Comparison Between Locking and Non-Locking Plates for Fixation of Metacarpal Fractures in an Animal Model

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Purpose The use of locking plates increases the primary load to failure, thereby reducing the rate of implant-related failure. The good clinical and biomechanical results of locking plates in long bones might be applicable to treatment of metacarpal fractures. The purpose of this study was to determine strength and stiffness of locking plates in a metacarpal fracture model with mono- and bicortical screw fixation in comparison to non-locking plate mono- and bicortical screw fixation, with both types of plates placed at the dorsal side of the bone.

Methods Fresh second metacarpals from domestic pigs (n=40) were randomized in 4 equal groups. Short, oblique, mid-shaft fractures were generated, using a standardized 3-point bending method. Fractures were plated with non-locking, titanium, 1-mm-thick monocortical (group 1, n=10) or bicortical (group 2, n =10) plates (Leibinger-Stryker; Stryker Corp, Freiburg, Germany). Newly designed locking titanium plates with the same width and thickness (Leibinger-Stryker) were used in the same manner for groups 3 (monocortical) and 4 (bicortical). The metacarpals were then tested to load to failure in a cantilever bending mode.

Results Bicortical, non-locking fixation (group 2, 359 ± 90 N) had a higher load to failure than monocortical non-locking fixation (group 1, 250 ± 56 N) in testing the maximum load to failure ($p < .01$). There was no significant difference in stiffness between group 1 (46 ± 12 N/mm) and group 2 (56 ± 21 N/mm). The difference in maximum load to failure between monocortical (group 3, 440 ± 85N) and bicortical (group 4, 378 ± 116 N) locking plate stabilization was not significant. Also, there was no significant difference in stiffness between monocortical (group 3, 83 ± 35 N/mm) and bicortical locking plates (group 4, 70 ± 31 N/mm). Comparing non-locking (group 1) and locking plates in a monocortical fixation technique (group 3) demonstrated significant differences in maximum load to failure (group 1, 250 ± 56 N; group 3, 440 ± 85 N) and stiffness (group 1, 46 ± 12 N/mm; group 3, 83 ± 35 N/mm). The stability of monocortical locking plates was stronger, although not statistically significant, than the non-locking bicortical plates (load to failure, 440 ± 85 N vs 359 ± 90 N; stiffness, 83 ± 35 N/mm vs 56 ± 21 N/mm).

Conclusions The new generation of locking plates can be used to achieve a higher stability for fixation of metacarpal fractures. Monocortical, stable fixation can minimize flexor tendon interference and probably reduce bone and soft tissue trauma. *(J Hand Surg 2010;35A:597–603. Copyright © 2010 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Biomechanics, fracture, internal fixation, locking plate, metacarpal.

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Received for publication September 2, 2008; accepted in revised form January 6, 2010.

Support was provided by Stryker Corporation, Freiburg, Germany, for implant and material costs. No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/10/35A04-0012$36.00/0
doi:10.1016/j.jhsa.2010.01.002

The key factors in the treatment of hand fractures are to allow bony union in good position, soft tissue healing, and early rehabilitation. Plate fixation has the potential of accomplishing these goals. Extensor tendon problems, additional cost, and the risk of stiffness are the principal disadvantages of plate fixation.[1–7]

The use of locking plates is established in the treatment of long bone fractures. The good clinical and biomechanical results of locking plates in long bones might be applicable to treatment of metacarpal fractures. Many studies compare locking and non-locking plates in long bone fractures, such as in the humerus, femur, and radius,[8–11] but we are unaware of any studies analyzing locking plates for hand surgery. Before locking plates can be used in hand surgery, biomechanical testing is necessary. The first biomechanical studies on plates in craniomaxillofacial fractures, using plates that also can be used in hand surgery, demonstrated a higher ultimate load to failure of locking plates compared to non-locking plates.[12] Clinical indications for using locking plates in hand surgery could be seen in complex, unstable metacarpal and phalangeal fractures with bone defects. Using locking plates, we have the opportunity of monocortical fixation of the plates. This less invasive technique avoids flexor tendon interference or secondary tendon ruptures compared to conventional bicortical fixation when the plate is placed on the dorsal surface of the metacarpal.

The purpose of this biomechanical study was to determine the strength and stiffness of locking plates in a metacarpal fracture animal model in comparison to non-locking plates. All plates had the same plate thickness, plate and screw material, and screw design (size and threads). In both groups, monocortical and bicortical screw fixation were tested.

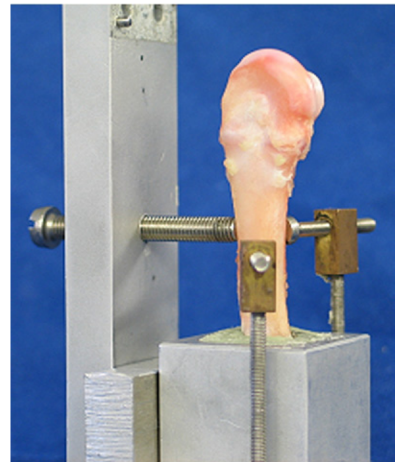

FIGURE 1: Fixation device and embedding of the metacarpals (14 mm of the proximal bone) using Palacos (Kulzer GmbH, Wehrheim, Germany).

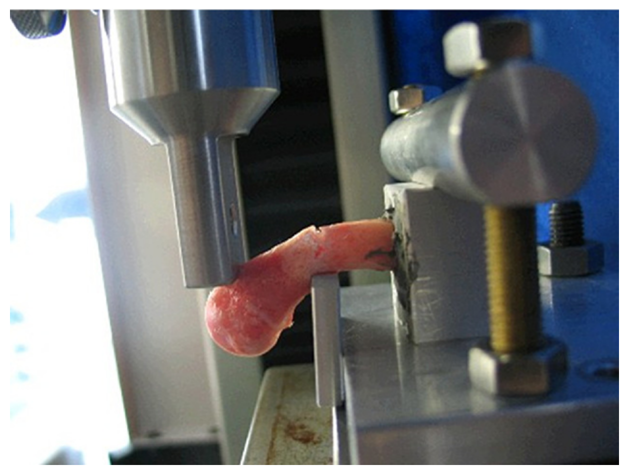

FIGURE 2: Modified 3-point bending test, load application apical distal with 100 mm/min, load to failure protocol (distance, block to edge 15 mm, edge to apex, 10 mm).

MATERIALS AND METHODS

Specimens

A total of 40 fresh second metacarpals from domestic pigs were used. This bone resembles human metacarpals and proximal phalanges, with minimal interspecies variations of structure compared to those of human cadavers.[13] Using pig metacarpals has been validated in several studies to test the biomechanical features of hand fixation.[13–16]

The specimens were dissected from soft tissue, their dimensions were measured, and they were stored at −70°C to preserve their mechanical properties as close as possible to those of fresh bones.[17] Immediately before use, specimens were defrosted and embedded in a fixation device (14 mm), using Palacos (Kulzer GmbH, Wehrheim, Germany) according to the manufacturer's instructions (Fig. 1). All specimens were kept moist with saline irrigation at room temperature during preparation, the surgical procedure, and biomechanical testing to prevent desiccation. A mid-shaft fracture was generated, using a standardized, modified 3-point bending method. Embedded specimens were placed on a waste edge at a reproducible position (distance, fixation device to waste edge, 15 mm). Load was applied apex distal (distance, waste edge to point of force transmission, 10 mm) with a constant speed of 100 mm/min until failure was noted (Fig. 2). This procedure resulted in a shaft fracture of the metacarpal as seen in Figures 2 and 3 (AO classification A2).