Long-term functional outcomes (median 10 years) after locked plating for displaced fractures of the proximal humerus

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\textbf{Background:} Locked plating has become an accepted treatment for displaced fractures of the proximal humerus. However, to our knowledge, long-term outcomes have not been reported.

\textbf{Methods:} Between February 2002 and March 2004, 121 patients with displaced proximal humeral fractures were treated by open reduction and locking plate fixation. Forty-three patients were available for 10-year (95\% confidence interval [CI], 9.8-10.1) follow-up, including Constant score (CS), Disabilities of the Arm, Shoulder and Hand score, and Short Form 36 questionnaire.

\textbf{Results:} Of 43 patients (72\% women; mean age at time of fracture repair, 58.2 years; 95\% CI, 54.2-62.2), the absolute CS 10 years after surgery was 75.3 (95\% CI, 69.2-81.4). The normalized CS was 88.4 (95\% CI, 81.7-95.1), and the CS in percentage to the contralateral side (%CS) was 83.7 (95\% CI, 78.5-88.9). In contrast, at 1 year, the CS was 73.9 (95\% CI, 67.8-80.2, \( P = .774 \)), the normalized CS was 87.2 (95\% CI, 80.4-94.0, \( P = .765 \)), and the %CS was 78.7 (95\% CI, 71.5-85.8, \( P = .355 \)). The CS at 10 years correlated with the CS at 1 year after surgery (\( r = 0.460, P < .01 \)) and with patient gender (\( r = 0.424, P < .01 \)), and it strongly correlated with patient age (\( r = -0.545, P < .001 \)).

\textbf{Conclusions:} Ten years after locked plating of displaced proximal humeral fractures, patients show good to excellent outcomes in the majority of cases with no relevant decline compared with the shoulder function 1 year after surgery. However, poor long-term outcome is seen in 16\% of patients and relates to a low CS 1 year after surgery. Thus, patients developing poor long-term outcomes may be identified at an earlier stage.

\textbf{Level of evidence:} Level IV, Case Series, Treatment Study.

\textbf{Keywords:} Proximal humeral fracture; locked plating; long-term; outcome; loss of fixation; Constant score

The incidence of proximal humeral fractures is rapidly increasing because of the combination of a larger elderly population and the increased risk of fractures for this age group. For the United States in 2030, 275,000 emergency department visits related to acute proximal humeral fractures are estimated, representing a 50% growth compared
with 2008. Although the majority of proximal humeral fractures may be nondisplaced and thus can be treated conservatively, an increase of the surgical treatment for displaced and unstable proximal humeral fractures is observed simultaneously.

The optimal treatment of displaced and unstable fractures of the proximal humerus is controversial. Various techniques from open or closed reduction and fixation by nailing or plating to primary hemiarthroplasty and reversed shoulder arthroplasty exist to address the individual characteristics in each case, attributed by the fracture's morphology (e.g., pattern, medial hinge, vascular supply), the patient's specifics (e.g., age, gender, general bone quality), and the surgeon's personal experience and preference. In particular, comminuted 3-part and 4-part fractures of the elderly patient with osteopenia have been identified as a challenge for the treating surgeon, and locking plates have been introduced to potentially improve the fixation of such fractures. Promising functional and radiographic 1-year results have been published, and locked plating has become a widely used and accepted technique for the treatment of displaced and unstable proximal humeral fractures.

However, recently published data show that complications after locked plating of proximal humeral fractures occur in up to 35%, including avascular necrosis of the humeral head, secondary varus displacement, and concomitant cutting out of screws into the glenohumeral joint. Many complications may be treated by observation or by early hardware removal alone; nevertheless, in some cases, a sequel of interventions is noted. In a selected series of patients with complications after angular stable plating for proximal humeral fractures, more than 50% of patients needed secondary shoulder arthroplasty, and the shoulder function remained substantially restricted even after revision surgery.

Despite numerous publications reporting short-term follow-up, there are few data by which to judge the long-term outcome that can be expected from locked plating of proximal humeral fractures. The purpose of the current study was to report on the long-term outcomes of patients treated by locking plates for proximal humeral fractures and to compare the results with those taken at short-term follow-up. The hypothesis was that the functional outcome after locked plating of proximal humeral fractures would deteriorate over time, and patients undergoing revision surgery would perform worse.

**Materials and methods**

Between February 2002 and March 2004, 121 patients with displaced (>45° angulation or >1 cm between the major fracture segments as outlined by Neer) and unstable proximal humeral fractures were managed by open reduction and internal fixation with a locking plate. None of the patients had an open or a pathologic fracture.

**Patient demographics**

The mean age of the 121 patients included in this study was 68.3 ± 15.5 years, and 72.7% were of female gender. At the time of surgery, 18 patients had a known history of high blood pressure, and 1 patient was diagnosed with diabetes. No patient had a known cancer disease, and no patient had a diagnosis of dementia at the time of inclusion into this study.

**Surgical procedure**

Operation was performed by 1 of 7 experienced senior trauma surgeons with the patient in beach chair position on a radiolucent table and under general anesthesia. An interscalene block was performed as standard perioperative analgesia unless it was refused by the patient. All patients received prophylactic intravenous antibiotics immediately before the procedure. Through a deltopectoral approach, open reduction and internal fixation of all fractures were accomplished. The humeral offset as well as the position of the greater and lesser tuberosities was restored. There were no bone grafts used to support the fixation. During the surgical procedure, the rotator cuff was evaluated for full-thickness rotator cuff tears. Tuberosity sutures (FiberWire No. 5; Arthrex, Naples, FL, USA) were used predominantly. Locked plating was performed by use of the proximal humeral internal locking system (PHILOS; Synthes DePuy GmbH, Oberdorf, Switzerland). Screws were meticulously placed in the subchondral layer not penetrating the articular surface. Accurate fracture reduction and correct position of screws were checked by use of multiple-plane fluoroscopy during all procedures. Furthermore, rotation of the humerus was performed while the radiographic intensifier was used to check the correct subchondral position of the screws. When necessary, screws were exchanged to obtain the intended position of the screw tip relative to the subchondral bone.

The postoperative rehabilitation protocol consisted of supervised passive and active-assisted range of motion starting from postoperative day 1. For the first 6 weeks, abduction and elevation up to 60° without forced external rotation were allowed. Thereafter, active exercises with full range of motion were started.

**Follow-up and outcome measures**

Patients were prospectively observed from the time of operation and longitudinally followed up. Informed consents were obtained from all patients; however, 8 patients refused to participate at long-term follow-up examination. Within the study period of 10 years, 49 patients (40.5%); mean age at time of surgery, 76.7 years; 95% CI, 73.1-80.4) died (Fig. 1). Twelve patients were referred to a nursing home or otherwise moved so that the patient’s contact information changed, making an objective functional assessment inaccessible. At final follow-up, 9 patients (7.4%); mean age at time of surgery, 80.8 years; 95% CI, 73.9-87.7) were diagnosed with dementia and were therefore excluded. In total, 43 patients (35.5%; mean age at final follow-up, 67.6 years; 95% CI,
63.6-71.6; 72.1% female) were evaluated at a median 10 years (95% CI: 9.8-10.1) after surgery, 49 patients (40.5%) died.

At the 1-year follow-up visit as well as at a median 10 years of follow-up, the patient was examined and interviewed in a standardized fashion. A physical examination including range of shoulder motion, strength, and the Constant score (CS) for the injured and contralateral shoulder was performed.9 The CS was accomplished in 3 manners: as a raw value, as a normalized CS according to Katolik,20 and in percentage to the uninjured side (% CS). The CS was described as excellent (86-100), good (71-85), moderate (56-70), and poor (0-55). In patients in whom physical examination at 10 years of follow-up revealed a decline of the CS of >20 points compared with the CS assessed at 1-year follow-up or the long-term outcome was classified as poor (CS: 0-55), detailed evaluation of the rotator cuff by means of physical examination and high-frequency linear transducer ultrasound (Flex Focus 1202; B-K Medical, Herlev, Denmark) was conducted. A full-thickness rotator cuff tear was defined as a hypoechoic or anechoic defect from the bursal to the articular margin.5,37

The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was assessed as a patient-focused outcome parameter at final follow-up visit.15 To evaluate the patients’ subjective results 10 years after surgery, the Medical Outcomes Study Short Form 36 Version 2.0 (SF-36), a standardized computer-administered survey assessing functional outcome, was completed additionally at final follow-up.26

Radiographic evaluation

True anteroposterior and outlet view radiographs were taken preoperatively to determine fracture patterns according to the Neer and AO Foundation and Orthopaedic Trauma Association (AO/OTA) classifications. Of the 43 patients available at 10 years of follow-up, the fracture patterns according to the Neer classification were as follows: 2-part, 8 (19%); 3-part, 26 (60%); 4-part, 8 (19%); and type VI with head split, 1 (2%). In regard to the AO/OTA classification, the patterns were as follows: A2, 2 (5%); A3, 3 (7%); B1, 15 (35%); B2, 11 (26%); B3, 1 (2%); C1, 1 (2%); C2, 9 (21%); C3, 1 (2%). Radiographs were taken routinely at 1 day, 6 weeks, 3 months, 6 months, and 12 months postoperatively to verify fracture alignment and healing. Radiographs were evaluated for loss of fixation, screw cutout, avascular necrosis, nonunion, or implant failure (loosening, breakage). In any case of postoperative complication or in the case that revision surgery was necessary, additional radiographs were conducted until the final treatment had been accomplished.

Statistical analysis

Continuous variables were described by means, 95% confidence intervals (95% CI), and medians. Spearman correlation was used to compute associations between variables.

The Mann-Whitney test was calculated to compare subgroups at one point in time. The Wilcoxon rank test was used to compare changes between the 1- and 10-year measurements. A stepwise regression analysis was calculated to test multivariate influence. Entry criteria were \( P < .1 \), and the criteria to remove were \( P < .2 \). The level of significance was set at \( P < .05 \) for all testing. Statistical analysis was performed with SPSS version 20 (SPSS Inc, Chicago, IL, USA).

Results

Of 43 patients (72% women; mean age at time of fracture repair, 58.2 years; 95% CI, 54.2-62.2) treated by locked
plating for displaced proximal humeral fracture, the absolute CS at median 10 years of follow-up (95% CI, 9.8-10.1) was 75.3 (95% CI, 69.2-81.4). The CS was excellent (86-100) in 44% of cases, good (71-85) in 19% of cases, moderate (56-70) in 21% of cases, and poor (0-55) in 16% of cases. The normalized CS (nCS) was 88.4 (95% CI, 81.7-95.1) and the CS in percentage to the contralateral side (%CS) was 83.7 (95% CI, 78.5-88.9). In contrast, at 1-year follow-up, the CS of these patients was 73.9 (95% CI, 67.8-80.2; \( P = .774 \)), the nCS was 87.2 (95% CI, 80.4-94.0; \( P = .765 \)), and the %CS was 78.7 (95% CI, 71.5-85.8; \( P = .355 \)). The CS at 10 years correlated with the CS at 1 year after surgery (\( r = 0.460; P < .01 \)) and with patient gender (\( r = -0.424; P < .01 \)), and it strongly correlated with patient age (\( r = -0.545; P < .001 \); Fig. 3).

In 6 of 43 patients (14%), the CS decreased more than 20% between 1 year and 10 years after surgery. There was no full-thickness rotator cuff tear evident during the surgical procedure; in 4 of these 6 patients, a full-thickness rotator cuff tear was diagnosed at long-term follow-up by ultrasound and clinical examination. All tears were chronic-type cuff tears of the supraspinatus and infraspinatus tendon with partial muscle degeneration. Patients suffering from a 4-part fracture had lower CS (63.0; 95% CI, 56.1-69.9) 10 years after surgery in comparison to patients with less complex 2-part fractures (77.6; 95% CI, 64.7-90.6) and 3-part fractures (77.9; 95% CI, 68.9-87.1), but there was no significant correlation between the CS at 10 years and Neer classification (\( r = 0.238; P = .125 \)). Table I gives an overview of patient demographics and Table II summarizes Spearman correlations.

The mean DASH score at 10 years of follow-up was 23.8 (95% CI, 15.4-32.1). The mean score of SF-36 questionnaire subgroups were as follows: physical functioning, 61.6 (95% CI, 47.9-75.3); role—physical, 72.2 (95% CI, 59.1-85.4); bodily pain, 71.4 (95% CI, 60.6-82.2); general health, 57.5 (95% CI, 49.2-65.8); vitality, 66.4 (95% CI, 56.7-76.2); social functioning, 66.7 (95% CI, 56.0-77.3); role—emotional, 62.8 (95% CI, 50.0-76.6); mental health, 62.9 (95% CI, 52.1-73.8); and mean overall, 68.1 (95% CI, 59.6-76.5). The DASH score showed strong correlation to the SF-36 (\( r = -0.831; P < .001 \)) and to the CS (\( r = -0.545; P < .01 \)) but was not correlated to other variables included (Table II).

Secondary loss of fixation was seen in 9 (21%), concomitant screw cutout in 4 (9%), and humeral head necrosis in 2 (5%) of the 43 patients. An unplanned second surgery was necessary in 6 cases (14%), managed by early hardware removal alone (\( n = 2 \)), revision osteosynthesis (\( n = 2 \)), humeral head arthroplasty (\( n = 1 \)), and total shoulder arthroplasty (\( n = 1 \)). For details, see Table III. In 17 cases (40%), hardware removal was performed after radiography confirmed complete healing of the fracture approximately 1 year after surgery. Hardware removal was indicated because of persisting rotation deficit, hardware-related impingement, or the patient’s request. Patients who had undergone hardware removal approximately 1 year after surgery had higher CS 10 years after surgery (84.5; 95% CI: 75.1-93.9) in comparison to patients in whom hardware removal was not undertaken (69.2; 95% CI, 61.7-76.8; \( P < .01 \)).

The CS 10 years after surgery correlated with the occurrence of secondary loss of fixation (\( r = -0.413; P < .01 \); Fig. 4) and with the event of an unplanned second surgery (\( r = -0.284; P = .06 \)). A stepwise linear regression analysis revealed a significant association with worse CS at 10 years for age (\( \beta = -0.478; P = .001 \)) and the CS at 1 year after surgery (\( \beta = 0.322; P = .021 \)) but no influence for gender (\( \beta = -0.226; P = .129 \)), Neer classification (\( \beta = -0.205; P = .141 \)), secondary loss of fixation (\( \beta = 0.188; P = .204 \)), and an unplanned second surgery (\( \beta = 0.158; P = .259; R^2 = 0.571; \) adjusted \( R^2 = 0.292; F = 9.7; P < .001 \)).

**Discussion**

We believe that this report is the first to describe the long-term outcomes of locked plating for proximal humeral fractures in a larger cohort of patients (\( n = 43 \)). One of the main results of our study is that the functional outcome at 10 years correlates with the outcome 1 year after surgery and does not decrease significantly over time in the majority of patients. A poor functional outcome, however, was observed in 16% of patients and was related to increasing age and the female gender.

The long-term outcomes in the present study (CS, 75; nCS, 88; %CS, 84) are comparable with those reported previously in shorter term follow-up studies. In a study by Brunner et al., the mean CS at 12 months of follow-up of 133 patients was 72 and 87% compared with the uninjured side. In a multicenter study by Südkamp et al., the mean...
absolute CS 1 year after angular stable plating of 187 patients suffering from proximal humeral fractures was 71 points. The relative CS in percentage to the uninjured site was 85%. With regard to longer term follow-up studies of proximal humeral fractures treated with locking plates, Greiner et al\textsuperscript{11} reported a mean CS of 66 and a mean relative CS of 78% in 48 patients 3 years after surgery. The relatively higher functional outcome in our study compared with the results of Greiner et al might be explained by a relatively lower complication rate of 21% in our study compared with 35%. However, both studies did not find significant differences in comparison with values taken after 12 months.

At 10 years of follow-up, the mean DASH score was 24. In comparison, the study of Brunner et al\textsuperscript{7} reported a mean DASH score 12 months after surgery of 16 points. In a prospective multicenter study by Laflamme et al,\textsuperscript{24} the mean DASH score at 1 year postoperatively was 26 in 27 patients with 2- and 3-part fractures of the proximal humerus treated by locking plates. In a retrospective study of 43 patients, Olerud et al\textsuperscript{14} reported a mean DASH score of 32 after 24 months with no significant difference compared with the results observed after 12 months. Jones et al\textsuperscript{18} described a mean DASH score of 27 in isolated proximal humeral fractures 2 years after locked plating. Comparison of DASH scores appears to be particularly difficult because of significant differences in the results. In our study, the mean SF-36 value after 10 years of follow-up was 68. In comparison, in the study by Inauen et al,\textsuperscript{17} the mean overall SF-36 value 12 months postoperatively was 77 in a cohort of 269 patients with angular stable plated proximal humeral fractures. Although the SF-36 has been proved to be easy to use, reliable, and valid, comparison is difficult because of different cohorts in means of fracture type, age, and study period.\textsuperscript{16} Nevertheless, the subjective outcomes 10 years after fixed angle plating for displaced fractures of the proximal humerus are considerably good.

Six patients (14%) had a decrease of the CS of more than 20% over time. In 4 of these 6 patients, a chronic-type full-thickness rotator cuff tear of the supraspinatus and infraspinatus tendon with partial muscle degeneration was diagnosed by ultrasound and clinical examination. Bahrs et al\textsuperscript{3} reported the prevalence of a rotator cuff tear in the fractured shoulder as 13% higher than the prevalence in the contralateral, uninjured shoulder, and 4-part fractures significantly related with a complete rotator cuff tear. Furthermore, of 74 patients with a satisfactory or poor outcome, 44.6% showed a full-thickness tear of the rotator cuff, whereas in 228 patients with a good or excellent result, the rate of rotator cuff tear was only 11.4%. We suggest that there is a relevant amount of rotator cuff tear in patients suffering from proximal humeral fractures throughout a long-term observation. However, rotator cuff tear as a sequel after locked plating for proximal humeral fracture may not yet be fully understood and is not clarified from this study.

One study observed 57 patients 5 years after locked plating for proximal humeral fractures.\textsuperscript{15} Hirschmann et al reported a mean CS of 70.5 and 87.5% in comparison to the uninjured side. One important finding of this study is that increasing age was found to be a predictive factor for unsatisfactory results, which was confirmed by our study.
However, the authors also reported that the first most predictive factor for an unsatisfactory outcome is the need for revision surgery, which is in contradiction to our results. Interestingly, their reoperation rate was 29% with mainly implant removal, resulting in an improvement of function, although this remained inferior to the shoulder function of patients who did not require a second procedure. In our study, 6 patients (14%) needed an unplanned second operation. We separated patients undergoing early hardware removal due to loss of fixation followed by revision osteosynthesis or shoulder arthroplasty, rather than an unplanned second surgery, from patients undergoing implant removal after complete healing of the fracture. Patients undergoing hardware removal after healing of the fracture indicated for hardware-related impingement or by the patient’s request had higher CS values 10 years after fracture fixation compared with patients in whom hardware removal was not performed. The higher CS was due to a decrease of pain and an increase in range of motion that was inhibited by pain before hardware removal. A previous study showed that clinical outcome significantly improves after implant removal in short-term follow-up; our results suggest that hardware removal is also beneficial with regard to long-term outcome.

There are several limitations to our study. First, the results represent only a fraction of those patients operated on 10 years before. Within the study period, 41% of patients (mean age at time of surgery, 77 years) died (not related to fracture treatment), 17% of patients either refused to participate or did not respond, and 7% were diagnosed with dementia (mean age at time of surgery, 81 years) and were therefore excluded from the study. At first, the resulting follow-up rate of 35% appears low. There are few data on long-term results and long-term mortality after proximal humeral fracture; however, in a study by Olsson, 258 patients suffering from a proximal humeral fracture were prospectively observed. At 13 years after the injury, 61% of patients had died, 12% of patients refused or were otherwise unavailable for the study, and another 9% were diagnosed with dementia and thus excluded, leaving a follow-up rate of 18% of all but 1 patient conservatively treated. The authors concluded that there is a substantial mortality in patients with a proximal humeral fracture.

Second, we report the clinical long-term outcomes after locked plating for proximal humeral fractures. Although a decline of function was notable in some patients, there is a reasonable concern about the long-term sequel of the proximal humeral fracture (e.g., avascular necrosis) in all patients. We did not routinely obtain radiographs at long-term follow-up because of additional radiation exposure. The rate of late avascular necrosis of the humeral head may increase over time and may have a relevant effect on the functional outcome 10 years after fracture fixation.

Although our cohort of 43 patients may well represent the patient suffering from a proximal humeral fracture, the mean age of these patients at the time of fracture repair was 58 years, which is younger compared with other studies of shorter term follow-up. Taken together, one
might assume that the older patients of the cohort are not assessed because of the reasons stated before, whereas the younger patients, alive and participating, may have biased the results in favor of a better outcome. However, to the authors' knowledge, this is the first study reporting on the clinical long-term outcomes of patients being surgically treated for a proximal humeral fracture by use of locking plates.
Figure 4  Absolute Constant score 1 year and 10 years after locked plating of proximal humeral fractures in 43 patients. ns, not significant; *P < 0.01.

Conclusion

Ten years after operative treatment for displaced proximal humeral fractures, the majority of patients showed good to excellent outcomes. Hence, locked plating may be a suitable treatment for displaced proximal humeral fractures with regard to long-term outcomes. In 16%, however, poor long-term outcome was observed, particularly in patients of higher age and of female gender. Because long-term outcomes correlate with the shoulder function 1 year after surgery, patients with poor long-term outcome may be identified at an earlier stage.

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