Treatment of Proximal Humeral Fractures – a Review of Current Concepts Enlightened by Basic Principles

Léčba zlomenin proximálního humeru – přehled současných přístupů s ohledem na základní principy

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SUMMARY

Fractures of the proximal humerus commonly affect elderly patients. The vast majority of proximal humeral fractures result from low-energy trauma in presence of osteoporosis. Incidence of proximal humeral fractures dramatically increased over the last decades. Recent epidemiological studies expect a rather stagnant incidence. Diversity of fracture types attenuates reliability of available classification systems. Even though, predictive morphologic criteria have been detected enabling a prognostic assessment. A short or absent metaphyseal head extension and disruption of the medial periosteal hinge reliably predict ischemia of the humeral head fragment. Still, humeral head necrosis may be prevented in early reduction and fixation. The range of treatment options consists of non-operative therapy, minimal-invasive osteosynthesis, open reduction and plate fixation, intramedullary nailing and primary arthroplasty. Most proximal humeral fractures in the elderly are stable injuries and can be successfully treated by non-operative means. Operative treatment of displaced, unstable fractures should resort to the least invasive procedure providing adequate reduction and fixation stability. To date, open reduction and locking plate osteosynthesis represents the standard operative procedure in displaced three- and four-part fractures. However, a number of risk factors may promote fixation failure or impair functional outcome, most important low local bone mineral density, residual varus displacement of the humeral head, insufficient restoration of medial calcar support, humeral head ischemia and insufficient fracture reduction. Innovation of fixation techniques (e. g. angular stable locking systems and bone augmentation) will further expand indications for operative fracture treatment. Outcome of hemiarthroplasty is closely related to anatomical tuberosity healing and restoration of rotator cuff function. Reverse shoulder arthroplasty may provide satisfactory shoulder function in geriatric patients, rotator cuff dysfunction or failure of first-line treatment. Choice of treatment should be individualized and base on careful evaluation of patient-specific, fracture-specific and surgeon-specific aspects.

INTRODUCTION

Proximal humeral fractures account for about 5% of all extremity fractures and 70% of patients are at least 70 years of age (11). The prevalence of female gender ranges between 73 and 85% (4,11). A 60-year-old women with a life expectancy of 81 years has an estimated residual lifetime risk of 8% of fracturing her proximal humerus (30). The fracture is caused by low-energy trauma in 87% of cases (typically a fall from stand) suggesting presence of osteoporosis (11). Proximal humeral fractures follow femoral neck and distal radius fractures as the third most common osteoporotic fracture type (8). In Finland, the incidence of low-energy proximal humeral fractures among women aged 80 years or older was 88 per 100.000 persons in 1970, sharply increased to 304 in 1995, but then stabilized at a level of 298 in 2007 (22).

Treatment options include non-operative therapy, minimal-invasive osteosynthesis, open reduction and plate fixation, intramedullary nailing and primary arthroplasty. Not least due to advanced fixation techniques, the rate of surgically treated patients continues to increase. Neer (37) estimated that approximately 20% of patients would benefit from surgery in his 1970 essay. In contrast, 53% of French patients were surgically treated in 2001 (34, 37).

This article elucidates presents current concepts in treatment of proximal humeral fractures on the basis of established principles. Common classification systems are introduced with regard to their clinical feasibility and relevance. A special focus is put on osteoporosis and its implications for treatment. The survey intends to assist therapeutic decision-making, which should base on careful case-related analysis and evaluation of patient-specific, fracture-specific and surgeon-specific aspects.

CLASSIFICATIONS

As long ago as 1934, **Codman** (9) proposed a still routinely used classification of proximal humeral fractures. He distinguished 12 fracture morphologies based on the configuration of the four main segments, nominally the shaft, the head, the greater and the lesser tubercle. Based on Codman's segment classification, **Neer** (36) defined 6 subgroups with therapeutic relevance. He recommended surgery when two main fragments were displaced > 45° or > 1 cm. The **AO classification** from 1990 differentiates between three main groups of fractures (extraarticular, partially articular and intraarticular) dividing into a total of 27 subtypes. **Resch et al.** (44) could demonstrate, that the fracture line in four-part fractures does not run through but 5-10 mm lateral of the bicipital groove. Thus, the sulcus is regularly attached to the lesser tuberosity fragment. They described two basic morphologic fracture types, the varus and the valgus fracture. The varus fracture may present as an impaction or distraction type. The valgus fracture may be impacted in straight lateral or posterolateral direction. Valgus fractures rarely occur without impaction. **Hertel et al.** (19) introduced a binary (Codman-LEGO) description system comprising 12 basic fracture types and examined morphologic risk factors of humeral head ischemia. Good predictors were a short metaphyseal head extension (< 8 mm) and disruption of the medial hinge with displacement of > 2 mm. However, Bastian and Hertel (2) pointed out, that initial ischemia may not reliably predict subsequent humeral head necrosis indicating the potential of reperfusion in early open reduction and osteosynthesis. Majed et al. (33) found only low to moderate **interobserver reliability** among available fracture classification systems despite application of CT-based 3D reconstruction models. The Codman-Hertel classification achieved the highest interobserver score (κ= 0.44) followed by the Neer (κ= 0.33), Resch (κ= 0.15) and AO classification system (κ= 0.11).

When is a fracture unstable?

Integrity of the medial calcar, the so-called medial hinge of the humerus, considerably improves biomechanical stability of proximal humeral fractures (26). The periosteum at the medial cortex starts to tear at a head-to-shaft displacement of about 3 mm. Complete rupture of the medial periosteal hinge occurs at displacements of about 35 mm. Therefore, varus-distraction fractures with destruction of the medial hinge represent highly unstable fracture types.

When is a fracture displaced?

To date, Neer's criteria for fractures benefiting from surgical treatment (displacement > 45° and > 1 cm) are continuously revised. With respect to the greater tuberosity, already displacements of > 2-5 mm may represent an indication for surgery (42). Operative treatment should be considered in head-to-shaft displacement of > 50% of the diaphyseal diameter and in varus or valgus deformity of the humeral head with deviation of > 20-30° from the physiological 130° head-to-shaft inclination (10, 35).

TREATMENT MODALITIES

Non-operative treatment

In view of the high prevalence of proximal humeral fractures, there is a lack of prospective, randomized-controlled trials on non-operative treatment, which can be explained by the difficulty of establishing comparability of patient cohorts, fracture types and implementation of treatment. Fjalestad et al. (13) found no significant difference of functional outcome after 12 months of follow-up between open reduction and locking plate osteosynthesis and non-operative treatment of displaced three- and four-part proximal humeral fractures in patients aged 60 years or older. The mean absolute Constant-Score was 52.3 and 52.2 points, respectively. The age- and gender-adjusted value was 74.4% in both groups. The mean ASES-Score measuring subjective outcome was 14.8 and 15.5 points, respectively. This study also included fractures with severe displacement, which was defined as malposition of at least 45° angular deviation and displacement of the greater or lesser tuberosity of at least 1 cm (Neer's criteria). Displacement between the head and metaphyseal main fragments must not have exceeded 50% of the diaphyseal diameter. A prospective study enrolling 160 patients, most of all with one-, two- and three-part fractures, observed a mean difference of 8.2 points between the injured and contralateral shoulder in Constant-Scores and of 10.2 points in DASH-Scores after 12 months of non-operative therapy (17). Foruria et al. (14) examined the relationship of fracture patterns and functional outcomes. In fractures with posteromedial impaction, a poorer outcome was noted as the articular surface displaced inferiorly increasing its distance from the acromion. Worse outcome was noted as a fractured greater tuberosity displaced medially overlapping with the posterior articular surface. Also, patients with lateral impaction fractures had inferior outcomes.

A prospective, observational study reported a predicted risk of delayed union or non-union of 7.0% (17). Occurrence of avascular necrosis of the head fragment is highly variable. Humeral head necrosis may develop in 6.5-15.4% (14, 32). However, reliable predictors could not yet be determined. Interestingly, the incidence of EMG-verified posttraumatic axillary nerve lesions was 30% after a mean of 13.4 weeks and decreased to 15% after 1 year of non-operative treatment (13). In general, closed reduction without fixation may not effectuate substantial improvement of fracture alignment or functional outcome. In consideration of potential risks for soft tissue and neurovascular complications, physicians should critically evaluate indications for closed fracture manipulations (17).

The author's standard therapeutic regimen for non-operative treatment includes shoulder immobilization in neutral or internal rotation for one week. Pendulum exercises are started from week two. Passive and active-assisted physiotherapy is performed during the fourth to sixth week and respects a limit of 90° abduction and flexion. From week 7, active range of motion is continuously increased according to patient's tolerance. Regular x-ray controls are mandatory and should be performed after each progress of the physiotherapeutic regimen. Frequently, non-operative management of proximal humeral fractures tends to be conducted too restrictive. Thereby, it is well known, that prolonged periods of immobilization (> 2 weeks) delay functional recovery (29). Supervised physiotherapy should definitely start within 2 weeks after trauma (24, 29).

Minimal-invasive osteosynthesis

Resch and coworkers (5, 45) introduced techniques of percutaneous reduction and fracture fixation with cannulated screws and K-wires. From a biomechanical point of view, the Humerusblock, using two crossed 2.2 mm K-wires, represents a dynamic type of fixation which enables neutralisation of stress forces occurring at the fracture site. Elasticity of the construct contributes to lower the incidence of secondary fragment or implant displacement particulary in elderly patients with osteopenic or osteoporotic bone structure. Patients with three-part fractures achieved a mean Constant-Score of 61.2 points corresponding to an intraindividual Constant-Score of 84.9% (compared to the non-injured arm). In four-part fractures, the mean Constant-Scores were 49.5 points and 68.5%, respectively.

Compared to isolated, percutaneous K-wire osteosynthesis without locked cortical fixation, the Humerusblock achieved considerably lower rates of secondary fragment or implant displacement (9.8%) (47,48). The rate of humeral head necrosis was 7.8%. Other intramedullary implants without locking mechanism (e.g. Helix wire, Rush pin, Hackethal, Prévot, Ender or Zifko nails) do not seem to provide sufficient biomechanical stability resulting in high rates of non-union and secondary fragment or implant displacements (56).

Current results of minimal-invasive (polyaxial) locking plate fixation are promising (47, 48). The mean absolute Constant-Score was 66.8 points corresponding to an age- and gender-related value of 87% after an average of 17 months of follow-up. Implant-related complications (plate impingement, screw perforation into the glenohumeral joint, loosening of screws) occurred in 17%. The rate of avascular necrosis was 5.5%. No cases of non-union were observed (47).

Intramedullary locking nail osteosynthesis

Ideal indications are displaced two-part fractures. Further indications are three-part and four-part fractures with metaphyseal comminution or diaphyseal involvement but no or minor displacement of the tuberosities. Open reduction and plate fixation is usually preferred in three- and four-part fractures with marked tuberosity displacement. Zhu et al. (58) compared intramedullary locking nail (PHN, Synthes, Switzerland) and locking plate (LPHP and PHILOS, Synthes, Switzerland) osteosynthesis for treatment of two-part fractures. After three years of follow-up, there were neither significant differences with regard to the ASES-Score (90.0 versus 94.0 points) nor the Constant-Score (93.3 versus 94.5 points). The complication rate was significantly lower in the locking nail group (4%) compared to the locking plate group (31%). Screw penetration into the articular surface was the most frequent complication in the locking plate group and required revision surgery in 19% within three postoperative months. A multicenter matched-pairs analysis enrolled 152 patients with displaced two-, three- and four-part fractures treated either with anterograde angular and sliding stable proximal interlocking nails or locking plates (16). After 1 year, functional results were similar with a mean age- and gender-related Constant-Score of 81% and 75%, respectively. Also, total rates of complications were not statistically different (22% and 28%). In the nail group, rotator cuff lesions occurred in 3% being associated with the necessity of arthroscopic treatment and implant removal. Interestingly, the rate of secondary fracture displacement was 18% in the plate group compared to only 1% in the nail group.

Angular stable locked intramedullary nails enhance biomechanical stability of fracture fixation which may be particularly beneficial in osteoporosis (20). Fig. 1 demonstrates treatment of a displaced, osteoporotic two-part fracture of the humeral surgical neck in a 79-year-old woman with an intramedullary locking nail (Multi-Loc Proximal Humeral Nail, Synthes, Switzerland). The implant provides multiple proximal and distal angular stable locking options.

Open reduction and locking plate osteosynthesis

Typical indications comprise two-, three- and four-part fractures with displacement of the tuberosity or head fragments (52). Reconstruction of compound fractures showing tuberosity or humeral head fragmentation usually requires open reduction. Open procedures offer superior control of reduction and more flexible fixation options compared to minimal-invasive procedures. Until

Fig. 1. Displaced, osteoporotic two-part fracture in a 79-year-old woman treated with intramedullary angular stable locking nail osteosynthesis.
Upper left and right: Osteoporotic two-part fracture of the surgical neck with medial disengagement of the shaft due to tension forces exerted by the pectoralis major muscle. Note the metaphyseal comminution zone.
Lower left and right: Postoperative radiographs of intramedullary osteosynthesis with the MultiLoc Proximal Humeral Nail (Synthes, Switzerland). The correct entry point restores head-to-shaft alignment. The nail end must not surmount the cartilage layer to prevent rotator cuff dysfunction. Angular stable locking bolts were inserted proximally and distally to enhance stability in osteoporotic bone.

now, the anatomical, deltopectoral approach represents the benchmark procedure (37). Extended deltoid-splitting approaches may improve posterior exposure but also impose the anterior terminal branch of the axillary nerve at risk (46). A comparative, retrospective study observed no statistically significant difference in clinical, radiographic, and electrophysiological outcomes between the deltopectoral and deltoid-splitting approach (57). It appears crucial to recognize and understand the morphology of the fracture to strategize its reduction and fixation. First, any varus or valgus deformity of the head fragment in relation to the shaft is corrected, which enables anatomical reduction of the tuberosities. The resulting head-tuberosity construct may be effectively stabilised by suture fixation. Next, residual ad latus and rotational deformities are addressed. Preliminary head-to-shaft K-wire fixation may support definite plate fixation. Cloverleaf, buttress and semitubular plates have been largely replaced by site-specific (preformed) locking plates, which provide more secure fixation particularly in osteoporotic bone (49).

A prospective multicenter, observational study reported a mean Constant-Score of 70.6 points 1 year after mono-axial locking plate fixation (LPHP and PHILOS, Synthes, Switzerland) corresponding to an intraindividual Constant-Score of 85.1% (53). The mean DASH-Score was 15.2 points. Complications were encountered in 34% of patients within a 12 months period of follow-up. Notably, 40% of complications were caused by an incorrect surgical technique being already present at the end of the operative procedure. The most common complication (14% of patients) was intraoperative screw perforation of the humeral head. Almost one fifth of patients had to undergo unplanned revision surgery within 12 postoperative months. Another multicenter study reported almost identical results after 1 year of follow-up (7). Secondary screw perforation and avascular necrosis occurred in 8%. In a systematic review of mid- and long-term results, the average Constant-Score was 73.6 points after a mean follow-up of 29.2 months (51). Four-part fractures scored significantly lower than two-part fractures (67.7 versus 77.4 points). The overall complication rate was 48.8% including a revision rate of 13.8%. The most common complications were varus malunion (16.3%), avascular necrosis (10.8%), intraarticular screw perforation (7.5%), subacromial impingement (4.8%) and infection (3.5%). Again, the most common cause for revision surgery was screw perforation. Recently, efforts were made to determine factors predicting functional outcome and failure rates in open reduction and locking plate osteosynthesis (table 1). Hardeman et al. (18) noted superior results in younger patients. More displaced fractures, AO type C fractures, varus fracture configuration and reduced head vascularity (according to the Hertel criteria) resulted in worse

Tab. 1. Selection of important factors influencing outcome in open reduction and locking plate osteosynthesis

Predictive Factors	Variables	Authors (exemplary)
age↑	failure rate↑ outcome↓	Krappinger et al. 2011 Hardeman et al. 2012
local bone mineral density↓	failure rate↑	Krappinger et al. 2011
initial fracture displacement and complexity↑	outcome↓	Suedkamp et al 2009, Hardeman et al. 2012
initial varus deformity deformity↑	failure rate↑ outcome↓	Krappinger et al. 2011 Gardner et al. 2007, Hardeman et al. 2012
quality of reduction↑	failure rate↓ outcome↑	Krappinger et al. 2011 Hardeman et al. 2012
restoration of medial support↑	failure rate↓ loss of reduction↓	Gardner et al. 2007, Krappinger et al. 2011 Gardner et al. 2007
head fragment vascularity↓	outcome↓	Bastian, Hertel 2008, Hardeman et al. 2012

results. Anatomical reduction was associated with a superior outcome. Patients with articular fractures achieved better results after treatment with a plate compared to primary arthroplasty. Gardner et al. (15) emphasized the importance of restoration of the medial support in locked plating of proximal humerus fractures and recommend meticulous placement of a superiorly directed oblique locking screw (calcar screw) into the inferomedial region of the proximal fragment in order to achieve more stable medial column support. Cement augmentation had no effect on maintenance of reduction. Krappinger et al. (27) pointed to the relevance of preoperative assessment of local bone mineral density at the proximal humerus. In addition, restoration of the medial support, anatomical reduction and patients' biological age significantly influenced failure rates. In a comparative clinical trial, fracture site augmentation with calcium phosphate cement significantly decreased secondary fracture settling and intraarticular screw penetration in locking plate osteosynthesis of proximal humeral fractures with metaphyseal comminution (12). However, little knowledge exists about its influence on fracture healing and long-term implications in general. So far, polyaxial locking plates failed to prove clinical superiority related to functional outcome and complications compared to monoaxial locking systems (55).

Fig. 2 illustrates the clinical example of a 45-year-old skier who had sustained a valgus-impacted three-part dislocation fracture. The patient showed excellent clinical and radiological results 4 months after open reduction and osteosynthesis with a locking plate (PHILOS, Synthes, Switzerland).

Primary arthroplasty

Indications for primary arthroplasty are fractures in which adequate reduction and fixation cannot be achieved, as is mostly the case in elderly patients with compound osteoporotic fractures. Arthroplasty should be considered in fractures featuring compromised vascularity of the head fragment. Morphologic critereria indicating the necessity for arthroplasty are an absent or short metaphyseal head extension, disruption of the medial periosteal hinge, a shell-like (thin) head fragment, non-reconstructable head-split fractures and non-reconstructable impression fractures of the humeral head (21).

Hemiarthroplasty is generally preferred to total prosthetic replacement in acute fracture situations. Modular fracture prostheses facilitate restoration of anatomical head-tuberosity-shaft relationships by variable adjustment of humeral height, off-set and retroversion (28, 39). The upper margin of the pectoralis major insertion site constitutes a reliable landmark to restore proper humeral height and retroversion (54). The average distance to the tangent to the humeral head is 5.6 cm. Due to the usually low bone quality in patients requiring arthroplasty, cementation of the stem is mostly preferred. Uncemented hemiarthroplasty with a proximally porous-coated stem represents a viable alternative in younger patients and selective cases (41).

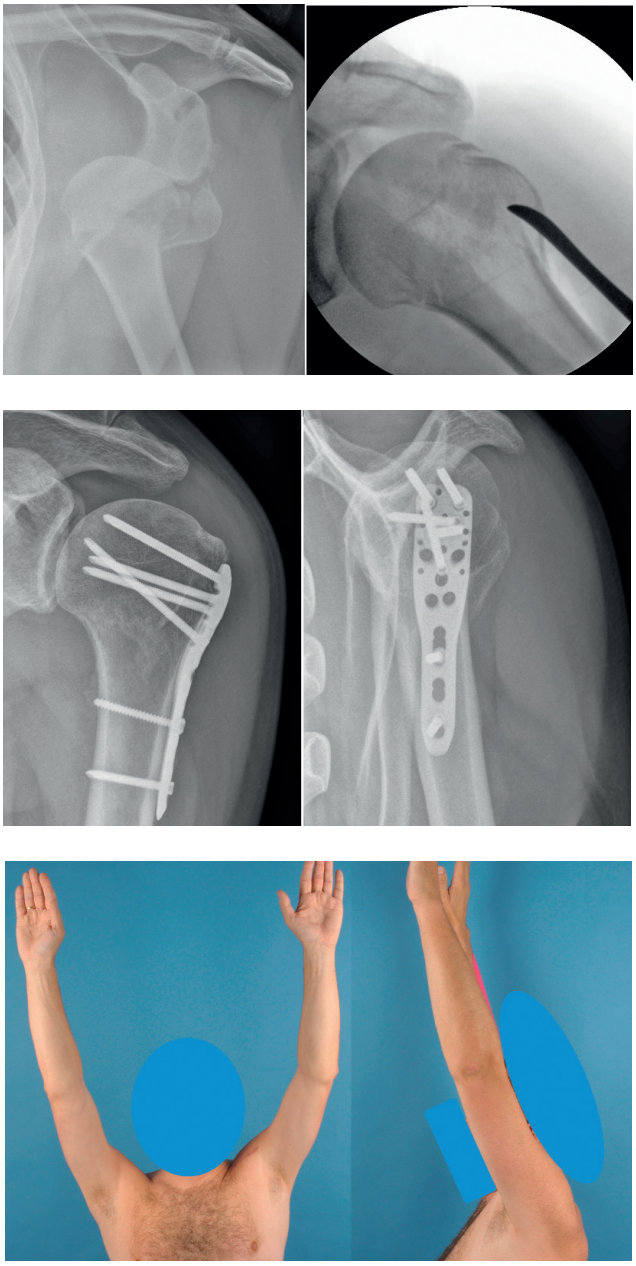

Fig. 2. Valgus-impacted three-part dislocation fracture in a 45-year-old man treated with open reduction and angular-stable locking plate osteosynthesis.
Upper left: Valgus-impacted three-part dislocation fracture.
Upper right: Restoration of the correct head-to-shaft inclination by cautious erection of the head fragment with a raspatorium.
Middle left and right: Follow-up radiographs 4 months after surgery show anatomical healing after locking plate osteosynthesis (PHILOS, Synthes, Switzerland) without signs of humeral head necrosis.
Lower left and right: Excellent clinical result 4 months after surgery with an almost identical range of motion of both shoulders.

Throughout literature, there is considerable discrepancy with regard to functional outcome of primary hemiarthroplasty for treatment of proximal humeral fractures. Subjective outcome often outranges objective clinical shoulder function. In a retrospective multicen-

ter study with a minimum follow-up of 1 year 79% of patients were asymptomatic or reported only minor pain (25). In contrast, only 41,9% were able to flex and only 34,7% of patients to abduct their shoulders above 90°. Anatomical tuberosity healing significantly improved subjective and objective shoulder function. In recent years, functional outcome steadily improved with advancement of both design of prostheses and operative technique. Bastian and Hertel (3) found a median Constant-Score of 70 points (39-84) and a median Subjective Shoulder Value of 90 points (40-100) at a mean follow-up of 5 years after hemiprosthetic replacement. In a long-term survey with a mean follow-up of 10.3 years not more than 47.4% of patients were satisfied with their outcome (1). The results of a randomized-controlled study demonstrated a significant advantage in quality of life in favour of hemiarthroplasty when compared to non-operative treatment in elderly patients with displaced four-part fractures (40). The main advantage appeared to be less pain while there were no differences in range of motion. A retrospective cohort study compared open reduction and locking plate osteosynthesis with hemiprosthesis in three- and four-part-fractures (50). After an average follow-up of 3 years, the cohort treated with locking plate achieved a significantly higher mean Constant-Score compared to the hemiprosthesis cohort (74.6 versus 63.8 points) despite a higher overall complication rate.

Complications specific for hemiarthroplasty may be divided into three chronologic categories (43). Intraoperative complications include component malpositioning (≤ 39%), iatrogenic fracture and axillary nerve injury (≤ 5%). Early postoperative complications consist of tuberosity pull-off (≤ 23%), glenohumeral stiffness (≤ 5%), instability (≤ 15%) and infection (≤ 6%). Tuberosity absorption (≤ 7%) or non-union (≤ 17%), rotator cuff dysfunction (≤ 23%), glenoid erosion or arthrosis (≤ 35%), loosening (≤ 3%), periprosthetic fracture (≤ 2%) and formation of heterotopic ossifications (≤ 30%) represent examples of late complications. Reattachment of the tuberosities with cable wire and additional bone grafting produced better radiographic (healing, displacement, absorption) and functional results than isolated suture fixation (28).

Fig. 3 outlines the clinical example of an 80-year-old female patient who presented with a 4-week-old osteoporotic four-part fracture with posteromedial impaction of the humeral head. The patient was treated with uncemented hemiarthroplasty (EPOCA, Synthes, Switzerland) after failure of non-operative treatment.

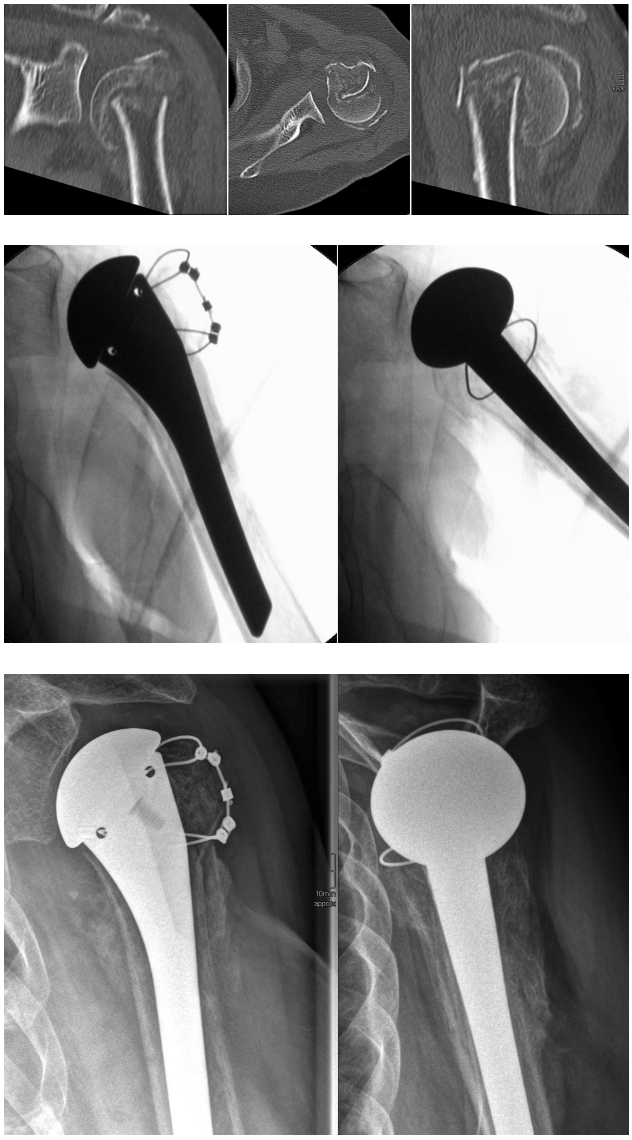

Fig. 3. Osteoporotic four-part fracture with posteromedial impaction in an 80-year-old woman treated with hemiarthroplasty due to failure of non-operative treatment.
Upper row: 4-week-old osteoporotic four-part fracture with posteromedial impaction.
Middle left and right: Intraoperative radiographs of the uncemented hemiprosthesis (EPOCA, Synthes, Switzerland). Both tuberosities are anatomically fixed with a multifilament cable system (TUBERCABLE, Synthes, Switzerland).
Lower left and right: Follow-up radiographs 6 months after surgery show anatomical healing of both tuberosities and correct glenohumeral centering of the prosthetic humeral head.

Reverse shoulder arthroplasty constitutes a second-line treatment option for elderly patients with complex fractures or existing or anticipatory rotator cuff deficiency. Klein et al. (23) evaluated clinical outcome after implantation of the Delta III reverse shoulder prosthesis in elderly patients with acute, comminuted fractures of the proximal humerus. Twenty patients with a mean age of 75 years achieved a mean Constant-Score of 67.9 points after an average follow-up period of 33.3 months. In the mid- and long-term, results consistently deteriorate. Reverse prosthesis may salvage failure of hemiarthroplasty e.g. due to secondary rotator cuff deficiency (31). Boileau et al. (6) radiographically distinguished 4 types of proximal humerus fracture sequelae: humeral head collapse or necrosis (type 1), unreducible dislocations or fracture-dislocations (type 2), surgical neck non-unions (type 3) and severe tuberosity mal-unions (ty-pe 4). The authors recommend non-constrained total shoulder arthroplasty in type 1 and 2, constrained low-

Fig. 4. Subcapital varus fracture in an 85-year-old woman with a massive preexisting rotator cuff tear.
Upper left and right: Two-part (subcapital) fracture with severe varus displacement of the humeral head. The patient suffered from a massive preexisting rotator cuff tear.
Lower left and right: Postoperative radiographs after treatment with a cemented-stem reverse prosthesis (Affinis Inverse, Mathys AG, Switzerland).

profile fracture prosthesis with additional bone grafting in type 3 and reverse arthroplasty in type 4 sequelae. To date, scapular notching still represents the most common complication (44-96%) following reverse shoulder arthroplasty leading to polyethylene wear, synovitis (PE disease), glenoidal bone up to loosening of the glenosphere (38). Further specific complications consist of scapular stress fractures and degeneration of the deltoid muscle.

Fig. 4 shows a subcapital humerus fracture with severe varus displacement in an 85-year-old female patient. The fracture was treated with a reverse prosthesis (Affinis Inverse, Mathys AG, Switzerland) taking account

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Fig. 5 A. Multi-fragmentary head-split fracture in a 67-year-old woman treated with primary hemiarthroplasty requiring secondary conversion to reverse arthroplasty due to tuberosity absorption.
Upper row: Non-reconstructable head-split fracture of the humeral head. Note the inferior migration of the humeral head due to neuropraxia of the motor branch of the axillary nerve.
Middle row: Primary treatment with hemiarthroplasty (EPOCA, Synthes, Switzerland) and additional screw osteosynthesis of the coracoid fracture.
Lower row: Follow-up examination 18 months after surgery showed radiographic tuberosity absorption associated with a clinically relevant dysfunction of the rotator cuff. Meanwhile, reinnervation of the deltoid muscle accomplished recentering of the prosthetic humeral head.

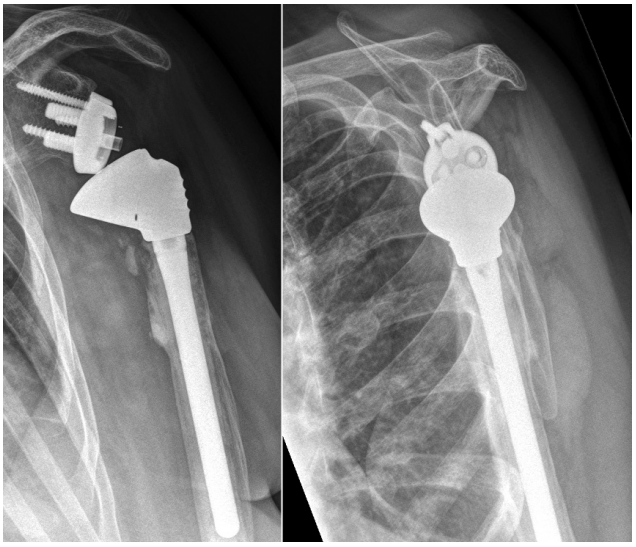

Fig. 5 B. Postoperative radiographs after secondary conversion to reverse arthroplasty.

of the preexisting massive tear of the rotator cuff. Fig. 5 A-B outlines the case of a multi-fragmentary head-split fracture in a 67-year-old woman treated with primary hemiarthroplasty. Tuberosity absorption accompanied by clinical rotator cuff dysfunction required secondary conversion to reverse arthroplasty.

Therapeutic decision-making

Fig. 6 proposes basic guidelines for treatment of proximal humeral fractures considering established predictive factors. It remains a challenge to choose the most suitable treatment option in each case. Therapeutic decisions need to be reassessed at regular intervals and possibly corrected in case of failure. Therapeutic decision-making should be individualized and base on careful case-related analysis and evaluation of patient-specific, fracture-specific and surgeon-specific aspects.

CONCLUSIONS

Most proximal humeral fractures are stable injuries, occur in elderly patients and can be treated non-operatively with good functional outcome. It is a future task to determine references being associated with an increased risk of complications and poor clinical outcome after non-operative treatment. Current classification systems and outcome evaluation tools hardly provide sufficient reliability to compare different treatment modalities on a high level of scientific evidence. Nonetheless, thorough identification of fracture morphology enables prognostic assessment and sets the basis for therapeutic decision-making. Osteoporosis considerably endangers outcome following operative fracture fixation. Range of treatment options includes non-operative therapy, minimal-invasive osteosynthesis, open reduction and plate fixation, intramedullary nailing and primary arthroplasty. Therapeutic decision-making should be individualized and base on careful case-related analysis and evaluation of patient-specific, fracture-specific and surgeon-specific aspects.

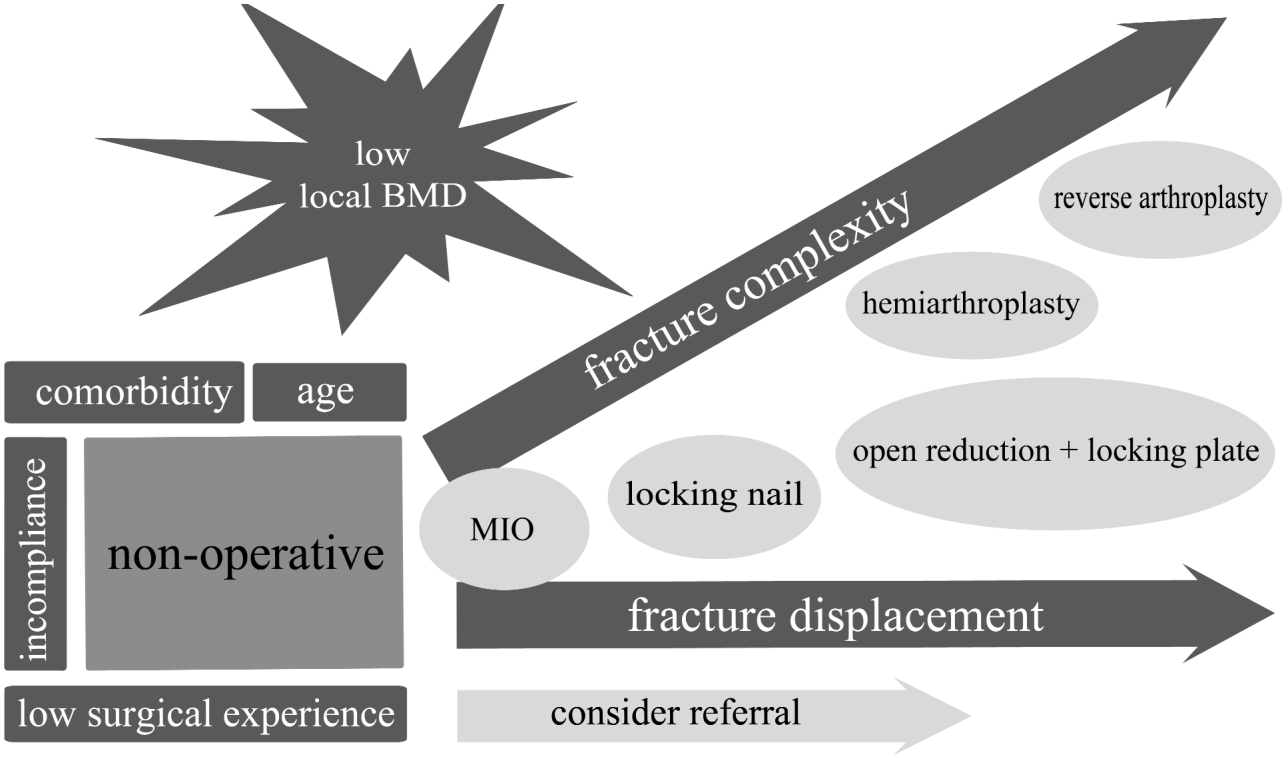

Fig. 6. Abbreviations:BMD: bone mineral density, MIO: minimal-invasive osteosynthesis.

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