Surgical Treatment With an Angular Stable Plate for Complex Displaced Proximal Humeral Fractures in Elderly Patients: A Randomized Controlled Trial

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Objective: The objective of the study was to evaluate functional outcome, patient self-assessment, and radiographic outcome at 1 year in displaced three- and four-part proximal humeral fractures (OTA group 11-B2 and 11-C2).

Design: Randomized controlled trial.

Setting: Academic medical center.

Patients/Participants: Fifty patients aged 60 years or older with displaced three- or four-part proximal humeral fractures and no previous shoulder injuries were randomized either to surgical treatment or to conservative closed treatment. Twenty-five patients were included in each group. Forty-eight patients completed 12-month follow-up. Two surgical patients died within 3 months.

Intervention: The surgically treated group had a standardized surgical treatment with open reduction and internal fixation using an angular stable plate and cerclages. Instructed physical therapy started the third postoperative day. The conservative treatment group had a standardized nonoperative treatment that included closed reduction if displacement between the head and metaphyseal shaft fragment exceeded 50% of the diaphyseal diameter. Physical therapy started on the fifteenth postoperative day.

Main Outcome Measurements: The main outcome was the mean difference in Constant score between the injured and noninjured shoulder at 12 months. The secondary outcomes were patient self-assessment (American Shoulder and Elbow Surgeons score) and radiographic ratings at 12 months.

Results: At 12 months, mean Constant scores favored conservative treatment by 2.4 points (nonsignificant; P = 0.62). There was no significant difference in mean patient self-assessment. However, radiographic outcomes were significantly better for surgically treated patients.

Conclusion: There is no evidence of a difference in functional outcome at 1-year follow-up between surgical treatment and conservative treatment of displaced proximal humeral fractures in elderly patients.

Key Words: proximal humeral fracture, displaced, surgical treatment, conservative treatment, randomized controlled trial, functional outcome, axillary nerve injury

Introduction

Treatment of displaced fractures of the proximal humerus in elderly patients is challenging. Advanced age is a main predictor of poor functional outcome, and loss of normal shoulder function may impair a patient's ability to manage the level of self-care necessary for independent living. Orthopaedic surgeons searching for the best treatment of a displaced proximal humeral fracture face a variety of options. Surgical treatments include open reduction and internal fixation (ORIF) with Kirschner wires, cerclages, screws, and an angular stable plate or a minimally open procedure using Kirschner wires and screws. Arthroplasty using a traditional prosthesis or a reversed prosthesis as well as nonoperative conservative treatment has also been advocated. In patients with poor bone quality and comminuted fractures, the use of an angular stable implant may be beneficial when surgery is necessary and would likely reduce osteosynthesis failure in the surgical treatment of proximal humeral fractures. However, the optimal treatment of these fractures remains controversial, and functional outcomes can be disappointing.

Although many displaced fractures seem to call for surgery, some question whether a surgical approach is truly advantageous in this population. The limited number of Level I and II studies on this subject lead the Cochrane Collaboration to conclude that there is still no clear evidence supporting the choice of treatment of a proximal humeral fracture. As such, the need for randomized clinical trials of treatment protocols is clear.

The aim of this study was to use a randomized clinical trial to compare functional outcomes after treatment with a standardized surgical treatment (using an angular stable implant)
PATIENTS AND METHODS

Ethics

The study was approved by the Norwegian Regional Committee of Research (Helse Øst). Patients were included after having received thorough oral and written information in accordance with regional ethic committee approval. All patients provided written consent.

Inclusion and Exclusion Criteria

Patients aged 60+ years with a displaced, unstable three- or four-part proximal humerus fracture of OTA group 11-B2 or 11-C2 (displaced fracture of extra-articular or articular, bifocal type) were included in this study. The subgroups 1, 2, and 3 were included for both B2 and C2 groups if the fracture was severely displaced. Severe displacement was defined as malposition of at least 45° angular deviation in true frontal or transthoracic radiographic projections regardless of whether or not the fracture was impacted. The greater or lesser tuberosity had to be displaced at least 10 mm. Furthermore, the displacement between the head and metaphyseal main fragments could not exceed 50% of the diaphyseal diameter.

Exclusion criteria were: 1) younger than 60 years old; 2) history of injury or illness of the injured or contralateral shoulder; 3) injuries of other parts of the humerus or the contralateral upper extremity; 4) alcohol or drug abuse; 5) dementia; 6) neurologic diseases; or 7) severe cardiovascular diseases that would contraindicate surgery. Patients of non-Scandinavian ethnicity were also excluded to reduce possible bias from differences in bone mineral content given the high incidence of osteoporosis in Scandinavians.

Interventions

Patients were randomized to two groups of 25 patients. Patients in the first group received standardized surgical (“open”) treatment, whereas in the second group, patients were treated using a standardized conservative (“closed”) treatment protocol. All patients were enrolled in the study within 48 hours of hospital admission.

Patients Allocated to Surgery

Patients allocated to surgery were operated on within 1 week of hospital admission. The goal of surgery was anatomic reduction of the fracture and fracture stabilization to allow for early mobilization. After surgery, patients were immobilized in a modified Velpau bandage until self-exercises and training instructed by a physical therapist were started on the third postoperative day.

Operative Technique

Surgery was performed under general anesthesia with the patient in a beachchair position. Surgeons were particularly concerned with atraumatic reduction and meticulous soft tissue technique. Surgery was performed using a 10-cm deltoid–pectoral approach with additional percutaneous techniques as needed. Osteosynthesis was performed with an angular stable locking plate device (a nonspecific LCT plate of the AO basic type; Synthes, Bettlach/Solothurn, Switzerland). After identification of the tuberosity fragments, three thin metal cerclage wires were placed at the insertion of the supraspinatus, infraspinatus, and subscapularis tendons. The humeral head fragment(s) was adjusted to anatomic inclination and retroversion using two short Kirschner wires as “joysticks.” The head fragment was temporarily held in position by percutaneous Kirschner wires inserted laterally to the deltoid–pectoral incision. The plate was introduced through the skin incision and slid down along the humeral shaft. The superior part of the locking plate was to be placed at least 1 cm below the top of the greater tuberosity and lateral to the biceps groove to avoid interference with the anterior branch of the humeral circumflex artery. A maximum of three screws can be used in the head fragment with this implant. As the locking screws in the humeral head were introduced through the deltoid–pectoral incision, the screws locking the plate to the humeral shaft were inserted by a percutaneous technique. The metal cerclages secured the greater and lesser tuberosities. An image intensifier was used throughout the procedure to confirm fracture reduction and hardware placement. Three surgeons performed all operations and were trained in the surgical technique before performing surgery on study participants. Surgeons 1, 2, and 3 performed 18, five, and two operations, respectively. Surgery occurred during daytime hours.

Patients Allocated to Closed Treatment

On admission to the hospital, patients were immobilized in a modified Velpeau bandage. All patients allocated to conservative treatment stayed in the hospital for at least 1 day and received the same instructions from the physiotherapist as patients allocated to surgery. If the displacement between the head and metaphyseal fragment (main fragments) exceeded 50% of the diaphyseal diameter, closed reduction was performed in the operating room under general anesthesia; an image intensifier confirmed reduction. Closed reduction was done within 48 hours of admission. After this procedure, the arm was immobilized in the modified Velpeau bandage (a sling bandage immobilizing the arm to the chest and a pillow in the axilla to apply “ligamentotaxis”) and fracture alignment confirmed by radiographic examination. Strict immobilization was required for 2 weeks before range-of-motion exercises were initiated under the guidance of a licensed physical therapist.

The Physical Therapy Protocol

The protocol consisted of physical therapy and recommendations for self-exercise. Both cohorts were treated with the same protocol, differing only with respect to timeline. Fractures treated surgically were regarded as stable, whereas closed treatment fractures were considered unstable. Passive motion and pendulum were introduced after 3 days in the open...
group and after 2 weeks in the closed group. Active motion started at 3 weeks in the open group, 2 weeks earlier than in the closed group. Strengthening exercises started after 6 weeks for both groups. Physical therapy and self-exercise were recommended for at least 6 months.

**Patient Inclusion and the Randomization Procedure**

A senior consulting orthopaedic surgeon determined patient inclusion in the trial after classification of the fracture. All but two of the participants were enrolled by one of the authors (TF); another senior consulting orthopaedic surgeon enrolled the remaining two participants.

Randomization was performed by means of consecutively numbered and sealed nontransparent envelopes containing each participant’s allocation to open or closed treatment. The procedure was designed with the computer software S-PLUS 6.0 for Windows 2002 (Insightful Corporation, Seattle, WA). The block length was 12. Blocks were equal; however, the last one was interrupted because of the number of patients (50).

**Outcome Parameters**

The primary outcome was the difference in mean Constant score between the groups at 1 year. Constant score was used to calculate power and sample size with the software nQuery Advisor 4.0 (Statistical Solutions Ltd, Cork, UK). To detect a difference in mean Constant score of 26 points, with a 5% significance level and 25 patients in each group, resulted in a power of 72%.

The secondary outcome was the difference between the groups assessed using the modified ASES self-assessment form and radiographic results.

**Constant Score**

The score original described by Constant and Murley was used to evaluate the functional outcome at twelve months. The maximum score for each shoulder is 100 points. Both shoulders were rated. To reduce the influence of age, the difference between the scores of the injured and the uninjured shoulder was used. For example, scores of 100, 90, and 80 would have a CSD12 score of zero. We also used the Constant score difference at 12 months. Thus normal function of the shoulder was used. This difference was designated as CSD12.

**Radiographic Evaluation**

The plain X-ray projections were: true anteroposterior projection, transthoracic with neutral rotation of the arm, and a modified West-Point view. Computed tomography scans were performed if subclassification was unclear and/or as a preoperative procedure if the patient was allocated to surgery. The fracture patterns were classified according to the OTA system into types, groups, and subgroups by two of the authors: an orthopaedic surgeon (TF) and a radiologist experienced in skeletal traumatology (JB). Radiographic outcomes were determined using postreduction or surgery radiographs and 1-year follow-up films. Radiographs were rated by an independent observer (orthopaedic surgeon). Agreement between the observers was mandatory. The radiographs were re-examined if there was disagreement after the first radiographic scoring.

The inclination of the head in a true frontal view and the position of greater and lesser tuberosity were rated. Inclination was evaluated as anatomic if there was less than 10° deterioration (2 points), 10° to 20° as 1 point, and severe deterioration as zero points. Anatomic position or less than 5-mm displacements of the greater or lesser tuberosity were rated as 2 points, 5 to 10 mm = 1 point, and more than 10 mm as zero points. Thus, the best rating was 6 points. Implant position was also rated. If the upper part of the locking plate was more than 10 mm below the top of the greater tuberosity, it was given 1 point; 10 mm or less rated zero points. Humeral head screws more than 5 mm from the subcondral surface were 1 point and 5 mm or less rated zero points.

Avascular necrosis was noted as no changes (2 points), changes in normal trabecular organization engaging less than 50% of the humeral head (1 point), and partial collapse of the humeral head surface and/or structural changes engaging more than 50% of the humeral head (0 points).

Measurements were performed with computerized tools (Siemens Magic Web 300 software, Erlangen, Germany).

**Electromyography of the Deltoid Muscle**

Electromyography (EMG) of the deltoid muscle was carried out both in the open and closed treatment groups to clarify if any concomitant injury of the axillary nerve was present that might disturb the functional results. This examination was performed after the 8-week follow-up if the patient gave consent for the additional examination. Clinical signs of atrophy of the deltoid muscle and radiographic signs of “inferior subluxation” of the humeral head were noted, if present, as potential indications of an axillary nerve injury. A positive EMG led to a repeat examination at the 1-year follow-up.

**Clinical Follow-Ups**

The clinical follow-ups were at 2, 8, 12, 26, and 52 weeks. An independent physical therapist performed Constant ratings at 3, 6, and 12 months. The physical therapist did not take active part in the treatment of either group but explained the prescribed self-training program to patients before they were discharged from the hospital. The physical therapists were not blinded to the treatment. Patients completed the ASES self-assessment form at the 6- and 12-month follow-ups. Radiographic examinations occurred at 2, 8, 26, and 52 weeks.
Statistics
The mean values, standard deviation, and 95% confidence interval (95% CI) were estimated for each group. Differences between the groups were tested with independent t-test and Mann-Whitney test as appropriate. We chose 0.05 as the level of significance and adopted the intention-to-treat principle. Analysis was performed with SPSS 16.0 for Windows (SPSS Inc, Chicago, IL).

PATIENTS
During the period May 2003 to May 2008, a total of 603 patients were admitted to the hospital because of a fracture of the proximal humerus. There were 223 Type 11-A fractures (A1 = 48, A2 = 71, A3 = 104), 222 Type 11-B fractures (B1 = 130, B2 = 87, B3 = 5), and 150 Type 11-C fractures (C1 = 52, C2 = 85, C3 = 13). Eight fractures (1.3%) could not be classified as a result of insufficient radiographic examinations.

One hundred seventy-two patients presented displaced proximal humeral fractures classified as OTA group 11-B2 and 11-C2, but 122 patients were not eligible. Eighty-nine patients did not meet the inclusion criteria and were excluded because of age younger than 60 years (n = 15), severe cardiovascular disease (n = 15), fractures less displaced than the radiographic criteria (n = 22), alcoholic abuse or drug addiction (n = 6), dementia (n = 19), former shoulder injuries (n = 10), or non-Scandinavian ethnicity (n = 2). Thirteen patients refused to participate in the study, whereas 20 patients were not included as a result of other reasons (misclassification of the fracture [n = 8], not asked [n = 7], medical reason other than exclusion criteria [n = 3], transferred to another hospital [n = 2]). Thus, 50 patients admitted with a displaced proximal humerus fracture OTA group 11-B2 or 11-C2 could be included and randomized to either closed or open treatment (Fig. 1).

RESULTS
In total, 23 patients treated with surgery and 25 patients treated closed could be analyzed according to the intention-to-treat principle and are presented in this study.

<table>
<thead>
<tr>
<th>TABLE 1. Demographic Baseline</th>
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<tbody>
<tr>
<td>Group Characteristics</td>
</tr>
<tr>
<td>Age, mean years (range)</td>
</tr>
<tr>
<td>Age, median years</td>
</tr>
<tr>
<td>Gender (female/male)</td>
</tr>
<tr>
<td>Injured arm (right/left)</td>
</tr>
<tr>
<td>Dominant arm (right/left)</td>
</tr>
<tr>
<td>Fracture types B2/C2</td>
</tr>
<tr>
<td>Living independently before fracture</td>
</tr>
<tr>
<td>Retired before fracture (%)</td>
</tr>
<tr>
<td>Prefracture medical conditions</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>Pulmonary disease</td>
</tr>
<tr>
<td>Diabetic disease</td>
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<tr>
<td>Concomitant injuries</td>
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Demographic of Included Patients

The two groups were well balanced at the baseline of the study with respect to age and prefracture conditions. However, gender distribution was dissimilar between groups. In both groups, three patients had additional injuries. In the open group, one had an ipsilateral olecranon fracture and one had a tibial condylar fracture. Both were treated with ORIF. Another patient had a vertebral fracture without neurologic signs that was treated with a brace. Among closed treatment patients, one had an ipsilateral olecranon fracture and another had a hip fracture, both treated operatively, whereas one had a wrist fracture treated with a cast (Table 1).

Functional Results

At 12 months, the mean Constant score difference at 12 months (CSD12) for patients treated open was 35.2 (95% CI, 27.7–42.6) and mean CSD12 for patients treated closed was 32.8 (95% CI, 26.1–39.5). The mean adjusted Constant score at 12 months (ACS12) were 74.4 (95% CI, 61.7–87.0) and 74.4 (95% CI, 65.0–83.9), respectively. The mean difference in CSD12 was 2.4 in favor of closed treatment (nonsignificant, \( P = 0.62 \)). The CSD during the follow-up and ACS at 1 year are presented in Table 2. The subdivision of outcomes concerning pain, activity of daily living, function, and strength at 1 year are listed in Table 3.

SELF-ASSESSMENT

Patients’ self-assessment (ASES score) at 12 months were 14.8 (95% CI, 11.9–17.6) for patients treated open and 15.5 (95% CI, 12.7–18.4) for patients treated closed. The difference was 0.7 points in favor of the closed group. The results for both shoulders at 6 and 12 months are presented in Table 4.

Radiographic Results

The interobserver reliability for group classifications according to OTA (plain radiographs and computed tomography scans) was rated as good (kappa value 0.74). Interobserver reliability for scoring of plain radiographs at 1 year was rated as moderate (kappa value 0.54).

At baseline, the two groups were equally balanced with regard to the fracture groups: 13 B2 fractures and 12 C2 fractures in each group. OTA subgroups are shown in Table 5. Eight patients in the closed treatment group required closed reduction as a result of a displacement between shaft and main head fragment exceeding 50%: B2.2 (n = 4), B2.3 (n = 3), and C2.2 (n = 1).

The mean value of radiographic ratings in the open patients was 4.9 points both postoperatively and at 12 months. In the closed group, the mean value was 2.5 points after closed reduction and 2.3 points at one year (Table 6). There were eight patients with avascular head necrosis (two rated as 0 point and six rated as 1 point) in the group treated open and 13 in the closed group (six rated as 0 point and seven rated as 1 point). Two closed group patients had nonunions (B2.2 and C2.2).

Complications

Two open group patients died within 3 months of inclusion. One woman (age 84 years, OTA group C2.2) with cardiovascular disease and diabetes developed peritonitis 6 days after shoulder surgery, underwent hemicolectomy for a colon perforation, and died 9 weeks later. Another woman (age 81 years, OTA group B2.3) with cardiac disease was discharged from the hospital in good condition after surgery but died at home 8 weeks later.

At the 6-month follow-up, one woman (62 years of age) was diagnosed with hardware failure and underwent reosteosynthesis with bone grafting. Subsequently, the fracture healed with good functional result (ACS12 = 89). One woman (88 years of age) allocated to closed treatment had surgery 2 weeks after inclusion as a result of redisplacement of the fracture. The fracture healed without any further complications (ACS12 = 75). Another two women in the closed group (86 and 78 years of age) developed painless nonunion of their fractures and required no further treatment (ACS12 = 28 and 57). Radiographic examination at 1 year revealed

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**TABLE 2. Functional Rating at Follow-Ups**

<table>
<thead>
<tr>
<th></th>
<th>3 Months CSD3</th>
<th>6 Months CSD6</th>
<th>12 Months CSD12</th>
<th>12 Months ACS12</th>
<th>Difference 12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical</td>
<td>52.6 (12.8)</td>
<td>45.6 (15.5)</td>
<td>35.2 (17.2)</td>
<td>74.4 (29.4)</td>
<td>2.4 (P = 0.62)</td>
</tr>
<tr>
<td>Conservative</td>
<td>47.1 (16.9)</td>
<td>40.5 (18.9)</td>
<td>32.8 (16.2)</td>
<td>74.4 (22.9)</td>
<td>0.0 (P = 0.99)</td>
</tr>
</tbody>
</table>

*Constant score difference (CSD) and adjusted Constant score (ACS) at 12 months.

SD, standard deviation.

**TABLE 3. Mean Subscores for the Injured Shoulder at 12 Months (No Adjustment for Age and Gender)**

<table>
<thead>
<tr>
<th>Subscores CS</th>
<th>Pain</th>
<th>ADL 1</th>
<th>ADL 2</th>
<th>ROM</th>
<th>Strength</th>
<th>CS Total (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical</td>
<td>11.1</td>
<td>5.5</td>
<td>7.7</td>
<td>17.0</td>
<td>10.9</td>
<td>52.3 (43.2–61.2)</td>
</tr>
<tr>
<td>Conservative</td>
<td>11.7</td>
<td>5.2</td>
<td>8.7</td>
<td>18.2</td>
<td>9.9</td>
<td>52.2 (44.6–59.7)</td>
</tr>
</tbody>
</table>

Best scores: Pain = 15 points; ADL 1 (activity of daily living) = 10 points; ADL 2 (positioning of the arm) = 10 points; ROM (range of movement) = 40 points; Strength = 25 points; Best score Total = 100 points.

CS, Constant score; CI, confidence interval.
penetration of 11 screws into the joint space in seven patients of which all but one had a C2 group fracture. The implants were removed in three patients. Two of these patients (both women aged 70 years) developed avascular head necrosis by the 1-year radiographic examination (rated 0 points) and had a low ACS12 (38 and 36). However, they had little pain and did not want prosthetic replacement. There were no infections or hematomas.

Twenty-one patients treated open and 20 patients treated closed had an EMG of the deltoid muscle at a mean of 13.4 weeks (range, 7–28 weeks) after injury. EMG verified partial axillary nerve lesions in seven patients treated surgically. Six patients treated closed showed an axillary nerve lesion (one severe lesion). Most lesions engaged the motor function in the anterior part of the deltoid muscle.

Repeat EMG examination at 1 year showed recovery in four patients treated open and three patients treated closed. Two closed treatment patients did not display either clinical or neurophysiological recovery. Three patients in the open group (one with persistent deltoid atrophy and strength reduction) and one in the closed group (persistent deltoid atrophy) were not re-examined at 1 year. The median CSD12 (range) for the seven open group patients with an axillary nerve injury was 28 (13–62) and 48 (1–55) for the six closed group patients with axillary nerve injury.

DISCUSSION

In this study, there is no evidence that ORIF with an angular stable device of severely displaced B2 and C2 proximal humeral fractures in elderly patients using an angular stable device results in better functional outcome compared with conservative closed treatment.

Our conclusion relies on a precise classification of the radiographs. In the literature, classification in Types 11-A, 11-B, and 11-C shows a good reliability in inter- and intraobserver studies. The classifications in Groups 1, 2, and 3 are less reliable, and further classification into subgroups produces poor kappa values.18 In this study, trained observers provided classification. Computed tomography was conducted before inclusion if there was doubt concerning B2 or C2 type. The interobserver reliability for classification of the radiographs, together with computed tomography scans, was good (kappa 0.74). This value corresponds to interobserver agreements reported by Brunner for AO/OTA classification in his study.19 Nevertheless, misclassification would lead to a false inclusion and an unfair comparison between groups.

In this study, both functional scoring by independent physical therapists and patients’ self-assessment led to the same conclusion. ACS12 for the open group was not inferior to functional outcome in other studies dealing with angular stable ORIF or percutaneous techniques in displaced proximal humeral fractures.10,20,21

The demographic baseline between the two groups showed little difference in age, but gender distribution was unequal. Although functional results are adjusted for age and gender, there is an inherent inequality. Shoulder function depends on both age and gender, especially with reference to strength, which is 25% of the total score.16 The 95% CI for mean CSD12 is less than 15 points for each group, which is within acceptable limits according to the responsiveness of the outcome measure. However, the differences between the groups are less than the smallest detectable change for the outcome measure and less than the assumption in the power calculation.22 This could result in bias in interpretation. The small sample size represents another limitation that could lead to a false conclusion if an existing difference between the two groups goes undetected.

The radiographic rating at 12 months was best in the open treatment patients (4.9 points), gaining 82% of maximum score versus 46% in the closed group (2.3 points) (Fig. 2 and 3). Avascular head necrosis was almost twice as high among the closed treatment patients (15 versus eight). However, this did not influence the functional outcome at 1 year nor did the two nonunions in the closed group, yet the radiographic scoring of avascular head necrosis as 1 point means a discrete change in the radiologic findings without symptoms. Nevertheless, despite the joint surface appearing normal at 1 year, the change in trabecular structure may progress to be symptomatic in the future. The higher incidence of avascular necrosis in the closed group is unusual, because previous series have generally described higher rates of avascular necrosis in surgically treated patients. Our results may be attributable to fracture consolidation in a less preferable position, as described in Hertel’s study.14

| TABLE 4. ASES Self-Assessment Score at 6 and 12 Months* |
|-----------------|-----------------|-----------------|
| ASES Score Shoulder | Surgical Injured | Noninjured | Conservative Injured | Noninjured | Difference Injured |
| Time 6 months (SD) | 13.5 (6.6) | 23.3 (1.2) | 13.4 (6.7) | 23.6 (1.1) | 0.1 (P = 0.98) |
| Time 12 months (SD) | 14.8 (6.6) | 23.4 (1.6) | 15.5 (6.9) | 23.2 (1.6) | 0.7 (P = 0.71) |

*Best score 24 points.
ASES, American Shoulder and Elbow Surgeons; SD, standard deviation.

| TABLE 5. OTA Subclassification of Included Fractures |
|----------------|-----------|-----------|
| OTA Group | No. | Percent | Surgery | Conservative |
| 11-B2.1 | 8 | 16 | 5 | 3 |
| 11-B2.2 | 8 | 16 | 2* | 6 |
| 11-B2.3 | 10 | 20 | 6 | 4 |
| 11-C2.1 | 12 | 24 | 4 | 8 |
| 11-C2.2 | 7 | 14 | 4* | 3 |
| 11-C2.3 | 5 | 10 | 4 | 1 |
| Total | 50 | 100 | 25 | 25 |

*Died during follow-up: one B2.3 and one C2.2.
The radiographic rating of implant position scored 60\% of maximum. “Sinking” of the head along the screw axis accounted for double the number of screws with less than 5 mm distance to the joint surface at the 1-year assessment as compared with the postoperative assessment. Penetration of screws into the joint space was observed in seven patients (11 screws) at 1 year compared with five patients (seven screws) at the first radiographic examination postoperatively. All but one patient had a C-type fracture and concomitant radiographic signs of avascular head necrosis at 1 year were present in all seven patients. Penetration of screws into the joint space and sinking of the head have been reported as occurring frequently when angular stable devices are used in the treatment of proximal humeral fractures, particularly with C-type fractures. 23,24

The biomechanical advantages of the angular stable locking plate technique seem to be superior to former fixation methods, 7,25 yet some authors have raised critical questions about the technique. 6,24 There are several predictors of success with surgical treatment of a proximal humeral fracture such as careful soft tissue management, anatomic reduction, and proper plate placement. Unfortunately, primary devascularization of the head fragments resulting from the injury itself, particularly in severely displaced Type B fractures and in most displaced C fractures, is an important problem that cannot be controlled by the surgeon. 14 Despite anatomic reduction, the humeral head may be subject to segmental collapse and deformation. To achieve normal shoulder function, fixation of the tuberosity is mandatory. We used thin nonwired metal cerclages as a tension band device to unload the forces acting on the fixed head fragment. The position of the tuberosity was rated “acceptable,” although not optimal, in this study.

We acknowledge several limitations to our study. First, anatomic reduction was not achieved for all patients, which may cause a change in the biomechanical forces acting on the glenohumeral joint. This may partly explain poor outcome for some of the patients treated with surgery. Precise anatomic reduction of severely displaced fractures in elderly patients with poor bone quality still remains a problem (Fig. 2). Additionally, use of a LCT plate does not correspond to the current trend, because anatomic preshaped plates including multiple small fragment locking screws are in common use today. 10,20 However, the T-shaped plate was a typical implant used for treating proximal humeral fractures before the anatomic shaped plates were available. 26 Complication rates related to hardware failure (one patient experienced pullout) with the LCT plate were low in this study.

Another option for surgical treatment of elderly patients with displaced proximal humeral fractures, especially of OTA group C2, is arthroplasty. The traditional use of hemiarthroplasty in the elderly has not proved to be superior to angular stable plates. 27 An important problem has been tuberosity nonunion and the rotator cuff degeneration common in many elderly patients. 28 Recently, reverse prosthesis has been recommended as a better option, 5 but to our knowledge, superiority has not yet been proven. 9

Physical therapy and early mobilization are important in both open and closed treatment of proximal humeral fractures. 1,29 Loss of range of motion is a known problem with these fractures. Despite efforts for early mobilization,
range-of-motion issues continued to be a major problem in our patients, because patients in both treatment groups lost 50% of their shoulder movement (Table 3). The difference in timeline of the physical therapy program may represent a bias in the interpretation of the results. After ORIF of an articular fracture, the principle of immediately functional treatment is important. To relieve pain for closed treatment patients, immobilization for a short period is necessary. To immobilize the open treatment patients for 2 weeks, to create the same mobilization protocol would present an ethical problem.

Several complications after proximal humeral fractures have been well described in the literature. A frequently reported complication is injury to the axillary nerve. Because the clinical diagnosis is reported to be imprecise, we decided to verify the diagnosis by neurophysiological examination. In our study, the incidence of EMG-verified axillary nerve lesions was 32% (13 of 41 EMG-verified patients). The lesions were equally distributed between the groups and showed acceptable recovery and therefore are unlikely to have confounded the outcome. However, it could not be clarified if the surgical procedure caused any of the seven partial lesions in the open treatment group. The equal distribution of examinations and nerve injuries between the two groups may suggest that this factor did not represent a bias to the final 1-year outcome. The difference in median CSD12 score (21 points) between the patients with axillary nerve involvement treated open compared with those treated closed is not significant. Although the fact that this favors open treatment is opposite to reports in the literature. As a result of the small number of patients in the study, it is not appropriate to draw final conclusions. Nevertheless, the results may indicate that the small deltopectoral approach used for surgery as well as the atraumatic reduction technique does not harm the nerve. Furthermore, consolidation of the fractures treated closed in a less preferable position may possibly be harmful to the nerve. One-year follow-up limits the validation of late complications such as head collapse resulting from avascular necrosis. Other authors have shown that follow-up for 12 months is sufficient for validation of operative treatment with internal fixation. However, function may deteriorate later than 1 year after surgery, because secondary glenohumeral osteoarthritis may develop and cause pain and impaired function. This could possibly favor the functional outcome in the closed treatment group later. In contrast to this assumption, several complications associated with the locking plate technique in three- and four-part fractures in patients older than 60 years of age have recently been the focus of a study with a mean follow-up of 31 months. Based on long-term results (10-year) after nonoperative treatment for three- and four-part proximal humeral fractures, closed treatment has been recommended for three-part fractures.

In validating the results of the present study, the limitation of short follow-up (1 year) has to be taken into account. However, after considering both study results and limitations, closed treatment of displaced proximal humeral fractures in elderly patients is a reasonable option to surgical treatment with ORIF using an angular stable device.

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