RESEARCH ARTICLE

Operative Treatment of Proximal Humeral Fracture-dislocations Through an Anterolateral Deltoid Split Approach

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Abstract

Background: Proximal humeral fracture-dislocations (PHFD) are a special entity in proximal humeral fracture treatment. The aim of this study is to present our minimally invasive plate osteosynthesis (MIPO) technique through an anterolateral deltoid split approach. In addition, we performed a retrospective cohort study analyzing the patient reported functional outcome and complications.

Methods: A single center cohort study was performed. All patients operated through a deltoid split approach for PHFD between 2009 and 2016 were eligible for inclusion. The primary endpoint was subjective shoulder function measured with QuickDASH and subjective shoulder value (SSV). Secondary endpoints were complications and implant-related irritation.

Results: 28 patients were included. The mean age was 49 (SD ± 10.3). The mean follow-up was 48 months (SD ± 23.7). The mean QuickDASH score was 6.8 (SD ±7.8) and the mean SSV was 86 (SD ±14.6). Four patients had a conversion into a reversed arthroplasty (14%), one patient (4%) a shortening of secondary perforated screws, four patients an early re-osteosynthesis (14%), four patients (14%) developed an AVN and in one patient damage of the axillary nerve was observed. 21 patients (75%) had their implant removed.

Conclusion: Patient reported functional results after humeral head preservation and internal fixation of PHFDs through an anterolateral deltoid spilt approach are promising. However, there is a high rate of re-operations either because of complications or for implant removal. Comparing our data to literature these rates are not depending on the approach chosen.

Level of evidence: IV

Keywords: Fracture fixation, Internal, Minimally invasive surgical procedures, Operative, Shoulder dislocation, Shoulder fractures, Surgical procedures

Introduction

Proximal humeral fractures are very common and account for 4% of all fractures (1). Proximal humeral fracture-dislocations (PHFDs) are a special entity in proximal humeral fracture treatment. PHFDs occur infrequently, with an incidence of 1-2% of all proximal humeral fractures (1). PHFD is defined as a proximal humeral fracture with a dislocation of the humeral head either anterior or posterior to the glenoid fossa (2). Non-dislocated fractures most often occur in the elderly population and are often treated conservatively (3, 4). PHFD occur more often in the younger, active population and are related to high-energy injuries (1, 2, 5). Treatment is primarily operative and traditionally suggested to be arthroplasty, especially in the elderly patient (6-8). With the introduction of angular stable screws new implants have been developed. A shift towards operative

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treatment of proximal humeral fractures in general has been observed (9-11).

PHFDs in younger patients have been suggested to be treated with a head preserving osteosynthesis, generally via an 'open' deltopectoral approach (2, 5). Trikha et al suggested the deltopectoral approach for anterior dislocations and the deltoid split approach for posterior dislocations (2). Plate positioning and the window to the rotator cuff is challenging through the deltopectoral approach. Even more with difficult fracture patterns. Therefore, we adopted the 'minimally invasive' anterolateral deltoid split approach for both anterior and posterior PHFDs (3).

The aim of this study was to present our technique for open reduction and internal fixation (ORIF) of PHFDs through an anterolateral deltoid split approach. Furthermore, we present the functional results and complications after minimally invasive osteosynthesis of these severe injuries.

Materials and Methods

Patient population

After approval from our institutional review board, a retrospective cohort study for PHFD was performed. All patients with a PHFD (AO 11-B3 or 11-C3) who were operated on with ORIF between 2009 and 2016 through a anterolateral deltoid split approach were eligible for inclusion (12). In our hospital young and active patients with a PHFD are treated with an osteosynthesis through an anterolateral deltoid split approach. Elderly and geriatric patients with a PHFD are treated with an arthroplasty.

Baseline characteristics, operation time, image-intensifier time, follow-up data and complications were obtained from electronic patient files. All patients were analyzed either during regular outpatient visits or by telephone by an independent research fellow to assess shoulder function using the QuickDASH questionnaire and the Subjective Shoulder Value (SSV) (13, 14). Implant removal was assessed using the algorithm of Hulsmans et al, diagnosis of symptomatic avascular head necrosis (AVN) and conversion to a shoulder arthroplasty were recorded (15). If patients could not be reached after a minimum of five telephone call attempts, their contact person and general practitioner were approached for contact details and the internet was searched for an alternative telephone number. If patients could not be reached by phone a letter was sent, asking the patient to contact us. Patients were considered lost to follow-up if all these attempts were unsuccessful.

Exclusion criteria were death, a second trauma to the operated arm, inability to answer questions and absence of informed consent.

This study was approved by the Cantonal Ethic Committee in Zurich (KEK-ZH-Nr. 2017-00554).

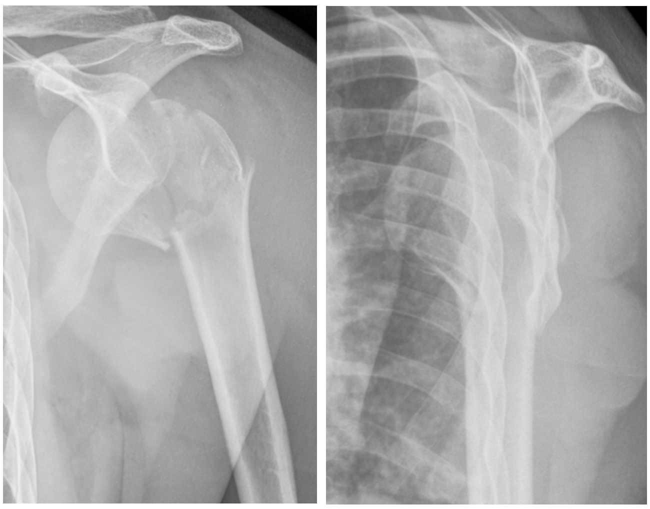
Operative technique

Until 2009 the classical 'open' deltopectoral approach was used to perform ORIF of PHFDs. This approach is well known and accepted (16). With growing experience in using the deltoid split approach for proximal humeral fractures, we changed our approach for PHFD from deltopectoral to deltoid split as well (10, 17).

As the deltoid split technique has not been described for PHFD, it is described in further detail.

After general anesthesia, patients are positioned in beach-chair position. Under antibiotic prophylaxis, an anterolateral deltoid split approach is performed. The incision starts at the end of the anterolateral acromion and runs down anterolateral about 5-7cm in length depending on the size of the shoulder. After blunt dissection through the deltoid muscle, the subacromial bursa is opened and partially resected to provide a better view onto the fracture site. The axillary nerve is protected by straight submuscular/periosteal dissection and the use of a rectangular retractor. Further access to the fracture fragments and the reduction techniques depend on the specific fracture pattern:

A) In 3- or 4-part fractures where the dislocated head fragment is separated from the tuberosity/ies, the approach provides direct access to the underlying tuberosities with the attached rotator-cuff, hiding the dislocated head fragment [Figure 1]. The greater tuberosity is found either direct beneath the incision or slightly posterior. The lesser tuberosity lies anterior. Access to the glenoid cavity is achieved either at the lower margin of the greater tuberosity by lifting it up, or through the fracture gap between the two tuberosities. Both tuberosities can be held apart using a small self-retaining retractor. Most often the dislocated head is found anteroinferior at the lower border of the now well visible glenoid cavity. From the fracture site opposite to the articular surface a Schanz screw (4.5 or 5mm diameter) is inserted directly into the center of the head fragment. This is done under direct vision and using the fluoroscopy controlling insertion depth [Figure 2a]. Attaching a T-handle on this firmly inserted Schanz screw allows for direct manipulation and reduction of the head fragment. It is very often



(a) (b)

Figure 1. X-rays from anterior-inferior proximal humeral fracture-dislocation on AP (1a) and Neer (1b) view.

impacted behind the border of the glenoid and has to be moved sideward (anteroinferior) for decompaction. This allows correct reduction into the glenoid cavity [Figure 2b]. The unstable fragment is held in place using a 2.0mm K-wire which is inserted through the head fragment into the glenoid for temporary transfixation [Figure 2c]. The Schanz screw is removed. Strong FiberWire sutures are placed at the base of the rotator-cuff tendons at the greater (supraspinatus and infraspinatus tendon) and, if fractured as well, at the lesser tuberosity (subscapular tendon). Using these sutures and smaller K-wires as joy-sticks, the tuberosities are now reduced to the head fragment and held in place by further inserting these K-wires into the head fragment [Figure 2d]. The reduction is checked by fluoroscopy. The 3-/4-part fracture-dislocation is now converted to a non-dislocated 2-part fracture. The next step is to reduce the shaft fragment to the head using indirect manipulation of the arm. Often the fist of the surgeon is put into the axilla as a hypomochlion to lateralize the displaced shaft onto the head fragment. Angulation of the arm helps for correct alignment. If possible, a strong 2.0mm K-wire is inserted from the top of the greater tuberosity medially downwards over the sub capital fracture level into the proximal medial part of the shaft fragment for temporary retention. For distal tunneling, blunt dissection is done underneath the deltoid muscle straight on the anterolateral aspect of the humeral shaft to protect the axillary nerve. The axillary nerve is further protected using a rectangle retractor. After inserting the previously described FiberWire sutures through the corresponding marginal plate holes, the 5-hole PHILOS-plate is slid down using the guiding arm until the correct height of the proximal plate end is reached (fluoroscopic control) [Figures 2e; 3]. The plate is fixed with four angular stable screws in the head and two

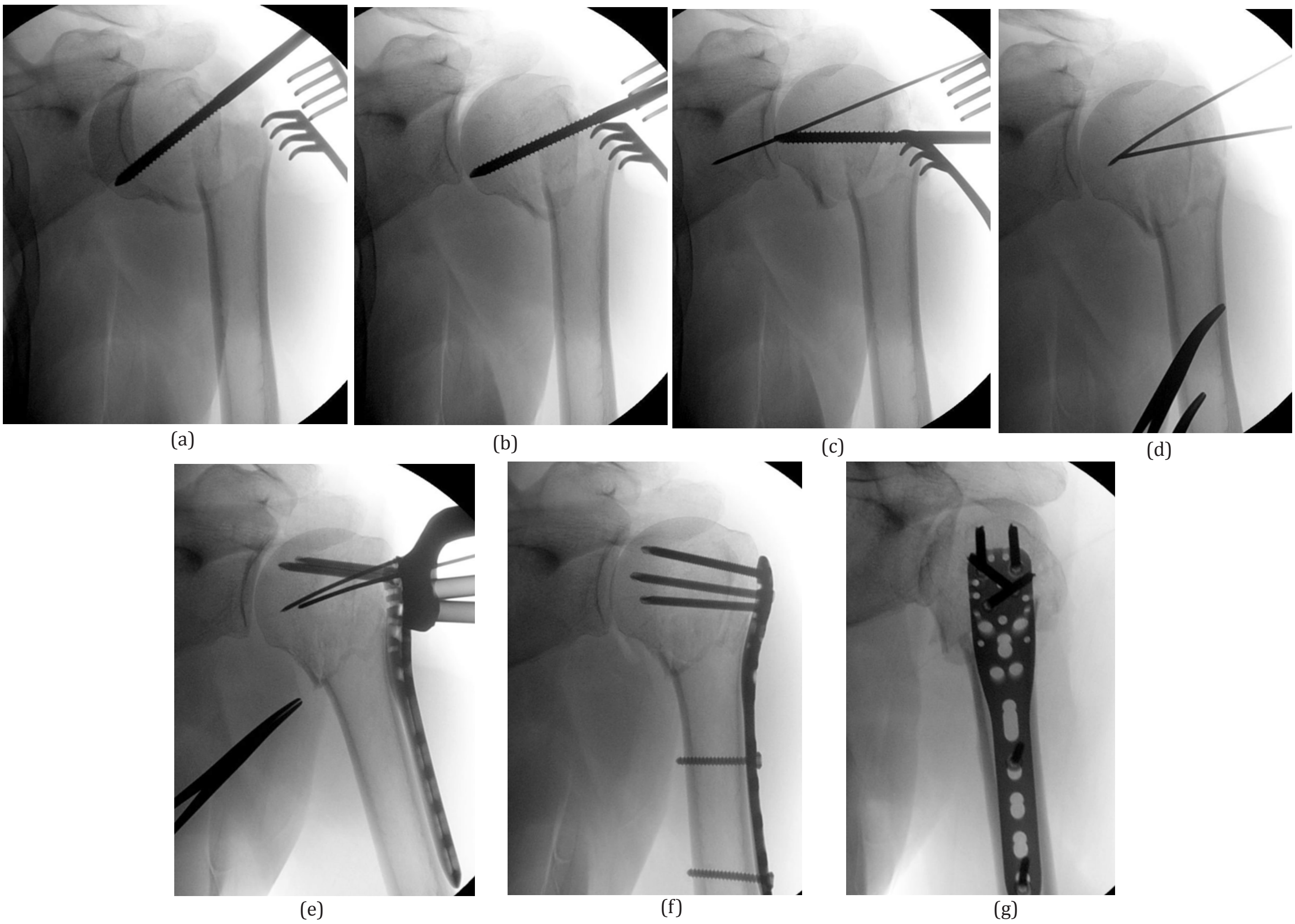


Figure 2. Intraoperative images of the osteosynthesis with a PHILOS plate through an anterolateral deltoid split approach. 2a insertion of a Schanz-screw in the humeral head. 2b reduction of the humeral head in the glenoid fossa using the Schanz-screw with T-handle. 2c temporary retention of the humeral head with a transfixation on to the glenoid using a K-wire. 2d reconstruction of the humeral head and temporary fixation with K-wires. 2e insertion of the PHILOS plate using the aiming device with proximal fixation with 2 angular stable screws. 2f and 2g final x-rays after PHILOS plate fixation with proximally 4 angular stable screws and distally 2 conventional screws in AP and lateral view fixation.

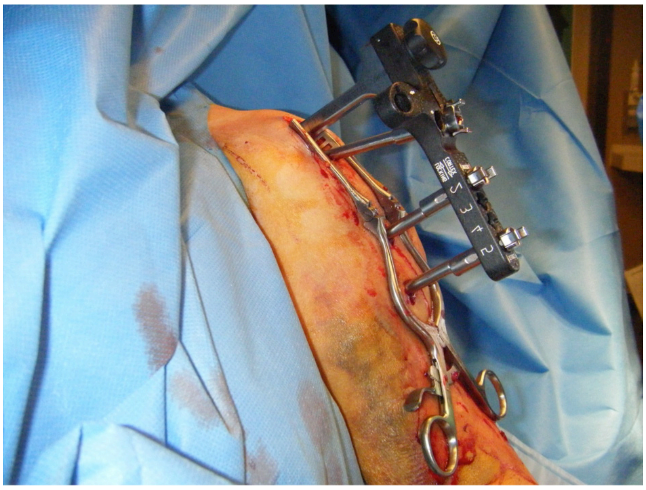


Figure 3. Plate and screw positioning with aiming arm.

to three conventional (in good bone) or angular stable (in osteoporotic bone) screws in the humeral shaft. Using the minimally invasive aiming device allows insertion of 4 angular stable screws proximally only. Insertion of more screws in the head puts the axillary nerve at risk via this approach. Reduction and fixation are checked under image intensifier [Figures 2f; 2g]. After removal of the aiming arm, the FiberWire sutures are tightly knotted over the plate for additional firm fixation of the tuberosities/ rotator cuff. After rinsing the wound, it is closed in layers.

B) In 2-part fractures, after splitting the deltoid muscle, the approach ends on the rotator cuff (supraspinatus tendon) that is under tension and still attached to the dislocated humeral head over the intact tuberosities. In this case, the greater tuberosity is located by the surgeons' index finger and the Schanz screw is inserted through the greater tuberosity into the head fragment. The reduction maneuver is the same as described above. Depending on the stability of the head fragment into the glenoid, a transfixation K-wire (2mm) is used. Further reduction onto the shaft fragment and plate fixation is performed as described above.

At the end of the operation, the stability of the osteosynthesis as well as the position of the head in the joint is tested clinically by careful manipulation of the upper arm. If in doubt, fluoroscopic control can be used. Depending on the stability, a sling for initial shoulder immobilization might be necessary; although, in most cases a stable situation is achieved by the reconstruction. Therefore, patients are allowed functional movement without weight bearing for the first 6 weeks. Abduction of more than 90 degrees and forced rotational movements are not allowed for the first 6 weeks. Physical therapy is started immediately postoperatively and is continued for the first 4-6 months. After six weeks, further mobilization and progressive weight bearing is allowed. X-ray controls are performed 2 days postoperative and then after 6 weeks, 12 weeks, 6 months and 1 year [Figures 4a; 4b; 4c]. Implant removal is performed on patients' request or because of implant-

(a) (b) (c)

Figure 4. Six months follow-up with consolidated fracture in inner rotation (4a), external rotation (4b) and axial (4c) view.

related irritation [Figure 5].

Outcome measures

The primary outcome measure was the patient reported shoulder function as measured by the QuickDASH and SSV score (14, 18). The QuickDASH score is a validated measure for disability of the arm, shoulder and hand. This is a summative score on a 100-point scale. A QuickDASH score of less than 15 is considered an excellent result and a score of >40 reflects a poor shoulder function (13). The SSV is a patient reported outcome measure determined by answering the following question: "What is the overall percent value of your shoulder if a completely normal shoulder represents 100%?", with 100% indicating the best function (14). Secondary outcome measures were conversion into a shoulder arthroplasty, implant-related irritation or implant removal and complications. Implant removal and implant-related irritation were discussed and analyzed using the algorithm of Hulsmans et al, developed to analyze the presence of implant-related irritation (15).

Complications were divided in short-term and long-term complications (19). Short-term complications like insufficient reduction and wound related complications as superficial or deep infections were analyzed using the electronic patient files. Superficial infection was defined as redness, swelling and/or purulent discharge from the wound that could be treated with antibiotics. Infections were considered deep if surgical debridement was performed together with antibiotic therapy. Long-term complications like symptomatic AVN, screw perforation, nonunion, implant breakage or loosening were also recorded. The incidence of symptomatic AVN was diagnosed during regular follow-up and it was discussed during the telephone interviews if this was diagnosed by any other doctor. An unsuccessfully healed proximal humerus by radiograph 6 months after surgery with clinical evidence of pain was considered a nonunion.

Actions taken because of complications like re-osteosynthesis, shortening of screws and/or conversions into a shoulder arthroplasty were noted (19).

Figure 5. AP follow-up x-ray after 3 years.

Statistical analysis

Data were described using frequencies and percentages for dichotomous and categorical variables, mean and standard deviation (SD) for normally distributed continuous data. Continuous variables were compared using Mann-Whitney U-test for non-normal distributed data. A *P value < 0.05* was considered significant. The analyses were performed with SPSS, version 22.0 (IBM Corp., Armonk, NY) for Windows.

Results

After informed consent was obtained, a total of 28 patients were available for follow-up and included for analysis [Figure 6]. The mean age at the time of accident was 49 (SD ± 10.3) years old and 25 (89%) patients were male [Table 1]. The most common trauma mechanism was injury during skiing or snowboarding (57%). There were 4 (14%) type B3 and 24 (86%) type C3 fractures according to the AO classification (12). 17 patients had an anterior fracture-dislocation and 11 a posterior fracture-dislocation. The mean operation time was 101 minutes (SD ± 42.5). The mean follow-up duration was 48 months (SD ± 23.7).

The mean QuickDASH score was 6.8 (SD ± 7.8) and the

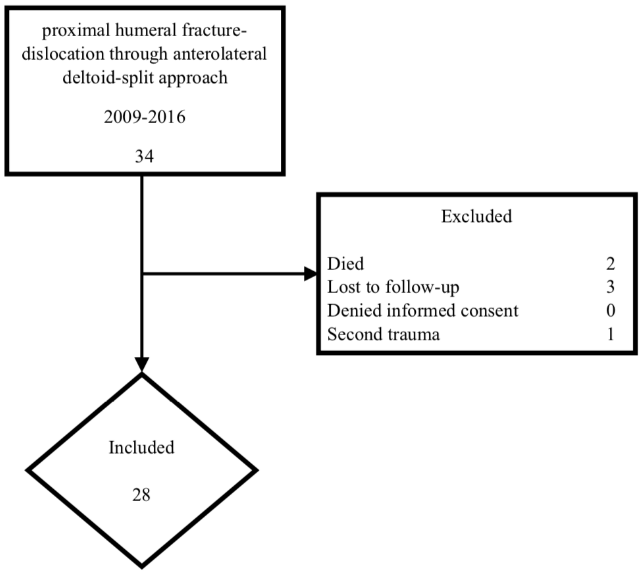


Figure 6. Flow-chart of patient inclusion.

mean SSV was 86 (SD ± 14.6) [Table 2]. 21 patients (75%) had their implant removed, 8 (29%) due to implant-related irritation.

Several complications occurred [Table 3]. Six patients had short-term complications. One patient had a repetitive pull-out of the Schanz screw from the humeral head that required a second deltopectoral approach and four patients had an insufficient primary reduction that resulted in an early re-osteosynthesis (14%). These are classified as treatment related adverse events. In one patient damage to the anterior branch of the axillary nerve was observed, a soft tissue related adverse event (19). There was full recovery after 6 months.

Five patients had long-term complications. One patient (4%) had an implant related complication with a secondary perforated screw tip leading to an osteoarthritis, which was treated by implant removal first and a reversed arthroplasty one month later. Four patients developed an AVN, a fracture related adverse event. Three of them, with a mean age of 59 years, got a conversion into a reversed arthroplasty (11%). AVN was diagnosed at an average of 19 months (SD ± 12.8) follow-up. Sub-analysis shows that patients who develop an AVN have a significant poorer functional outcome according

Table 1. Baseline characteristics

Variable	n (%)
Age, mean (SD)	49 (10.3)
Male	25 (89)
Side	
right	16 (57)
left	12 (43)
Dominant side	
right	25 (89)
left	3 (11)
Trauma mechanism	
Ski / Snowboard	16 (57)
Low energy	6 (20)
Traffic accident	2 (7)
Other	4 (14)
AO classification	
B3	4 (14)
C3	24 (86)
ASA classification	
1	15 (54)
2	11 (39)
3	2 (7)
4	0
Operation time, minutes, mean (SD)	101 (42.5)
Image intensifier time, seconds, mean (SD)	128 (105)
Time to operation, days, mean (SD)	0.5 (2.13)
Follow up time, months, mean (SD)	48 (23.7)

SD Standard deviation

Table 2. Results

Variable	N=28
Functional outcome	
QuickDASH, mean (SD)	6.8 (7.8)
SSV, mean (SD)	86 (14.6)
Implant related irritation / removal, n (%)	
Implant not removed, no irritation	7 (25)
Implant not removed, irritation but implant removal not necessary	0
Implant not removed, irritation, no request for removal due to fear of surgery	0
Implant not removed, irritation, considering removal	0
Implant removed on patient's request without irritation	13 (46)
Implant removed due to implant irritation	8 (29)

SD Standard deviation

Table 3. Complications

Complication groups	Patient cohort N=28
	n (%)
Local complications	
Implant/device	2 (8)
Secondary screw perforation	1 (4)
Implant loosening	0
Implant breakage	0
Other	1 (4)
Bone/fracture/cartilage	8 (28)
Loss of reduction	0
Impaction	0
Nonunion	0
Avascular necrosis	4 (14)
Other	4 (14)
Soft tissue of musculoskeletal system	1 (4)
Bursitis	0
Other	1 (4)
Wound/other soft tissue	0
Superficial infection	0
Deep infection	0
Heamatoma	0
Other	0

Table 4. Avascular necrosis after PHFD

Variable	AVN Yes (N=4) mean (SD)	AVN No (N=24) mean (SD)	*P-value*
QuickDASH	18.9 (11.9)	4.9 (5.21)	**0.009**
SSV	71 (24.3)	89 (11.4)	0.082

SD Standard Deviation

to the QuickDASH (*P=0.009*) and a poorer SSV (*P=0.083*) [Table 4].

Discussion

Osteosynthesis of PHFDs can be performed through a minimally invasive anterolateral deltoid split approach. Above we described our operation technique for MIPO of PHFD. Our results show that osteosynthesis for PHFD through the deltoid split approach can lead to good patient reported functional outcomes. However, 36% of the patients required a re-operation for either conversion into an arthroplasty, shortening of perforating screws or a revision-osteosynthesis. Furthermore, with a total of 75%, we found a very high implant removal rate.

The indication for operative or conservative treatment of proximal humeral fractures in general is still under debate (3, 4, 10). However, the indication for operative treatment of PHFD, either with arthroplasty or osteosynthesis, seems accepted (2, 5, 6). A literature search did not reveal any publications about conservative treatment for PHFD. The standard approach for osteosynthesis of proximal humeral fractures in general is the open deltopectoral approach (20). Over the past decade, there has been increasing interest in the deltoid split approach for proximal humeral fracture treatment (10, 11, 17, 21). With our growing experience in the deltoid split approach for proximal humeral fractures, we started using this approach for difficult cases like fracture-dislocations. In our experience, using this approach, the operative procedure itself becomes easier to perform. The "window" for access to the dislocated head fragment as well as to the tuberosities (esp. the greater, usually posteriorly displaced) is much more direct and "inline" compared to the deltopectoral approach. This facilitates the reduction of these fragments, especially the greater tuberosity. The plate itself is placed directly underneath the approach, what makes the insertion of the proximal screws easier. Another advantage, however hypothetical, might be a positive influence on the blood supply of the humeral head which may reduce the incidence of AVN. Through an anterolateral deltoid split approach there is a smaller risk of damaging the anterior circumflex artery compared to the deltopectoral approach. However, this potential benefit cannot be concluded from this study but might be analyzed in future studies.

The functional outcome in this study is comparable to two other larger studies on PHFD (2, 5). Soliman et al published the results of osteosynthesis of 39 patients who were younger than 40 years old (5). They analyzed four-part PHFD that were treated with ORIF through a deltopectoral approach with either K-wire or locking plate fixation. With an average Constant score of 77, after a mean follow-up of 26 months, they concluded that rigid fixation could lead to satisfactory results. In addition, Trikha et al reported on 33 PHFDs treated patients through a deltopectoral approach for anterior dislocations and through a deltoid-split approach for posterior dislocations (2). In their mean-aged cohort of 35 years old, they found a mean Constant score of 78 after a mean follow-up of 40 months. They concluded that young patients can achieve a good functional outcome after locking plate fixation. Our study, in combination with current literature, supports the choice for primary osteosynthesis of PHFDs, especially in young and active patients.

Several complications have occurred and need to be discussed. As published by Robinson et al. there is a high rate of AVN of the humeral head after ORIF of PHFD (22). They found a radiological AVN in 6 out of 30 patients (20%) treated with ORIF. Three of these patients were asymptomatic and treated conservatively. The other three were converted into a hemiarthroplasty. Our rate of AVN is comparable with literature (2, 5, 22). In our series four patients (14%) were diagnosed with an AVN, of whom three were converted into an arthroplasty. As shown in Table 4, patients who develop an AVN have a poorer functional outcome. Even though Schliemann et al. showed good functional results for reversed total shoulder arthroplasty after AVN (23). According to Hertel and the nature of the fracture-dislocation, one can expect avascularity of the humeral head (24). However, a primarily avascular head does not necessarily result in a symptomatic AVN (25). Radiological AVN can develop without any symptoms and stay asymptomatic or revascularization may occur (22, 25). Therefore, the clinical symptomatic (and not only radiological) AVN seems most relevant. In our analysis we assumed that patients with complaints, possibly because of AVN, have contacted us or another specialist and that x-rays have been made. A possible AVN would have been diagnosed and the patient would know this. Therefor we discussed this actively in the telephone interviews. We are aware however, that, despite the fact that 22 patients had partly or complete outpatient follow-up in our clinic, this might have resulted in an underestimation of AVN.

Besides AVN, several other complications occurred. One patient had screw perforation of the humeral head. The shoulder was converted into a reversed arthroplasty. Temporary axillary neuropraxia occurred in one patient. One patient had a conversion of a deltoid split approach into an open approach due to failure to retrieve the humeral head. Furthermore, four patients needed a re-osteosynthesis after insufficient primary fixation. All the re-operations were performed through the deltoid split approach. Compared to the above mentioned other studies on the operative treatment of PHFD our complication rates are equal (2, 5).

We analyzed our implant removal rates using the algorithm of Hulsmans et al (15). This analysis revealed a high rate of implant removal. 21 patients (75%) had their implant removed, of whom eight (29%) were due to implant-related irritation. Included in these 21 patients are the four patients with shoulder arthroplasty. One of these patients had no irritation of the implant and only one patient had the implant removed at the same time as the reversed shoulder arthroplasty was implanted. We assume the high rate of removed implants reflects our young population as thirteen patients had their implant removed on request without irritation. Unfortunately, we don't have pre- and postoperative functional data before and after the implant removal.

Several limitations regarding this study need to be addressed. First of all, this is a retrospective study that has the usual 'retrospective' drawbacks. Second, a selection was made. Patients who were primarily treated with an arthroplasty for a PHFD were not included. Unfortunately, we were not able to include these patients as they are not recorded in our trauma registry. However, as discussed above, our indication for osteosynthesis of PHFD is in young and active patients. Less active elderly and geriatric patients are treated with an arthroplasty. In addition, our study population is younger than many other studies about proximal humeral fracture treatment in general. This is partially caused by our geographical location in the mountains with young and active patients as can be concluded from the trauma mechanisms. They might have better bone quality and therefore better results. Another limitation is that we used telephone interviews in order to get sufficient follow-up. This resulted in a high rate of follow-up, but we were not able to perform a clinical examination of the shoulder or to obtain long-term radiological follow-up. And lastly, 18% of the patients with a PHFD treated through an anterolateral deltoid split approach were lost to follow-up.

Patient reported functional results after open reduction and internal fixation of PHFDs using the deltoid split approach, analyzed with patient-oriented questionnaires are promising. In 86% preservation of the humeral head was successful. However, there is a high rate of re-operations either because of complications or for implant removal.

Patient consent: All procedures performed involving human participants were in accordance with the ethical standards of the institutional and regional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

Disclosure: All the authors declare that they have no conflict of interest.

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