm). Comparing the two studies, it seems that both treatment options are valid. Conservative treatment seems to be a viable alternative in cases of concentrically reduced glenoid rim fractures.

Several authors have described arthroscopic treatment using suture anchors or transcutaneous screws to re-fix the glenoid fragment [1, 3, 19]. Sugaya et al. [25] published a series of 42 shoulders with an average bone loss of 24.8% (range 11.4–38.6%). Twenty-two of these shoulders had an involved glenoid surface of more than 25%. Unfortunately, the authors did not provide separate data for this subgroup. In contrast to the present study, re-dislocation occurred in 5% of cases. Good clinical results were reported for the other patients. The authors state that despite the arthroscopic confirmation of excellent reposition, the postoperative 3D CT scan often showed the fragment to be suboptimal. In the past decade patients with Bankart lesions or small chip fractures of the anterior glenoid have also been treated arthroscopically using suture anchors in our institutions. Only in cases with large fractures, ORIF has been performed as described in the current study.

Tauber et al. [26] reported 10 patients with a large glenoid fracture treated by arthroscopically assisted percutaneous screw fixation. With a minimum follow-up of 24 months, the study showed good or excellent midterm clinical results for 90% of the patients. They reported one patient with an intra-articular screw head that caused damage to the humeral cartilage and necessitated revision surgery. Another patient had a traumatic re-dislocation. Although the introduction of a drill–guidewire system provides high accuracy when positioning the screws, insertion of screws during open procedures can be accomplished simply and reliably. We believe that both techniques have advantages. With ORIF the surgeon has an excellent overview of the anterior glenoid and the fracture can be set manually under direct visual control. The main disadvantage using this technique is the detachment of the subscapularis muscle. However, we were able to show that no significant differences in strength for internal rotation were found using the Biodex (Tables 3 and 4). The arthroscopic refixation technique gives a good overview of the whole shoulder joint and the rotator cuff preserving the subscapularis muscle. We believe that next to the technical equipment, a surgeon requires extensive experience to achieve results comparable with those described by Tauber et al.

Scheibel et al. [23] reported on ten patients who underwent ORIF after traumatic anterior glenoid fracture involving more than 25% of the articulating area. They found a high early complication rate, including one patient with metal loosening and three patients suffering constant pain due to screw impingement. No recurrent dislocation was observed. For patients with small glenoid rim fractures suture anchor repair was recommended, with excellent clinical results. This differentiated approach is comparable to our treatment of patients with glenoid rim fractures in the past decade as mentioned above.

Other authors have also reported on the operative treatment of glenoid fractures. Their results are difficult to evaluate as they include other fractures of the glenoid [3, 15].

Schandelmaier et al. [22] included all intra-articular glenoid fractures in their report of the long-term outcomes of 22 patients. With a minimum follow-up of 5 years (mean follow-up 10 years) they reported good clinical results with a mean relative Constant score of 79% after ORIF. To our knowledge, this is the only study describing long-term outcomes after this procedure. Of the 22 patients, five (22.7%) developed degenerative changes on radiographs. Of these, three had an excellent clinical outcome and two had unsatisfactory results after developing deep infection of the shoulder. Amongst our patients, postoperative mild and moderate osteoarthritic changes according to Samilson and Prieto [21] occurred in six patients (20.7%). Although the results are not comparable to ours because complex scapula fractures were included, ORIF remains a good treatment option for these cases. The mean Constant score in our cohort was higher (93%) but this could be due to the severity of fractures in Schandelmaier's cohort.

Open procedures are often criticised for causing functional deficits following detachment of the subscapularis tendon. To quantify this effect we used isokinetic muscular strength analysis. For the functional assessment we used a well-established standardised protocol for the Biodex 3 Pro

[7, 16, 27]. Excellent functional results were achieved in 25/29 (86.2%) patients; four patients had a deficit between 15% and 20% of strength when compared to the unaffected shoulder for all directions of motion. Interestingly, we found a significant deficit in strength for active external rotation between the affected and unaffected shoulders. We also found a significant difference in the range of motion for mean external rotation (40.2 vs. 43.1, $P \leq 0.014$), which could be related to the surgical approach including detachment and later repair with shortening of the subscapularis muscle and the capsule. However, no patient avoided external rotation because of fear of further dislocation and in no case was a positive apprehension test result found.

One limitation of the current study is the retrospective design, but because of the rarity of this type of injury it is difficult to perform prospective trials with a sufficient number of patients.

However, we are presenting the largest number of patients treated with ORIF for large fractures of the anterior glenoid to date. By focusing on the surgical procedure and its consequences, this study provides a background for further discussions about the treatment of choice for this type of injury.

In conclusion, ORIF of large anterior glenoid fractures leads to good clinical, functional and radiological results both in the mid- and long-term. In particular the small number of complications and the low rate of osteoarthritic changes are notable. Complete anatomic reconstruction of the glenoid can provide joint stability and additional capsular shift may not be necessary.

To compare our findings with those after non-operative or arthroscopic treatment, a prospective randomised trial is necessary.

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