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THE POSITION OF THE IMPLANT FOR EXTRAARTICULAR FRACTURES OF THE DISTAL HUMERUS - THE NEW HYPOTHESES FOR MANAGEMENT

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Abstract

Through many stages of development, from conservative to operative treatment, open reduction and internal fixation with dual plating systems are the golden standard for fixation of distal humerus fractures. The plates are placed with a slight offset, posteromedially and posterolaterally. In recent publications, a higher stiffness and strength of osteosynthesis in the parallel plating technique were compared to the perpendicular technique with different plate designs. As noted in previous studies, non-union of the distal humerus usually occurs in the region at the metaphyseal and supracondylar level of radial columns due to varus stresses. Therefore the hypothesis is that in the case of extraarticular methphyseal fractures, which are treated with two plates perpendicular or parallel to form, the radial side of the plate should be longer than the ulnar side in order to prevent varus stresses as the main cause of the distal humeral pseudoarthrosis. Sufficient stability can be ensured with newly designed Y-shaped plate which should have a longer radial arm and be configured to prevent varus stresses. To prove this hypothesis, biomechanical studies at the supracondylar metaphyseal level on the border of the distal humerus diaphysis should be performed.

Keywords: distal humerus, extraarticular fracture, biomechanics

1. INTRODUCTION

Fractures of the distal humerus in adults are often challenging in operative treatment (1). In practice, it has been shown that 16% of humeral shaft and 10% of distal humerus fractures in adults are distal humeral shaft and extraarticular supracondylar humerus fractures (2).

The focus of this article is comminuted extraarticular distal humeral fracture. This type fracture often results from a gunshot wound (Figure 1) or motor vehicle injuries in the younger population (2). Such injuries can also result from a simple fall in the elderly population (3).

A B

Figure 1. Gunshot fracture of the distal humerus treated with an external fixator (A) and later treated with osteosynthesis with two plates in the perpendicular position (90-90°) (B).

Slika 1 Prostrijelni prijelom distalnog humerusa liječen vanjskim fiksatorom (A) i osteosintezom s dvije pločice u perpendikularnoj konfiguraciji (90°-90°) (B)

The principal objective of treating extraarticular distal humeral fractures is restoring alignment and achieving stable fixation aimed at facilitating early elbow range of motion, essential for a good functional outcome. It is often difficult to obtain rigid fixation in distal fractures of the humeral diaphysis without compromising the elbow (4).

However, fixation of these fractures remains a challenge due to the restricted space for instrumentation at the distal segment and the need to maintain repair integrity under a large range of motion and low to moderate loading (5).

Through many stages of development, from conservative to operative treatment, open reduction and internal fixation with dual plating systems are the golden standard for fixation of distal humerus fractures (1,2,4,5,8-14). Double-plating techniques using two 3.5mm reconstruction plates or LCP plates in dorsal plating, 90-90 or 180-180 (Figure 2) pattern are generally accepted, for intra- (1,4,5,7-14,15-19) as well as extraarticular fractures (2,4,6,7). Previous studies have shown that surgery surpasses the results of conservative treatment (3,7). In the essence, the triple plating approach

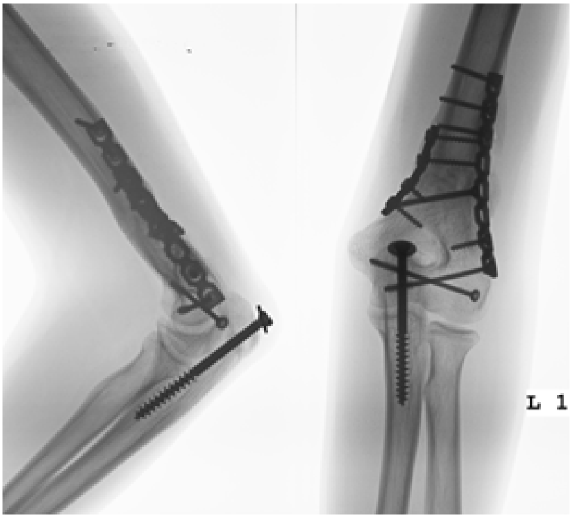

Figure 2. Double-plating techniques using two 3.5mm reconstruction plates in parallel (180-180°) pattern model

Slika 2. Osteosinteza s dvije rekonstrukcijske pločice 3,5 mm u paralelnom (180°-180°) položaju

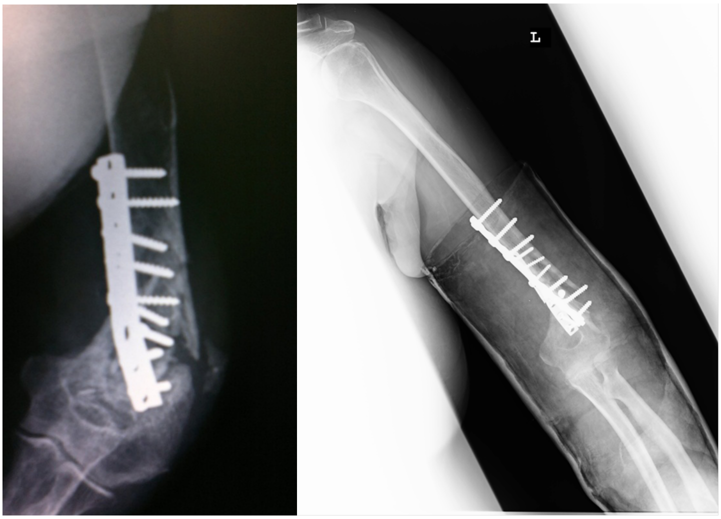

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Figure 3. Varus deformity after non-union of the extraarticular distal humeral fracture after osteosynthesis with one (A) and two (B) plate

Slika 3. Varusni deformitet kao posljedica nedostatnog cijeljenja ekstraartikularnog prijeloma distalnog humerusa nakon osteosinteze s jednom (A) i s dvije pločice (B) is a combination of the above techniques. It is used in cases with severe comminution where additional fixation is required. Typically, the third plate is placed laterally to provide additional support for the radial column (20).

Even if the above mentioned techniques are applied this does not exclude a complication of distal humerus fractures, with a reported incidence of 20% to 25% (12). Poor initial fixation, which is not easily manageable in the presence of extensive comminution and osteopenia, can be the main factor for hardware failure (21).

Non-union with cubitus varus deformity (gunstock deformity) can occur when applied to inadequate osteosynthesis (Figure 3).

2. THE HYPOTHESES

Having applied the findings from previous biomechanical studies, as well as the results of clinical trials - particularly the complications in the form of pseudoarthrosis occurring in the postoperative period, and the findings relating to the ways of transferring the load to the distal humerus - we would like to present the following hypotheses:

1. In the case of extraarticular methphyseal fractures, which are treated with two plates (reconstruction or locking compression), perpendicular or parallel to form, the radial side of the plate should be longer than the ulnar side in order to prevent varus stresses as the main cause of the distal humeral pseudoarthrosis.

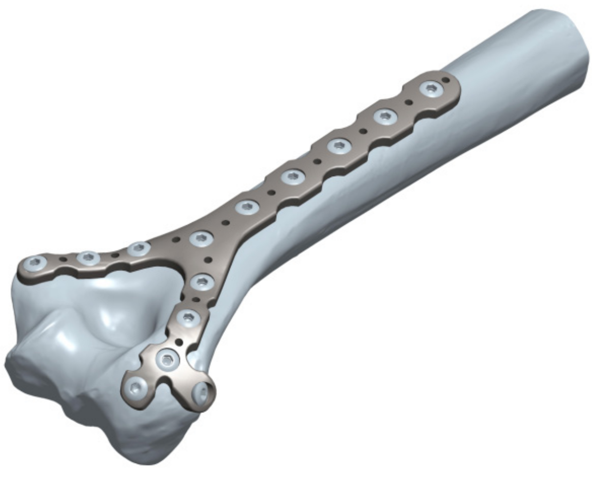


Figure 4. The new designed Y shaped plate should have a longer radial arm and should be configured to prevent varus stresses

Slika 4. Novodizajnirana Y pločica treba imati dulji radijalni krak i treba biti konfigurirana s ciljem izbjegavanja varusnih naprezanja

2. Sufficient stability can be ensured with new design Y-shaped reconstruction or Y-shaped locking compression plate. The Y shaped plate should have a longer radial arm and should also be configured to prevent varus stresses (Figure 4).
3. Parallel configuration is stronger than the perpendicular configuration on supracondylar metaphyseal level of the distal humerus under axial load in a position of flexion of 50^0 and in case of anterioposterior load in a position of flexion of 75^0 when the radial column carries 60% and 40% of the ulnar load. No significant difference in strength between the parallel and perpendicular configurations was observed on the radial condyle load.
4. The new design Y-shaped plate, as previously described, has a similar strength in the anterioposterior load, less strength in the axial load, and better strength in the lateral load to the radial condyle when compared with the parallel and perpendicular configuration. In addition, the plate is much stiffer in the anteroposterior and lateral load on the radial condyle and the lower axial load in comparison with the perpendicular configuration.

3. EVALUATION OF THE HYPOTHESES

The majority of non-unions happen at the supracondylar level, while healing of the articular components may occur in their reduced position. Nonetheless, the stability of the construct requires adequate bony contact with interfragmentary compression. In case of a distal humeral fracture, by far the greatest number of fixation failures occurs at the supracondylar level, while typically the articular fragments unite, and, with time, fracture union at this level.

Maximizing stability between the distal fragments and the shaft of the humerus at the metaphyseal level should be the focus of the fixation strategy (4,6). O'Driscoll (6) lists the technical principles to apply in order to achieve stable internal fixation of distal intraarticular humeral fractures.

Concerning the plates used for fixation, he writes that they should be applied in such a manner so as to achieve compression at the supracondylar level for both columns; at the same time the plates used must be strong enough and stiff enough to resist breaking or bending before union occurs at the supracondylar level (6).

The practical application of these principles involves "parallel" plates that permit a total of at least 4 to 6 long screws to be placed in the distal fragments, from one side across to the other. The plates are placed with a slight offset, posteromedially and posterolaterally (14).

Pajarinen et al (22) conclude that satisfactory results can be obtained when stability of the humeral columns is achieved and the articular platform reconstructed.

O'Driscoll (6) points out that the literature on fractures of the distal humerus pays far too little attention to how the failure of fixation generally begins in the lateral column. The force of gravity acting on the long lever arm (the forearm), while the elbow is flexed and extended during apparently minimal-use activities leads to repetitive varus stresses across the elbow. This can be typically seen in the action of a person reaching out to grab something, a glass of water for instance, followed by bringing the hand to the mouth. This causes varus torque across the elbow, distracting the lateral column away from the fixation placed along its posterior surface (6).

The load transfer in the elbow joint can be described by a two column model (1,23). The medial ulnar column and the lateral radial column form the articular block. The lateral column shares 60% of the load and the medial column 40% (1,18,23). This two-column model is the basic principle of the double plating osteosynthesis of C-type fractures of the distal humerus (1,6,12).

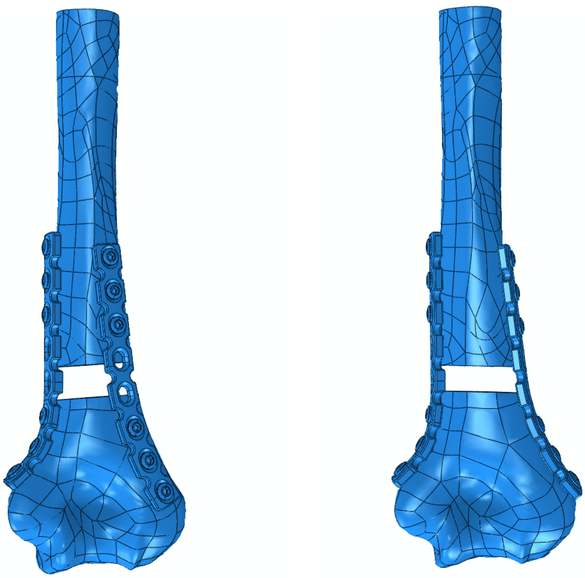
In recent publications, a higher stiffness and strength of osteosynthesis in the parallel plating technique were compared to the perpendicular technique with different plate designs. The mechanical advantages of a parallel plate configuration have been demonstrated for conventional reconstruction plate design (24), as well as for locking plate constructs (19). In other studies did not find a significant differences (1,5). As noted in previous studies, pseudoarthrosis of the distal humerus usually occurs in the region at the metaphyseal and supracondylar level of radial columns due to varus stresses.

So far, there have been no biomechanical studies on the supracondylar metaphyseal level on the border of the distal humerus diaphysis. Previous studies have examined intraarticular or low supracondylar fractures (16-19,24).

We believe that fractures in this part of the humerus have different biomechanical demands than intra-articular fractures of the distal humerus. The previously described new design Y shaped plate, which supports both columns and is at the same time longer in the radial, more loaded column, could be at least of the strength equal to the strength as the two plates.

To prove the hypotheses, the following tests should be performed: biomechanical studies at the supracondylar metaphyseal level on the border of the distal humerus diaphysis using the finite element method, where the gap would be done at the level of the distal humerus 3 cm above the fosse olecrani (Figure 5). The gap is shown in the figure as an interruption of the bone continuity.

The biomechanical study should be made to the axial load in a position of flexion of 5 , the bending load in a position of flexion of 75^0 and the lateral load on the radial condyle. After applying the finite element method in order to choose the optimal position of the plates, a biomechanical study of the synthetic or cadaver humerus would



A B

Figure 5. Biomechanical model at the supracondylar humerus level of the distal humerus- perpendicular (A) and parallel configurations (B)

Slika 5. Biomehanički model suprakondilarnog dijela distalnog humerusa – perpendikularna (A) i paralelna konfiguracija (B)

be undertaken. This study would compare the stiffness of the new design Y-shaped parallel and perpendicular plate configuration by applying the same loads as those applied in the finite element method.

4. DISCUSSION

The incidence of distal humeral fracture is relatively small, with a large number of fracture subtypes. Clinical studies are often functionally insufficient because of the limited number of patients. There are no published prospective randomized studies, the majority of the studies were retrospective and carried out on a small number of samples. Therefore, on the basis of these clinical studies it is not possible to draw conclusions about the recommendable implant configuration in case of fractures of the distal humerus. A biomechanical study is therefore required.

In their publication, Penzkofer et al (1) state the following: "the system stiffness is influenced by two kinds of factors: factors which cannot be influenced by the surgeon and factors which allow the individual adjustment of an osteosynthesis. The initial situation is the fracture pattern and fracture geometry with the number and shape of the fragments. This initial fracture situation strongly dictates the options for plate positioning. On the other hand, the overall construct stability can largely be influenced by placing the plates at different anatomical positions". In their study they do not take into account the lateral load, as there is already a load in the position of flexion and extension.

Zalavras et al (19) found that parallel plate constructs had significantly higher stiffness than the perpendicular ones during cyclic varus loading. The measurement of displacement is not made precise measuring instruments at the gap. In this article loosening of the implants was defined as gross displacement (backing-out) of the screws during cyclic loading of the specimens. When done varus loading to failure resulted in ligamentous disruption in all specimens, which occurred prior to any catastrophic failure of fixation (19). In this way, they could't see a shift in the gap and assess the mechanical stability of the specimens.

Recent biomechanical studies, considered loads on the distal segment of the humerus in a position of flexion of 75^0 (18,19) or 50^0 (20) to the longitudinal axis of the humerus, or a position of flexion of 5^0 (19) or 15^0 (18). Only Zalavras et al (20) have performed radial varus loads.

In clinical studies, significantly better results were achieved with surgical rather than with conservative treatment of extra-articular distal humeral fracture (3,7). Shin et al (13) compared clinical outcomes in patients with intraarticular distal humerus fractures and concluded that both parallel and orthogonal plate positioning can provide adequate stability and anatomic reconstruction of the distal humerus fractures, while Sanchez-Sotelo et al (12, 14) preferred the parallel configuration.

Prasarn et al (4) recently reported their good clinical experience with the use of the locking compression plate for extraarticular fractures of the distal humerus, adding two additional reconstructive plates to the radial column.

As noted in previous studies, pseudarthrosis of the distal humerus usually occurs in the region at the metaphyseal and supracondylar level of the radial columns due to varus stresses.

Previous studies have been variously designed with different directions and types of loads, different static and dynamic forms and in different cycles and with very varied samples. Furthermore, measuring instruments and their degree of precision in measuring displacements and deformations are different and hardly comparable. Therefore, it is difficult to compare the results of biomechanical studies. Also, so far, displacements in different directions when loads are significantly different have not been taken into account. Therefore, we believe that the direction of the load which causes greater displacements has a greater impact on the overall evaluation of the stability of the implant. Consequently, displacements in the bending and lateral loads to the radial condyle are considerably larger than the axial load, and thus with a greater significance in the overall assessment of the structural stability of implants. Therefore, the role of the implant is to neutralize the forces that cause the greater displacements in the area. Likewise, in the case of osteoporotic fractures, we should know that osteoporosis is more pronounced in the posteriolateral part of the radial condyle (25), and that the area of the lateral columns, especially the capitelum and the distal part of the lateral column, has very thin cortices (26).

After the biomechanical studies were conducted with the aim of proving or rejecting the hypothesis, randomized clinical medical trials should be performed. A disadvantage of biomechanical studies of this kind is the inability to take account of all factors that influence the treatment outcome. Dynamic loads that occur during everyday activities have important place among them.

Well known issue of anatomical variations in the distal humerus requires making plates of different size with the ability of remodeling regarding the anatomical differences.

The biomechanical study as described above can provide proof of the hypothesis that two plates where the plate at the radial side is longer or a new design Y-shaped plate as previously described provide improved biomehanical stability in comparison with two plates of equal length in fractures of distal humerus diaphysis at the turn of the distal humerus. The former method would prevent varus stresses and complications that arise due to this load.

5. CONFLICTS OF INTEREST STATEMENT

None declared.

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Položaj implantata kod ekstraartikularnih prijeloma distalnog humerusa – nove hipoteze za liječenje

Sažetak

U razvojnom procesu od konzervativnog pa do operativnog liječenja prijeloma distalnog humerusa, otvorena repozicija te unutrašnja fiksacija pločicama i vijcima su se pokazale kao najbolja metoda liječenja. Pločice se postavljaju uz blagi pomak posteromedijalno i posterolateralno. U posljednjim biomehaničkim studijama uglavnom je analizirana i uspoređivana krutost i stabilnost osteosinteze s različitim pločicama u paralelnoj i perpendikularnoj konfiguraciji. Dosadašnja istraživanja su također pokazala da su loši rezultati liječenja prijeloma distalnog humerusa uglavnom posljedica neadekvatnog cijeljenja u metafizarnoj i suprakondilarnoj regiji radijalne kolumne zbog varusnih naprezanja. Stoga je hipoteza rada da kod ekstraartikularnih metafizarnih prijeloma koji se liječe s dvije pločice u paralelnoj ili perpendikularnoj konfiguraciji, pločica na radijalnoj strani treba biti dulja od ulnarne kako bi se izbjegla varusna naprezanja koja su u većini slučajeva glavni uzročnik pojave pseudoartroze distalnog humerusa. Dovoljna stabilnost koštanih ulomaka može se osigurati novodizajniranom Y pločicom koja je konfigurirana na način da ima dulji radijalni krak, čime se znatno smanjuju varusna naprezanja. Da bi se navedena hipoteza dokazala, potrebno je provesti biomehanička istraživanja u suprakondilarnoj i metafizarnoj regiji na prijelazu u dijafizarnu regiju distalnog humerusa.

Ključne riječi: distalni humerus, ekstraartikularni prijelom, biomehanika

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