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REVIEW ARTICLES

**At the International Congress of Shoulder and Elbow Surgery (ICSES) in Edinburgh, Scotland, in September 2010, Dr Herbert Resch presented his talk entitled "Proximal Humeral Fractures: Current Controversies" as the prestigious Codman Lecture. We are honored to be able to reproduce Dr Resch's talk in the *Journal of Shoulder and Elbow Surgery* - Bill Mallon, MD, Editor-in-Chief.**

# Proximal humeral fractures: current controversies

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## Epidemiology

According to Horak and Nilsson,[13] 5% of all fractures of the human body are fractures of the proximal humerus. Palvanen et al[17] reported an increase in these fractures of more than 3-fold between 1970 and 2002. Court-Brown et al[7] found that 70% of all 3- and 4-part fractures are seen in patients aged over 60 years and 50% in patients aged over 70 years. These results indicate that poor bone quality or even advanced osteoporosis will be found in the majority of patients with humeral head fractures.

Conservative treatment of displaced fractures has not shown consistently satisfactory results.[2,6,9,25] Reconstructive surgery with locked plating has shown good results in younger patients but was accompanied by a high complication rate in older patients with poor bone quality.[23,24,26] Hemiarthroplasty was seen as the treatment of choice for a long time, but it is associated with a high rate of malunion of the tuberosities, which is responsible for poor functional outcome. The malunion rate has been reported to be even worse in older patients.[14] To date, new prosthetics specially designed for fracture care have not improved the healing rate of the tuberosities.[4,14,15,23,24] From the literature, it can be summarized that better outcome in terms of function can be expected with reconstructive surgery than with prosthetic replacement, despite the high complication rates of both procedures.[23,24,26] Unfortunately, most articles compare implants with other implants without any information on either the fracture pattern or the quality of reduction.

In case of a humeral head fracture, the following issues are of interest:

1. Classification
2. Reduction
3. Vascularity
4. Implant characteristics
5. Bone quality

## Classification

In 1993, Siebenrock and Gerber[22] and Sidor et al[21] found very low interobserver reliability for the existing and commonly used classification systems. They concluded that it is not valid to compare classified studies from different centers. According to these authors, the low reliability is caused by several factors: first, the amount of displacement measured in millimeters or degrees; second, a slight change of arm position causes a large change in the radiologic appearance; and third, the use of illustration on just 1 plane instead of 2 planes. Therefore, a new classification system should be characterized by 3 features:

1. It should be easy to understand.
2. It should include the second plane.
3. It should include accepted findings of recent years, such as varus/valgus deformity[23,24] and length and displacement of the medial hinge.[11,12,18-20]

All of these factors are possible only for a purely descriptive classification system. The so-called Lego system

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of Hertel et al[11,12] corresponds to the 4-part system of Codman with the option of 12 possible fracture types. This system fulfils almost all criteria but does not differentiate between varus- and valgus-type fractures, a distinction that is crucial for reduction and fixation. In varus-type fractures, the head is disrupted from the shaft and remains in the varus position as a result of the persisting attachment of the rotator cuff muscles. In the case of an additional fracture of the greater tuberosity, the head may follow the subscapularis muscle and rotate into an internally rotated position (3-part fracture according to Neer[16]). An investigation of 200 consecutive cases showed that 2 varus types could be differentiated.

## Varus disruption type

The varus disruption type is characterized by complete avulsion of the head from the shaft. The shaft is separated from the head in an anteromedial position (Fig. 1).

## Varus impaction type

The varus impaction type is characterized by impaction of the head on the medial side whereas no disruption occurred on the lateral side. In the sagittal plane, the anterior angulation angle is increased, but in contrast to the disruption type, the shaft is not in a separated position (Fig. 2).

Valgus-type fractures are characterized by the impaction of the head into the metaphysis of the shaft. The fractured tuberosities remain in the normal longitudinal position and are still attached to the shaft by the undisrupted periosteum. Again, the 2 types could be differentiated by factors such as the presence/absence of lateral displacement of the head (Fig. 3).

Of the 200 investigated consecutive fractures, 43% had a varus deformity and 31% had a valgus deformity; 25% had a normal position ($<20°$ displacement). Within the varus group, 25% were of the varus disruption type and 18% were of the varus impaction type. On the basis of this investigation, we developed the so-called HCTS classification system. H stands for head, C for the medial calcar, T for the tuberosities, and S for the shaft. Each region is described separately, and all regions are finally assembled. The system provides information on the expected vascularity and the expected difficulties during reduction and fixation. The HCTS classification system will be published in a separate article.

## Reduction

Two questions have to be answered. One is what degree of displacement is tolerable, and the second is how reduction can be achieved. We know from our own experience and from that of the study of Solberg et al[23,24] that varus deformity of more than 20° should not be left uncorrected, because this level of deformity is not well tolerated by patients. In comparison to varus deformity, valgus deformity is better tolerated. According to our own experience, displacement of the greater tuberosity of more than 5 mm in any direction should not be accepted. For the achievement of good reduction, knowledge of the fracture type is important because this provides information on the preserved periosteum. Varus-impacted fractures are characterized by residual primary stability, as a result of the periosteum still being preserved on the lateral side. The calcar on the medial side has to be reduced, which can usually be achieved just by traction and manipulation of the arm. In contrast to the impaction type, the varus disruption type with additional fracture of the greater tuberosity presents quite often with the head in an internally rotated position (3-part fracture according to Neer[16]). Reduction of this fracture type can only be achieved by a step-by-step procedure. At first, the shaft has to be brought into alignment with the head, and then the head has to be derotated by pulling on the lesser tuberosity with a hooked instrument. At the moment when alignment and derotation are achieved, either temporarily or permanently, Humerusblock K-wires (Synthes, Bettlach, Switzerland) are introduced through the shaft into the head. As the last step, the greater tuberosity is pulled downward by means of a hooked instrument and fixed with cannulated screws. All of the maneuvers are performed percutaneously (but even with an open procedure, the various steps remain the same).

Valgus-type fractures without lateral displacement are easy to reduce, because only the head has to be raised with an elevator that is introduced between the fractured tuberosities. The periosteum on the medial side serves as a mechanical hinge when performing this maneuver. In the case of severe lateral displacement, the mechanical-hinge periosteum on the medial side is torn and the head fragment is very unstable and difficult to reduce. By means of an elevator, the hinge has to be reduced first, and then the head fragment is raised until alignment with the tuberosities is achieved. K-wires (Humerusblock) that have been inserted previously are in the so-called waiting position. They can be introduced into the head fragment at the moment when reduction is achieved.

## Vascularity

Gerber et al[10] stated that in the case of an existing avascular necrosis, it is the deformity rather than necrosis that causes disability. Therefore, the risk of limited blood supply of the articular fragment does not influence our decision making in terms of treatment. Like Gerber et al, we believe that the alignment of the tuberosities is very important in cases in which prosthetic replacement might be necessary as a secondary procedure because of head necrosis. In young patients who have sustained a 4-part fracture-dislocation, in which the head is completely separated, a bone block procedure for additional blood supply is performed. The

**Figure 1** Varus disruption fracture. (**A**) Coronal plane. The head fragment is in a varus position and completely separated from the shaft. (**B**) Sagittal plane. The shaft fragment is in an anterior position to the head.

**Figure 2** Varus impaction fracture. (**A**) Coronal plane. The head fragment is in a varus position with impaction into the shaft on the medial side. There is no distance between fragments on the lateral side. (**B**) Sagittal plane. There is increased anterior apex angulation between the head and shaft but no separation.

bone block is harvested from the anterior part of the acromion together with the attached muscle pedicle of the deltoid muscle. From a previous anatomic study, we know of an artery that is found in this part of the muscle supplying the end of the acromion. The bone block is inserted right below the central part of the articular segment. This technique has not been published so far, but early results are encouraging.

## Implant

For the treatment of fractures with osteoporotic bone conditions, 2 features seem to be relevant for an implant: semi-rigidity and controlled impaction.

### Semi-rigidity

In porotic bone, using rigid implants such as locked plates will destroy the soft bone as the load is transferred from the stronger bone of the shaft to the weak bone of the head by the plate and the angle-stable screws. Semi-rigid implants, such as the K-wires provided with the Humerusblock implant, show better load distribution at the metal-bone interface.

### Controlled impaction

According to the studies of Niederberger (A. Niederberger, personal communication, 2010), who measured the sintering

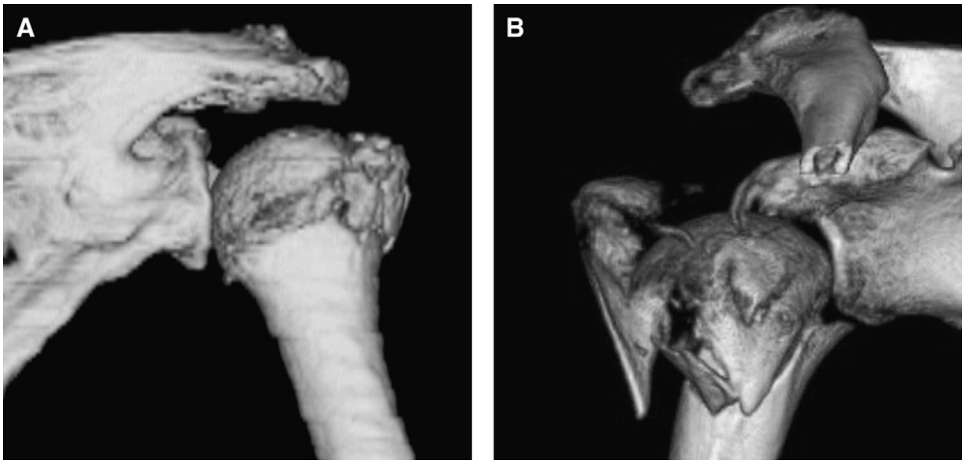

**Figure 3** Valgus impaction fractures with high fracture level on medial side. (**A**) No lateral displacement between head and shaft. (**B**) Lateral displacement of head in relation to shaft.

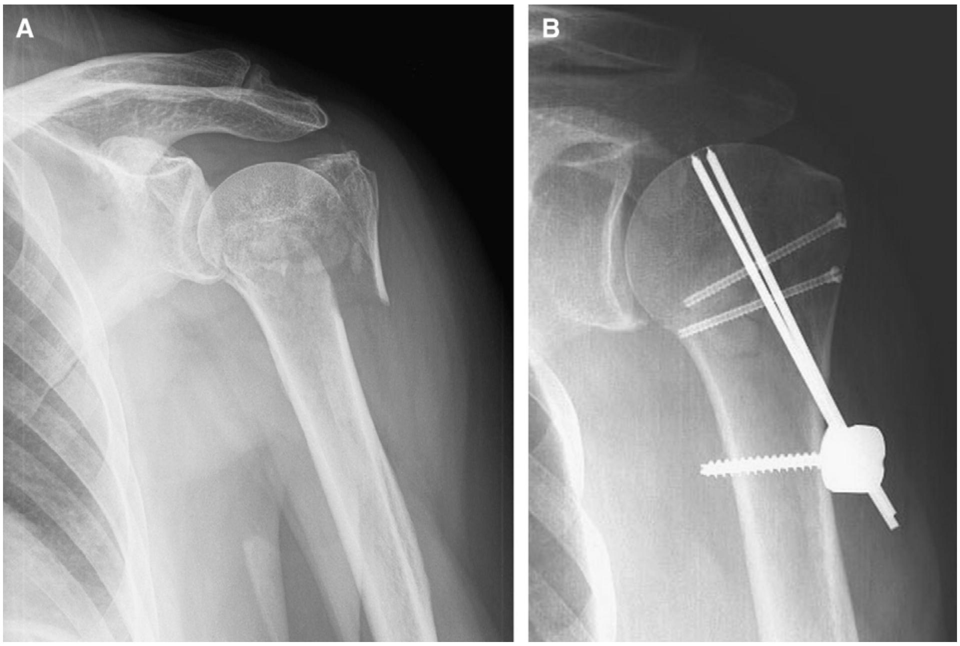

**Figure 4** Humerusblock implant. (**A**) Valgus impaction fracture. (**B**) Postoperative radiograph immediately after surgery. The K-wires show perfectly the direction of the load peaks described by Bergmann et al.[1]

effect of a fractured humeral head fixed with the Humerusblock implant in 66 cases, this effect was found in all cases. A sintering effect of, on average, 5.2 mm (± 4.89 mm) was seen and was significantly correlated to the age of the patients. The sintering effect was also found by Gardner et al[8] in fractures treated with locked plates. Bergmann et al[1] published a report on the direction of load peaks entering the humeral head measured in an in vivo model. According to their studies, the load peaks enter the head from a superior-medial direction in the frontal plane and from a superior-posterior direction in the sagittal plane within a very small range (17° in the frontal plane and 9° in the sagittal plane). From these 2 studies, we can conclude that in a fractured proximal humerus, the head has a strong tendency toward impaction during the first weeks. To permit the sintering effect, the implant should be inserted in the direction of the load peaks measured by Bergmann et al.

## Humerusblock (Synthes)

The key features of the Humerusblock implant are two 2.5-mm K-wires that are fixed in a cylindrical device. The 2 K-wires are introduced through the cylindrical device and through the cortical bone of the shaft into the humeral head. The K-wires, which are inserted in a diverted direction in the sagittal plane, show perfectly the direction of the load peaks described by Bergmann et al[1] (Fig. 4).

## Results

Bogner et al[3] published the results of 48 patients with 3- and 4-part fractures treated by percutaneous reduction and fixation with the Humerusblock implant. All patients were aged over 70 years, with a mean age of 79 years. Reduction was assessed and compared with the radiologic result after consolidation. Postoperatively, reduction was assessed as good in 39 of the 48 patients and fair in 9 patients. At consolidation, 35 were assessed as good, 11 as fair, and 2 as poor. In other words, only 8% of all cases changed from one group to another. One of the disadvantages of the Humerusblock implant is that K-wire perforation through the head requires removal of the implant. In 25% of all patients, the K-wires had to be withdrawn but not removed before consolidation.

## Bone quality

The biomechanical perforation testing of Niederberger showed that bone mineral density measured by quantitative computed tomography correlates positively with the resistance and the failure load. The central part of the head showed the highest resistance against perforation, whereas the lowest was found in the superior-anterior region.

## Design of future implants

In my opinion, future implants should be characterized by 4 features:

1. Controlled impaction: As shown by Niederberger and Gardner et al,[8] the humeral head has a strong tendency toward impaction. In porotic bone conditions, an implant that does not allow impaction will cause a high rate of failure, such as perforation of screws or secondary varus displacement.[5,23,24,26] In fractures with poor bone quality, the implant should be a guiding tool rather than a rigid fixation device, allowing impaction of the head.
2. Direction of peak forces: On the basis of the studies of Bergmann et al[1] showing that the peak forces enter the head from the superior-medial and superior-posterior directions within a very small angle, the implant should be introduced in the same direction, allowing controlled gliding of the porotic head.
3. Semi-rigid implant: To reduce the stress on the bone-metal interface, the implant should not be rigid. K-wires with an elastic 3-point fixation system fulfill these requirements better than angle-stable plates.
4. ‘‘Intelligent’’ K-wires: K-wires are characterized by the advantage that they can be introduced into the head up to the subchondral bone, where the best bone quality is found. On the other hand, K-wires that are fixed in the cylindrical Humerusblock device will perforate the cartilage when sintering occurs. This perforation may require another intervention for withdrawal of the K-wires. Therefore, K-wires migrating together with the sintering head (so-called intelligent K-wires) are desirable. The concept will be that, based on expected resistance measured by quantitative computed tomography scanning, the tips of the K-wires will provide a certain resistance but will not perforate.

## Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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