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ORIGINAL PAPER

Inferior glenoid fossa fractures: patho-anatomy and results of operative treatment

Jan Bartoníček[1] · **Michal Tuček**[1] · **Daniel Klika**[2]

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Abstract
Introduction A typical feature of inferior glenoid fractures is a distal fragment separated from the glenoid fossa. In most cases, the inferior glenoid fractures are associated with a fracture of the scapular body. However, there are no detailed studies of inferior glenoid fractures, and only brief mentions can be found in the literature in this respect.
Material and methods The basic group comprised 42 patients, with the mean age of 48 years, who sustained 42 fractures of the inferior glenoid. In this group, the scapular fracture anatomy was evaluated, based on 3D CT reconstructions. A total of 29 patients operated on were followed up for 12 to 128 months after injury (average, 52 months), three patients were lost to follow up. The results of the operative treatment, including complications, were assessed radiologically and functionally.
Results Fracture anatomy was described from various aspects, i.e., the size of the articular surface carried by the separated glenoid fragment, the existence of multiple articular fragments, the size of the separated glenoid fragment and the extent of injury to the scapular body. All 29 operatively treated fractures radiologically healed within three months. Full and pain-free range of motion was restored in 18 patients; in eight patients it was limited by 20 degrees and in three patients by more than 40 degrees. The mean Constant score was 82.
Conclusion Fractures of the inferior glenoid fossa requires CT examination, including 3D CT reconstruction with subtraction of the surrounding bones. Displaced fractures are indicated for operative treatment.

Keywords Scapular fractures · Glenoid fossa fractures · Inferior glenoid · Operative treatment

✉ Jan Bartoníček
bartonicek.jan@seznam.cz

Michal Tuček
tucekmic@uvn.cz

Daniel Klika
daniel.klika@uvn.cz

[1] Department of Orthopaedics, First Faculty of Medicine, Charles University and Central Military Hospital Prague, U Vojenské nemocnice 1200, 169 02 Prague 6, Czech Republic

[2] Department of Radiology, Central Military Hospital, U Vojenské nemocnice 1200, 169 02 Prague 6, Czech Republic

Introduction

Glenoid fossa fractures are one of the most severe injuries to the scapula. The growing interest in scapular fractures, introduction of 3D CT reconstructions into their diagnosis and development of their operative treatment have raised the need for a new classification of fractures of the glenoid fossa (GF), since the existing classifications are no longer adequate [1–13]. Analysis of CT scans of 90 glenoid fractures revealed five basic types of glenoid fossa injuries, the most common of them being inferior glenoid fractures, accounting for 42% of all glenoid fossa fractures [14].

In inferior glenoid fractures, a distal fragment was separated from the GF, involving, to a varying extent, the lateral border of the scapula. The separated fragment carried part of the inferior glenoid articular surface of variable size. In most cases, the inferior glenoid fracture was associated with a fracture of the scapular body.

The aim of this retrospective study is to describe a detailed pathoanatomy of inferior glenoid fractures and present outcomes of their operative treatment.

Material and method

Group of patients The retrospective analyzed group of patients was treated at our Department between January 2005 and December 2015. It comprised 42 patients (36 men, six women), who sustained 42 fractures of the inferior glenoid (Figs. 1 and 2), of these 16 on the right and 26 on the left side. The mean age of patients was 48 (range, 17–92) years. All patients with previous injuries to, or degenerative diseases of, the shoulder girdle were excluded from the study. A total of 17 patients sustained the fracture after a fall from a bicycle, 15 patients after a fall from a motorcycle at a slow speed. In four cases, the injury resulted from a traffic accident. However, only four of these 36 patients were classified as polytraumatized. In six patients, the fracture was caused by a fall from a small height (stairs, ladder). In seven cases, the inferior glenoid fracture was associated with a diaphyseal clavicular fracture, in one case with acromioclavicular (AC) dislocation and in one case with fracture of the proximal humerus.

A total of 32 patients were operated on, of which 29 (27 men, two women), with the mean age of 44 (range, 18–70) years, were followed up for 12 to 128 months after injury (average, 52 months). Three patients were lost to follow-up.

Radiological assessment In 38 non polytraumatized patients, ap radiographs of the affected shoulder girdle were taken, including Neer I and II views. All 42 patients underwent CT examination, including 3D CT reconstruction with subtraction of the humeral head, ribs and clavicle from the anterior, posterior and lateral views.

Treatment The method of treatment was chosen in view of the degree of fragment displacement, the patient's general condition and the local condition of soft tissues. Four patients were primarily indicated for non-operative treatment due to only a minimal displacement of articular fragments. Primary indication for operative treatment included displacement of articular fragments (gap or step-off) of more than 3-4 mm and involvement of at least one third of the glenoid fossa. Secondary indication was severe displacement of fragments of scapular body. These criteria were met by 38 patients. Operation was contraindicated in six patients due to their general or local condition. In total, ten (24%) patients were treated non-operatively and 32 (76%) patients were operated on.

The aim of the operative treatment was to restore the congruence of the GF and continuity of the scapular body, as well as stability and pain-free motion of the shoulder. The first author of the article performed 24 operations and assisted in another five operations performed by the second author. The remaining three operations were performed by three other surgeons. The mean injury-operation interval was nine (range, 2–30) days.

Operative technique In all 32 patients, the modified Judet posterior approach in semiprone patient position was used to expose the surgical site [15]. Modification of the Judet approach consisted in a three-phase dissection of the posterior aspect of scapula. In the first phase, the spinal portion of the deltoid muscle was released; in the second phase, the interval between the infraspinatus and the teres minor was identified; and, where necessary, in the third phase, the infraspinatus was released and retracted proximally. The teres minor was always left in situ. Full mobilization of the infraspinatus was not necessary in three cases (Figs. 3 and 4).

Where the posterior joint capsule was not ruptured, incision of the capsule ran parallel to the posterior rim of the GF, in order to allow visualization and palpation of the GF. It is interesting that in more displaced inferior glenoid fractures, the posterior portion of the articular capsule and the glenoid labrum remained almost always intact. During reconstruction of the GF, the main emphasis was put on the two inferior thirds of the articular surface. It was always necessary to reduce anatomically the fragment carrying the articular surface along the whole fracture line. Following anatomical reduction of the GF fragment(s) and temporary fixation by K-wires, final fixation was performed with 2.7 or 3.5 lag screws and 2.7 or 3.5 mm plates. In most cases, these plates also helped reconstruct the lateral border (pillar) of the scapular body [16]. The third, smaller anterior fragment, if present, was sometimes

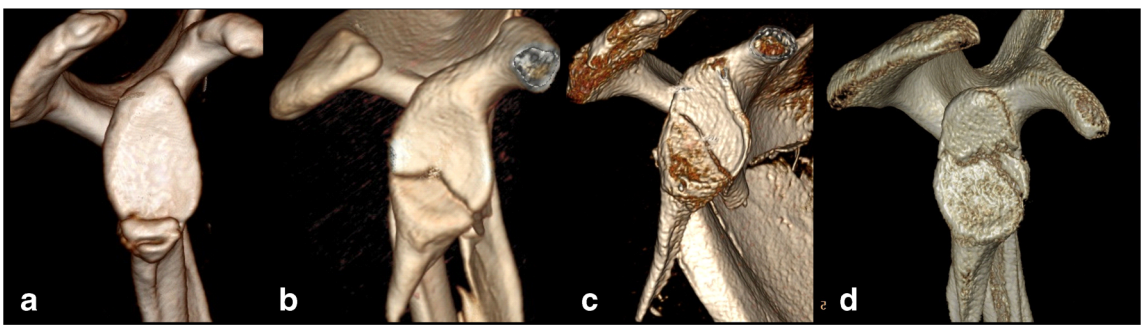

Fig. 1 Anatomy of inferior glenoid fractures – size of avulsed articular surface. **a** – avulsion of ¼ of GF; **b** – avulsion of 1/3 of GF (most frequent); **c** – avulsion of ½ of GF, **d** – avulsion of 2/3 of GF

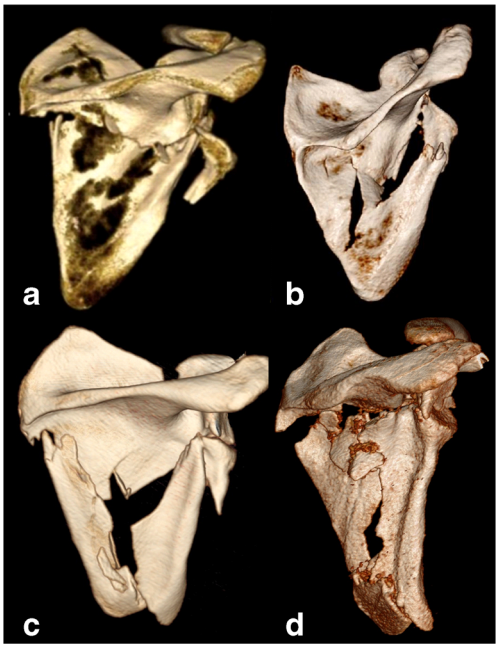

Fig. 2 Anatomy of inferior glenoid fractures – types of infraspinous scapular body fractures. **a** – transverse two-part fracture, most frequent type; **b** – longitudinal (vertical) fracture; **c** – three-part "Y"fracture; **d** – comminuted fracture

difficult to fix and was therefore left without fixation. Postoperative CT examination of four such cases confirmed its union with the GF in a good anatomical position.

Reconstruction of the GF was followed by reconstruction of the scapular body, usually by 2.7 mm reconstructive plates applied circumferentially or across the scapular body. In certain cases, absolute anatomical reduction of the scapular body was not necessary and displacement of several millimetres or degrees was tolerated. The first step was internal fixation of the lateral pillar (border) of the scapular body. It was always performed with standard screws. In transverse fractures of the scapular body, stability of fragments in the spino-medial angle was subsequently assessed. Where fragments moved only minimally (2-3 mm), internal fixation was not used. Marked instability was addressed by internal fixation, using as a rule 2.7 mm plates with two screws inserted into each fragment. In a thin bone, locking screws were used in four cases. Inferior scapular angle was checked for angulation which, if more than 10 degrees, would probably affect smooth movement of scapula on thorax post-operatively.

In one case, anatomical reduction and fixation of acromion fracture was performed in the next step. In seven cases, plate fixation of diaphyseal clavicle fracture was performed from separate oblique incision, with the patient still in the semiprone position. In one case AC dislocation was treated by hook plate. The fracture of proximal humerus was treated nonoperatively. Twenty one operated on cases were documented by intra-operative photos. The mean operative time, including clavicle fixation, was 150 (range, 90–210) minutes.

Post-operative treatment Passive ROM exercises by CPM machine were started on first post-operative day, followed by active ROM exercises as a rule two to three weeks post-operatively.

Patients were regularly followed up, including radiographic examination, at six weeks, three, six, and 12 months after the injury (operation). In ten patients, follow-up CT examination, including 3D CT reconstruction with subtraction of the humeral head was performed after bone union, i.e., in the interval between three and 12 months after injury (Figs. 5 and 6).

Evaluation In the basic group, i.e., in 42 patients, the scapular fracture anatomy was evaluated, including the associated injuries to the ipsilateral shoulder girdle. In the first assessment round, all three authors reviewed all radiographs, CT scans and intra-operative photos independently. In the second round, in cases of differing classification, consensus was reached by reviewing the respective radiographs and scans jointly.

In the group of 29 operated on patients with a minimal follow-up of 12 months, the results of the operative treatment,

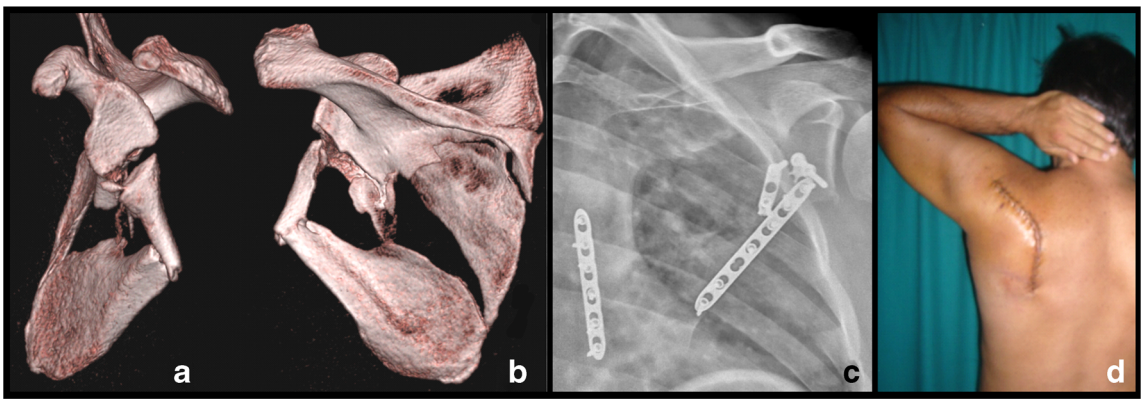

Fig. 3 Inferior glenoid fracture and comminuted infraspinous fracture of scapular body (man, 53 year old). **a** + **b** – 3D CT reconstructions after injury; **c** – post-operative radiograph; **d** – shoulder function one week postoperatively, in this case, the limited Judet approach without infraspinatus mobilization was used

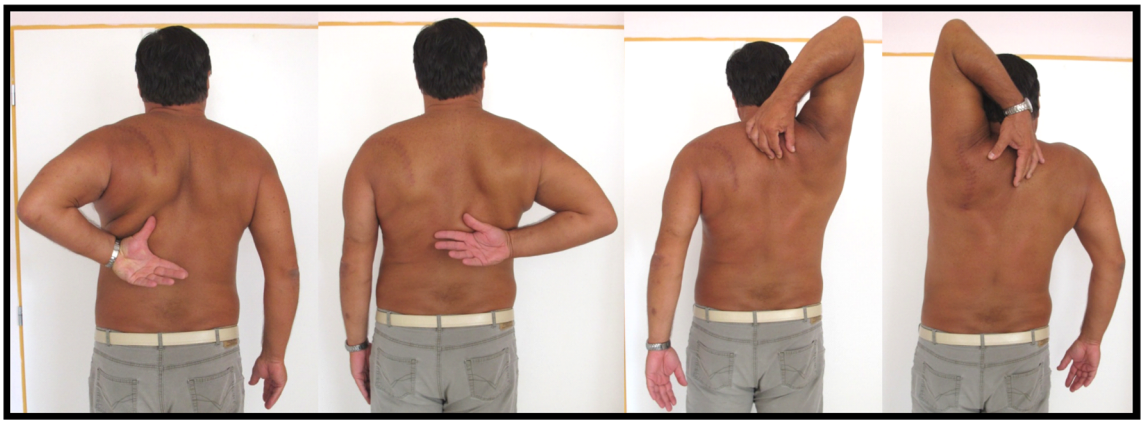

Fig. 4 A patient from Fig. 3 – functional result 3 months post-operatively

including complications, were assessed radiologically and functionally. Functional assessment was based on the Constant score [17].

Results

Fracture anatomy The fracture pattern was analyzed in all 42 cases and was assessed from various aspects, i.e., the size of the articular surface carried by the separated glenoid fragment, the existence of multiple articular fragments, the size of the separated glenoid fragment and the extent of injury to the scapular body.

The size of separated articular surface In one case (2.5%), the glenoid fossa fragment carried only the distal quarter of the articular surface, in 17 cases (40%) the distal third, in 15 cases (36%) the distal half and in nine cases (21.5%) the distal two thirds of the articular surface (Fig. 1).

Number of fragments of the articular surface In 28 cases (67%), there was only one separated fragment and the fracture line passed transversely, obliquely or had the shape of a "V" or inverted "V". In 13 cases (31%), there was an additional small fragment that, except for one case, was broken off the anterior rim of the glenoid fossa. In one case (a 92-year-old female patient), there was comminution of distal third of glenoid fossa.

The fragment size In 26 cases (62%), the articular fragment was short, extending into the lateral border of the scapular body, 3-4 cm below the lower pole of the GF. In six cases (14%), the separated fragment extended as far as the middle third of the lateral border of scapula. In ten cases (24%), the articular fragment also carried part of the inferior scapular angle (Fig. 7).

The extent of injury to the scapular body The lateral border of the scapular body alone was involved in six cases (14%), the infraspinous part of the scapular body in 30 cases (72%) and the whole scapular body was injured in six cases (14%). Fractures of the infraspinous part of the scapular body may be divided into four types (Fig. 2). Most frequently (13 cases), the main fracture line extended transversely from the lateral border of the scapular body to the spino-medial angle and the glenoid fragment was always short. Six of these cases were associated with a clavicle fracture. In seven cases, the main fracture line passed along the lateral border of the scapular body to the inferior angle. Another seven cases were a combination of both above mentioned types and the main fracture line had the shape of a horizontal "Y". Three cases were a comminuted fracture of the infraspinous part of the scapular body.

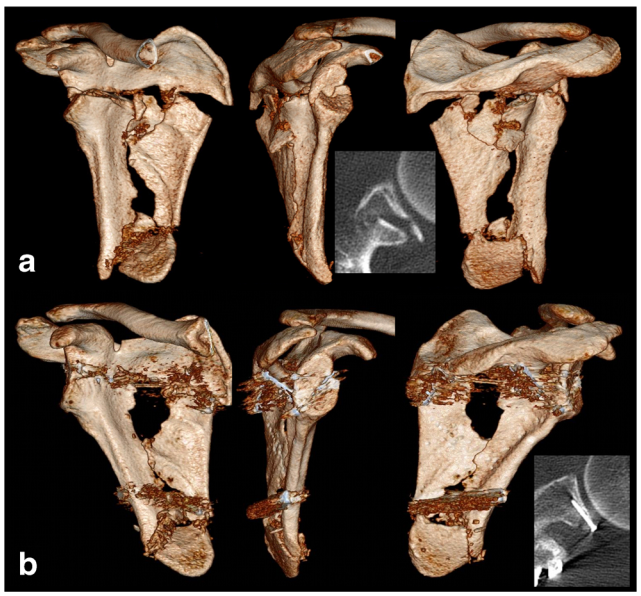

Fig. 5 3D CT reconstructions of inferior three-part glenoid fracture and comminuted fracture of infraspinous part of scapular body. This patient was operated on 1 month after injury. **a** – CT after injury; **b** – CT 3 months post-operatively

Fig. 6 A man, 55 years, from Fig. 5 – functional result one year post-operatively. A full range of motion despite infraspinatus atrophy

Radiological and functional evaluation of operative treatment A total of 29 patients were evaluated. In all of them anatomical reduction was achieved and intraarticular fragment(s) fixed, which was confirmed in ten patients by post-operative CT scan. All 29 fractures radiologically healed within 3 months, without secondary displacement of fragments. The same applies to all seven clavicle fractures treated by plate fixation. Post-traumatic osteoarthritis of the glenohumeral joint was not encountered in any of the patients.

In 18 patients a full pain-free range of motion in the shoulder was restored (Figs. 8 and 9), in eight patients it was limited by 20 degrees (see Fig. 4) and in three patients by more than 40 degrees. The mean Constant score was 82 (66–100) points. In all nine patients with atrophy of the infraspinatus, the external rotation strength was limited.

Complications No intra-operative complications were recorded. Post-operatively, one 30-year-old patient developed post-operative haematoma that had to be evacuated. It had no impact on the final outcome. Nine years post-operatively, the patient has a full range of motion in the shoulder. One 27-year-old patient developed superficial infection in the lower pole of the surgical site. The complication was treated by surgical debridement and antibiotics and healed, again with no impact on the final outcome. In a 70-year-old patient, a radiograph taken six weeks post-operatively revealed breakage of 2.7 mm plate stabilizing the lateral pillar, although without displacement of fragments. This complication was caused by the patient's regular weightlifting when he started to train with 20 kg dumbbell three weeks after operation! Currently, three years after operation, the patient has a full range of motion. Two patients aged 57 and 58 years, transferred after operation to their local hospital for further treatment, exhibited one year post-operatively a markedly limited range of motion due to inadequate post-operative rehabilitation. Nine patients developed atrophy of the infraspinatus, always after mobilization of the muscle (Fig. 6). As a result, the external rotation strength was limited in all of them, however, with no impact on the range of motion.

Discussion

The first to describe an inferior GF fracture were Spence and Steel in 1863 [1]. Internal fixation of this type of fracture, including radiograph, was first published by Hardegger in 1984 [18].

Classification of a fracture pattern and indication for operation requires CT examination, including 3D reconstruction and subtraction of the surrounding bones. However, fractures of the GF are most commonly classified according to Ideberg-Goss, although this radiologic classification does not deal in

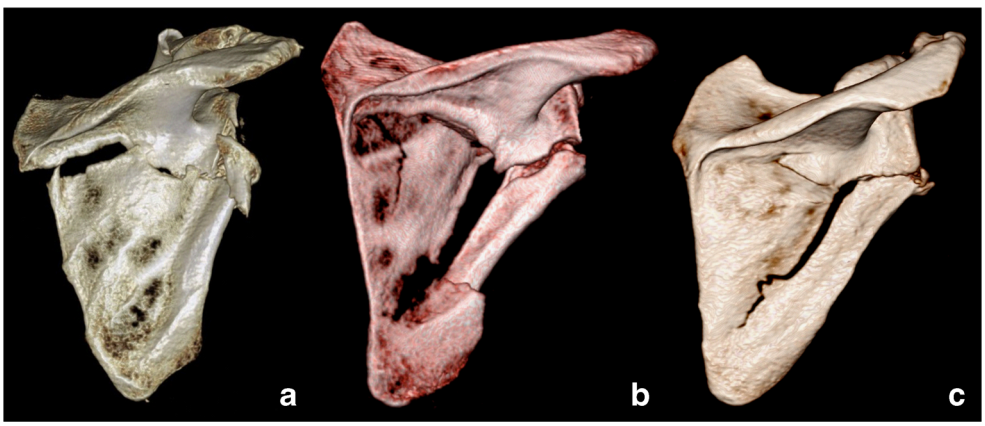

Fig. 7 Anatomy of inferior glenoid fractures – size of inferior glenoid fragment. **a** – small fragment; b – medium fragment; c – large fragment

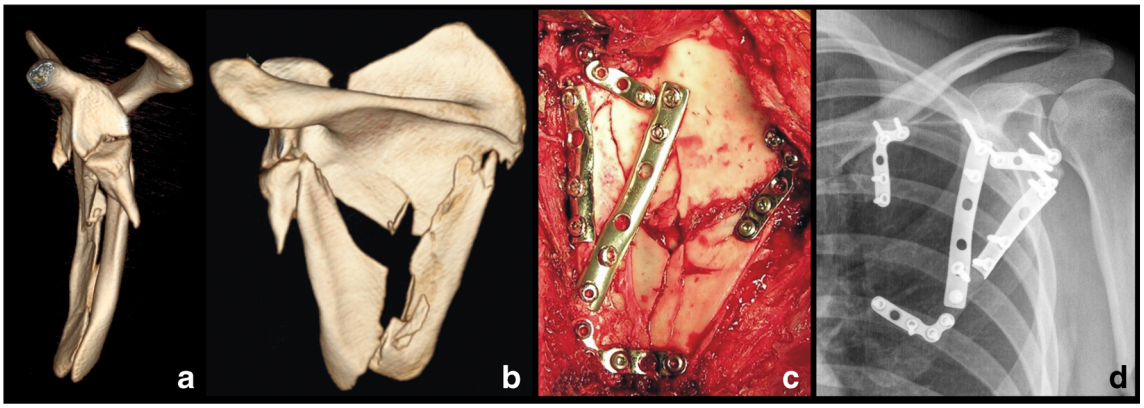

Fig. 8 Inferior glenoid fractures and three-part infraspinous fracture of scapular body (female, 18 year old). **a** + **b** – 3D CT reconstructions after injury; **c** – intraoperative view after internal fixation; **d** – radiograph nine years post-operatively, the radiologic and functional results are excellent

detail with a simultaneous involvement of the scapular body. We have already published our comments in this respect before [14, 15], nevertheless, when comparing our definition of inferior glenoid fractures and the Ideberg-Goss classification [2, 3], certain analogy may be found with Goss types II and V.

Inferior glenoid fractures occur most often after a fall from a bicycle, or motorcycle, by landing on the elbow of abducted limb, with the humeral head hitting the inferior half of the glenoid fossa. Typical of these fractures is an associated injury to the scapular body the extent of which in combination with the number of articular surface fragments, increases fracture severity.

In line with a number of studies, displaced fractures of inferior glenoid involving more than one third of the articular surface are in our view indicated for operative treatment.

Isolated displaced fractures of the inferior glenoid without involvement of the scapular body are sometimes treated from the direct posterolateral approach (Dupon-Evrard, Kavaganah). However, its major disadvantage is a limited access to the glenoid and the scapular body which is difficult to extend, if necessary. Therefore, in inferior glenoid fractures we prefer the Judet approach allowing to treat, if need be, all associated fractures of the scapular body [16]. Our long-term experience has shown that release of the spinal part of the deltoid is well tolerated by patients during post-operative rehabilitation, provided that the subsequent reduction and fixation of the fracture is performed from a limited approach, i.e., from so called lateral and medial windows [15, 16]. Mobilization of the infraspinatus is worse tolerated and often results in its post-operative atrophy even if its innervation has not been impaired. However, in most (26) of our patients with an inferior glenoid fracture, the infraspinatus had to be mobilized due to both the fracture anatomy and a longer injury-operation interval when fragment reduction was hindered by a rapid callus formation and contracture of muscles, the infraspinatus in particular.

Of vital importance during operation is anatomical reconstruction of the distal two thirds of the glenoid fossa (circular area). Fractures of the scapular body do not require an absolutely anatomical reduction of fragments and several millimetre displacement (up to 5 mm) or several degree angulation (up to 10 degrees) may be tolerated. In internal fixation we prefer 2.7 mm implants (plates, screws) which better fits the scapular skeleton and provide sufficient stability at the same time.

Comparison of our results of operative treatment with other authors is not quite exact due to heterogeneity of their groups of patients from the viewpoint of patterns of glenoid fossa fractures (Table 1). A number of important studies dealing with operative treatment of displaced glenoid fractures have reported good results in type II to VI of Goss classification but none of them includes a detailed analysis of fracture pattern [4–7, 10, 12, 13].

Kavanagh [5] reported nine patients with the mean age of 35 (range, 22–49) years treated for fractures of the glenoid

Fig. 9 A patient from Fig. 3 – functional result 3 months post-operatively

Table 1 Basic characteristics of cohorts of individual authors. N – number of evaluated patients. M – months, y – year, fxs – fractures

Author Publication year	N	Age (y)	Fx type of GF	F-U (M)	CT, 3D CT
Kavaganah 1993	9	35 (22–49)	stellate transverse vertical	48 (24–120)	In some cases CT
Leung 1993	14	35 (23–53)	Ideberg II-V	30 (18–68)	No
Mayo 1998	27	29 (15–64)	Goss I-V (14 type IV)	43 (25–75)	in all cases CT, in some cases 2D C, in some cases 3D CT
Schandelmaier 2002	22	34 (16–68)	Ideberg II-V (17 type II + V)	240 (60–276)	In some case CT
Nork 2008	17	39 (22–58)	Goss IV + V+ comminuted fxs	Not specified	In some cases 3D CT
Anavian 2012	30	44 (18–75)	displaced intrarticular fxs	27 (20–73)	all patients 3D CT
Lewis 2013	15	51	Goss I-V (9 type V)	49 (24–87)	CT
Hu 2015	11	39 (23–59)	Ideberg IV + V	28 (12–50)	all patients 3D CT
Authors 2017	29	44 (18–70)	inferior glenoid	52 (12–128)	all patients 3D CT

(stellate, transverse, vertical) fixed through a posterior approach with average follow up of four (range 2–10) years. They recorded one heterotopic ossification in this cohort. Although all patients were satisfied with the outcome no scoring system was used.

Leung et al. [6] published a study of 14 glenoid fractures of Ideberg types II to V, with the mean age of patients of 35 (range, 23–53) years. The mean follow-up was 30 (range, 18–68) months. An excellent result was achieved in three and a good result in 11 patients, using Rowe's scoring system. No complications related to the initial operation were reported.

Mayo et al. [4] evaluated the results of 27 operatively treated glenoid fractures with a mean follow-up of 43 (range, 27–75) months. The most common of Goss types I-V were type IV fractures, namely in 14 cases. The mean age of patients was 29 (range, 15–64) years. Anatomical reduction was achieved in 89% of cases. Results were based on the Shoulder rating score and were excellent in 22%, good in 60%, fair in 11%, and poor in 7% of cases. They recorded one case of superficial infection and two cases of infraspinatus palsies of indeterminate origin. The authors point out the importance of 2D and particularly 3D CT reconstructions in operative treatment.

An outstanding study was published by Schandelmaier et al. [7], presenting 22 cases of glenoid fractures of Ideberg types II to V, operated on over 20 years (1974–1994) by 15 surgeons. The mean age of the patients was 34 (range, 16–68) years. The mean follow-up was ten (range; 5–23) years, which is the longest follow-up period of all the studies so far published! The group included nine fractures of type II and eight fractures of type V, which means that the authors operated on a total of 17 inferior glenoid fractures. The median Constant score was 94% of the opposite shoulder, in four patients it was less than 50%. In two cases, internal fixation failed and two patients developed a deep infection. A further two had an associated complete palsy of the brachial plexus. They did not find any deterioration of the functional result over time.

Nork et al. [10] operated on 17 patients with the mean age of 39 (range, 22–58) years with displaced glenoid fractures of Goss type IV, V, and comminuted glenoid fracture from a modified Judet approach. No complications were encountered and all fractures healed. However, the authors do not specify the period of follow-up or the functional outcomes. Unlike other authors, they begin with reduction and internal fixation on the medial border (spino-medial angle) and then continue on the lateral pillar.

Anavian et al. [12] reported 33 patients (three of which were lost to follow-up) after operative management of complex and displaced intra-articular glenoid fracture, with extra-articular scapular involvement in 24 cases. The mean age of patients was 44 (range, 18–75) years and the follow-up lasted for an average of 27 (range, 20–73) months. CT 2D and 3D reconstructions were made for all patients. Suprascapular nerve injuries were detected during approach at the level of the spinoglenoid notch in eight cases. All fractures healed and anatomic restoration of articular surface was achieved in 91%; 87% of patients were pain-free and 90% patients returned to their preinjury level of work. Surgical complications included one intra-articular screw placement and one postoperative stiffness requiring manipulation.

Lewis et al. [13] operated on 15 glenoid fractures of Goss type I-V, with the highest representation of type V, namely in nine cases. Part of the pre-operative examination were CT scans. The mean age of patients was 51 years, the mean follow-up was 49 (range, 24–87) months. All fractures healed uneventfully, only in one case the patient developed superficial infection. The mean ASES score reached 90 points.

Hu et al. [19] treated operatively 11 patients with the mean age of 39 (range, 23–59) years, with a GF fracture of Ideberg type IV and V, always from the Judet approach. The mean follow-up was 28 (range, 12–50) months, all fractures healed without complications, the mean Constant score was 92 points.

The overview shows that the outcomes of operative treatment are very good. However, but for one exception [7], there is no study evaluating long-term results. Our results are comparable with other studies and support operative treatment of displaced glenoid fossa fractures. The strength of our study is the second highest number of operated on patients (29), the second longest mean follow-up (52 months) and assessment of a single type of injury to the GF.

Conclusion

Inferior glenoid fossa fractures are mostly associated with fractures of the scapular body and constitute a specific type of glenoid fossa fractures. Their exact diagnosis is impossible without CT examination, including 3D CT reconstructions with subtraction of the surrounding bones. In displaced fractures, CT examination is important also in terms of indication for operation, planning of the surgical approach and operative technique. Mastering of the Judet approach is indispensable in this respect. Operation always starts with reconstruction of the glenoid fossa and is followed, if necessary, by reconstruction of the scapular body. The best have proved to be 2.7 mm implants, both in terms of their size and stability of fixation. Post-operative rehabilitation is essential, particularly in elderly patients. Radiological and functional results of operative treatment of displaced interior glenoid fractures justify its use.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval This study has been approved by the Institutional Ethical Board.

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

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