SCIENTIFIC ARTICLE

Biomechanical Properties of 3-Dimensional Printed Volar Locking Distal Radius Plate: Comparison With Conventional Volar Locking Plate

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Purpose This study evaluated the biomechanical properties of a new volar locking plate made by 3-dimensional printing using titanium alloy powder and 2 conventional volar locking plates under static and dynamic loading conditions that were designed to replicate those seen during fracture healing and early postoperative rehabilitation.

Methods For all plate designs, 12 fourth-generation synthetic composite radii were fitted with volar locking plates according to the manufacturers' technique after segmental osteotomy. Each specimen was first preloaded 10 N and then was loaded to 100 N, 200 N, and 300 N in phases at a rate of 2 N/s. Each construct was then dynamically loaded for 2,000 cycles of fatigue loading in each phase for a total 10,000 cycles. Finally, the constructs were loaded to a failure at a rate of 5 mm/min.

Results All 3 plates showed increasing stiffness at higher loads. The 3-dimensional printed volar locking plate showed significantly higher stiffness at all dynamic loading tests compared with the 2 conventional volar locking plates. The 3-dimensional printed volar locking plate had the highest yield strength, which was significantly higher than those of 2 conventional volar locking plates.

Conclusions A 3-dimensional printed volar locking plate has similar stiffness to conventional plates in an experimental model of a severely comminuted distal radius fracture in which the anterior and posterior metaphyseal cortex are involved.

Clinical relevance These results support the potential clinical utility of 3-dimensional printed volar locking plates in which design can be modified according the fracture configuration and the anatomy of the radius. *(J Hand Surg Am. 2017;■(■):1.e1-e6. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words 3-dimensional printing, volar locking plate, distal radial fracture.

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With the development of locking plates, there has been an increased use of internal fixation of unstable distal radial fractures. The procedure is often undertaken because of its technical simplicity, favorable outcomes, and reliable stability.[1,2]

Previous studies have demonstrated that many conventional volar locking plate constructs meet

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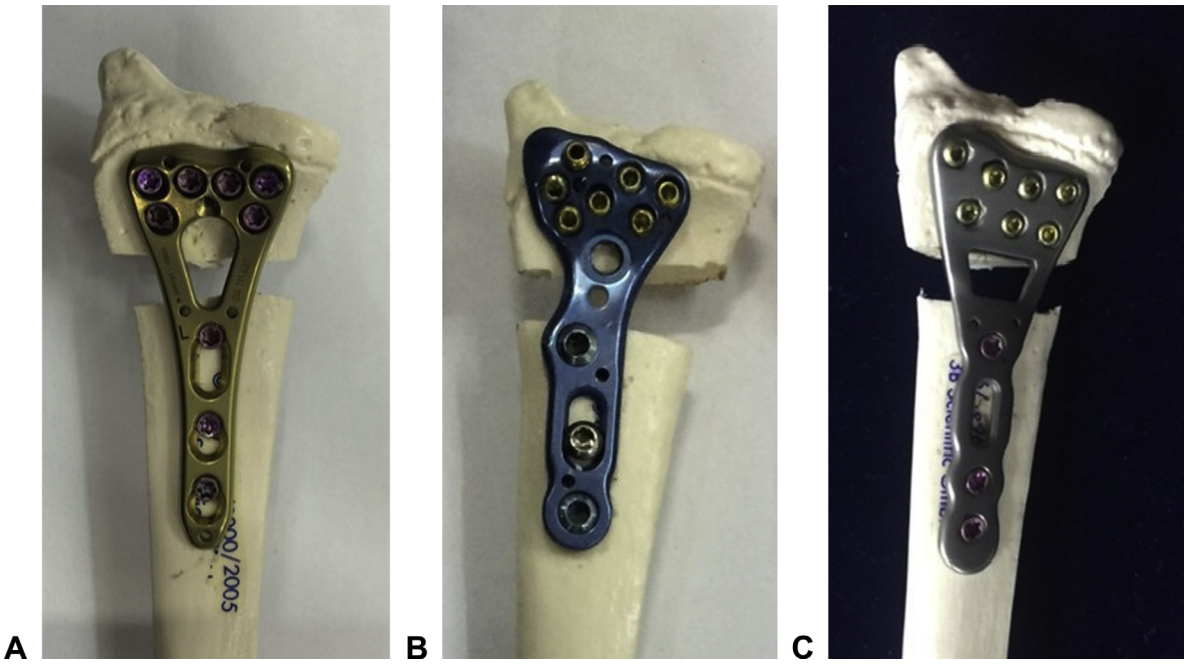

FIGURE 1: Plate preparation. **A** Synthes; the variable angle LCP 2-column distal radius plate. **B** Acumed Acu-Loc plate (Hillsboro, OR). **C** 3-Dimensional printed volar locking plate.

the anticipated demands of loads transmitted across the wrist.[3] Fracture configuration, screw placement, cost, and surgeon familiarity with instrumentation should be the main considerations when selecting a plating system for distal radius fracture treatment.[4] However, no single implant is likely to match the spectrum of shapes of the volar cortex of the distal radius, and additional implants may be needed to achieve rigid fixation when the locking screws do not provide sufficient purchase on the distal fragment of the radius.[5] These variables could be addressed by the availability of a customized plate. The design of a customized plate should match the patients' unique distal radius anatomy and screw placement should be modifiable to address the fracture configuration and provide rigid fixation.

Three-dimensional printing could enable such customized treatment. In 3-dimensional printing, successive layers of material are formed under computer control to create an object. These objects can be of almost any shape or geometry and are produced from a 3-dimensional model or other data source. Only a few studies have reported the use of 3-dimensional printed guiding templates in clinical trials,[6,7] and to our knowledge, no studies have compared the biomechanical properties of 3-dimensional printed implants with conventional medical implants.

This study evaluated the biomechanical properties of a new volar locking plate made with 3-dimensional printing using titanium alloy powder and 2 conventional volar locking plates under static and dynamic loading conditions that were designed to replicate those seen during fracture healing and early postoperative rehabilitation.

MATERIALS AND METHODS

Plates preparation

We tested the 2 conventional volar locking plates that are used most often to treat distal radial fractures in South Korea: the variable angle locking compression 2-column distal radius plate (LCP) (Synthes, Paoli, PA) and the Acu-Loc plate (Acumed, Hillsboro, OR). We also tested a volar locking plate made by 3-dimensional printing. The M2 cusing metal laser melting system (Concept laser, Lichtenfels, Germany) was used to assemble, under computer control, successive 15 to 60-μm layers of titanium alloy powder (Concept laser) according to the plate design. The plate was designed with a low profile and a thickness of 2.5 mm. The screw holes of the printed plate were made by a cutting process using a machining center tooling system. Abrasive blasting with zirconia was added to smooth the rough surface of the printed plate.