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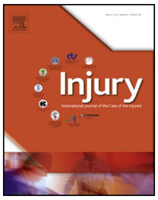

Biomechanical evaluation of two innovative locking implants for comminuted olecranon fractures under high-cycle loading conditions

F.C. Wagner [*], L. Konstantinidis, N. Hohloch, L. Hohloch, N.P. Suedkamp, K. Reising

Department of Orthopedic and Trauma Surgery, Freiburg University Medical Center, Freiburg, Germany

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ABSTRACT

Introduction: The relatively high complication rate after fixation of olecranon fractures has led to an increasing application of anatomically pre-contoured locking plate systems. The purpose of the present study was to conduct a biomechanical comparison of olecranon osteosyntheses by applying the Olecranon VA-LCP and the 3.5 mm LCP Hook Plate (LCP, locking compression plate) to an unstable fracture model under high-cycle loading conditions.

Methods: After creating an unstable fracture (Schatzker type B), osteosynthesis was performed on eight pairs of fresh-frozen cadaveric ulnae by application of either the Olecranon VA-LCP (Synthes, Solothurn, Switzerland) or the 3.5 mm LCP Hook Plate (Synthes, Solothurn, Switzerland).

Loading (50,000 alternating loads, cyclic and sinusoidal 10–300 N) was conducted by application of tensile load with the elbow in 90° flexion to simulate the tensile strength of the triceps brachii. For statistical analysis, angular displacement in the region of the humeral trochlea was taken as a measure of olecranon dislocation.

Results: In Group 1 (Olecranon VA-LCP), a median angular displacement of 0.36° (minimum 0.10°; maximum 0.80°) was observed after 500 alternating loads. In Group 2 (3.5-mm LCP Hook Plate), the medial displacement was 0.80° (minimum 0.13°; maximum 2.72°). The difference was nonsignificant ($p = 0.128$).

The mean value for angular displacement in Group 1 after 50,000 cycles was 0.80° (minimum 0.31°; maximum 1.99°), whereas in Group 2 a mean angular displacement of 2.02° (minimum 0.71°; maximum 6.40°) was recorded. The difference was statistically significant ($p = 0.017$). In Group 2, implant failure in the form of proximal plate pullout occurred in one construct after 756 cycles.

Conclusion: A significantly higher biomechanical stability can be achieved in the fixation of unstable olecranon fractures by application of the Olecranon VA-LCP rather than the 3.5 mm LCP Hook Plate.

Introduction

Nowadays, the most common technique in the treatment of simple olecranon fractures is tension banding, whereby the principle of tension banding has not yet been proven in the clinical setting or in biomechanical studies [1,2]. Wilson et al. conducted a biomechanical study and reported distinctly greater interfragmentary compression after plate osteosynthesis compared to tension banding, whereby the latter was more susceptible to fragment distraction under load [2]. Given these more recent biomechanical findings, there is a general preference for plate fixation systems, especially in multifragmentary situations where there is a lack of intrinsic fracture stability and, consequently, the risk of imminent reduction loss. In addition to simple one-third tubular plates, the application of anatomically pre-contoured locking plate systems is increasing as their fixation options are better even in poor-quality bone [3]. The superiority of intramedullary fixation techniques has already been proven in clinical and biomechanical studies in terms of implant removal rates and construct stiffness [4–8]; however, the high cost of materials and lack of expertise have impeded their rapid acceptance in the marketplace.

An incidence of up to 20% has been reported in the literature for implant-related complications after plate fixation of olecranon fractures; this includes not only wound dehiscence and wound infection but also implant failure, delayed fracture healing, and pseudarthrosis. However, the most common reason for revision

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[*] Corresponding author at: Department of Orthopedic and Trauma Surgery, Freiburg University Medical Center, Hugstetter Str. 55, D-79106 Freiburg, Germany. Tel.: +49 76127024010.

E-mail address: ferdinand.wagner@uniklinik-freiburg.de (F.C. Wagner).

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surgery accounting for 18–20% is by far prominent implants [9,10], whereby bulkier plate systems do not yield higher rates in this regard than tension-banding techniques [11].

Given the general trend towards plating solutions in the treatment of olecranon fractures, the purpose of the present study was to conduct a biomechanical comparison of olecranon osteosyntheses by applying the Olecranon VA-LCP and the 3.5-mm LCP Hook Plate (LCP, locking compression plate) to an unstable fracture model under high-cycle loading conditions.

Materials and methods

This biomechanical in vitro test series was performed on eight pairs of fresh-frozen cadaveric ulnae. These were tested for bone density by dual X-ray absorptiometry to exclude statistically significant differences in quality (mean values for bone mineral density in gram per centimetre squared: Group 1, 0.73 ± 0.19; Group 2, 0.77 ± 0.20). First, all soft tissue except the tendon of the triceps brachii was stripped from the bones, and then a standardized Schatzker type B fracture was created. This was achieved by osteotomy in the bare region of the trochlear notch followed by excision of a 5-mm wedge proximal to it on the side of the joint to simulate impaction of the joint surface (see Fig. 1). The next step was pair-by-pair stable fracture fixation by application of the Olecranon VA-LCP (Synthes, Solothurn, Switzerland) (Group 1) or the 3.5 mm LCP Hook Plate (Synthes, Solothurn, Switzerland) (Group 2). All osteosyntheses were performed by the same surgeon.

Osteosynthesis was performed strictly in accordance with the instructions for surgical technique as issued by the Synthes company [12,13], whereby one bicortical screw in the shaft was implanted in the locking technique and the other as a non-locking cortical screw. In Group 1, the proximal fracture fragment received three 2.7-mm locking head screws monocortically, whereas in Group 2 a bicortical cortex screw was implanted to bridge the fracture gap.

Correct implant positioning was verified by radiology (see Fig. 1).

Testing was carried out in the universal testing device UTS 20/test control (Zwick/Röll, Ulm, Germany). For the test set-up, the bones were shortened to 12 cm and embedded to a depth of 5 cm in polymethylmethacrylate (PMME-Technovit 3040, Heraus Kulzer GmbH, Wehrheim, Germany) in stainless-steel sleeves.

The procedure for testing was the simulation of tensile load on the triceps brachii with the elbow joint in 90° flexion. To perform this, the embedded bones were placed horizontally and secured tightly in brackets to the testing device. A 20-mm-diameter pulley was fixed firmly in the region of the trochlear notch to simulate the biomechanical effect of the humeral trochlea. The triceps tendon retained at dissection was locked into a clamp that was attached to the moving crosshead of the testing device via the load cell (see Figs. 2 and 3).

Data acquisition was performed by means of an ultrasound-based motion analysis system CMS 20 (Zebris Medical, Isny, Germany), which had already been employed effectively for motion analysis in other biomechanical studies [14–18]. Measurement is based on the transmission of ultrasound waves and records motion in all three degrees of freedom at an accuracy of 0.1 mm. The sensors were calibrated such that the *x*-axis corresponded to the direction of pull of the triceps brachii, the *y*-axis the humeral

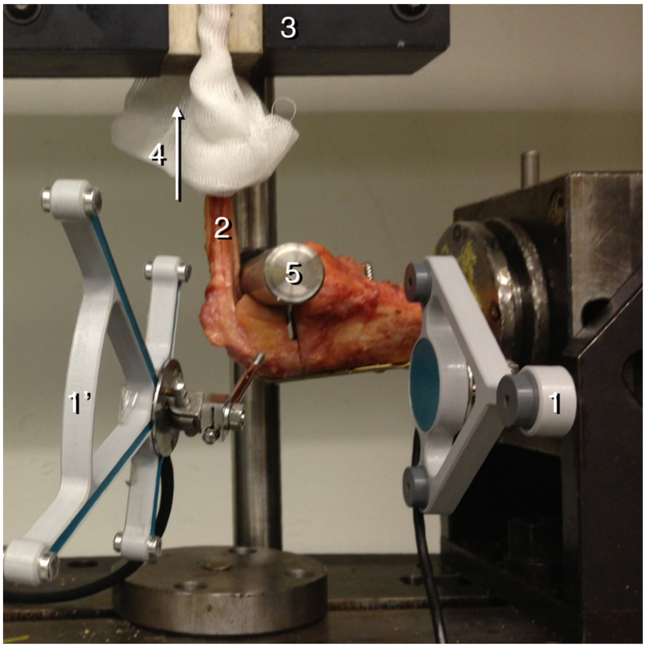

Fig. 2. Test set-up showing the polymethylmethacrylate-potted olecranon with an Olecranon VA-LCP implanted and the ultrasound transmitter (1) and receiver (1′) at each side of the fracture. The triceps tendon (2) is fixed to the moving crosshead by a clamp (3) to apply the dynamical pull force (4). A hypomochlion (5) is used to simulate the humeral trochlea.

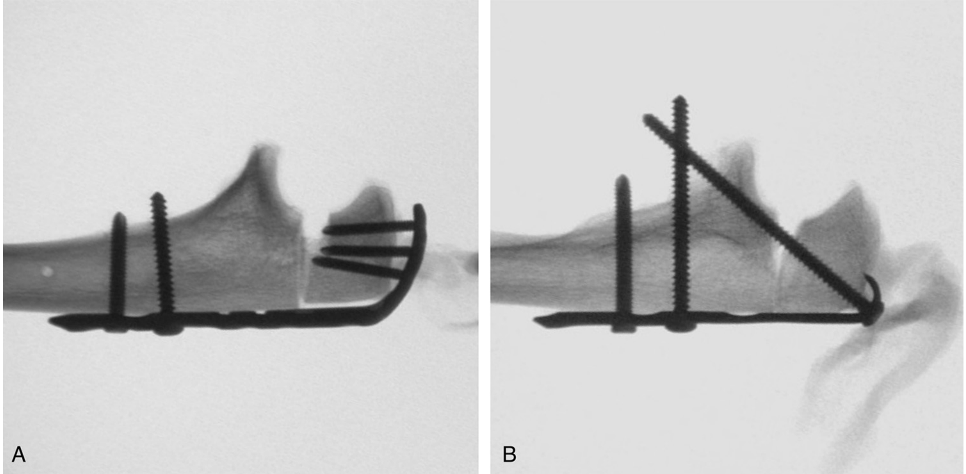

Fig. 1. Radiological controls of the individual bone-implant constructs with a wedge osteotomy to simulate an unstable olecranon fracture (Schatzker type B). (A) Olecranon VA-LCP, (B) 3.5 mm LCP Hook Plate.