SCIENTIFIC ARTICLE

Scaphoid Healing Necessary for Unrestricted Activity: A Biomechanical Cadaver Model

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Purpose To determine if scaphoid fractures with bridging bone of 50% of their width treated with a centrally placed screw will restore biomechanical integrity equivalent to that of the intact scaphoid.

Methods Twenty-four fresh cadaver scaphoids were used. Six were left intact to serve as the control group. Six were osteotomized 50% of their width and made up the osteotomy without screw group. Six were included in the 50% osteotomy plus compression screw group. The remaining 6 were to be treated with an osteotomy of 25% or 75% with a screw, based upon the results of the 50% osteotomy with screw group. Biomechanical testing was performed using an Instron testing machine, with a load applied to the scaphoid's distal pole. Load to failure and stiffness were measured.

Results Intact scaphoids had an average load to failure of 610.0 N. The average load to failure of the 50% osteotomy group without a screw was 272.0 N and with a screw was 666.3 N. There was no significant difference in load to failure between the 50% osteotomy plus screw and the intact scaphoid. The 75% osteotomy plus screw was found to have a load to failure of 174.0 N, significantly lower than the intact scaphoid. The 50% osteotomy plus screw had a significantly higher stiffness than the intact scaphoid control.

Conclusions A 50% intact scaphoid with a centrally placed screw showed similar load to failure and significantly higher stiffness than the intact scaphoid when tested in cantilever bending.

Clinical relevance This study demonstrates that patients with scaphoid waist fractures who undergo surgery with a compression screw may be able to return to unrestricted activity with 50% partial healing. *(J Hand Surg Am. 2017;■(■):■−■. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Scaphoid fracture, scaphoid nonunion, screw, partial.

THE SCAPHOID IS THE MOST COMMONLY FRACTURED carpal bone, yet treatment remains problematic.[1] The scaphoid heals more slowly than other bones owing to its limited blood supply and lack of periosteum. In the United States, it has been estimated that 345,000 scaphoid fractures occur annually and that, even with appropriate treatment, at least 5% fail to unite.[2–4] Complications of scaphoid fractures are frequent including delayed union, nonunion, arthritis, reduced wrist motion, and loss of strength.[4–6]

Surgery to address scaphoid fracture nonunion is not a guaranteed success. Surgical repair of a scaphoid nonunion has reported success rates ranging from 50% to 95%.[1,6–9] Successfully repaired scaphoid nonunions require, on average, an additional 6 months to heal.[1,6–9] Clinically, there is a subset of scaphoid fractures that heal with partial union. Serial computed tomography (CT) imaging

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Medartis (Basel, Switzerland) donated titanium headless compression screws. Medartis had no role in study planning, in the collection, analysis and interpretation of data, in writing the report, and in the decision to submit the article for publication.

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demonstrates partial union across the fracture site, and it is questionable whether these fractures will progress toward further union.[10,11]

The degree of partial healing sufficient to allow unrestricted use of the wrist remains unclear. To date, there have been no biomechanical or clinical studies defining how much bridging bone across a fracture site would be necessary to mimic the native, uninjured scaphoid. The use of headless compression screws adds to scaphoid stability and strength in the healing fracture.[12–15] We hypothesized that bridging bone of 50% of the scaphoid width with a centrally placed screw would restore scaphoid biomechanical integrity. Clinically, this would allow a treating physician to be confident that a partially united scaphoid fracture with a centrally placed headless compression screw is as strong as the uninjured bone, thus allowing patients to return to unrestricted activity without further treatment.

MATERIALS AND METHODS

Twenty-four fresh cadaver scaphoid specimens were obtained and cleaned of all soft tissue. The density of the scaphoids was calculated using Archimedes principle (mass/volume by displacement).[16] Six scaphoids were left intact to serve as the control group. The remaining scaphoids were osteotomized to varying degrees on the dorsal side of the anatomical waist, transverse to the longitudinal axis of the bone, to simulate a scaphoid waist fracture. The osteotomy was made with a scroll saw and measured with digital calipers. After osteotomy, there was a small dorsal gap of less than 2 mm, corresponding to the width of the saw blade, in the partial osteotomy specimens. Six scaphoids were osteotomized 50% of the scaphoid width to simulate a 50% healed scaphoid waist fracture. These made up the osteotomy without screw group. Six scaphoids were osteotomized 50% of the scaphoid waist and a titanium headless compression screw, with a modulus of elasticity similar to cortical bone, was placed down the central axis of the scaphoid according to the manufacturer's recommendations. These made up the 50% osteotomy plus compression screw group. The remaining 6 scaphoids were planned to be treated similarly with an osteotomy of 25% or 75% based upon the results of the 50% osteotomy group. If the 50% osteotomy with a scaphoid screw group had similar load to failure of the intact scaphoid group, a second round of testing with 25% of the scaphoid intact was to be performed. If the 50% osteotomy with a scaphoid screw group was not as mechanically sound as the intact scaphoid group, a second round of testing with 75% of the scaphoid intact was to be performed. Scaphoids were randomly assigned to the 4 study groups.

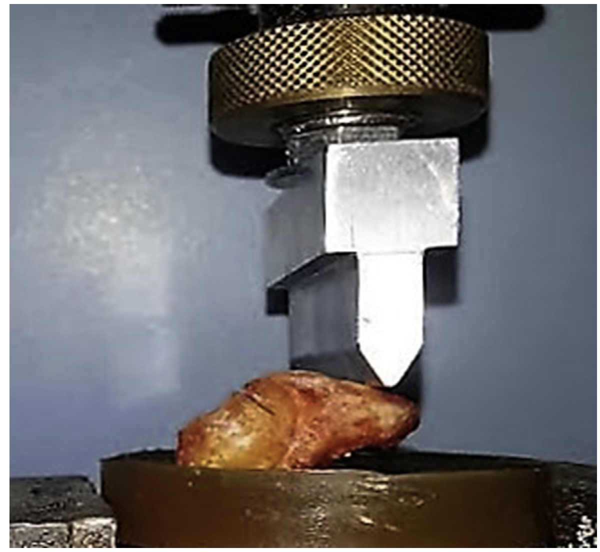

FIGURE 1: Photograph of experimental setup. This photograph demonstrates testing of a scaphoid with a 50% osteotomy without screw. The scaphoid was oriented at a 45° angle to the horizontal plane and the load was applied in a dorsal-to-volar orientation. The plunger loaded the scaphoid at a rate of 0.014 mm/s. The load was increased until catastrophic failure (fracture or loss of reduction) occurred.

The Medartis 3.0-mm headless compression screw was utilized (Medartis, Basel, Switzerland). The diameter was kept the same for all specimens. The length of the screw was determined by the length of the scaphoid, which was measured with digital calipers. Screws with a length 4 mm less than the scaphoid length were chosen to keep the screw subchondral.

The mechanical testing protocol has been validated by several studies.[12,15] For biomechanical testing, the scaphoids were potted in a holder with a polyurethane epoxy. A Kirschner wire was inserted in the proximal aspect of the scaphoid to provide additional anchoring stability. The scaphoid was oriented at a 45° angle to mimic the normal position of the scaphoid in the wrist. This enabled a dorsal to volar cantilever bending load, which represents the mode of failure of scaphoid nonunions with a screw in place. The scaphoid was then placed in an Instron testing machine where a pneumatically driven plunger applied the load to the distal pole at a rate of 0.014 mm/s until failure (Fig. 1). The load was