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TRAUMA SURGERY

Open fixation of acute anterior glenoid rim fractures with bioresorbable pins: analysis of clinical and radiological outcome

Dirk Maier[1] · Kaywan Izadpanah[1] · Peter Ogon[2] · Maximilian Mützel[1] · Jörg Bayer[1] · Norbert Paul Südkamp[1] · Martin Jaeger[1]

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Abstract
Introduction The purpose of this study was a detailed analysis of clinical and radiological results following open fixation of acute-traumatic, displaced anterior glenoid rim fractures with bioresorbable pins.
Materials and methods This retrospective study included 17 patients with glenoid defect sizes ≥20 %, as directly measured in preoperative sagittal en face CT. The mean glenoid defect size was 25.3 % (20–35, SD 4.7). Two or three polylactid pins were used for fixation. Mean age of patients at the time of surgery was 50.1 years (27–71). The mean follow-up period was 6.2 years (2.0–11.1). Follow-up included comprehensive objective and subjective evaluation of shoulder function as well as standard radiographs.
Results The majority of 15/17 patients obtained good or excellent clinical results according to the absolute and normalized Constant score, the Rowe score, the Oxford shoulder score, the simple shoulder test, the shoulder pain and disability index and the subjective shoulder value. Quality of life (SF-36) showed reference values. Mean or subitem values of all outcome measures did not differ from the contralateral, uninjured side. Radiographically, all fractures healed without secondary dislocation. Radiological signs of glenohumeral arthritis developed in two patients and progressed in two other patients. There were no implant-related complications. No patient experienced glenohumeral instability or had to undergo revision surgery.
Conclusions Bioresorbable pin fixation is a feasible and safe method of osteosynthesis for anterior glenoid rim fractures up to a glenoid defect size of about 35 % and enables immediate active range of motion. Good or excellent clinical outcome can be expected and glenohumeral stability is reliably restored. The most common mid- and long-term complication is occurrence or progression of osteoarthritis. The major benefits of bioresorbable pin fixation are redundancy of implant removal, minimal risk of implant-related complications and early functional rehabilitation.

Keywords Acute-traumatic · Anterior glenoid rim fracture · Glenoid defect · Open fixation · Bioresorbable pin · PolyPIN®

Introduction

Operative treatment of acute anterior glenoid rim fractures is recommended in case of intra-articular displacement ≥4 mm and biomechanically relevant involvement of the glenoid surface [1, 6, 16, 25]. Itoi et al. [9] showed in a cadaveric study, that osseous defects with a width ≥21 % of the glenoid length cause relevant persistent glenohumeral instability after isolated soft tissue Bankart repair.

Aim of surgery is to restore glenohumeral stability and function to prevent instability and osteoarthrosis. Operative treatment strategy mainly depends on the fragment type as well as on the glenoid defect size. Reported methods include isolated capsule–labrum repair [14], refixation of the fragment(s) using (cannulated) screws and/or suture anchors [6, 17, 21, 23], autologous bone graft [15] and

✉ Dirk Maier
dirk.maier@uniklinik-freiburg.de

[1] Department of Orthopaedic and Trauma Surgery, University Medical Center Freiburg, Hugstetter Strasse 55, 79106 Freiburg, Germany

[2] Center of Orthopaedic Sports Medicine Freiburg, Breisacher Strasse 84, 79100 Freiburg, Germany

coracoid transfer procedures [2] performed either open or arthroscopically. Still, open reduction and screw fixation may be regarded as the gold standard procedure for treatment of acute, large anterior glenoid rim fractures [3, 6, 17, 19, 21]. However, screw osteosynthesis is associated with high risks of hardware-related complications (e.g., intra-articular impingement, loosening and breakage) [17, 19, 21].

In this context, use of bioresorbable fixation devices appears beneficial in view of lower implant-related complication rates and redundancy of implant removal, particularly for treatment of articular fractures. The bioresorbable polylactid *D*/DL (70 %/30 %) pins allows direct osteosynthesis of osteochondral fragments close to the articular surface providing sufficient primary stability of fixation for early functional rehabilitation [4]. Biomechanical stability, biocompatibility, technical feasibility and efficacy for fracture treatment have been proven for various bone and joint locations such as the radial head [5]. Moreover, there are no metal artifacts to compromise postoperative MRI assessment.

Therefore, the purpose of this a retrospective study was a detailed analysis of clinical and radiological results following open fixation of anterior glenoid rim fractures with bioresorbable pins.

Materials and methods

Eligibility for this study required fulfilment of all of the following inclusion criteria:

(1) acute-traumatic, anterior glenoid rim fracture type F1(1a–c) or F2 according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) scapula fracture classification system (Fig. 1) [10]; (2) intra-articular displacement with a gap and/or step-off $\geq$4 mm and (3) fracture involvement of $\geq$20 % of glenoid surface as measured in sagittal en face CT. Exclusion criteria were (1) fracture fixation not exclusively performed with bioresorbable pins and (2) relevant concomitant injury with presumable persistent impairment of shoulder function (e.g., rotator cuff tear, persistent neurological deficit).

Thus, 17 patients (4 female, 13 male) were included in this retrospective study, who underwent surgery between September 2001 and November 2012. Mean age at the time of surgery was 50.1 years (range 27–71) and the mean follow-up period was 6.2 years (range 2.0–11.1). The dominant right arm was affected in 10 cases and the non-dominant left arm in 7 cases. Five fractures sports-related had occurred (3 bicycle accidents, 1 skiing accident and 1 ice hockey injury). The underlying mechanisms of injury were primary-traumatic anterior shoulder dislocations in seven patients, a fall on the outstretched arm (indirect mechanism) in 5 patients and a direct lateral impact on the shoulder in 5 patients.

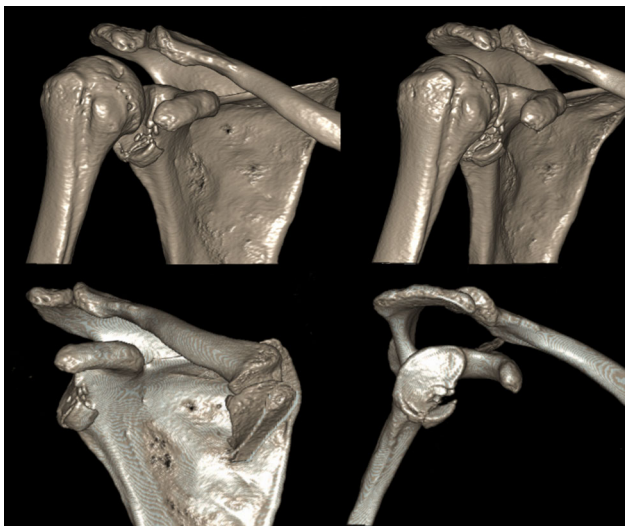

Fig. 1 3D-CT reconstruction of an acute-traumatic, anterior glenoid rim fracture type F1(1) according to the AO Foundation and Orthopaedic Trauma Association (AO/OTA) scapula fracture classification system [22]; first-line anterior views and second-line true anterior and outlet views with substraction of the humeral head

None of the patients had experienced previous shoulder surgeries, shoulder dislocations or symptoms of glenohumeral instability. A standardized physical examination was performed. There were no neurovascular deficits. Asymptomatic generalized ligamentous laxity was noted in two patients. Preoperative imaging included standard radiographs (true AP, outlet and transaxillary view) and computed tomography (CT) in all patients. Three patients underwent additional magnetic resonance imaging (MRI) to exclude a traumatic tear of the rotator cuff.

Surgical technique

All procedures were performed in beach-chair position under general anesthesia and facultative use of an interscalene block. A deltopectoral approach was used in all cases. A longitudinal skin incision was performed parallel to Langer's lines of cleavage starting just below the coracoid process. The superficial fascia was incised over the lateral margin of the pectoralis major muscle. The cephalic vein was preserved and retracted laterally. The common shoulder fascia was cleared of bursal tissue and incised along the coracoacromial ligament and the proximal muscle belly of the short head of the biceps. The subscapularis tendon was detached approximately 1.0 cm medial to its insertion at the lesser tuberosity preserving the anterior humeral circumflex vessels (Fig. 2a). The interval between the tendon and anterior capsule was identified. Then, the

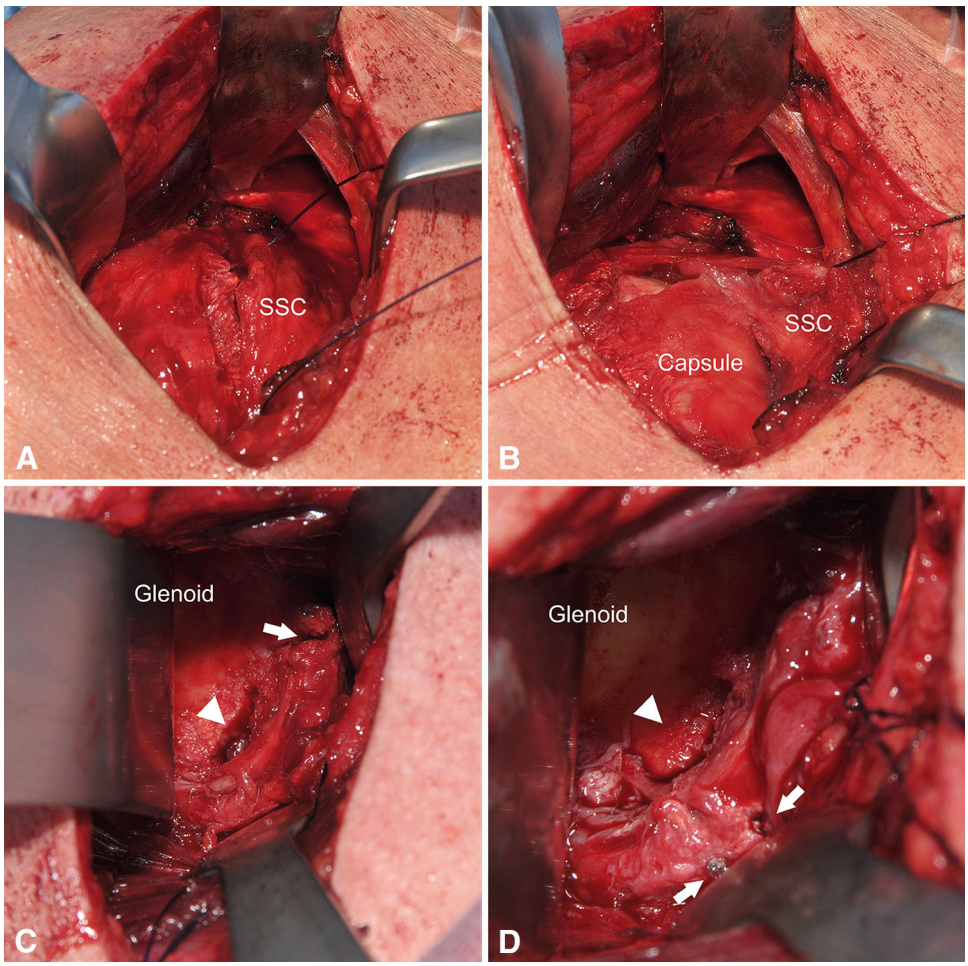

Fig. 2 Stepwise illustration of the surgical procedure, **a** sharp oblique detachment of the subscapularis tendon approximately 1.0 cm medial to the top of the lesser tuberosity, **b** exposition of the anterior joint capsule after separation from the subscapularis tendon which is reflected medially with holding sutures, **c** displaced anterior glenoid rim fracture, a Fukuda retractor is used for posterior subluxation of the humeral head, two Hohmann retractors inserted into the anterior capsulo-labral recessus improve fracture visualization (*white arrowhead* fracture line with posterior step-off, *white arrow* radial labral tear), **d** anatomic reduction (*white arrowhead*) and fixation with three 2.0 mm bioresorbable pins implanted medial to the labrum (*white arrows* radiopaque heads of two PolyPINs®, the third pin located superiorly is not visible due to capsular coverage)

subscapularis tendon was dissected from the anterior capsule, retracted medially and armed with holding sutures (Fig. 2b). The capsule was vertically incised close to its humeral insertion and retracted medially. A Fukuda retractor was placed onto the posterior glenoid rim for posterior subluxation of the humeral head. Hohmann retractors were inserted into the anterior capsulo-labral recessus to improve visualization of the anterior glenoid rim fracture (Fig. 2c). A singular fragment was found in 11 patients, whereas a multi-fragmentary situation was present in 6 patients. The capsule–labrum complex was firmly attached to the fragment(s) in all cases. The fragment(s) including the attached capsule–labrum complex were anatomically reduced and temporarily fixed with 1.4–1.8 mm K-wire(s). Two to three 1.5 or 2.0 mm PolyPIN® (Consept GmbH, Wiesbaden, Germany) were used for definite fracture fixation (Fig. 3). A total of 38 PolyPINs® were implanted.

The PolyPIN® consists of bioresorbable polylactid D/DL (70 %/30 %) and degrades within a period of 15 months as specified by the manufacturer. The pins were inserted press-fit close to the articular surface just medial to the capsulo-labral complex and flush with bony surface of the fragment (Fig. 2d). Any radial tear of the capsulo-labral complex was repaired with resorbable sutures. The capsule was reattached to the humerus using absorbable sutures. No additional anteroinferior capsular shift was performed. The

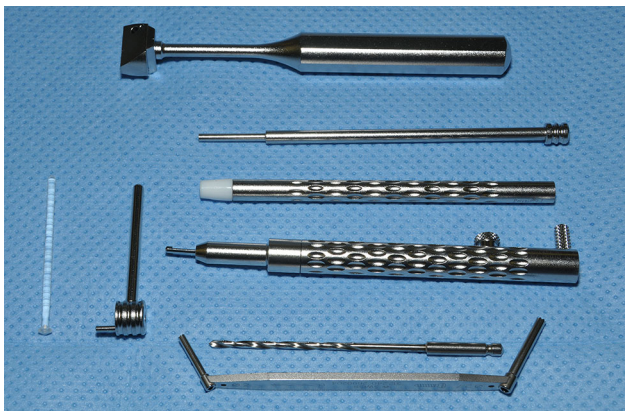

Fig. 3 Instrumentarium for bioresorbable pin implantation using the example of the PolyPIN® system (Consept GmbH, Wiesbaden, Germany); *right* margin (bottom-up): drill guide, drill, depth gauge, impactors, sharpener; *left* margin: 2.0 mm PolyPIN® and cutter

subscapularis tendon was reinserted anatomically with the arm in 15° of abduction and neutral rotation. The superficial fascia was readapted and the wound was closed.

One patient had an anterior humeral avulsion of the inferior glenohumeral ligament (HAGL lesion), which was repaired by transosseous sutures. Another patient had sustained an ipsilateral proximal humerus fracture (3-segment) with involvement of the greater tuberosity. The minimally displaced fracture was simultaneously stabilized by tubular plate osteosynthesis and healed anatomically.

Postoperative management

Supervised physiotherapy started on the first day after surgery including active range of motion. Active abduction was limited to 45° for two postoperative weeks and to 90° for another 4 weeks. Active external rotation was limited to 0° for 2 postoperative weeks and to 20° for another 4 weeks. Patients refrained from active internal rotation for 6 weeks. During periods of rest, the shoulder was immobilized in internal rotation for two postoperative weeks during daytime and for four postoperative weeks during nighttime. Standard radiographs (true AP, outlet and transaxillary view) were routinely taken after drainage removal, 6 weeks and 3 months after surgery to control fracture reduction and consolidation. Further follow-up X-rays were taken after 6 months and 1 year and then annually.

Outcome measures

Clinical

An experienced, independent senior orthopedic residence performed a comprehensive physical examination of the shoulder joint. We used specific and general clinician-based, patient-based and combined scores to measure functional outcome and quality of life: the absolute Constant score (CS_{abs}), the normalized (age- and gender-matched) Constant score (CS_{norm}) as described by Katolik et al. [12], the Rowe score, the Oxford shoulder score (OSS), the simple shoulder test (SST), the shoulder pain and disability index (SPADI), the subjective shoulder value (SSV) and the SF-36 [7].

Radiological

The glenoid defect was quantified by direct computerized measurement (IMPAX 6, Agfa HealthCare GmbH, Bonn, Germany) of the missing area (mm^2) in an en face sagittal CT view as previously described and validated by Huijsmans et al. (Fig. 4) [8]. The percentage defect size (%) was calculated by dividing the missing area by the total surface of the inferior glenoid circle (Fig. 5). Each measurement was repeated three times and the mean value was used for statistical analysis. The fracture type was classified as simple or multi-fragmentary. Gaps and step-offs were measured in postoperative radiographs to assess the quality of fracture reduction. Preoperatively and at follow-up, osteoarthritic changes of the glenohumeral joint (osteophytes, joint space width, subchondral sclerosis and cysts) were noted and classified as suggested by Samilson and Prieto [20].

Statistics

Statistical analysis was performed using the software package SPSS version 17 (SPSS Inc., Chicago, IL, USA). Descriptive results are given as the mean value ± standard deviation (SD). All data were tested for normal distribution using the Kolmogorov–Smirnov test. If normally distributed, subgroup data were compared using one-way analysis of variance (ANOVA). Otherwise, a Mann–Whitney *U* test was used for independent and a Wilcoxon signed-rank test for related data. Statistical significance was assumed for p values <0.05.

Results

Clinical results

The mean length of the deltopectoral approach was 9.3 cm (range 7.0–11.5).

Mean values for active range of motion were 165° (SD = 22.6°) for abduction, 43° (SD = 14.4°) for adduction, 172° (SD = 14.7°) for anteversion, 63° (SD = 13.6°) for low external rotation (from neutral position), 85° (SD = 7.4°) for high external rotation (from 90° abduction), 90° (Th-11) for low internal rotation from neutral position (range L3–Th-8) and 78° (SD = 16.1°) for high internal rotation (from 90° abduction). None of the patients showed clinical signs of glenohumeral instability. Three patients presented with a positive Neer sign indicative for subacromial impingement syndrome. Four patients had a mildly positive lift-off test.

Mean values for functional outcome scores were: 86.1 points (range 56–97, SD 10.5) for CS_{abs} (pain: 13.8 points, activity: 18.6 points, motility: 37.4 points, strength: 16.4 points), 94.3 points (range 69–106, SD 8.6) for CS_{norm}, 95.0 points (range 75–100, SD 6.8) for the Rowe score, 14.7 points (range 12–23, SD 3.0) for OSS, 10.8 points (range 6–12, SD 1.7) for SST, 7.5 points (range 0.0–31.6, SD 8.4) for SPADI (pain: 8.8 points, disability 6.3 points), 88.3 % (range 50–100, SD 13.3) for SSV, 49.5 points (range 23–59, SD 9.6) for the physical component

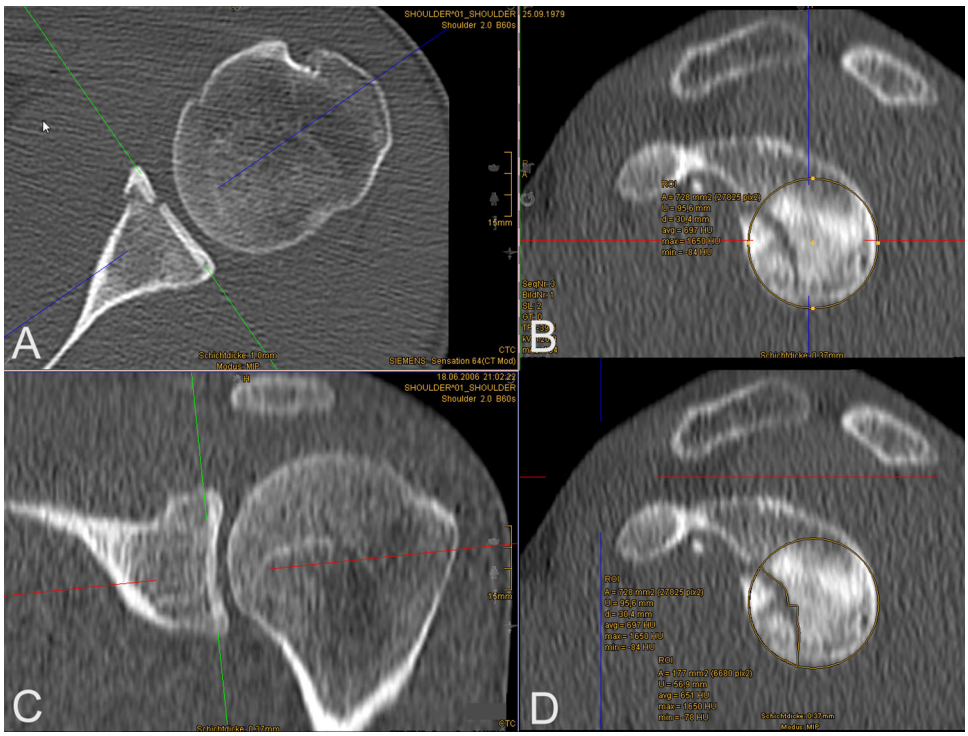

Fig. 4 The glenoid defect (fracture involvement) was quantified by direct computerized measurement (IMPAX 6, Agfa HealthCare GmbH, Bonn, Germany) of the missing area (mm^2) in en face sagittal CT reconstruction as described by Huijsmans et al. [8]; **a** axial plane, **b** sagittal en face plane with inferior glenoid circle, **c** paracoronary plane and **d** sagittal en face plane with direct glenoid defect measurement

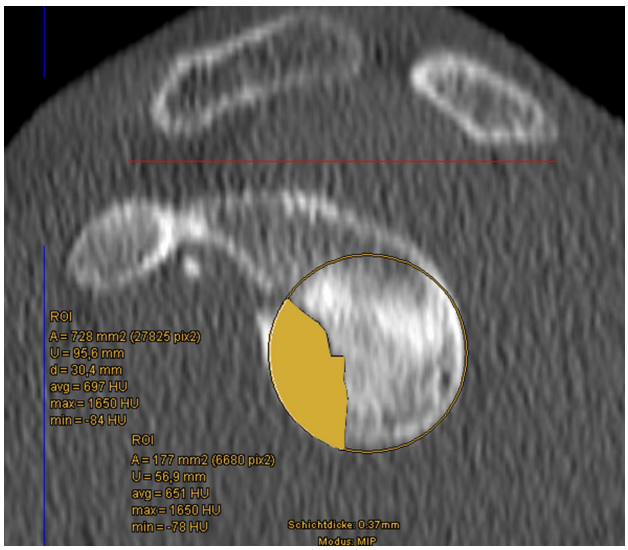

Fig. 5 In this case, the fracture involved 24 % of the glenoid surface. The percentage glenoid defect (GD) was calculated by dividing the missing (*yellow*) area (177 mm^2) by the total surface (728 mm^2) of the inferior glenoid circle: GD (%) = (177 mm^2/728 mm^2) × 100 = 24 %

summary and 51.9 points (range 32–61, SD 9.0) for the mental component summary of the SF-36.

Neither clinical findings of subacromial impingement syndrome ($n = 3$) nor mild subscapularis insufficiency ($n = 4$) significantly impaired the total or subitem value of any outcome score. All outcome scores were measured bilaterally for intra-individual comparison. There were no significant differences between total or subitem score values. Significant differences existed in active ability of rotation. Low active internal rotation was significantly inferior on the affected side (8.3 points versus 9.1 points corresponding approximately to Th-12 versus Th-8; $p = 0.034$) as well as high active internal rotation (78° versus 85°; $p = 0.040$). Also, high active external rotation was significantly inferior on the affected shoulder (85° versus 90°; $p = 0.014$). The slight restriction of low/high internal rotation was not caused by the mild insufficiency of subscapularis function found in four patients ($p = 0.206$/$p = 0.513$).

Radiological results

The mean size of fracture involvement related to the inferior glenoid rim area was 25.3 % (range 20–35, SD 4.7). The anterior glenoid rim consisted of singular fragment in nine cases. Multiple fragments were present in eight patients. All fractures united without secondary fragment and/or implant displacement. Early postoperative radiographs showed anatomic reduction and fixation in 8/17 patients (Fig. 6). A detectable step-off or gap of ≤2 mm was noted in 9/17 patients. At follow-up, these steps or gaps were unverifiable in five of these nine patients. In five patients, the glenoid showed radiological signs of remodeling with a re-contoured articular surface at the former fracture site and enlargement of its anterior-inferior portion. Osteoarthritic changes

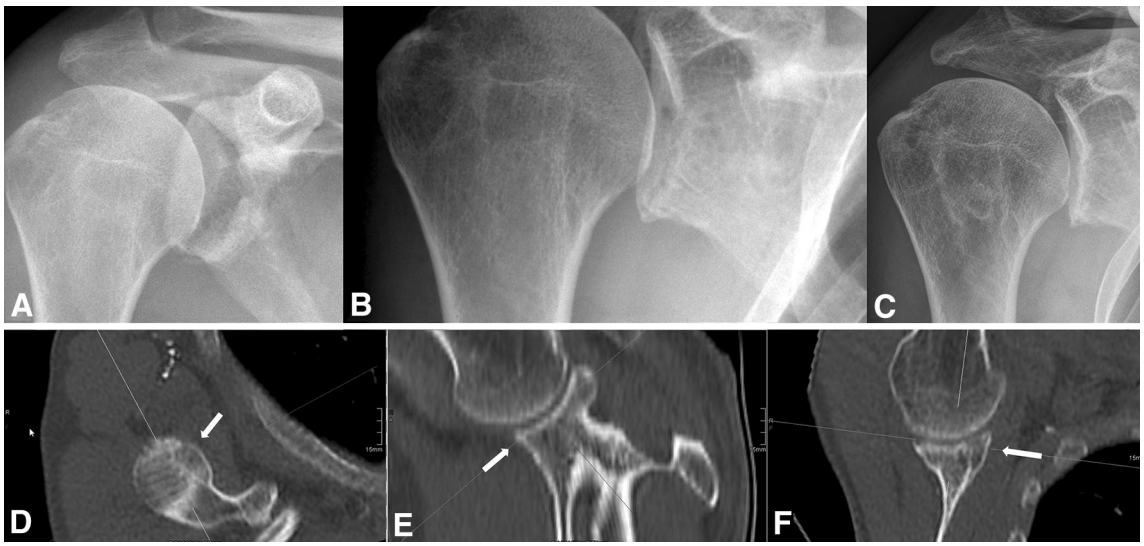

Fig. 6 First-line **a** preoperative anterior radiograph of displaced anterior glenoid rim fracture, **b** postoperative control following anatomic reduction and fixation with three bioresorbable pins, **c** follow-up radiograph 9.8 years after surgery showing anatomic fracture union without signs of secondary osteoarthrosis. Second-line CT thorax due to pulmonary disease (arm in abducted position) shows congruent osseous consolidation in reconstructed **d** sagittal en face, **e** paracoronar and **f** axial plane 12.4 years postoperatively

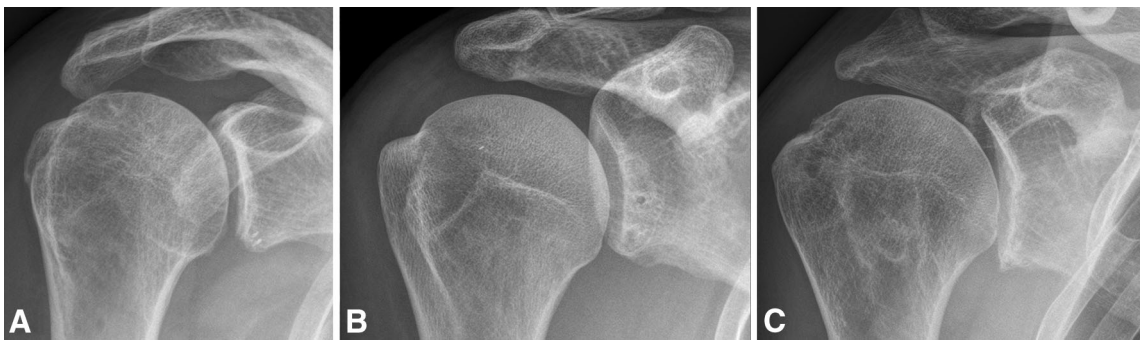

Fig. 7 Exemplary follow-up radiographs: **a** fracture union with bony replacement of all three bioresorbable pins (2 × 2.0 mm, 1 × 1.5 mm) 3.4 years after surgery. The new generation of 2.0 mm PolyPINs® is available with radiopaque heads, which are still visible, **b** fracture union with partial bony replacement of the two inferior bioresorbable pins (1 × 2.0 mm, 1 × 1.5 mm) 2.3 years after surgery. The implantation site of the superior 2.0 mm pin is still visible without surrounding osteolysis **c** fracture union showing complete radiographic disappearance of all three bioresorbable pins (3 × 2.0 mm) 9.8 years after surgery suggesting their bony replacement

preexisted in three patients ($n = 2$ stage-I and $n = 1$ stage-II according to Samilson and Prieto). Two of these patients showed progradient osteoarthrosis at follow-up ($n = 1$ stage-II and $n = 1$ stage-III). Two other patients had developed stage-II osteoarthritic changes within the follow-up period. The mean acromio–humeral distance (AHD) was 9.2 mm (range 4.4–12.8). AHD was ≥8 mm in 10 patients and <8 mm in seven patients. We did not observe any osteolysis exceeding the pin implantation site (Fig. 7a, b). In follow-up radiographs, the pins were fully resorbed in 11/17 patients. A proportion of 30/38 implants were no longer detectable suggesting their full bony replacement (Fig. 7c).

Subgroup analysis of all patients revealed no significant influence of glenoid defect size (≤25 %, >25 %), fracture type (simple/multi-fragmentary), quality of postoperative reduction (anatomic, quasi-anatomic with step-off/gap ≤2 mm), presence of posttraumatic osteoarthrosis and AHD (≥8 mm, <8 mm).

Complications

We did not experience technical or implant-related complications (implant failure, osteolysis, adverse bone or soft tissue reactions). Secure fracture fixation was achieved in all cases. There were no infections. Transient postoperative axillary nerve palsy occurred in one patient showing full short-term recovery within 4 postoperative weeks. Two patients showed a progress of glenohumeral osteoarthrosis,

whereas two patients developed de novo osteoarthritic changes. No patient had to undergo revision surgery.

Discussion

This first study on open fixation of large anterior glenoid rim fractures with bioresorbable pins found good or excellent mid- and long-term functional results in 15/17 patients (88 %). At the time of final follow-up, a proportion of 14/17 patients (82 %) did not experience relevant pain and had achieved full return to all preinjury activities of daily living, profession and sports. Total mean values of all outcome measures (CS_{abs}, CS_{norm}, Rowe score, OSS, SST, SSV) did not differ from the contralateral, uninjured side. Also, quality of life, as measured with the SF-36 health survey, was comparable to reference populations. Detailed subgroup analysis revealed minor intra-individual limitations, particularly affecting range of glenohumeral rotation. We observed a slight loss of internal (7°) and external (5°) rotation, most likely caused by capsular and/or subscapularis shortening. We were unable to distinguish between posttraumatic and postoperative causes. However, none of the patients felt clinically handicapped. The minor restriction of internal rotation was not associated with the slight insufficiency of subscapularis function observed in four patients. Postoperatively, none of the patients experienced symptoms of shoulder instability. There were no shoulder (re)dislocations. Secure fixation was achieved even in multi-fragmentary situations and all fractures healed uneventfully. Reduction and fixation succeeded (quasi-)anatomically in all cases. Radiological signs of glenoid remodeling without negative influence on outcome were observed in 5/17 patients (29 %), a phenomenon already known from autologous bone graft procedures [15]. Two patients showed a progress and two patients (12 %) de novo formation of osteoarthritic changes within the follow-up period. Though, it was impossible to determine, to which extent these changes were trauma- or surgery-related.

Since it is the first study of this kind, clinical and radiological results can only be compared to those of other open and arthroscopic techniques of refixation treating similar fragment types and sizes. Raiss et al. [19] performed open screw osteosynthesis in 29 patients (mean age: 42 years, mean follow-up: 6.5 years). Intraoperatively, all defects were rated as >25 % involvement of glenoid bone stock. The age- and gender-related Constant score was 93 %. Six patients (21 %) showed radiological signs of osteoarthritis. The authors also found a significant loss of external rotation (3°) and strength, which they attributed to postoperative capsule and subscapularis shortening. These results are almost identical with ours. However, eight patients (28 %) had to undergo open revision surgery for screw removal. Osti et al. [17] reported a mean Constant score of 78 points and a mean Rowe score of 90 points after open screw osteosynthesis of anterior glenoid rim fractures as a result of shoulder dislocation (n: 20, mean age: 49 years, mean follow-up: 3.1 years, mean defect: 23 %). In addition, four patients (20 %) had to undergo revision surgery (one screw removal, three arthrolysis). Three patients (17 %) developed osteoarthritic changes. Scheibel et al. [21] reported an early postoperative complication rate of 40 % following screw osteosynthesis and recommended suture anchor repair for glenoid defects <25 %. Clinical results of suture anchor repair were favorable (mean Constant score 86 points, mean Rowe score 94 points), but anatomic fragment fixation was rarely accomplished. Porcellini et al. [18] introduced the arthroscopic suture anchor repair for acute bony Bankart lesions of limited size (<25 % defect). Sugaya et al. [24] expanded this technique to even larger defects, but experienced shoulder redislocations in 2/42 cases (5 %). Jiang et al. [11] evaluated the influence of reduction and healing following arthroscopic bony Bankart repair. Anatomic reduction was only achieved in 18/47 cases (38 %) and non-union occurred in 5/47 patients (9 %). The relatively small preoperative glenoid defect of a mean of 14.9 % was only reduced to a mean of 10.4 %. Clinical failure occurred in 4/47 cases and was associated with a reconstructed glenoid size of <80 %. All so far described suture anchor techniques have some drawbacks: suture and/or anchor material within the articular surface, non-anatomic reduction, suspension-type of fixation without interfragmentary compression, thus low biomechanical stability of primary fixation requiring an immobilization period of 3 weeks [13, 18, 23].

The present study in review of the literature suggests the following major benefits for open bioresorbable pin fixation: (1) low risk of implant-related complications; (2) redundancy of implant removal; (3) high rate of anatomic fixation and healing even in multi-fragmentary and severely displaced fracture situations and (4) sufficient stability of primary fixation to enable immediate active range of motion. The disadvantages are: (1) open procedure with subscapularis tendon detachment and necessity of reconstruction potentially leading to shoulder stiffness, rotational restriction, subscapularis tendon retear, neuromuscular denervation and functional impairment particularly following open revision surgery with repeated subscapularis tendon detachment [19, 22]; (2) lower stability of primary fixation compared to screw osteosynthesis and (3) minimum fragment diameter of approximately 5 mm to achieve secure fixation. In recent years arthroscopic techniques further developed, e.g., single and double-row suture anchor fixation being associated with

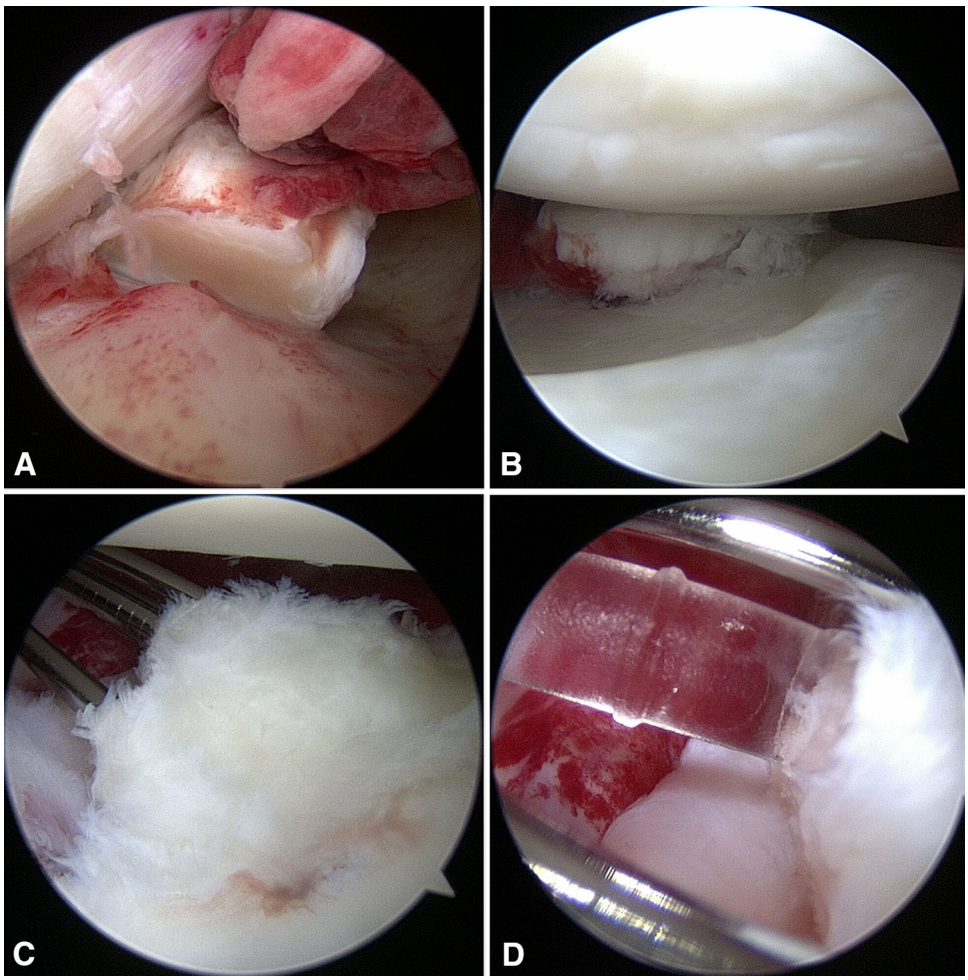

Fig. 8 Arthroscopic fragment fixation with bioresorbable pin in a right shoulder (lateral decubitus): **a** loose fragment located at 6–7 p.m. position and horizontally flipped by 180°, **b** arthroscopically reduced fragment (backflip), **c** anatomic reduction, temporary fixation with two 1.4 mm K-wires and creation of a 2.0 mm drill hole, **d** arthroscopic implantation of a 2.0 mm bioresorbable pin for fragment fixation

obvious benefits such as lower postoperative pain, morbidity and faster recovery [13, 23]. However, arthroscopic fixation has drawbacks in addition to lower primary biomechanical stability. Anatomic reduction and fixation of loose and/or severely displaced fragments is hard to achieve potentially resulting in necessity for fragment removal or conversion to open surgery. With regard to bioresorbable pin fixation, arthroscopic implantation appears feasible (Fig. 8) but so far a specific instrumental set is not yet available.

Limitations

The retrospective design is a methodological weakness, but does not substantially impair conclusiveness of the study. Preoperative, all relevant data were available, most importantly CT scans for exact evaluation of fracture types and sizes. The low incidence of this injury and rigorous inclusion criteria implicated the rather small number of patients. However, it was necessary to exclude patients with relevant concomitant injuries or patients treated with a mixture of implants to draw valid conclusions. Nonetheless, the case number is comparable to the literature. With a mean follow-up period of over 6 years, the results have a long-term character.

In conclusion, open bioresorbable pin fixation is a feasible and safe method of osteosynthesis for anterior glenoid rim fractures up to a glenoid defect size of about 35 % and enables immediate active range of motion. Good or excellent clinical outcome can be expected and glenohumeral stability is reliably restored. The most common mid- and long-term complication is occurrence or progression of osteoarthritis. The major benefits of bioresorbable pin fixation are redundancy of implant removal, minimal risk of implant-related complications and early functional rehabilitation. Development of an instrumental set for arthroscopic implantation is desirable, which could prove beneficial in selective cases.

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Conflict of interest None of the authors has personal or financial conflicts of interest to disclose.

References

1. Anavian J, Gauger EM, Schroder LK, Wijdicks CA, Cole PA (2012) Surgical and functional outcomes after operative management of complex and displaced intra-articular glenoid fractures. J Bone Joint Surg Am 94(7):645–653. doi:10.2106/JBJS.J.00896
2. Bhatia S, Frank RM, Ghodadra NS, Hsu AR, Romeo AA, Bach BR Jr, Boileau P, Provencher MT (2014) The outcomes and surgical techniques of the latarjet procedure. Arthro J Arthro Related Surg Off Publ Arthro Assoc North Am Int Arthro Assoc 30(2):227–235. doi:10.1016/j.arthro.2013.10.013
3. Bigliani LU, Newton PM, Steinmann SP, Connor PM, McLlveen SJ (1998) Glenoid rim lesions associated with recurrent anterior dislocation of the shoulder. Am J Sports Med 26(1):41–45
4. Claes LE, Ignatius AA, Rehm KE, Scholz C (1996) New bioresorbable pin for the reduction of small bony fragments: design, mechanical properties and in vitro degradation. Biomaterials 17(16):1621–1626
5. Helling HJ, Prokop A, Schmid HU, Nagel M, Lilienthal J, Rehm KE (2006) Biodegradable implants versus standard metal fixation for displaced radial head fractures. A prospective, randomized, multicenter study. J Shoulder Elbow Surg/Am Shoulder Elbow Surg [et al] 15(4):479–485. doi:10.1016/j.jse.2005.10.010
6. Hu C, Zhang W, Qin H, Shen Y, Xue Z, Ding H, An Z (2015) Open reduction and internal fixation of Ideberg IV and V glenoid intra-articular fractures through a Judet approach: a retrospective analysis of 11 cases. Arch Orthop Trauma Surg 135(2):193–199. doi:10.1007/s00402-014-2129-y
7. Huber W, Hofstaetter JG, Hanslik-Schnabel B, Posch M, Wurnig C (2004) The German version of the Oxford Shoulder Score–cross-cultural adaptation and validation. Arch Orthop Trauma Surg 124(8):531–536. doi:10.1007/s00402-004-0716-z
8. Huijsmans PE, Haen PS, Kidd M, Dhert WJ, van der Hulst VP, Willems WJ (2007) Quantification of a glenoid defect with three-dimensional computed tomography and magnetic resonance imaging: a cadaveric study. J Shoulder Elbow Surg/Am Shoulder Elbow Surg [et al] 16(6):803–809. doi:10.1016/j.jse.2007.02.115
9. Itoi E, Lee SB, Berglund LJ, Berge LL, An KN (2000) The effect of a glenoid defect on anteroinferior stability of the shoulder after Bankart repair: a cadaveric study. J Bone Joint Surg Am 82(1):35–46
10. Jaeger M, Lambert S, Sudkamp NP, Kellam JF, Madsen JE, Babst R, Andermahr J, Li W, Audige L (2013) The AO Foundation and Orthopaedic Trauma Association (AO/OTA) scapula fracture classification system: focus on glenoid fossa involvement. J Shoulder Elbow Surg/Am Shoulder Elbow Surg [et al] 22(4):512–520. doi:10.1016/j.jse.2012.08.003
11. Jiang CY, Zhu YM, Liu X, Li FL, Lu Y, Wu G (2013) Do reduction and healing of the bony fragment really matter in arthroscopic bony Bankart reconstruction?: a prospective study with clinical and computed tomography evaluations. Am J Sports Med 41(11):2617–2623. doi:10.1177/0363546513499304
12. Katolik LI, Romeo AA, Cole BJ, Verma NN, Hayden JK, Bach BR (2005) Normalization of the Constant score. J Shoulder Elbow Surg/Am Shoulder Elbow Surg [et al] 14(3):279–285. doi:10.1016/j.jse.2004.10.009
13. Millett PJ, Horan MP, Martetschlager F (2013) The "bony Bankart bridge" technique for restoration of anterior shoulder stability. Am J Sports Med 41(3):608–614. doi:10.1177/0363546512472880
14. Mologne TS, Provencher MT, Menzel KA, Vachon TA, Dewing CB (2007) Arthroscopic stabilization in patients with an inverted pear glenoid: results in patients with bone loss of the anterior glenoid. Am J Sports Med 35(8):1276–1283. doi:10.1177/0363546507300262
15. Moroder P, Hirzinger C, Lederer S, Matis N, Hitzl W, Tauber M, Resch H, Auffarth A (2012) Restoration of anterior glenoid bone defects in posttraumatic recurrent anterior shoulder instability using the J-bone graft shows anatomic graft remodeling. Am J Sports Med 40(7):1544–1550. doi:10.1177/0363546512446681
16. Mulder FJ, van Suchtelen M, Menendez ME, Gradl G, Neuhaus V, Ring D (2015) A comparison of actual and theoretical treatments of glenoid fractures. Injury. doi:10.1016/j.injury.2015.01.037
17. Osti M, Gohm A, Benedetto KP (2009) Results of open reconstruction of anterior glenoid rim fractures following shoulder dislocation. Arch Orthop Trauma Surg 129(9):1245–1249. doi:10.1007/s00402-009-0828-6
18. Porcellini G, Campi F, Paladini P (2002) Arthroscopic approach to acute bony Bankart lesion. Arthro J Arthro Related Surg Off Publ Arthro Assoc North America Int Arthro Assoc 18(7):764–769
19. Raiss P, Baumann F, Akbar M, Rickert M, Loew M (2009) Open screw fixation of large anterior glenoid rim fractures: mid- and long-term results in 29 patients. Knee Surg Sports Traumatol Arthro Off J ESSKA 17(2):195–203. doi:10.1007/s00167-008-0677-9
20. Samilson RL, Prieto V (1983) Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 65(4):456–460
21. Scheibel M, Magosch P, Lichtenberg S, Habermeyer P (2004) Open reconstruction of anterior glenoid rim fractures. Knee Surg Sports Traumatol Arthro Off J ESSKA 12(6):568–573. doi:10.1007/s00167-004-0495-7
22. Scheibel M, Tsynman A, Magosch P, Schroeder RJ, Habermeyer P (2006) Postoperative subscapularis muscle insufficiency after primary and revision open shoulder stabilization. Am J Sports Med 34(10):1586–1593. doi:10.1177/0363546506288852
23. Sugaya H, Kon Y, Tsuchiya A (2005) Arthroscopic repair of glenoid fractures using suture anchors. Arthro J Arthro Related Surg Off Publ Arthro Assoc North America Int Arthro Assoc 21(5):635. doi:10.1016/j.arthro.2005.02.006
24. Sugaya H, Moriishi J, Kanisawa I, Tsuchiya A (2005) Arthroscopic osseous Bankart repair for chronic recurrent traumatic anterior glenohumeral instability. J Bone Joint Surg Am 87(8):1752–1760. doi:10.2106/JBJS.D.02204
25. van Oostveen DP, Temmerman OP, Burger BJ, van Noort A, Robinson M (2014) Glenoid fractures: a review of pathology, classification, treatment and results. Acta Orthop Belg 80(1):88–98