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ORIGINAL STUDY

Proximal humeral fractures in geriatric patients. Is the angle-stable plate osteosynthesis really a breakthrough ?

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This is a retrospective study of the results of angle-stable plating of displaced 3- or 4- part fractures of the proximal humerus in 92 geriatric patients treated between 2/2000 and 2/2004. At final follow-up patients were clinically evaluated using the Constant-Murley score and were examined radiologically.

The mean non-age-related Constant-Murley score was 69.8 points. A clear correlation was found between the final score and the quality of reposition of the tuberosities and/or plate position. Accurate reduction and plate positioning led to a significantly better functional result. For 28 patients (30.4%), sinkage of the humeral head into the shaft occurred despite angle-stable anchoring.

The currently celebrated angle-stabilising plates did not lead to a significant improvement in functional outcome, compared with other established osteosynthesis procedures.

Keywords : proximal humeral fracture ; angle-stable plate osteosynthesis ; clinical results ; complications ; geriatric patients.

INTRODUCTION

Proximal humerus fractures account for approximately 5% of all extremity fractures. The incidence in the total population is 73 per 100.000 inhabitants per year (*1-3,12,14,16-19,22,27,34*). The age peak lies in the 6th and 7th decades of life. Over 75% of all proximal humeral fractures occur in patients over 60 years of age and over 75% of all proximal humeral fractures occur in women (*1,2,4,13,19,40,44*). Treatment planning must take into account the elevated morbidity that may frequently be expected among these patients. For elderly patients, early recovery and independence in everyday life is a decisive therapy goal (*1,3,13,19,23,25,28,40,44,45,51*).

Displaced 3-or 4-part fractures in elderly individuals represent a surgical challenge despite the availability of numerous fixation devices and implants. Even today, such injuries often lead to poor clinical outcomes. The problems with this

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type of fractures arise from mechanically unfavourable fragment constellations, the complex anatomy of the rotator cuff, the poor anchoring possibilities for any kind of implant owing to osteoporosis, and the risk of nonunion, soft tissue contractures, periarticular ossifications, infection, and avascular necrosis of the humeral head. The goal of surgery is anatomical and stable reconstruction. An unrestricted, early rehabilitation should ideally lead to a good final functional result, allowing satisfactory daily living.

Angle-stable plates have biomechanical advantages over conventional plates. The mechanical problem with classical 4.5mm T-plates (AO) is the absence of angle and length stability of the screws against the plate. Sufficient stability of the humeral head fragment on the shaft cannot be achieved, especially in geriatric patients with osteoporotic bone. Often the head fragment tips off and the screws secondarily become loose. The screw heads present a further disadvantage, as their prominence may cause subacromial impingement, especially when they loosen out. Early functional rehabilitation is thereby made much more difficult ; and re-osteosynthesis sometimes is necessary (*1,3,5,8-10,18,20,21-23,29,32,38-39,41,45,50,52-53*).

Angle-stable plates assure high primary fixation stability. The pitch difference between the wide shaft thread of an angle-stable screw against the fine thread of the screw head has a limited compression effect during final screwing home. Loosening of the screw from the plate is theoretically not possible when correctly anchored. Theoretically, these design characteristics should enable an early passive and active functional rehabilitation, and considerably improve the clinical outcome. The new angle-stable implants were therefore greeted euphorically (*2,5,14-17,21,25,28-29, 33,36*).

The present retrospective study presents the functional results that were achieved with angle-stable implants on the proximal humerus after complex 3-and 4-part fractures among older patients, in comparison with published results of other established fixation options. Since angle-stable implants are more expensive, the choice of implant is also of socio-economical interest.

PATIENTS AND METHODS

From February 2000 to February 2004, 113 patients over 70 years old were treated at our institutions for 3- or 4- part proximal humeral fractures.

Out of the 113 patients, 92 underwent primary internal fixation with an angle-stable plate (Königsee, Aschau, Germany). Angle stable plate fixation was alternated with the following osteosynthesis procedures : the conventional 4.5mm T-plate (12 patients), in rare cases with a K-wire-osteosynthesis (2 patients) or an isolated screw osteosynthesis (3 patients). Nail systems were not used. Primary implantation of a shoulder prosthesis was performed in only 4 patients. All these 21 patients were excluded form this investigation. In the framework of this retrospective study, 92 of the 113 patients (57 women and 35 men, mean age 75.4 years, range 70-96 years) were followed-up clinically and radiologically. Of the 92 followed patients 48 had a 3-part fracture, and 44 patients had a 4-part fracture. Fracture-dislocations were found in 13 of the 92 patients (4 with 3-part fractures and 9 with 4-part fractures).

In 81 cases the fracture was caused by a fall at home, in 8 cases by a car or bicycle accident and in 3 cases, by a sports accident. Associated injuries were present in 12 of the 92 patients.

The clinical and functional results were assessed using the standard Constant-Murley score (max. 100 points) (7). The deltoid muscle was selected to measure force with a force gauge. The mean value of repetitive measurements was recorded. Arbitrarily the results were noted as excellent with a score between 85 and 100, good between 71-84, satisfactory between 56-70 and poor between 0-55.

The first clinical and radiological progress-check took place in the outpatient clinic 6-8 weeks after discharge from the hospital. Subsequently, all 92 patients were invited to a one-year follow-up examination. The latest follow-up examination took place on average 12.4 months postoperatively (range : 11-32 months). Radiographs were evaluated by two independent orthopaedic surgeons.

Operative Technique

The operation was performed under general anaesthesia with intubation, in the supine position, with the patient's upper body slightly raised (not a beachchair position though). Additionally, a small arm support or an arm table was used. All patients received prophylactically an intravenous dose of 2 g Cefazolin® immediately preoperatively. A standard delto-pectoral approach was used to access the proximal humerus. The cephalic vein and the deltoid muscle were retracted laterally. Total removal of the muscle or tendon attachments was not attempted for any patient. The deltoid and pectoralis major muscles were partially loosened from the shaft. Extensive exposure of the fracture with periosteal stripping was avoided in all cases. The goal in all cases was anatomical repositioning of the head and the tuberosities. This was done using indirect pull with small periosteal elevators, before application of the plate. When the humeral head was displaced dorsally, the arm was raised and the shaft was repositioned on the displaced head and after temporary K-wire transfixation, the arm was brought back in the neutral position, following which the plate was applied. The plate was positioned laterally, avoiding excessive cranial positioning as this would cause subacromial impingement. It was first placed against the humerus head and shaft and temporarily fixed with a 1.8 mm K-wire through a hole in the upper end of the plate. With intraoperative fluoroscopy, repositioning was checked in two planes. The tuberosities were secured in an anatomic position with additional transosseous sutures or sutures through the insertion of the supraspinatus or subscapularis tendon. Thereafter, the plate was fixed to the shaft with a cortical screw in the slide hole of the plate. In the humeral head, three diverging angle-stable cancellous screws were brought in, care being taken not to perforate the subchondral bone. Fixation to the shaft was mostly with cortical screws.

On the 3rd postoperative day, we started a physiotherapeutic exercise regime in 83 of 92 patients, first passively, subsequently with active movement exercises of the injured arm to a horizontal position. At the same time, isometric tension exercises were carried out with the patients under supervision from the physiotherapist. The plate was subsequently removed in 26 patients.

Statistical Analysis

Statistical analysis was performed with SPSS 11.0® for Windows®. A test for normal distribution of the data was negative, so exclusively non-parametric statistical procedures (Wilcoxon-Test, Mann-Whitney-U-Test) were used for the group comparisons and the correlation analysis. A probability of $p < 0.05$ was accepted as significant.

RESULTS

Clinical and Functional Outcome

The mean Constant-Murley score was in the upper range of a satisfactory final result : 69.8 (± 20) points (range 22-94 points). The mean score of the uninjured contralateral side was 89.4 (± 17) points (range 46-100 points). The mean age-adjusted Constant-Murley score was 75.2% ± 13% (range 47.5-94.0%).

Eleven patients developed head necrosis (HHN), partial in 6 and complete in 5. HHN was associated with a significant drop in the clinical functional score ($p < 0.05$). These patients only achieved a mean Constant-Murley score of 52.8 ± 18 points, and the age-related score was only 59.8% ± 17%. In 9 of the 11 cases it was associated with a fracture-dislocation. Thus 9 of 13 patients with fracture-dislocation developed HHN (69.2%). Nine of the 11 patients with HHN subsequently underwent hemiarthroplasty owing to severe functional disability and/or considerable pain.

Exact anatomical repositioning of the tuberosities and/or an exact plate position was associated with a significantly better functional result ($p < 0.05$). Table I provides an overview.

A mean Constant-Murley score of 85.2 points was reached for 21 patients (3-part fractures) when reduction and plate position were anatomically correct, whereas, 27 patients (3-part-fractures) with non-anatomical reduction had a mean score of only 67.4 points ($p < 0.05$). Similar patterns were found in patients with 4-part fractures.

Complications

Besides the 11 cases of humerus head necrosis, 28 patients (30.4%) at follow-up showed a sinking of the head shell on the shaft, not prevented by angle-stable anchoring. Thereby, the screws cut out through the head fragment, followed in some cases by a considerable loss of reduction. In 12 of 28 cases (42%), operative revision with replacement of the screws and/or implant was necessary, or early removal of the implant when bony consolidation was reached.

Table I. — Constant-Murley scores in correlation to postoperative reduction (* $p < 0.05$)

Correct anatomical repositioning (including tuberosities)				
Fragments (Number)	Patients (Number)	Constant-Score (injured side)	Constant-Score (healthy side)	Relative Score (%)
3 4	21 19	85.2* (± 19) 82.4* (± 21)	91.8 (± 7) 89.3 (± 9)	92.8* (± 7) 92.2* (± 6)
Non-anatomical repositioning (Varus / malrotation of the tuberosities / incorrect plate position)				
3 4	27 25	67.4* (± 19) 62.8* (± 20)	92.0 (± 5) 90.2 (± 10)	73.3* (± 5) 69.6* (± 16)

Table II. — Complications and their treatment

Complications	Number / %	Comments / Treatment
Humerus head necrosis (HHN) complete	5 (5.4%)	Secondary hemiarthroplasty
Humerus head necrosis (HHN) partial	6 (6.5%)	4 patients : hemiarthroplasty 2 patients : observation
Secondary displacement of cephalic fragment	28 (30.4%)	12 patients : revision surgery (replacement or early removal of the implant)
Soft tissue infection (superficial)	3 (3.2%)	Operative Revision
Soft tissue infection (deep)	1 (1.0%)	Operative Revision
Fixation failure (shaft)	3 (3.2%)	Operative Revision (replacing plate / screws)
Sepsis	1 (1.0%)	Patient died of multiple organ failure

The screw anchoring of the plate in the shaft loosened in 3 further patients (3.2%), but the implant was left in place. Three patients developed superficial soft tissue infection, and one patient developed a deep soft tissue infection (total infection rate : 4.2%). These patients were also treated operatively. A 94-year-old woman with multiple comorbidities died perioperatively, from fulminant sepsis and multiple organ failure. The observed complications are summarised in table II.

The mean operating time was 81.6 ± 19 min (range : 34-143 min) in the investigated patients. The mean total hospital stay was 16 ± 14 days (range : 8-44 days). The mean intra-operative fluoroscopy time was 126 ± 32 seconds (range : 58-348 sec).

DISCUSSION

The treatment of complex humeral 3- or 4-part fractures represents a challenge. The surgeon must obtain an exact anatomical reduction and stable fixation, and at the same time minimise the iatrogenic risk of avascular head necrosis by maximal protection of the periarticular soft tissues (*1-3,5,6,11,14-17, 19,26,27,30-31,42-43,47,51*).

Poor results in these complex fractures are often attributable to one of two causes or to both : 1) inadequate fracture reduction especially of the tuberosities and 2) unstable fixation or incorrect positioning of the fixation devices (10,14,21,29,32,34). There is consensus in the literature that, regardless of the procedure and the implant chosen, a good functional final result depends decisively on anatomical reduction of the fracture combined with a stable fixation, and early initiation of functional rehabilitation of the shoulder (*2,3,6,7,10,14,21,29-30, 33,40,48,51*). In recent years, angle-stable implants have been increasingly used in the operative care of complex proximal humeral fractures. It was hoped that these implants despite an early and secure functional postoperative therapy, would reduce the risk of secondary reduction loss, in particular in elderly patients with osteoporotic bones (*2,3,914-16, 21,26,28,30,32,36,50*).

The average clinical result obtained in our study, with a mean Constant-Murley score of 69.8 points (age adjusted score : 75.2%) is satisfactory.

A correct anatomical reduction with proper plate positioning led to a significantly better result. The Constant-Murley score was significantly lower if anatomical reconstruction did not succeed or a non-anatomical reconstruction was accepted intraoperatively, and/or when the plate was not correctly positioned on the shaft at the proper height to avoid subacromial impingement.

The development of aseptic humerus head necrosis (11 patients or 12%) significantly affected the clinical result ; these patients only achieved a mean Constant-Murley score of 52.8. In the literature the rate of necrosis for 3-and 4-part fractures has been between 0% and 50%, depending on the osteosynthesis procedure (5,9,10,11,14,17,20-22,24,29, 38,40,42,48,51). The rate of HHN (12%) in our study is acceptable and lies in the lower range reported in the literature.

In 28 of the 92 patients, sinking of the humeral head fragment relative to the shaft was seen at follow-up, due to secondary loss of reduction. The praised "stability" of the angle-stable anchoring must be disputed. The angle-stability of the material implanted was not able to secure the repositioning of the head fragment on the shaft. As a consequence, an operative revision was necessary in 12 of the 28 cases (42%). Retrospectively, 23 of these 28 patients underwent iterative surgery within the first 14 months after the index surgery. The learning curve with this implant certainly also plays a role. In later cases we decided to refrain from "drilling through" the cortical shell of the head and we selected a screw length about 5 mm shorter than measured. The results attained in our patients underscore the importance of the restoration of the correct anatomical relationship between the individual fragments. Our results with angle-stable implants lie somewhat behind those published until now for similar injury patterns and similar patient cohorts. The mean patient age in our series is high and the study is limited to complex 3-and 4-part fractures. Bartsch *et al* were able to attain a post-operative exercise-stability in 93.1% of the cases treated with an angle-stable humeral plate, and overall a majority of good to very good clinical result was achieved in their patients (2). The rate of humerus head necrosis was 6.6%. Hente *et al* were able to achieve good and very good clinical results in 64% of the cases with angle-stable plates for displaced 3 and 4-part fractures including fracture-dislocations (*15*). Fankhauser *et al*, Koukakis *et al*, Lungershausen *et al* and Mückler *et al* reported similar experiences with angle-stable plates on the proximal humerus : the mean scores achieved were 74.6, 73.6, 76.1 and 82.8 points respectively (*9,25,32,36*). Kettler *et al* reported about 176 patients, who achieved an average Constant score of 70 ± 19 points after a 9 month follow-up period (*21*). The comparison of our results with those of the individual research groups is not always easy, as the Constant-Murley score is occasionally applied variably (side-adapted, age-adapted, "normalised" or non-adapted). Occasionally the results are not given with numerical values (*2,9,15,21,25,28,32,36*). Some of the studies were on a clearly younger patient population and/or less complex fractures. Taking this into consideration and after eliminating the 2-part fractures or the younger patients, the Constant-Murley score in other publications is similar to ours. The Constant-Murley score in the study of Fankhauser *et al* drops about 10 points from 74.6 to 64.6, when only the complex C-injuries (AO-classification) are considered (*9*).

The functional outcome after angle-stable plating at present is not convincingly better than with traditional implants. The scores obtained with a variety of surgical options is highlighted in table III. Paavolainen *et al* were able to achieve predominantly good results with non-angle-stable upper-arm plates. Wijgman *et al* achieved a mean Constant-Murley score of 80 points with non-angle-stable plates (*52*). Comparing our data with those of Kollig *et al* from our institution shows that the application of an angle-stable implant did not lead to a significant improvement in the Constant-Murley score (*23*).

In an evaluation of a cloverleaf plate, Esser achieved excellent results and an ASES score of 84.6% (*8*). A 2006 prospective study reported an average Constant score of 72.4 points using cloverleaf plates, and 59% of the treated patients achieved good or very good results (*26*). Kohler *et al* achieved good results using the Neer score in 95% of the cases with a clink plate (*22*). With the

Table III. — Functional scores achieved with different treatment options for proximal humeral fractures in the current literature (*Relative Score* : % of opposite healthy shoulder score ; *ASES-Score :* American-Shoulder-Elbow-Surgeons-Score ; *Age and gender adjusted Constant-Score* : Age- and gender-matched to a normal population)

Authors	Treatment / Procedures	Results / Scores		Fracture Types
Bartsch *et al* (2003)	Angle-stable humerus plate	Constant :	Ø 76.4 pts Ø 60.8 pts	3 - fragment 4 - fragment
Hente *et al* (2004)	Angle-stable humerus plate	Constant :	Ø 74.0 pts Ø 83.0 pts	3 - fragment 4 - fragment
Lill *et al* (2004)	Angle-stable humerus plate	Constant :	Ø 77.6 pts Ø 75.1 pts Ø 64.8 pts	2 - fragment 3 - fragment 4 - fragment
Fankhauser *et al* (2005)	Angle-stable humerus plate	Constant :	Ø 74.6 pts	
Kettler *et al* (2006)	Angle-stable humerus plate	Constant : Constant (normalized) :	Ø 70.0 pts Ø 81.0 pts	2 - / 3 - / 4-fragment
Mückler *et al* (2001)	Angle-stable humerus plate	Constant :	Ø 82.8 pts	3 - / 4 - fragment
Koukakis *et al* (2006)	Angle-stable humerus plate	Constant :	Ø 73.6 pts	3 - / 4 - fragment
Lungershausen *et al* (2003)	Angle-stable humerus plate	Neer-Score : Relative Score :	Ø 71.8% Ø 73.6%	
Own patients (2006)	Angle-stable humerus plate	Constant : Relative Score :	Ø 69.8 pts Ø 75.2%	3 - / 4 - fragment
Wijgman *et al* (2002)	Classic T-plate o. cerclage	Constant :	Ø 80.0 pts	3 - / 4 - fragment
Kollig *et al* (2003)	AO-T-plate, screws o. K-wires	Constant :	Ø 72.1 pts	3 - / 4 - fragment
Paavolainen *et al* (1983)	Non angle-stable humerus plate	Neer :	92% 81%	3 - fragment 4 - fragment
Esser (1994)	Cloverleaf plate	ASES-Score :	84.6% very good 7.7% good 7.7% satisfactory	3 - / 4 - fragment
Savoie *et al* (1989)	AO-T-plate	Neer :	89% satisfactory	3 - fragment
Kohler *et al* (1995)	Clink plate / modified DC-plate	Neer :	95% good	subcapital
Küchle *et al* (2006)	Cloverleaf plate	Constant :	Ø 72.4 pts	2 - / 3 - / 4 - fragment
Zingg *et al* (2002)	Percutaneous K-wires	Constant (age-adapted) : Relative Score :	 Ø 90.2% Ø 77.1%	3 - / 4 - fragment
Jiang *et al* (2004)	Percutaneous K-wires	Constant : ASES-Score :	Ø 88.2 pts Ø 91.2%	2 - / 3 - fragment
Lu *et al* (2004)	Percutaneous K-wires + transosseous sutures	Constant : Constant :	Ø 80.8 pts	3 - fragment
Resch *et al* (1997)	Percutaneous K-wires	Constant :	Ø 85.4 pts Ø 82.5 pts	3 - fragment 4 - fragment
Wachtl *et al* (2000)	Prevot-Nails	Neer : Constant :	Ø 63.0 pts 74.0% good	3- /4-fragment
Mathews *et al* (2004)	Proxinal humerus nail (angle-stable)	Constant (age-adapted) :	Ø 57.0 pts Ø 86%	2 - / 3 - / 4 - fragment
Speck et Regazzoni (1997)	PDS-cord	Neer :	27.7% very good 44.4% good 27.7% poor	4 - fragment
Christoforakis *et al* (2004)	Primary shoulder hemiprosthesis	Constant :	Ø 70.4 pts	3 - / 4 - fragment
Anjum *et al* (2005)	Primary shoulder hemiprosthesis	Constant :	Ø 47.5 pts	3 - / 4 - fragment
Kollig *et al* (2003)	Primary shoulder hemiprosthesis	Constant :	Ø 66.2 pts	3 - / 4 - fragment
Hoellen *et al* (1997)	Primary shoulder hemiprosthesis	Constant :	Ø 49.0 pts	3 - / 4 - fragment
Schmal *et al* (2004)	Primary shoulder hemiprosthesis	Constant :	Ø 52.0 pts	4 - fragment

exclusive use of Kirschner wires good results have likewise been reported (*41,51*). Zingg *et al* reported a Constant-Murley score of 77.1 points, Jiang *et al* even a mean score of 88.2 points (*20,53*). Wachtl *et al* used Prevot nails and found at follow-up a mean Constant-Murley score of 63 points (*50*).

A recent retrospective study by Mathews *et al* reported predominantly good to very good results with proximal angle-stable humerus nails, especially in old patients (33). A comparative biomechanical *in vitro* study with humerus nails published by Hessmann *et al* showed theoretical advantages of the nails studied compared to the conventional proximal humerus plate and the angle-stable proximal humerus plate (17). Primary shoulder hemiarthroplasty in multifragment fracture- dislocations reached Constant-Murley scores between 47 and 70 points (*1,6,18,24,27,39,43,45,48-49*).

In summary, comparison of all published results with angle-stable plate fixation and all sorts of other osteosynthesis procedures shows that the results are not significantly different (*1,6,8,18,20,22-23,31,33,40-43,46-47,50,53*). The overall average Constant Murley score in all publications with angle-stable implants is 72 points (*2,9,14,15,21,28,32,36*). The question remains whether angle-stable plates really represent a breakthrough in the care of complex humerus fractures, as it is sometimes purported. An implant that is currently three times as expensive should deliver clearly better results. If not, it is hard to justify the additional expense. Angle-stable plating can in our opinion not reliably prevent the secondary reduction loss and thrusting through of the humeral head shell. Nevertheless, predominantly good results with a mean Constant-Murley score of 82.8, can be achieved using an angle stable implant in older patients with complex humeral head fractures, if an anatomical reduction is obtained and the plate is placed properly.

Whether refinement of technique can improve the outcome remains to be seen.

CONCLUSIONS

The issue of the optimal surgical care of multifragment fractures of the proximal humerus will continue to be a matter of scientific discussion and investigation. On the basis of the results in the current literature and our own experience, the value of angle-stable implants in such cases should be critically questioned. The angle-stable bone plate cannot always effectively prevent secondary reduction loss. Accurate anatomical reduction appears to be more important than the implant used, to achieve a good final functional result, and this factor is independent from the implant design and procedure selected. Equivalent results without angle-stable plating are possible if the surgeon succeeds in restoring anatomy and respects soft tissues.

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