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Triangular block bridge method for surgical treatment of complex proximal humeral fractures: theoretical concept, surgical technique and clinical results

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Proximal humeral fracture
Triangular block bridge
Isostatic structure
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Synthesis

ABSTRACT

Introduction: Criteria for classification, indication and choice of a surgical device to treat proximal humeral fractures are still controversial. We report an original technique based on a mechanical concept with a structural principle of a triangle as a rigid body applied to the humeral head fractures in association with other devices. This retrospective study aims to describe in detail the surgical technique and results at long time follow up.

Methods and Material: We analysed two series of 101 patients with proximal humeral fractures (mean age, 52.9 y; range 19–78 y) treated between 2001 and 2012 reporting the clinical and radiological results. In the first series of 23 cases (mean age 51.4 y, range 35–74 y) we used as support a bone piece taken from allograft or autologous tricortical iliac crest and shaped as a triangular pyramid during the operation; while in the second series of 78 cases (mean age 53.6 years, range 29–78 years, SD 13.5 years) a triangular titanium cage was used in 69 patients while in 9 allograft or bone substitute was used as augmentation. An analytical retrospective study was done to understand the mechanical function of medial augmentation composed by a solid body in association with different types of synthesis to stabilize properly a proximal humeral fracture.

Results: We obtained excellent and good results in 83,2% of patients, fair in 12,8% and bad in 4% in terms of active anterior elevation, external and internal rotation, pain and strength according to Constant and DASH score.

Conclusion: A medial solid body, especially in titanium material and shaped as trapezoidal/pyramidal form used to fill the secondary bone loss in complex instable proximal humeral fracture, allows an anatomic reduction and stable fixation in association with simple and more complex tools and it provides a better biomechanical environment for union and maintenance of alignment.

Introduction

Minimally displaced proximal humeral fractures can be conservatively treated while the displaced ones often need a surgical treatment with an increasing number of these patients in the last years [1]. The management of these injuries is still controversial especially for classification, indication and patients' age [2–4].

In the Literature there are no techniques and devices that give better results than the others [3–7]. In the last years the use of locked plates is increased with different complications reported such as the loss of reduction, joint violation for screws penetration and the high number of cut-out with raising percentage of reoperations [4]. The purpose of this study is to report clinical and radiographic results after open reduction and internal fixation of proximal humeral fractures with the Triangular Block-bridge method [7]. We used this technique since 2001 with a pyramidal bone graft (handcrafted from allograft or iliac crest bone) as medial or internal augmentation associated with minimal osteosynthesis. In 2005 the tool was changed for a titanium triangular prism (Da Vinci system) [8] in 5 different sizes (Arthrex Naples Florida) in combination with non-absorbable osteosutures and minimal osteosynthesis such as cannulated screws or K-wires, and a small low-profile plate (Depuy Synthes) with minimal osteosynthesis. We describe some theoretical aspects of this method, the surgical technique and report the clinical results in 101 patients.

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Physical and mechanical device principles

The triangular shape of da Vinci system (Figure 1) has been developed for the necessity to have a versatile support in order to stabilize as much as possible a displaced humeral head with two, three or four parts.

The current classification as described by Neer and after from AO foundation in two, three and four parts with subgroups could be not enough to describe the patho mechanical patterns of proximal humeral fracture [9] due to the complex aspects of some of them especially when there is a comminution of medial hinge. For this reason, we have developed a new CT scan assessment of broken medial column [8], useful also for the interpretation of all types of fractures from 2 to 4 part. We evaluated the calcar region in the patho-mechanics analysis of fractures not as a linear structure but as a three-dimensional one based on a 3D CT-scan model. Moreover, according to his displacement in axial, coronal and sagittal planes of the space we can evaluate the degree of complexity from a 2 part to four-part fracture patterns. In all cases, from the simplest to the most complex humeral proximal fracture, a solid biocompatible body with triangular shape was used and put into medullary cavity and allowed the stable distribution of rotator cuff and deltoid compressive forces due to an adequate fracture support with a limitation of torsional forces. Our device is very similar to an extruded triangle (Figure 2) that respects the condition of an isostatic structure. More specifically, the system follows the isostatic equivalence:

$$a = (2 \times n) - 3$$

where a is the rod and n is the node of the structure. In our case, $a = 9$ and $n = 6$, and thus the equivalence is satisfied. Furthermore, the device scarce depth has a negligible impact on its mechanical properties. Consequently, the overall system can be modeled as a structure composed by three rods hinged among them in a triangle. Thus, the prototype behavior can be assumed like a rigid body. As a matter of fact, in consideration that the angular momentum of the three conceptual rods must be the same, their triangular chain behaves only like a stiff body. If at this solid "bridge" inside the medullary canal, are added tension band outside from the cuff to the cortical bone of the diaphysis and external pins crossing the triangular structure from the diaphyseal cortex to inside, according to neck-shaft angle, it transforms into a stable system allowing the minimum bearing loads due to normal muscle tone and movement during the rehabilitation process. This system represents the mechanical concept of the non-deformable triangle as an inclined arrangement and it opposes horizontal to vertical stresses in compression and torsion thereby avoiding varus deformity and retroversion of the humeral head. Moreover, the neck-shaft angle can be stabilized by metal supports placed from the top to the bottom of the fracture; in addition, bending and torsional moments are reduced by external tie rods. Eventually, in order to prevent the deformity, our triangular structure opposes to varus torsional forces because of its geometric shape. In addition, it promotes healing as the fragments are stable and loss of reduction is prevented.

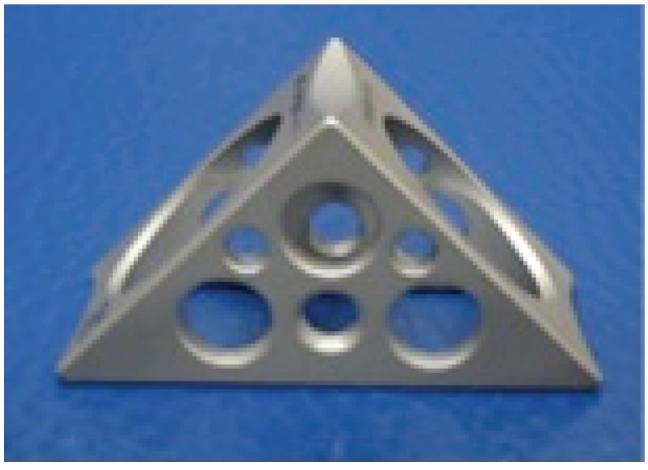

Fig. 1. Da Vinci system.

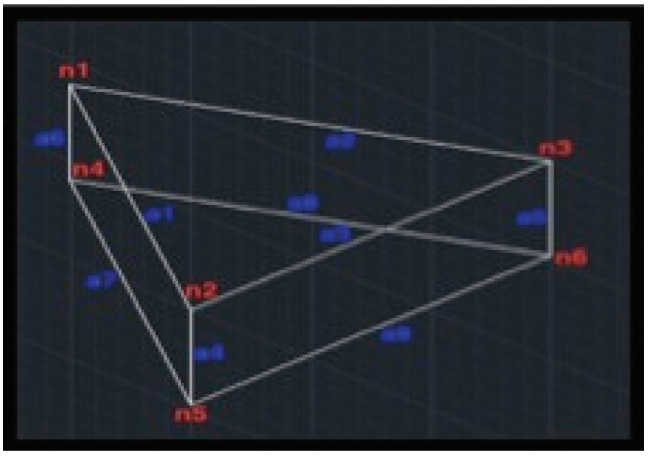

Fig. 2. Da Vinci system design.

Subjects and methods

This study was based on a retrospective case control analysis on 101 patients (65 right arm, 35 left arm, 1 bilateral) with mean age of 52.4 y (19–78 years) treated for complex humeral fractures between 2001 and 2012. All investigations were conducted in conformity with ethical principles of research and for this type of study. The inclusion criteria were acute, traumatic two-part, three-part and four-part fracture patterns according to Neer classification [10]. At the beginning in the first group there were 33 patients (20 men, 13 women; 21 right arm, 2 left arm) with a mean age of 56 years (range 34–74 years) and the fractures were classified as 6 displaced 3-part fractures, 12 displaced 4-part fractures, 8 anterior 4-part fracture-dislocations, and 7 comminuted [7]. Of this group we reviewed 23 patients (3 died and 7 lost at follow-up) at mean 77 months follow-up (range 84 to 156 months) with a mean age of 51.4 years (range 35–74 years; 15 men, 5 women, 18 right side, 5 left side) with 5 displaced 3-part fractures, 10 displaced 4-part fractures, 5 anterior 4-part fracture-dislocations and 3 comminuted. In the second group we reviewed 78 patients (79 shoulders; 45 men and 33 women; mean age 58.3 years; range 19–78 years; 48 right and 31 left shoulders) at mean 72 months follow up (range 12–132 months) with 2–3 – or 4-part fractures, fracture-dislocations, or unclassifiable complex fractures of the proximal humerus. The fractures were classified in 9 patients as 2-part, in 23 as 3-part, in 22 as 4-part fracture, in 15 as fracture-dislocation, or unclassifiable fracture in 10 cases.

Patients were examined at follow-up according to Constant-Murley score [11] and the Disabilities of the Arm Shoulder and Hand score to evaluate the function. At x-ray control the fractures healing were evaluated with radiographic union score and clinical evaluation [12] (malunion, avascular necrosis, varus and valgus alignment and development of post-traumatic osteoarthritis). Humeral head alignment was considered normal with a deviation in all planes from 0° up to 10°. In the first group of patients, between 2001 and 2005, the technique used was an open reduction and medial endo-osteal augmentation with autologous tricortical bone harvested from the iliac crest (more rarely) or dry bone bank block shaped as triangular trapezoidal block. In the second group, treated between 2005 and 2012, 9 shoulders were managed using allograft or bone substitute,