Fixation of Proximal Humeral Fractures with an Intramedullary Nail: Tipps and Tricks

Hans-Werner Stedtfeld[1], Thomas Mittlmeier[2]

Abstract

Antegrade interlocking nailing has been established as a valid option of treatment in proximal humeral fractures which follows the principles of minimum invasive surgery. The introduction of angular stability into intramedullary nailing has increased the stability of reconstruction even in osteoporotic fractures. The outcome of the surgical procedure essentially depends on the adequate intraoperative management of the specific features and challenges of the corresponding fracture type. The creation of the correct nail entry point is crucial for anatomic reduction and stability of the reconstruction, as well. The knowledge on intraoperative reduction aids and additional tools of enhancing the stability of the reconstruction alleviates a mechanically sound application of antegrade intramedullary nailing in most highly unstable proximal humeral fractures.

Key Words

Proximal humeral fracture · Fixation · Intramedullary nailing · Tubercle refixation · Transmedullary support screw · Rehabilitation

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Introduction

Various types of intramedullary devices have been introduced into clinical use for proximal humeral fractures during the last decade [1–7]. Many nail constructs rely on a spatial arrangement of the screws fixing the head fragment. Parallel to the development and refinement of locking plates the principles of angular stability have been realized in intramedullary interlocking nailing of the proximal humerus, as well [4]. This constructional feature proved to be favorable in particular in osteoporotic fractures [8]. In vitro biomechanical studies mostly comparing the stiffness of the implant-bone construct yielded differing results regarding the stiffness and potential advantages or disadvantages of the corresponding nail – bone composites compared with conventional and locking plates which may presumably be due to substantial differences in implant features and biomechanical testing conditions [8–11].

Meanwhile, an encouraging clinical outcome after intramedullary nailing of two-part, three-part and even four-part fractures of the humeral head has been reported with various implants [1, 4, 7, 8, 14]. Some authors outlined the particular usefulness of intramedullary nails in combined head and neck fractures, which represent an increasing entity in the geriatric population [1]. But, intramedullary nailing offers some specific inherent risks. The creation of the correct entry point is crucial for the definite position of the head fragment and related problems as subacromial impingement. Once the entry point has been established in the size of the corresponding nail diameter a correction can hardly be accomplished without substantial loss of the anchoring strength of the implant. Depending on the issue if a bent or a straight nail is used different entry points have to be taken into account and strictly be followed. This may be rendered more difficult in fractures with comminuted tubercles and a small head fragment [2] where additional measures should improve the reconstruction [14, 15].

[1]Department of Trauma, Klinikum Nürnberg Klinikum Süd, Nürnberg, Germany,
[2]Department of Trauma and Reconstructive Surgery, University of Rostock, Rostock, Germany.

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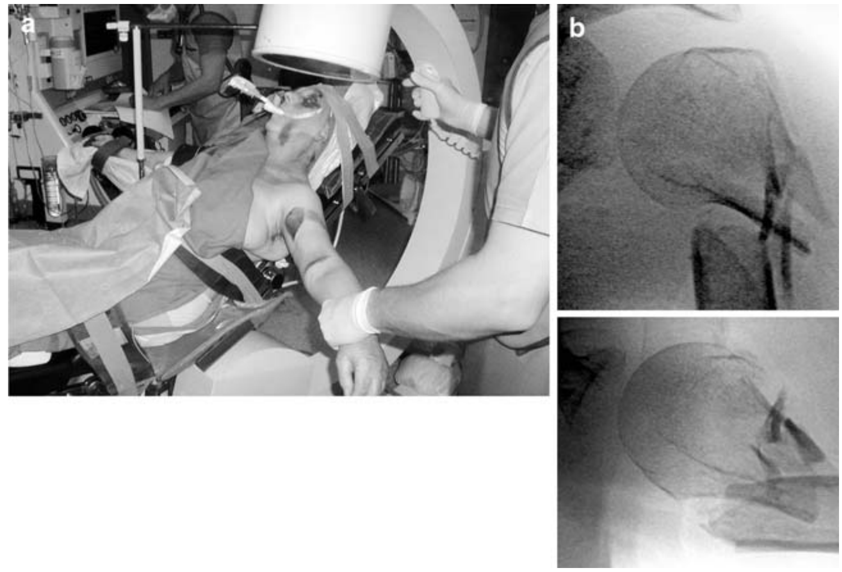
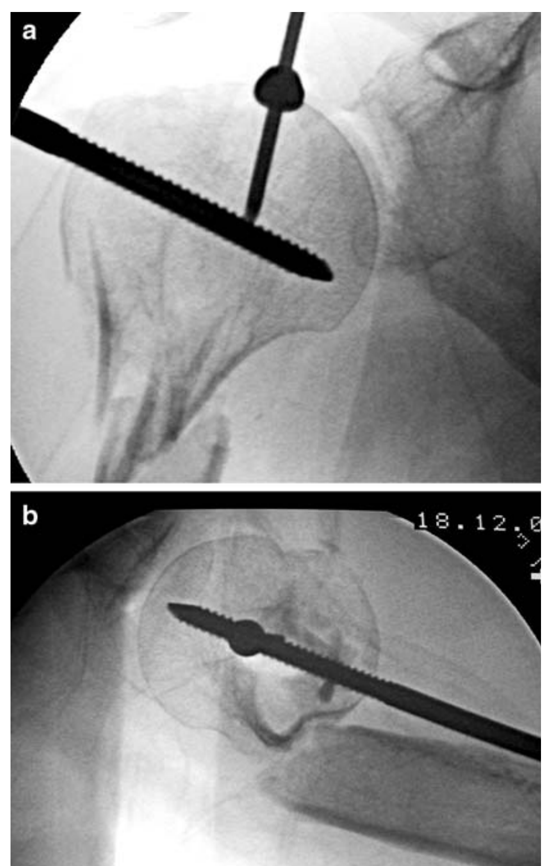


Figures 1a and 1b. a) Positioning of the patient and fluoroscopic control before draping b) true a.p. and axial fluroscopic view.

In the following, a subjective selection of hints has been made which may facilitate the beneficial use of intramedullary interlocking nails in specific intraoperative situations.

Positioning of the Patient and Intraoperative Fluoroscopy

The beach chair position is the recommended position for antegrade interlocking nailing of proximal humeral fractures (Figure 1a). Checking the intraoperative standard views with the fluoroscope before draping is mandatory before sterile draping (Figure 1b). Otherwise, elements of the surgical table and anatomical characteristics of the individual patient may interfere with the intraoperative fluoroscopic control of the fracture reduction and the nail entry hole, as well. If the fluoroscope is positioned at the ipsilateral side of the fractured arm near the head and parallel to the trunk of the patient a true a.p. and an axial view (Figures 1a, 3) can be performed just by rotation of the C-arm around the horizontal axis. The axial view as the second plane of fluoroscopic evaluation is less time-consuming than the Y-view which makes it necessary to move the body of the fluoroscope by 30° and often narrows the working field of the anaesthesiologist at the head side of the patient. Furtheron, the preoperative fluoroscopic control gives the surgeon the information about the option of closed reduction and the degree of instability of the fracture, as well.



Figures 2a and 2b. Fluoroscopic control (a. a.p. view, b. axial view) of the reduction of the humeral head fragment by a Schanz screw can be performed independently from the reduction of the shaft fragment to create the correct nail entry point.

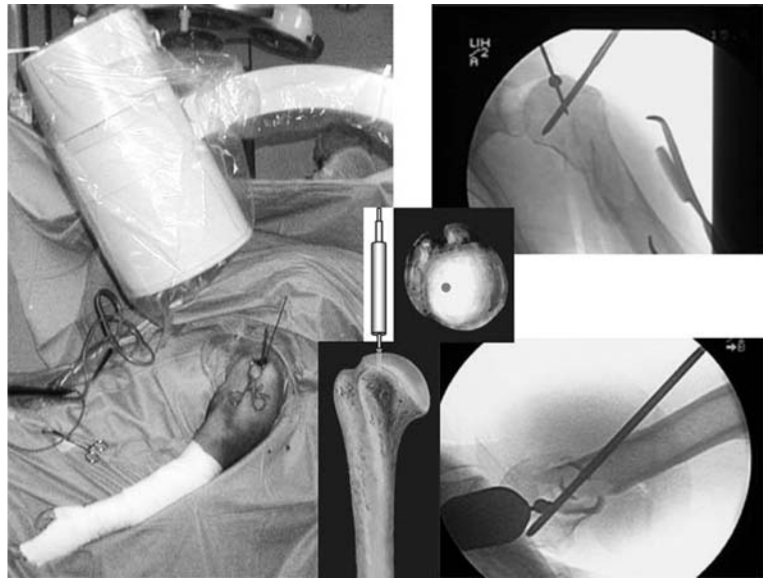
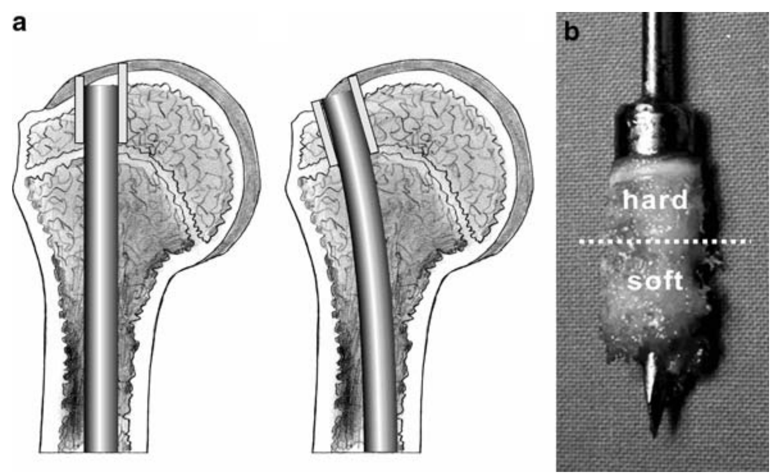


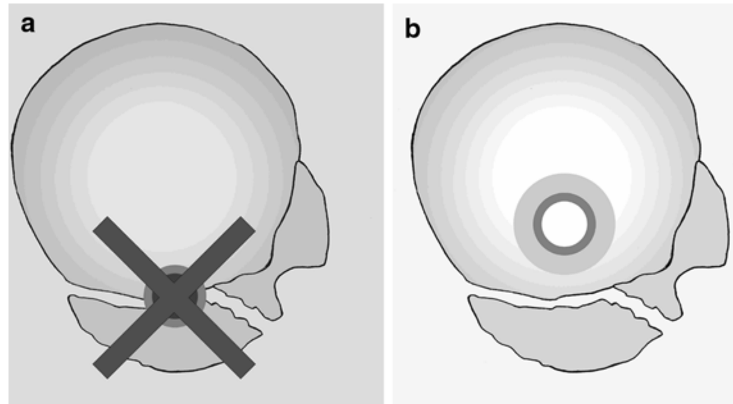
Figure 3. Intraoperative verification of the correct nail entry point using an antegrade Straight nail.



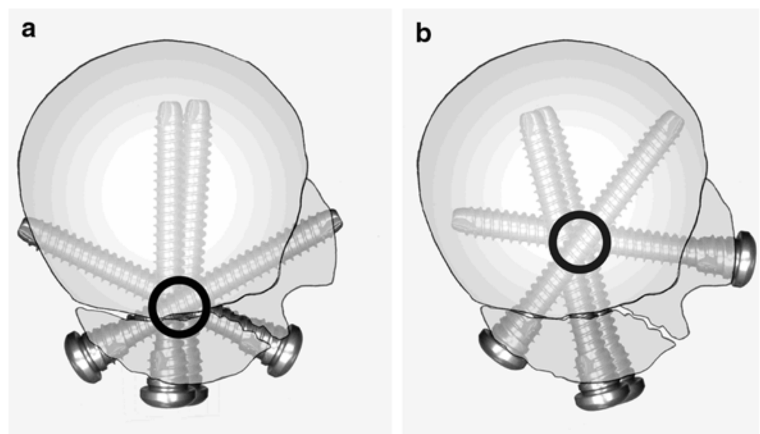
Figures 4a and 4b. a) Nail insertion point with a straight (left) and a bent (right) intramedullary nail. b) cartilage/bone cylinder after reaming in a straight nail type. The dense subchondral bone provides additional anchoring stability.

Surgical Technique in Neer III Fractures

In two-part fractures the antero-superior transdeltoid approach can be limited to a minimum exposure of about 2–3 cm in length (Figure 3). The preparation should be oriented at the palpable antero-lateral rim of the acromion. The parietal bursal layer of the subacromial bursa should be exposed separately from the supraspinatus tendon. In straight nails where a radial incision of the rotator cuff at the level of the supraspinatus tendon is necessary to get insight to the entry point area of the intramedullary nail, reduction of the regularly dorsally tilted head fragment is mandatory before the incision at the supraspinatus tendon is made. Otherwise, either the blind incision into the supraspinatus tendon will prevent adequate nail insertion making a second incision of the rotator cuff necessary or a permanent malalignment will be transfixed. Therefore, for manipulation of the head fragment a thick K-wire (diameter 2.2 or 2.5 mm), a Steinmann pin with an universal handle, a small fragment raspatory or a small fragment elevator can be utilized (Figure 2). Fluoroscopic control can confirm the correct reduction of the head fragment in two planes. The consecutive radial incision of the supraspinatus tendon should be immediately in front of the anterior edge of the acromion. The entry point at the apex of the humeral head should be reconfirmed by fluoroscopy (Figures 2b, 3). At that stage of the procedure the surgeon should consider the correct position of the head fragment, only. With a correct nail



Figures 5a and 5b. a) With a straight nail type the selection of a wrong entry point at the sulcus between the head fragment and the major tubercle may exert additional damaging forces on the humeral head fragment b) The correct entry point at the apex of the humeral head in both planes creates an intact bony ring around the proximal end of the nail.



Figures 6a and 6b. a) A lateral entry point in a straight nail type endangers the stability of the construct due to altered positions of the screws within the head fragment. b) Correct screw positions with a straight nail type.

entry point the shaft fragment will be reduced ''automatically'' when the nail is driven into the shaft segment. Using straight nails the creation of an entry hole completely within the cartilage zone of the head fragment which is intraoperatively demonstrated by a complete cartilage/subchondral bone cylinder after reaming provides additional stability to the head fixation screws (Figures 4, 5). If the nail entry hole is not found adequately the positions of the humeral head fixation screws are altered (Figures 6a, 6b). Generally, this induces a reduced fixation strength and an increased risk of secondary dislocation. This applies to the straight and the bent nail types, as well.

The typical dense subchondral bone layer which is always present even in manifest osteoporotic bone offers increased stability as a fifth anchoring point in addition to the four head fixation screws (Figure 4). As such, the proximal nail end should not be inserted deeper than 3–4 mm below the cartilage surface in order that the most cranial fixation screw should get purchase in the corresponding subchon-

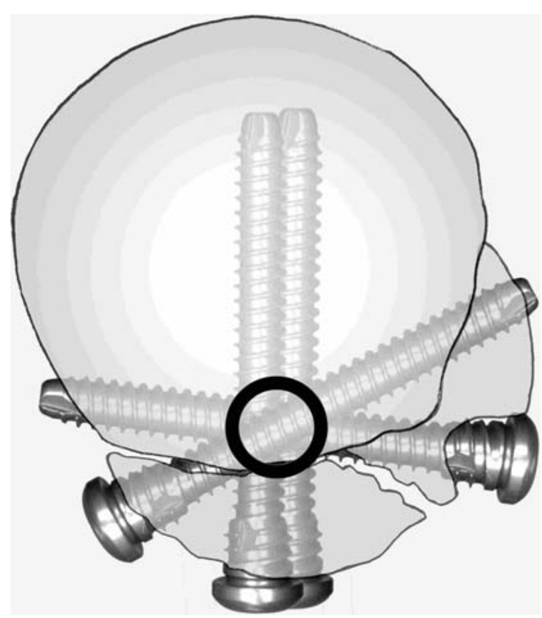
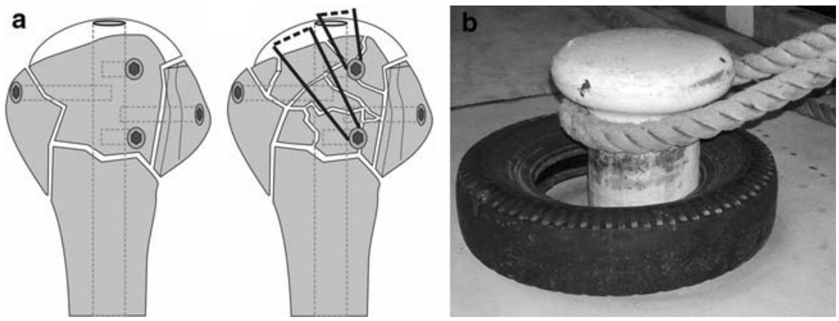


Figure 7. A too central position with a bent nail type alters the intended screw directions and may lead to a tenodesis of the long biceps tendon.



Figures 8a and 8b. a) Only with solid fragments of the tubercles in 3- and 4-part fractures the standard interlocking mode with fixation screws can be applied (left). With comminuted tubercles additional tension band sutures are tied around the screw heads which fix the tendinous portions of the rotator cuff according to the "rope-over- bitt"-principle (Figure 8b).

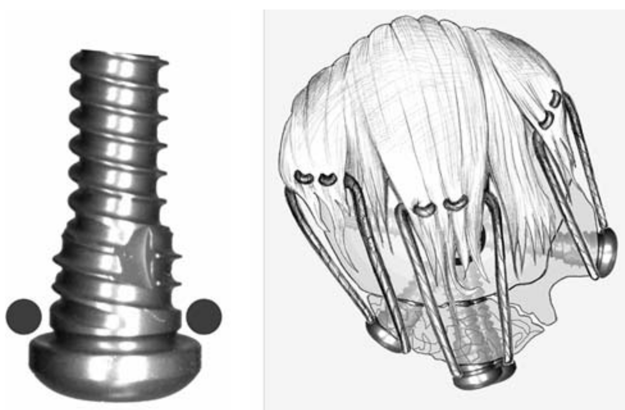


Figure 9. The construction of the double-threaded screws provides a groove for the tension band non-resorbable sutures which may allow to fix the main portions of the rotator cuff to the screw heads.

dral bone layer (Figure 8). Usually, bent nails cannot make use of this apparent advantage due to their intended entry point at the sulcus between the major tubercle and the head fragment (Figure 4). With a small head fragment where creation of a complete circular nail entry hole is questionable (e.g. fractures at the anatomical neck or head split fractures) a locking plate should be preferred to the use of an intramedullary nail system.

Correct rotation of the nail is necessary before insertion of the humeral head fixation screws to avoid an accidental biceps tenodesis in the sulcus while limited exposure prevents the visualization or palpation of the lateral rim of the minor tubercle. If a bent nail is inserted more centrally than its original entry point an analogous problem may occur (Figure 7). Typically, the major tubercle is fixed by two screws corresponding to its expansion with a lateral and a posterior portion: the superior lateral and the posterior oblique screw (Figure 6b). During drilling within the head fragment the medial cortex can be felt and should preferably not be perforated to avoid damage to the glenoid surface. Choosing the fixation screw length generally 4 mm less than the measured distance from the lateral to the medial cortex provides a high degree of safety that the medial cortex is not inadvertently perforated by the fixation screw during the primary procedure or secondarily due to a loss of humeral head volume which may occur during healing, e.g. with manifestation of a partial humeral head necrosis. Correct screw length determination is particularly made difficult in the two oblique screw positions. Before the shaft locking screws are implanted the anatomic metaphyseal length and rotation can be adapted and should be controlled by fluoroscopy, again. A layer-wise reconstruction of the soft tissues with particular attention to the parietal bursa provides the premise for avoidance of subacromial adhesions.

Surgical Technique in Neer IV/V Fractures

Compared with two-part fractures displaced three-and four-part fractures generally require a more extensile approach to get adequate intraoperative control of reduction and the choice for application of additional fixation measures as sutures which is of paramount importance in multifragmentary fractures of the tubercles where the pure screw fixation does not provide enough stability for permanent refixation or where the fixation screws may just displace the multiple tubercular fragments (Figures 8, 9). The reduction technique differs from the procedure in simple fracture types. First, the tubercular fragments may be secured with U-type stitches placed at the more central portion of the rotator cuff to manipulate them together with the corresponding portions of the rotator cuff and to expose the head fragment which is often displaced into a valgus impacted position. Before reducing the head fragment it may be easier to create the nail entry hole now as in the valgus position there occurs less mechanical interference from the instrumentation and the antero-lateral rim of the acromion. Thereafter, the head fragment may be anatomically reduced ''closing the curtain'' by consecutive reduction of the tubercular fragments. Preliminary intraoperative fixation before inserting the nail may be achieved by K-wires (2–3) which should be placed at the periphery of the fracture segments to leave enough space for the passage of the nail into the intramedullary canal. Following reduction of the humeral head fragment and the tubercle fragments the correct incision of the rotator cuff can be performed now to identify the nail entry hole which has been created before in the dislocated state.

The ''rope-over-bitt'' technique allows for additional stability in comminuted fractures of the tubercles (Figures 8, 9). Non-absorbable sutures (2–3) tied around the flat double-threaded screw heads can be used in multifragmentary tubercles. The sutures are usually tied around the screw heads and find their position in a corresponding groove (Figure 9) before the screws are turned into their final position to avoid loosening of the loops. The application of the sutures around the flat screw heads does not promote the risk of subacromial impingement.

The reconstruction of the parietal bursal layer is performed in analogy to the procedure in two-part fractures to avoid subacromial adhesions.

Surgical Technique in Intermuscular Fractures

Until now, little interest has been dedicated to a specific fracture type which is seen with increasing frequency in the elder population: the intermuscular fracture. This represents a highly unstable fracture type due to the divergent pull of the pectoralis and the deltoid muscle.

In order to achieve anatomic reduction two surgical strategies can be followed. One option would be the application of a reduction tool for the humeral head segment as a Steinmann pin or a thick K-wire to adequately reduce the head fragment be-

Figure 10. Schematic reduction technique of a highly unstable intermuscular fracture with a reduction tool (e.g. a Steinmann pin) before inserting a preferably long version of an intramedullary interlocking nail.

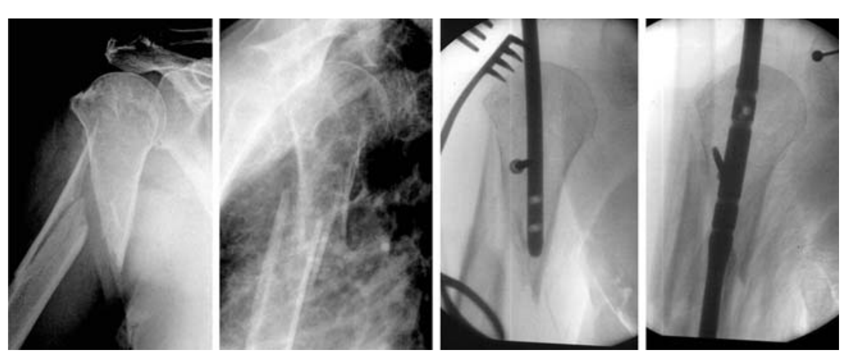


Figure 11. Sequence of reduction in an intermuscular fracture applying the use of a transmedullary support screw in the short fracture segment (preoperative (left) and intraoperative views (right)).

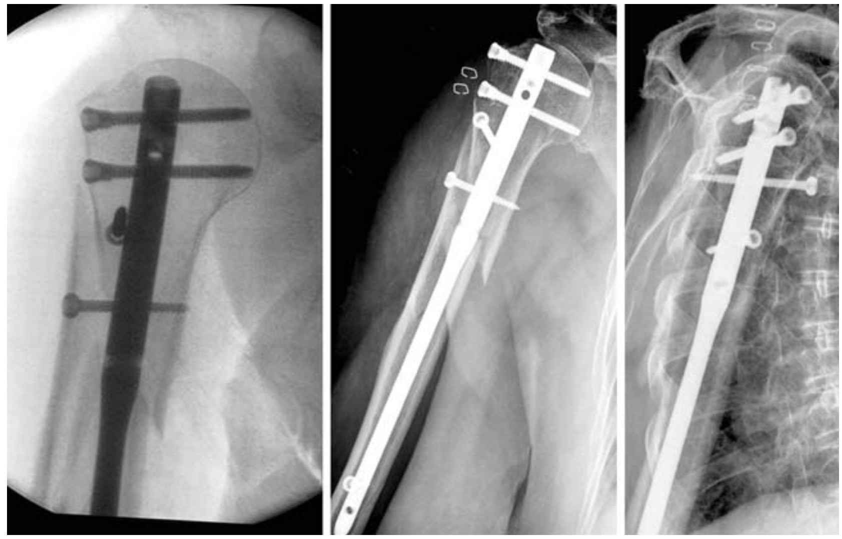


Figure 12. The transmedullary support screw does not only improve the ease of reduction (left), but also enhances stability during the healing period as the risk of toggling of the nail within the wide proximal intramedullary canal is diminished (right).

Figure 13. Postoperative self-assisted exercises represent a key-element of postoperative mobilization.

fore addressing the entry hole for the intramedullary nail (Figure 10). The second option would represent the application of a blocking or transmedullary support screw [17] (sometimes addressed as ''poller screw'' in literature) which have the advantage to act as an intraoperative reduction tool and a method of enhancing stability of the nail – bone construct during the healing process, as well (Figures 11, 12). Three basic rules determine the adequate placement of a transmedullary support screw: (1) it should always be inserted into the short fragment (2) it should be placed near the fracture zone (3) it should be placed at the concave side of the deformity [17]. In particular, in osteoporotic fractures and patients with a very wide proximal intramedullary canal the transmedullary support screw narrows the width of the canal and prevents toggling of the nail during the healing period within the canal. Relying only onto an intraoperative reduction tool may provoke redislocation due to the muscular pull which is limited by contact of the lateral wall of the nail and the inner cortex of the proximal fragment, only.

Postoperative Rehabilitation

A postoperative rehabilitation which is adapted to the fracture type and the quality of bone is crucial for the final functional outcome and the avoidance of mechanical complications during the healing phase. While early active exercises do rarely endanger the mechanical integrity of the reconstruction in patients with a good bone stock, patients with osteoporotic fractures and comminuted three- or four-part fractures should perform assisted and/or self-assisted exercises during the first 4 weeks after surgery (Figure 13). The use of crutches or any kind of walker, a forceful leaning of a patient against a support with major percentage of the body weight and a forceful rotation of the shoulder may compromise the surgical reconstruction in the early phase. In analogy, the pull at the injured and extended arm, e.g. by a nurse who assists the sitting-up of a patient, should be avoided. Consequently, the shoulder should be protected during nighttime within the first 3–4 weeks after surgery in cases at risk against inadvertent motions by wearing a Gilchrist brace.

Conclusions

Antegrade intramedullary interlocking nailing of proximal humeral fractures is a valid option for many fracture types and can be applied according to the principles of minimum invasive surgery. The surgical strategy of intraoperative reduction has to respect the particular fracture type. Depending on the nail type used the correct identification of the nail insertion point is crucial for the anatomic reconstruction and the primary stability achieved. Reduction aids and measures to gain additional stability may facilitate the optimized use of an intramedullary nail in the dislocated proximal humeral fracture.

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Address for Correspondence
Prof. Dr. Thomas Mittlmeier
Department of Trauma and Reconstructive Surgery
University of Rostock
Schillingallee 35
18055 Rostock
Germany
e-mail: thomas.mittlmeier@med.uni-rostock.de