SCIENTIFIC ARTICLE

Biomechanical Comparison of Volar Fixed-Angle Locking Plates for AO C3 Distal Radius Fractures: Titanium Versus Stainless Steel With Compression

Tyler Marshall, MD,* Amit Momaya, MD,* Alan Eberhardt, PhD,* Nilesh Chaudhari, MD,* Thomas R. Hunt III, MD†

Purpose To determine biomechanical differences between a fixed-angle locking volar titanium plate (VariAx; Stryker, Kalamazoo, MI) and a fixed-angle compression locking volar stainless steel plate (CoverLoc Volar Plate; Tornier, Amsterdam, Netherlands) in the fixation of simulated AO C3 distal radius fractures.

Methods Eighteen cadaveric upper extremities (9 matched pairs) with an average age of 54 years were tested. A 4-part AO C3 fracture pattern was created in each specimen. The fractures were reduced under direct vision and fixed with either the fixed-angle locking volar titanium plate or the fixed-angle compression locking volar stainless steel plate. Motion tracking analysis was then performed while the specimens underwent cyclic loading. Changes in displacement, rotation, load to failure, and mode of failure were recorded.

Results The fragments, when secured with the fixed-angle compression locking stainless steel construct, demonstrated less displacement and rotation than the fragments secured with the fixed-angle locking titanium plate under physiological loading conditions. In the fixed-angle compression locking stainless steel group, aggregate displacement and rotation of fracture fragments were 5 mm and 3° less, respectively, than those for the fixed-angle locking titanium group. The differences between axial loads at mechanical failure and stiffness were not statistically significant. The compression locking stainless steel group showed no trend in mode of failure, and the locking titanium plate group failed most often by articular fixation failure (5 of 9 specimens).

Conclusions The fixed-angle compression locking stainless steel volar plate may result in less displacement and rotation of fracture fragments in the fixation of AO C3 distal radius fractures than fixation by the fixed-angle locking volar titanium plate. However, there were no differences between the plates in mechanical load to failure and stiffness.

Clinical relevance Fixation of distal radius AO C3 fracture patterns with the fixed-angle compression locking stainless steel plate may provide improved stability of fracture fragments.

Key words Biomechanical analysis, distal radius fracture, locking, volar plate.

*From the *Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL; and the †Department of Orthopedic Surgery, Baylor College of Medicine, Houston, TX.*

Received for publication August 14, 2014; accepted in revised form June 16, 2015.

T.R.H. received royalties from Tornier and Wolters Kluwer/Lippincott Williams & Wilkins. Funding for this study was provided by Tornier (Saint-Ismier Cedex, France).

Corresponding author: Nilesh Chaudhari, MD, University of Alabama at Birmingham, 1313 13th St. South, Birmingham, AL 35205; e-mail: nchaudhari@uabmc.edu.

0363-5023/15/4010-0014$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2015.06.098

Intra-articular fractures of the distal radius are complex injuries that require near-anatomical reduction to achieve successful outcomes. Complex intra-articular fracture patterns have been associated with difficult reduction and residual articular incongruity, particularly when volar and dorsal lunate facet fragments are present. Many authors have reported loss of initial fixation of the volar or dorsal lunate facet fracture fragments at short-term follow-up.[1–4] This is concerning because fracture displacement and articular stepoff greater than 2 mm have been linked to radiologically observed early posttraumatic arthritis in several studies,[1,3,4] although there remains debate about the consequences of residual articular displacement.[5] Appropriate treatment of these fractures should aim for stable, anatomical fixation that allows early motion.

Various treatment strategies have been employed in the fixation of distal radius fractures including percutaneous pinning, external fixation, volar and dorsal plating, and fragment-specific fixation.[6–12] Selection of the optimal treatment construct must take into account patient-specific factors, fracture pattern, and surgeon experience, and thus, no one method will be ideal for all distal radius fractures.

In recent years, volar plating has gained popularity. Anatomical fracture reduction using volar plates allows early motion and a reduction in tendon injuries associated with other methods of fixation.[13] Biomechanical studies have shown that many of the volar plating systems adequately stabilize extra-articular distal radius fractures.[6–8]

The purpose of this study was to mechanically evaluate 2 different volar plate designs in the fixation of simulated distal radius fractures with AO C3 fracture patterns with a fixed-angle locking volar titanium plate or a fixed-angle compression locking volar stainless steel plate. It was our hypothesis that the fractures fixed using the fixed-angle compression locking volar stainless steel plate would exhibit less interfragmentary displacement and rotation under physiological loading conditions owing to the increased friction at the bone-plate interface.[14,15]

MATERIALS AND METHODS

Specimen preparation

After obtaining institutional review board approval, 11 matched pairs of fresh-frozen cadaver upper extremities were obtained. Two of the matched pairs of cadavers were discarded and not used in the analysis owing to Kirschner (K)-wire slippage and inadequate data acquisition. Of the remaining 9 matched pairs, the average age was 54 years (range, 39–72 years). There were 8 male pairs and 1 female pair. None of the specimens had visual evidence of injury or surgery.

The left limbs were placed in the locking volar plate group (VariAx; Stryker, Kalamazoo, MI). The plate is composed of titanium. This construct has both a fixed-angle drill guide and a variable-angle drill guide, locking and nonlocking screws, and fully threaded and partially threaded screws. Only the fixed-angle drill guide with fully threaded screws was used.

The right limbs were placed in the fixed-angle compression locking group (CoverLoc Volar Plate; Tornier, Amsterdam, Netherlands). The plate is composed of stainless steel. The distal screws have nonthreaded heads, allowing the screw to continue turning in the hole to compress the bone fragment to the plate. A fixed-angle guide was used for the placement of all distal screws.

All extremities were thawed to room temperature and prepared in similar fashion. Soft tissue was stripped from the olecranon tip to 8 cm distally and from all 5 metacarpals to allow for potting. The distal radii were approached volarly and dorsally, stripping the skin and muscle tissues to allow for accurate data collection. Care was taken to leave the wrist capsule and ligamentous structures intact to allow for physiological loading conditions.

Fracture model

A 4-part AO C3 fracture was created in each of the specimens in an identical fashion. The technique was adapted from a previous study.[16] In order to accurately simulate fracture behavior under physiological loading conditions, all soft tissue attachments including the wrist ligaments and capsule were left in place. This is in contrast to some other studies, which eliminated soft tissue stabilizers from the carpus and distal radius.[6–8] A single investigator (T.M.) created the fractures and applied the plates to minimize variability. A 15-mm-wide dorsal wedge osteotomy was created using a sagittal saw 20 mm proximal to the articular surface to simulate comminution. The volar cortex was fractured manually to ensure anatomical reduction. A second osteotomy was created directly ulnar to the Lister tubercle in the sagittal plane. A third osteotomy was made coronally in the medial fragment to simulate a 4-part fracture. The coronal cut in the medial fragment was made from the fracture site to the articular surface of the radius. Each osteotomy in the medial fragment was designed to cut the fragment in half. The fractures were reduced under direct visualization, and the plates were applied. The fractures were then examined fluoroscopically to ensure adequate fixation and reduction (Fig. 1).