SHOULDER

Arthroscopic screw fixation of large anterior glenoid fractures

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Abstract Ten patients after traumatic shoulder disloca-
tion with resulting instability due to an acute anterior
glenoid fracture involving at least 21 percent of the glenoid
length were treated by arthroscopic screw fixation of the
fragment. The average fragment size measured 26.2% of
the glenoid length. Pre- and postoperative radiographic
evaluations were performed with three-dimensional CT
scans. A cannulated titanium screw system was used for
fragment fixation. All ten patients were followed up
radiographically and, by evaluation of the Rowe score,
clinically after a minimum of 2 years. At follow-up the
Rowe score averaged 94 points. According to the rating
scale, seven patients had an excellent result, two patients a
good result, and one, fair result. In all patients CT scan
confirmed that the fracture had healed in an anatomical
position. One patient had one episode of traumatic redis-
location with a positive apprehension test at follow up. In
one case, removal of the screw was necessary due to
mechanical impingement. We recommend this arthroscopic
technique allowing for closed reduction and internal screw
fixation of large anterior glenoid fractures, ensuring ana-
tomical fracture healing and gleno-humeral joint stability.

Keywords Shoulder dislocation · Glenoid fracture ·
Arthroscopy · Internal fixation · Cannulated screws

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Introduction

A fracture of the glenoid rim that results in a large anterior
fragment is reported to cause anterior shoulder instability
[1, 2], especially in depression fractures with antero-infe-
rior displacement of the fragment. To avoid chronic
instability or degenerative joint disease [3], surgical treat-
ment consisting of anatomical reduction and internal
fixation is recommended [4, 5]. Increasingly, arthroscopic
techniques of glenoid fracture fixation [6–9, 10] that
replace open procedures, are described [11–13, 14]. In this
context of glenoid fragment fixation, it is also necessary to
consider the arthroscopically treated large bony Bankart
lesions using suture anchors, which involve less than 25%
of the glenoid surface [15]. Particularly, dealing with gle-
noid fractures, special attention has to be paid to soft-tissue
management. Minimally invasive techniques preserve
blood supply and reduce the risk of restricted motion,
which can complicate open procedures.

In a biomechanical study, it was found that a fragment
width that was 21% of the glenoid length (average width
6.8 mm) was the maximal fragment size that preserved
gleno-humeral stability [16]. Resecting a fragment wider
than 6.8 mm and refixing the capsular-ligamentous com-
plex to the glenoid defect creates instability and signi-
ficantly reduces the range of external rotation.

Out of those findings, we graded anterior glenoid frag-
ments involving more than 21% of the glenoid length as
large and indicated surgical treatment if displacement
occurred. For the treatment of large anterior intra-articular
glenoid fractures, we use cannulated titanium screws
introduced percutaneously under arthroscopic view. The
hypothesis was stated that arthroscopic screw fixation of
large anterior glenoid fractures provides fracture healing
with glenohumeral joint stability, with contemporaneously

reduced soft tissue complications. Our novel arthroscopic technique of fragment fixation and the resulting radiographic and clinical outcome of a series of large anterior glenoid fractures are presented and analyzed.

Methods

Between June 1997 and December 2004, ten patients with large intra-articular anterior glenoid fractures underwent surgery with arthroscopic screw fixation at our institution. The inclusion criteria for minimally invasive treatment were as follows: (1) acute anterior glenoid fracture corresponding to Type Ia in the Ideberg classification system [17] and involving at least 21% of the glenoid length; (2) a solid fragment; (3) fragment depression with step formation of more than 2 mm at the articular glenoid surface (Fig. 1); and (4) no concomitant neurological injuries such as brachial plexus lesions. One patient had an associated tear of the supraspinatus tendon. He was also treated with arthroscopic osteosynthesis, but the rotator cuff was repaired in the same session. In one case concomitant avulsion of the greater tuberosity had occurred. The tuberosity was fixed concurrently, percutaneously and with the same cannulated titanium screw system. All patients were re-evaluated clinically and radiographically after a minimum follow-up time of 2 years. Mean time of follow-up was 56 months (range 24–90 months). Six patients were males and four were females. The average age at the time of treatment for fracture was 38.2 years (range 26–69 years). The left shoulder was involved in six cases and the right in four; in five cases the dominant side was affected. The primary injury was sports injury in nine (skiing in six, soccer in two, motorcycle racing in one) and a fall in one case (see Table 1). In all patients, the primary injury mechanism was a shoulder dislocation requiring reduction by a physician with resulting shoulder instability. The average time between the primary injury and arthroscopic fixation of the fragment was 6.6 days (range 1–21 days).

Clinical evaluation

At follow-up a modified Rowe score-rating system [18] was used to evaluate the final clinical outcome. Active abduction, flexion and external rotation were measured in degrees. Internal rotation was graded according to the posterior spinal level that the thumb was able to reach. The result was rated as excellent (score between 100 and 90), good (89–75), fair (74–51), or poor (50 or less). The patient's subjective satisfaction with the condition of the involved shoulder was indicated by the patient on a visual

Fig. 1 AP radiograph of the right shoulder showing an anterior glenoid fracture of Ideberg Type Ia with anterior subluxation of the humeral head

analog scale (VAS) extending from 0 (unsatisfied) to 10 (maximal satisfaction) points. Shoulder joint stability was evaluated using the anterior apprehension test with grades 1 (normal), 2 (without discomfort) and 3 (with discomfort). All patients were evaluated by the same independent examiner (M.T.), who was not the surgeon.

Radiographical evaluation

In all patients, preoperative radiographs in two planes, a true antero-posterior (a.p.)-view with the adducted arm in neutral position and an axillary view were carried out. Computed tomography (CT) was performed to determine the exact fragment dimensions, orientation and alignment. For the first two patients a 2D reconstruction was carried out, but for the last eight patients an additional three-dimensionally reconstructed CT (3D-CT) with the humeral head eliminated [19] was available. Thus, an exact quantification of the fragment size was possible. According to Itoi et al. [16], the fragment size is calculated as a percentage of the glenoid length to a line, inclined 45°, drawn through the fracture gap (Fig. 2) with the equation $(A \times 96.5\% - B)/A \times 100$. A represents the diameter of the outer fitting circle and B the length of the diameter from the outer circle to the fracture line (arrow in Fig. 2).

The width of the glenoid fragment in our series averaged 26.2% (range 21–35%) of the glenoid length (see Table 1).

All radiographs and CT-scan images were reviewed by two independent examiners (M.E. and H.K.), who were blinded to patient data and clinical results. Interobserver differences were evaluated using intraclass correlation

Table 1 Patient's data with the clinical results at follow up

Patient	Sex	Age (years)	Side	Injury	Fragment size	FU	Flex	Abd	ER	Rowe score	Rowe Score u.s.	VAS
1.	M	31	Left	Skiing	24	90	180	180	80	100	100	10
2.	W	69	Left	Fall	30	80	150	145	45	70	100	7
3.	W	50	Left	Skiing	32	76	145	140	40	88	100	8
4.	W	35	Right	Skiing	26	74	180	180	70	100	100	10
5.	M	36	Right	Soccer	21	66	180	180	80	100	80	10
6.	M	32	Left	Soccer	35	52	175	175	70	100	100	10
7.	M	33	Left	Skiing	23	44	180	180	80	82	100	10
8.	M	41	Right	Motorcycle	24	32	180	180	70	100	100	10
9.	M	26	Left	Skiing	22	26	180	180	70	100	100	10
10.	W	29	Right	Skiing	25	24	180	180	65	100	100	10

Age, patient's age at the time of injury, fragment size in % of the glenoid length, FU, follow up time in months, Flex, active flexion in degrees, Abd, active abduction in degrees, ER, active external rotation in degrees, u.s., unaffected side, VAS, visual analog scale for subjective satisfaction

coefficient (ICC) [20]. The ICC was calculated by comparing results between the two examiners. An ICC score from 0 to 0.4 was rated poor, 0.4–0.75 fair or moderate, and >0.75 excellent.

Intraoperative fluoroscopic control and immediate postoperative a.p. and trans-scapular (Fig. 3) radiographs were taken to evaluate anatomical fragment reduction and correct screw positioning. Standard radiographs in two planes (a.p.-view and axillary view) were performed after 4, 8, and 24 weeks. In addition, a computed tomography was carried out at last follow-up. Thus, the final healing process of the glenoid fragment, bone changes such as osteoarthritis or pseudarthrosis, and possible loosening of the titanium screws could be assessed with high sensitivity.

Fig. 2 En face view to the glenoid in a 3D-CT. An outer fitting circle that fit the supero-inferior diameter of the glenoid was constructed and through the fracture gap a line inclined 45° to the superoinferior diameter was drawn. The fragment width in percentages of the glenoid length is calculated with the equation $(A \times 96.5\% - B)/A \times 100$. A diameter of the *outer fitting circle*. B length of the *arrow*

Surgical technique

All patients were operated on by the same surgeon. The procedure is performed in the beach chair position under general endotracheal anaesthesia combined with an interscalene cervical plexus block. A 2 kg of traction were applied on the arm over an elbow-holder. The image intensifier, when needed, was positioned cranially for an axillary view to control screw length and positioning in the glenoid. The arthroscope was introduced via a standard posterior portal. Anteriorly, a working cannula was inserted via an antero-superior portal (1 cm superior to the coracoid process), and irrigation of blood, fibrin, and loose articular debris by a shaver was followed by diagnostic assessment (Fig. 4) of the glenohumeral joint. Mobilization of the glenoid fragment together with the capsuloligamentous complex was performed using elevators, rasps, and a shaver through the antero-superior portal. At that point it was of paramount importance to gain anatomical fracture reduction without step formation at the articular cartilage. For fragment fixation an Arthroscopic and Percutaneous Screw Fixation System (Leibinger®, Freiburg, Germany) was used through an antero-inferior transsubscapularis approach [21]. The Leibinger®-set consists of cannulated, self-tapping titanium screws with a diameter of 2.7 mm and a length of 10–40 mm (Fig. 5). The use of a cannula set with a blunt trocar helps minimize damage to soft tissues. The screws are inserted over a guide wire, which is part of a drill-guide-wire combination with a diameter of 2.2 mm. This combination is used like a K-wire for temporary fixation of the glenoid fragment (Fig. 6). Fragment fixation was performed as follows: in the horizontal plane, the tip of the drill-guide wire combination was placed medial to the labrum a few mm away from the bony rim, and in the sagittal plane, in the middle of the superoinferior diameter of the fragment in cases requiring only one screw or with a distance of 5–7 mm from each other in cases needing two screws. When the radiological check confirms

Fig. 3 Postoperative trans-scapular view of the shoulder documenting the anatomical reduction of the fracture and correct implant positioning. Ideally, the two screws run parallel

Fig. 4 After irrigation of the joint, diagnostic assessment is performed and the fragment size is evaluated. The fracture gap is debrided of blood and fibrin for reduction

Fig. 5 A Leibinger® cannulated titanium screw is shown with the guide-wire inserted. The screws are available in lengths from 10 to 40 mm. Notice the flat screw head
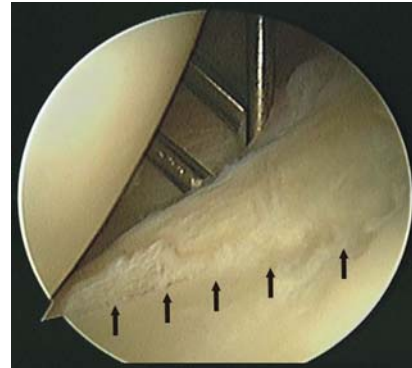

Fig. 6 The fragment is fixed temporarily by two drill-guide-wire combinations. With a hooked instrument, anatomic fracture reduction is checked. After removing the cannulated drills, the screws are inserted over the remaining guide-wires into the fragment. The fracture line is marked by *arrows*

correct guide-wire position, the drills are removed, whereas the guide-wires remain in place. The screws, usually 24 to 30-mm long, are inserted over the wire. In most cases the screws were used without washers in order not to protrude beyond the joint surface. After definitive arthroscopic and radiographic control, the guide-wires are removed.

In three patients, the labrum was detached in the superior portion of the anterior glenoid rim. In these cases, an additional anchor was set on the edge of the healthy cartilage to reattach the capsular–labral complex closely to the glenoid, known from the classical arthroscopic Bankart repair. In two cases, two anchors were necessary to reattach the labrum. No accompanying SLAP lesion was identified in this series.

In one patient concomitant avulsion of the greater tuberosity was treated by percutaneous screw fixation. The associated isolated supraspinatus tendon tear in a 41-year-old patient was refixed using suture anchors.

Postoperative management

Postoperatively, the patient's arm was immobilized in a shoulder sling for 4 weeks. During this period only passive exercises were permitted under the physiotherapist's guidance. External rotation was limited to the neutral position, whereas forward elevation to 60° was allowed. After 4 weeks, the sling was removed and active assisted range-of-motion exercises in all planes began, carefully avoiding provocation of pain. After 3 months, patients were permitted to practice non-contact sports, but only after 6 months were full return to manual work and contact or throwing sports allowed.

The rehabilitation program of the patient with associated rotator cuff repair differed only in the time of immobilization, which was extended to 6 weeks.

Results

Clinical evaluation

All ten patients were evaluated at least 2 years after treatment. The average Rowe score was 94 points (range 70–100 points), compared to 98 points (range 80–100

points) on the unaffected side. The results were graded as excellent in seven patients, as good in two, and fair in one patient. All patients except the one with the traumatic re-dislocation had a negative apprehension test at follow-up with no recurrence of dislocation.

The active range of motion was free in all patients but two. The average active flexion was 173° (range 145–180°), active abduction was 172° (range 145–180°), external rotation was 67° (range 40–80°) and internal rotation was Th12 (range L3–scapular). The average active external rotation of the uninvolved side was 71° (range 60–85°). Thus, the mean difference in active external rotation from the unaffected side was 4°.

The self-assessed VAS satisfaction score was, on average, 9.5 points (range 7–10 points). Active range of motion, bilateral Rowe score and the self-assessed VAS are shown in Table 1.

The patient with the grade 2 positive apprehension test had suffered a traumatic redislocation 58 months after the index procedure and 4 months before the last follow-up. Primary glenoid fragment width measured 23% of the glenoid length and the postoperative course was free of complications. The patient is professional ice hockey player and had returned to full practice of his sports. Until redislocation after an adequate trauma during an ice hockey exhibition, the patient had no restrictions and an absolute stable shoulder joint.

The actual CT scan showed no screw breakage and a healed glenoid fracture. The Hill-Sachs lesion had not increased in size.

Radiographic evaluation

The interobserver reliability was graded as excellent with an intraclass correlation coefficient (ICC) of 0.81.

In all patients, glenoid fracture healing was shown in the CT-scan at follow-up. No screw breakage or loosening was observed. No loss of reduction had occurred. One patient had mild osteoarthritis at follow-up.

Complications

In the first treated case of this series, damage to the cartilage was observed in the anterior region of the humeral head due to mechanical impingement with the screw head. Implant removal became unavoidable because of pain and restricted internal rotation and was carried out 54 months after arthroscopic screw fixation. Clinical suspicion, based on complaints and physical exam, was complemented by a CT-scan, which revealed moderate sticking out of the screw head (Fig. 7). Meticulous study of the postoperative

radiographs led us to believe that the screw was initially placed too close to the cartilage. After this first case, no implant complication occurred any more.

A comminuted fragment, a possible complication that necessitates an intraoperative switch to an open procedure, makes screw fixation impossible. This has occurred once since introduction of this new arthroscopic technique. Comminution was not detected in the preoperative CT-scan, and only revealed during diagnostic arthroscopy. Also intraoperative fragment fracture inserting the screw makes open continuation of the procedure necessary.

Discussion

The general trend towards minimally invasive surgery is also observed in shoulder surgery, especially with the progressive development of arthroscopic techniques. Aesthetically, minimally invasive surgery allows minimization of the wound area, conservation of the soft tissues with reduced surgical trauma and preservation of the blood supply, which is of major importance in fracture management. Thus, the risk for severe complications, as infection or vascular and nerve injuries [22, 23] is minimized.

Some authors [6–9, 10] have reported their modest experiences in various arthroscopic techniques of glenoid fracture treatment with thoroughly convincing results. For example, Cameron [7] reported the first case of arthroscopic screw fixation of a glenoid fracture using a 3.5-mm cannulated screw through the subscapularis tendon.

Our technique of arthroscopic screw fixation fulfils the demands on minimally invasive procedures of glenoid fracture management. A major advantage of arthroscopic-assisted fracture treatment is the direct visualization of the articular surface with the opportunity to reduce and fix fracture fragments more accurately. Screw fixation conducted under arthroscopic control assures restoration of normal anatomic relationships and stable internal fixation that permits early range of motion.

The use of our screw set offers several advantages: (1) screws provide more stability than pins or wires; (2) due to the drill-guide-wire system, the reduced fragment can be fixed temporarily; (3) the guide wire can control the positioning of the cannulated screws; (4) the screws are self-tapping and have a flathead to cause less prominence; (5) titanium reduces the risk of implant intolerance and allows possible later magnetic resonance imaging; and (6) implant removal is not necessary.

In all patients bone healing was observed with no cases of non-union or secondary displacement. No cases of screw loosening or breakage occurred, confirming the suitability of our screw system for arthroscopic glenoid fracture treatment.

In the use of a transsubscapularis approach we observed no complications regarding the axillary nerve or any sign of injury of the muscle itself. Internal rotation was not impaired and no suspicion for a subscapularis lesion was evident in the final clinical examination. This may be of major advantage compared to open procedures that require takedown of the subscapularis with a certain rate of tendon morbidity, especially in revision cases [24].

Looking at open glenoid fracture treatment, the results reported in the literature are not always convincing. A comparable study group including ten patients was treated by open reduction and internal fixation using cannulated screws [25]. The reported Rowe score at follow-up averaged 90 points with non-union of the fragment in one case. Implant failure had occurred in four patients with screw impingement in three and screw loosening in one. No recurrence of instability had been observed. Slightly better results were observed by other authors in open glenoid fracture management though including not exclusively anterior intra-articular glenoid fractures. Schandelmaier et al. [14] treated 22 glenoid fractures by open reduction and internal fixation with a failure rate of 10% and a complication rate of another 10%. Mayo et al. [13] achieved anatomical healing in 89% of their patients with a good functional outcome in 88% in their series of 27 displaced fractures of the glenoid fossa. Kavanagh et al. [11] reported on good results in their series of nine patients with no implant complications and no loss of fracture reduction.

Certainly, the retrospective study design has to be mentioned as one of the limitations of our study. However, the

Fig. 7 2D-CT scan at follow-up shows fracture healing in anatomical position. The screw head at the anterior glenoid rim protrudes the articular surface and was removed due to mechanical impingement with the humeral head

influence on the study results is limited. All preoperative relevant data are objective measurements obtained by CT-scan. The clinical examination at follow-up was performed by an independent examiner and both, the preoperative and postoperative, radiological measurements were compared by two independent examiners with determination of the interobserver reliability. Thus, the observer-dependent bias was minimized. Furthermore, the number of patients included in this series is modest, resulting in a preliminary character of this study. It has to be taken into account though that the low incidence of this fracture type and the rigorous inclusion criteria are responsible for the small group of patients. However, this is the largest group reported of arthroscopically treated large glenoid fractures. The serious problem of screw impingement with intra-articular damage could not be ignored. The implant-related complication had occurred in the first case of this series and was related, retrospectively, to the technical fault of setting the screw too close to the glenoid cartilage. Therefore, correct implant positioning using the drill-guide-wire system is essential to minimize the failure rate.

To obtain convincing clinical and radiological results, it is of crucial importance to precisely define the indications for this procedure. Contraindications include comminuted or unacceptably small fragments, since there is a high risk of splitting the fragment during insertion of the drill-guide-wire combination. For these acute glenoid rim fractures with limited fragment size, fragment stability can be obtained using appropriate sutures around the bone fragment [10, 15]. However, precise imaging diagnosis with radiographs in two planes and complementary CT scan for exact quantification of the fragment size is indispensable. A two-dimensional or, better yet, a three-dimensional CT reconstruction with the humeral head eliminated [19], represents an easy, practicable, non-invasive, reliable method accurately measuring and assessing fragment displacement.

The age of the patient, however, does not present a contraindication to this procedure. The bone quality at the glenoid bone stock is good in older patients, so we also operated on two patients of advanced age (50 and 69 years).

Finally, in addition to having low morbidity, arthroscopic techniques allow diagnosis and treatment of associated injuries. The coincidental underlying rotator cuff tear in a 41-year-old man could be diagnosed easily during visual inspection and repaired by suture anchors in the same session. The concomitant avulsion fracture of the greater tuberosity in another case could concurrently be treated percutaneously.

In large anterior glenoid fractures, arthroscopic screw fixation ensures anatomical fracture healing and glenohumeral joint stability. Respecting the contraindications and technical recommendations, excellent functional
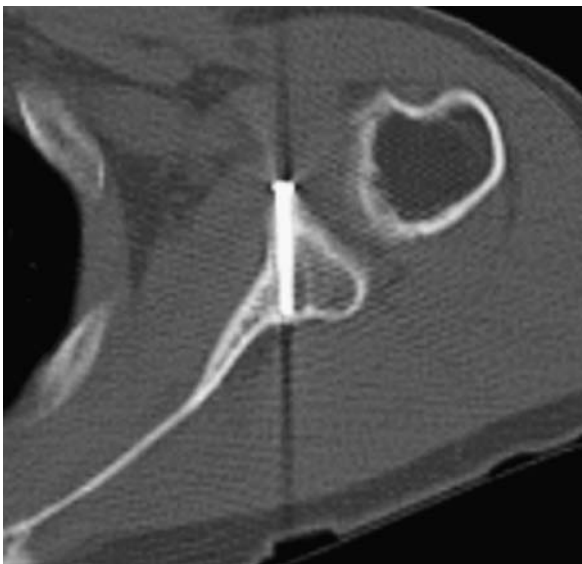
results can be expected gaining all advantages of minimally invasive fracture management.

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