The optimal treatment for proximal humeral fractures is controversial. Few data exist concerning the influence of the surgical approach on the outcome. The purpose of this study was to evaluate the clinical and radiological outcomes of proximal humeral fractures treated with locking plate fixation through a deltopectoral vs an anterolateral deltoid-splitting approach.

Of 86 patients who met the inclusion criteria, 70 were available for follow-up examination. Thirty-three patients were treated through a deltopectoral approach and 37 through an anterolateral deltoid-splitting approach. In all cases, open reduction and internal fixation with a PHILOS locking plate (Synthes, Umkirch, Germany) was performed. Clinical follow-up included evaluation of pain, shoulder mobility, and strength. Constant score and Disabilities of the Arm, Shoulder and Hand (DASH) score were assessed. A clinical neurological examination of the axillary nerve was also performed. Consolidation, reduction, and appearance of head necrosis were evaluated radiographically. After a mean follow-up of 33 months, Constant scores, DASH scores, and American Shoulder and Elbow Surgeons scores showed no significant differences between the groups. Clinical neurologic examination of the axillary nerve revealed no obvious damage to the nerve in either group.

Deltoid-root and anterolateral deltoid-splitting approaches for plate fixation of proximal humeral fractures are safe and provide similar clinical outcomes. The results of this study suggest that the approach can be chosen according to surgeon preference.
Proximal humeral fractures are the third most common fracture in elderly patients, with more than 90% of the patients aged 60 years and older. The increased incidence in the older population is thought to be related to osteoporosis. According to epidemiologic studies, proximal humeral fractures are increasing in incidence as the population ages.

Up to 80% of proximal humeral fractures are nondisplaced fractures or fractures with minimal displacement and adequate stability that can successfully be treated nonoperatively. However, the optimal treatment of displaced or unstable fractures remains controversial. Various techniques, including open reduction and internal fixation with proximal humeral plates, intramedullary nailing, percutaneous or minimally invasive techniques with pins or screws, and arthroplasty, have been described in literature. Over the past decade, the trend has been toward angular stable plate fixation. Several biomechanical studies showed better stability for angular stable implants when compared with conventional plates and numerous clinical studies reported good clinical results for proximal humeral fractures treated with angular stable plates.

Despite many studies that address the treatment of proximal humeral fractures, the influence of the surgical approach on the outcome has been reported in few studies. For many years, the deltotegmental approach to the proximal humeral region was seen as the gold standard, even for plating of proximal humeral fractures. Currently, many surgeons agree that a deltopectoral approach may not be the best option when performing an angular stable plate fixation due to the substantial soft tissue dissection. Therefore, the less-invasive deltid-splitting approach, well known from rotator cuff surgery or intramedullary nailing, has recently been used for plate fixation of proximal humeral fractures. In contrast, opponents of the deltid-splitting approach argue that it involves the risk of injury to the axillary nerve, which is historically seen as a limitation of the anterolateral deltid-splitting approach.

The purpose of the current study was to evaluate the clinical and radiological outcome after locking plate osteosynthesis of displaced proximal humeral fractures depending on the surgical approach (deltoid-splitting vs deltid-splitting) and to identify clinically obvious influences on the axillary nerve function. The authors hypothesized that the choice of approach would not have crucial influence on the clinical outcome.

**Materials and Methods**

Eighty-six patients sustained acute fractures of the proximal humerus and were treated by locking plate fixation between 2004 and 2008 at the authors’ institution. Seventy (81.4%) of 36 women and 41 men; mean age, 59 years (range, 31-83 years) of the 86 patients were available for follow-up examination at a mean of 33 months (range, 12-60 months). All fractures met the indications for operative treatment as outlined by Neer (ie, angulation of the articular surface of more than 45° or displacement of more than 1 cm between the major fracture segments) or were classified as unstable during the passive examination with the use of an image intensifier, as previously described in the literature. Patients were included in the current study if they were older than 18 years and skeletally mature. Patients with multiple injuries, pathological fracture or refracture, nonunion, previous surgical treatment of the proximal humerus, and concomitant ipsilateral fracture of the distal part of the humerus, the shoulder, or the elbow joint were excluded from the study. Other exclusion criteria included a post-traumatic brachial plexus injury or peripheral nerve palsy. All fractures were classified by a single experienced surgeon (T.F.) using plain radiographs (anteroposterior and transscapular views). The group distribution of fracture types according to the Neer classification is shown in Table 1.

Surgery was performed through a deltopectoral approach in 33 patients and through an anterolateral deltid-splitting approach in 37 patients. All procedures were performed by 5 experienced trauma surgeons (U.S., T.F., F.E.) who preferred 1 approach over the other. Therefore, the choice of approach for each patient was random depending on the surgeon involved because each surgeon used only 1 approach.

The distribution of age and sex by group was 24 (65%) women and 13 (35%) men with a mean age of 59 years (range, 30-83 years) in the deltid-splitting group and 12 (36%) women and 21 (64%) men with a mean age of 56 years (range 35-74 years) in the deltopectoral group. The dominant upper limb was affected in 13 (35%) patients in the deltid-splitting group and in 11 (33%) patients in the deltopectoral group.

**Surgical Technique**

Deltoid-splitting Approach

A minimally invasive deltid-splitting approach was used in 37 patients. The first

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**Table 1**

<table>
<thead>
<tr>
<th>Neer Classification</th>
<th>Deltoid-splitting Group</th>
<th>Deltopectoral Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Constant Score</td>
</tr>
<tr>
<td>2-part</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>3-part</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td>4-part</td>
<td>27</td>
<td>14</td>
</tr>
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</table>
skin incision was made from the anterolateral tip of the acromion extending approximately 5 cm distally. A skin bridge was left over the region of the palpated lateral branch of the axillary nerve, as described by Lill et al.\textsuperscript{23} The avascular raphe between the anterior and middle head of the deltoid muscle was identified and split. The fracture was reduced under fluoroscopic control and fixed temporarily with K-wires. A PHILOS plate (Synthes, Umkirch, Germany) was inserted along the humeral shaft and positioned correctly with the help of a mounted aiming device (5 to 8 mm distal to the upper end of the greater tuberosity and 2 mm posterior to the bicipital groove).

A second skin incision was then made over the distal 3 holes of the plate, and the plate was fixed temporarily with a nonlocking screw. For definitive fixation, a mean of 6 locking screws were placed in the humeral head. Finally, 3 locking screws were inserted into the distal holes of the plate (Figure 1). A 5-hole plate was used with this approach to protect the axillary nerve, which typically crosses the plate over the proximal holes (Figure 2).

**Deltopectoral Approach**

A standard deltopectoral approach was used in 33 patients. A 10- to 12-cm incision was made at the coracoid process and ran laterally toward the insertion of the deltoid muscle. The deltopectoral interval was dissected medially to the cephalic vein, and the subdeltoid and subpectoral spaces were created by blunt dissection. The deltopectoral groove was opened distally until the insertion of the pectoralis. The clavipectoral fascia was split vertically just lateral to the conjoined tendon and up to the coracoacromial ligament, and the fracture was exposed by internal and external rotation. The fracture was reduced and temporarily fixed with K-wires. The fracture was finally fixed with a shorter 3-hole plate using a mean of 7 locking screws for the humeral head and 3 screws for the distal holes of the plate.

In all 3- and 4-part fractures, the tuberosities were reattached with additional FiberWire (Arthrex, Inc, Naples, Florida) cerclages knotted against the plate or additional screws in large fragments.

**Postoperative Protocol**

Postoperatively, the arm was immobilized in a sling. Passive motion and pendulum exercises were started immediately to avoid a loss of mobility. Active range-of-motion exercises with terminal stretching of the capsule were started 3 to 6 weeks postoperatively depending on the achieved stability. Strengthening exercises were started after fracture union.

**Clinical and Radiographic Evaluation**

Clinical examination involved measuring active and passive range of motion and strength. Functional outcome was assessed with the Constant score.\textsuperscript{24} Isometric muscle strength was measured with an Isobex dynamometer (Cursor, Bern, Switzerland). The Disabilities of the Arm, Shoulder and Hand (DASH) score\textsuperscript{25} and American Shoulder and Elbow Surgeons (ASES) score\textsuperscript{26} were used to assess subjective results. Pre- and postoperative and follow-up radiographs were reviewed. Anteroposterior and y-view radiographs were evaluated for fracture healing or signs of malunion, implant failure, loss of reduction, and avascular necrosis.

**Statistical Analysis**

Statistical analysis was performed by a statistical consultant with SPSS version 11.5 software (SPSS Inc, Chicago, Illinois). Chi-square test and Fisher’s exact test were used to compare the results between the 2 groups. A P value of .05 or less was considered significant. A multivariate linear regression was performed to simultaneously account for both surgical approaches and time to follow-up.

**RESULTS**

Thirty-three patients were treated through a standard deltopectoral approach, and 37 patients were treated through a minimally invasive anterolateral deltoid-splitting approach. Average time
from injury to surgery was 0.9 days for both groups. Average operative time was 107 minutes in the deltoid-splitting group and 106 minutes in the deltopectoral group. Average time to follow-up was 20 months in the deltoid-splitting group and 48 months in the deltopectoral group.

Mean nonnormalized Constant score for all fractures was 74 (range, 27.5-95). No significant differences existed in Constant scores between the 2 approaches. Mean Constant score was 75.1 (range, 37-95) in the deltoid-splitting group and 72.8 (range, 27.5-89) in the deltopectoral group ($P = .7$). Mean normalized Constant score according to Katolik et al$^{27}$ was 86.7 in the deltoid-splitting group and 81.4 in the deltopectoral group.

Linear regression revealed that, even when accounting for time to follow-up, none of the outcome measures were significantly different between the 2 groups (Constant score, $P = .14$; ASES score, $P = .209$; DASH score, $P = .885$).

Clinical neurological examination at follow-up revealed no evidence of axillary nerve palsy, such as obvious atrophy or weakness, in either group. One deep early-onset wound infection occurred in the deltopectoral group, and none occurred in the deltoid-splitting group ($P = .94$). Mean ASES score was 88.2 in the deltoid-splitting group and 85.4 points in the deltopectoral group ($P = .46$). Multivariate linear regression revealed that, even when accounting for time to follow-up, none of the outcome measures were significantly different between the 2 groups (Constant score, $P = .14$; ASES score, $P = .209$; DASH score, $P = .885$).

Regarding radiological results, 56 (80%) of 70 fractures healed uneventfully in an anatomic position. Fourteen (20%) fractures (6 [19.4%] in the deltoid-splitting group and 8 [21.6%] in the deltopectoral group) showed a slight varus position (within 10°). In 7 (10%) cases, complete (n=3: 1 stage 3 and 2 stage 4 according to Cruess$^{29}$) or partial humeral head necrosis (n=4) involving the tuberosities was observed; six (18.2%) occurred in the deltopectoral group (Figure 3) and 1 (2.7%) in the deltoid-splitting group. Furthermore, 1 patient per group ($P = .94$) had radiological signs of fracture nonunion but without pain or clinical restrictions, so no revision surgery was performed.

One screw cutout occurred in the deltopectoral group, leading to revision surgery with removal of the screw ($P = .29$). Two broken plates and 2 aseptic screw loosenings occurred in the deltopectoral group, and 1 screw loosening occurred in the deltoid-splitting group. However, no significant difference existed between groups in terms of these complications ($P > .05$), and all fractures were bony healed and stable during revision surgery. Therefore, an isolated removal of the implant was performed in these patients.

**DISCUSSION**

This study supports the hypothesis that the surgical approach for plate fixation of proximal humeral fractures has no crucial influence on the clinical outcome.

In the past few decades, displaced proximal humeral fractures have increased in number due to osteoporosis in the aging population. Studies have shown that osteoporosis negatively influences the anchorage of internal fixation and leads to an increased failure rate of osteosynthesis$^{29,30}$. Especially among patients with 3- and 4-part proximal humeral fractures, poor clinical results and high failure rates were reported when internal fixation was performed with conventional nonlocking plates.$^{31,32}$

To improve the clinical outcome and avoid complications, various locking implants have been designed for the
proximal humerus.\textsuperscript{11,33} These plates provide more stability than conventional plates commonly used in the past.\textsuperscript{13,34,35} Numerous authors have reported good functional outcomes after open reduction and internal fixation of proximal humeral fractures with locking plates.\textsuperscript{8,14-16,36,37} Therefore, the use of locking plates, especially in elderly patients with poor bone quality, has become the gold standard in the past 10 years.\textsuperscript{8,14-36}

For surgical management, the deltopectoral approach to the proximal humerus is the procedure of choice.\textsuperscript{38,39} However, several surgeons agree that this approach may not be the best option when performing an angular stable plate fixation of a proximal humeral fracture.\textsuperscript{17-19,21} They criticize the substantial soft tissue dissection, including partial release of the deltoid muscle, the retraction of the deltoid muscle, and the humeral manipulation to access the lateral aspect of the humerus. As a result, it is difficult to gain the correct drill angle, possibly leading to slight anterior plate placement. Partial release of the deltoid muscle has been described to obtain the appropriate drill angle using a standard deltopectoral approach.\textsuperscript{40,41} However, this procedure should be considered carefully because a release of more than one-fifth of the deltoid insertion can compromise anterior deltoid function.\textsuperscript{52} It is also assumed that a deltopectoral approach may negatively influence postoperative outcomes due to the devascularization of fracture fragments during dissection and plating or disruption of the critical blood supply to the humeral head.\textsuperscript{17-19,21}

Many studies in the literature have evaluated the blood supply to the proximal humerus region.\textsuperscript{43-48} Hertel et al\textsuperscript{49} reported that injury to the vasculature of the proximal humerus and subsequent development of avascular necrosis depends on the severity of the trauma and the fracture pattern. Thus, care must be taken to not deteriorate the initial situation by plating or dissection.

Recently, the deltoid-splitting approach has become more popular. Originally described as an approach in rotator cuff surgery\textsuperscript{38} and intramedullary nailing,\textsuperscript{39} this minimally invasive approach is used for osteosynthesis of proximal humeral fractures in a sliding-in technique. Gardner et al\textsuperscript{50} examined the vascular implications during angular stable plate fixation of proximal humeral fractures in a cadaveric study. They concluded that plating through a minimally invasive anterolateral acromial approach allows direct access to the appropriate plating zone, a bare spot between the humeral head-penetrating vessels from the anterior and posterior circumflex system. Moreover, they reported that this approach avoids exposure of the anterior blood supply, precludes deltoid release, and may minimize further devitalization of fracture fragments during reduction and fixation.\textsuperscript{50}

The current study showed no significant difference in functional outcome between displaced proximal humeral fractures treated with a deltoid-splitting vs a deltopectoral approach. Constant, DASH, and ASES scores revealed no significant differences between groups (Table 2). A significant impairment of the deltoid muscle, leading to lower values of isometric muscle strength, could also not be proven for either group (Table 2). Constant scores of 75.1 in the deltoid-splitting group and 72.8 in the deltopectoral group are comparable with previous studies, which report values from 71 to 76 after locking plate fixation of proximal humeral fractures.\textsuperscript{8,14-16,36}

Six (18.2\%) cases of avascular necrosis occurred in the deltopectoral group, whereas 1 (2.7\%) case occurred in the deltoid-splitting group. Previous studies showed a lower rate of avascular necrosis after minimally invasive plating compared with open techniques,\textsuperscript{17,19,21}; however, the different follow-up periods in the current study do not allow a clear statement about these complications.

Many studies have analyzed functional outcome after locking plate fixation of proximal humeral fractures.\textsuperscript{8,14,16,18,21,36,51-53} However, only 1 study in the literature has reported approach-related results after 1 year.\textsuperscript{20} The authors examined the proximal humerus of 83 patients (follow-up at 3, 6, and 12 months). Surgery was performed through an anterolateral deltoid-splitting approach in 39 patients and a standard deltopectoral approach in 44 patients. The authors observed less pain and higher activities of daily living scores in the deltoid-splitting group at early follow-up but higher Constant scores in the deltopectoral group after 1 year, and they concluded that the choice of approach to the shoulder may influence the functional outcome.\textsuperscript{20}

A possible injury to the axillary nerve during plate fixation through an anterolateral approach is historically seen as a limitation of the approach. Several anatomical studies report that the axillary nerve proceeds in a predictable way.\textsuperscript{18,54-57} The current authors observed no lesions to the axillary nerve. Gardner et al,\textsuperscript{18,21} Laflamme et al,\textsuperscript{52} and Hepp et al\textsuperscript{20} also used the anterolateral approach for plate fixation of proximal humeral fractures and observed no lesions to the axillary nerve. Hence, the current authors agree with Smith et al\textsuperscript{48} that the approach is a safe alternative when correctly implemented with palpating or visualizing the nerve before plate insertion and using the longer 5-hole PHILOS plate to insert the screws a certain distance above and below the lateral branch of the axillary nerve.

The current study had several limitations, including its retrospective study design and the 2 groups’ different follow-up periods. The development of avascular necrosis has been shown to potentially occur at a later point in time. Greiner et al\textsuperscript{59} reported that the incidence of avascular necrosis had doubled after 45 months compared with the incidence observed after 12 months. Therefore, the current study cannot answer the question of whether the approach may influence the humeral head blood supply and, therefore, the occurrence of avascular necrosis.
However, the multivariate linear regression showed that patients in both groups regained equal shoulder function. Furthermore, no significant differences existed in short-term complications, such as surgery-related complications or hardware problems.

**Conclusion**

The anterolateral deltoit-splitting approach and the deltopectoral approach showed comparable results after locking plate fixation of proximal humeral fractures. Both techniques are safe and can be used according to surgeon preference.

**References**


