Biomechanical Comparison of Double-Row Locking Plates Versus Single- and Double-Row Non-Locking Plates in a Comminuted Metacarpal Fracture Model

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Purpose Open or unstable metacarpal fractures frequently require open reduction and internal fixation. Locking plate technology has improved fixation of unstable fractures in certain settings. In this study, we hypothesized that there would be a difference in strength of fixation using double-row locking plates compared with single- and double-row non-locking plates in comminuted metacarpal fractures.

Methods We tested our hypothesis in a gap metacarpal fracture model simulating comminution using fourth-generation, biomechanical testing–grade composite sawbones. The metacarpals were divided into 6 groups of 15 bones each. Groups 1 and 4 were plated with a standard 6-hole, 2.3-mm plate in AO fashion. Groups 2 and 5 were plated with a 6-hole double-row 3-dimensional non-locking plate with bicortical screws aimed for convergence. Groups 3 and 6 were plated with a 6-hole double-row 3-dimensional locking plate with unicortical screws. The plated metacarpals were then tested to failure against cantilever apex dorsal bending (groups 1–3) and torsion (groups 4–6).

Results The loads to failure in groups 1 to 3 were 198 ± 18, 223 ± 29, and 203 ± 19 N, respectively. The torques to failure in groups 4 to 6 were 2,033 ± 155, 3,190 ± 235, and 3,161 ± 268 N mm, respectively. Group 2 had the highest load to failure, whereas groups 5 and 6 shared the highest torques to failure ($p < .05$). Locking and non-locking double-row plates had equivalent bending and torsional stiffness, significantly higher than observed for the single-row non-locking plate. No other statistical differences were noted between groups.

Conclusions When subjected to the physiologically relevant forces of apex dorsal bending and torsion in a comminuted metacarpal fracture model, double-row 3-dimensional non-locking plates provided superior stability in bending and equivalent stability in torsion compared with double-row 3-dimensional locking plates, whereas single-row non-locking plates provided the least stability. *(J Hand Surg 2009;34A:1851–1858. Copyright © 2009 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Metacarpal, fracture, comminuted, plate, locking.

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Although most metacarpal fractures can be treated with nonsurgical stabilization, open or unstable fractures, fractures with excessive soft tissue stripping, and multiple fractures are most often treated by open reduction and internal fixation. Numerous techniques have been proposed for the internal fixation of metacarpal fractures, but no single method has emerged as being clearly superior.[1–8] Plate and screw fixation remains a popular choice and a variety of configurations have been proposed in this category.[7,9–11] Dorsal plating has been shown by several studies to produce a stronger construct than many other methods, including crossed K-wires, intraosseous wiring, multiple intramedullary K-wires, and simple lag screws.[2,11–13] Standard AO, or the Association for the Study of Internal Fixation technique, uses a 6-hole single-row plate that is placed over the dorsal surface with 3 bicortical screws on either side of the fracture. Although the results of this method of fixation are good, complications such as tendon irritation, tendon rupture, finger stiffness, and the need for plate removal have been reported.[14–16] The staggered-design 3-dimensional double-row plates may improve outcomes with regard to some of these complications.

In our previous biomechanical study, we found that double-row 3-dimensional non-locking plates with the screws aimed for convergence may provide better stability and strength of fixation compared with single-row non-locking plates with cantilever apex dorsal bending in a transverse metacarpal fracture model.[17] The double-row plates are shorter, and their configuration was thought to provide added stability similar to the 90-90 double-plate fixation construct that is often used in complex and severely comminuted distal humerus and distal radius fractures.[18,19] This finding may eventually lead to less invasive procedures with shorter incisions, limited soft tissue dissection, and decreased scarring and soft tissue complications postoperatively. The complications of tendon irritation, tendon rupture, finger stiffness, and plate removal may therefore be decreased in theory with the use of these shorter plates. The simple transverse fracture model in our previous study, however, does not adequately account for the complexity of comminuted metacarpal fractures warranting surgical management.

The advent of locking technology has greatly advanced the treatment and management of complex fractures, particularly in cases where there is severe comminution or notably osteopenic bone. The increased stability and preservation of the periosteal blood supply offered by locking plates may lead to enhanced bone healing and improved clinical outcomes.[20] Locking plates have recently become available for the fixation of metacarpal fractures. Although it seems reasonable to expect locking plates to provide a stronger and stiffer construct in comminuted metacarpal fractures based on their success with comminuted fractures of the distal radius, we believed that the fundamental differences in bone type and forces experienced *in vivo* may influence the outcomes of locking plates for metacarpal fractures. We hypothesized that there would be a difference in strength of fixation using double-row locking plates compared with single- and double-row non-locking plates in comminuted metacarpal fractures. In the current study, we sought to examine biomechanically the strength of fixation of double-row 3-dimensional locking plates compared with single-row non-locking and double-row 3-dimensional non-locking plates in a gap metacarpal fracture model.

MATERIALS AND METHODS

We tested our hypothesis in a gap metacarpal fracture model using fourth-generation, biomechanical testing–grade composite sawbones (Sawbones; Pacific Research Laboratories, Vashon, WA). To simulate a comminuted fracture, we used a custom-made jig and a bone saw to remove a 3-mm block of bone from the diaphysis at the midpoint of each metacarpal, thereby creating a 3-mm gap. This technique has been used previously to model comminuted fractures in composite tibia bone models, where a 25-mm diaphyseal gap was created to achieve the effect of comminution.[21] A similar technique of creating an oblique-gap osteotomy dorsally has also been used to simulate comminuted extra-articular dorsal fractures in distal radius models.[22]

Each of our metacarpals was then randomly assigned to one of 6 groups, each containing 15 metacarpals. Each group corresponded to a particular plate type (single-row non-locking, double-row 3-dimensional non-locking, or double-row 3-dimensional locking) and applied stress type (cantilever apex dorsal bending or torsion). The jig was then used to hold each metacarpal securely while the plate and screws were applied. The plates were positioned along the dorsal surface of each bone with the midpoint of the plate centered over the 3-mm gap, and 3 screws positioned on either side of the gap. After plating all of the constructs, we individually measured the defect size in each of our constructs using a caliper and rounded our measurements to the nearest hundredth of a millimeter. We confirmed using 1-way analysis of variance (ANOVA) that there was no statistical difference in the defect size among our 6 groups.

Groups 1 and 4 were plated with a standard 6-hole Stryker (Kalamazoo, MI) Profyle, 2.3-mm non-locking