



SCAPHOID FRACTURE REPAIR: A BIOMECHANICAL COMPARISON OF CONTEMPORARY CANCELLOUS BONE SCREWS

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INTRODUCTION

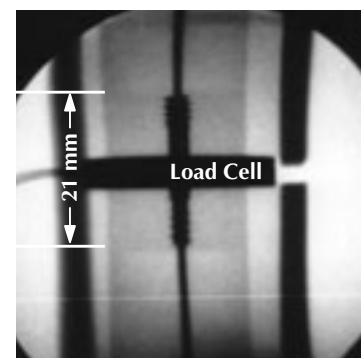
Scaphoid fractures are common, but often challenging to treat. Clinical studies have demonstrated that both conservative treatment and internal fixation have successful long-term results with the latter providing earlier recovery of motion, decreased immobilization and early return to activity.^{1,4} Additionally, internal fixation is indicated as the preferred treatment for displaced or unstable scaphoid fractures, nonunions and late presenting fractures.³ Many surgeons have also advocated internal fixation for the treatment of acute nondisplaced fractures.²

Cancellous screw fixation of the scaphoid is one of the more popular and effective methods of treatment, as evidenced by the number of designs available to the orthopaedic surgeon. However, the clinical success of internal fixation is highly dependent upon the ability of the screw to obtain initial compression across the fracture site and its retention, under physiologic loading.

This study compares the performance characteristics for seven, contemporary, scaphoid screw designs: Acutrak Headless Compression Screw System (Acumed, Hillsboro, OR), CBS Standard Compression Screw System (Normed Medizin-Technik GmbH, Tuttlingen, Germany), CBS High Compression Screw System (Normed Medizin-Technik GmbH, Tuttlingen, Germany), Herbert™ Bone Screw (Zimmer, Warsaw, IN), Herbert/Whipple® Cannulated Bone Screw System (Zimmer, Warsaw, IN), Synthes 3.0mm Cannulated Screw System (Synthes, Paoli, PA) and TwinFix® (Stryker Leibinger, Kalamazoo, MI).

MATERIALS

All screws were 20mm in length. Synthetic bone blocks of polyurethane foam (Pacific Research Laboratories, Vashon, WA), with a density of 15 lbs/ft³, were utilized to simulate cancellous bone of the scaphoid. A mini c-arm (FluoroScan Imaging Systems, Bedford, MA) was employed for the preparation of all test specimens. Testing was performed on a closed loop servo-hydraulic Materials Testing System (MTS Systems Corporation, Eden Prairie, MN) and an Instron Testing Machine (Instron Corporation, Canton, MA). Compression was measured using a washer load cell (Entran, Fairfield, NJ).



Captured fluoroscope image defining the location of the transducer and the successful clinical placement of the screw.

METHODS

A washer load cell was interposed between two foam blocks to facilitate measurement of compression in a simulated, fully reduced, nondisplaced scaphoid fracture. For a specimen to be included in the study, the screw had to be inserted per the manufacturer's instructions, and the screw captured within the 21mm bone window.

Clinical Seating Compression

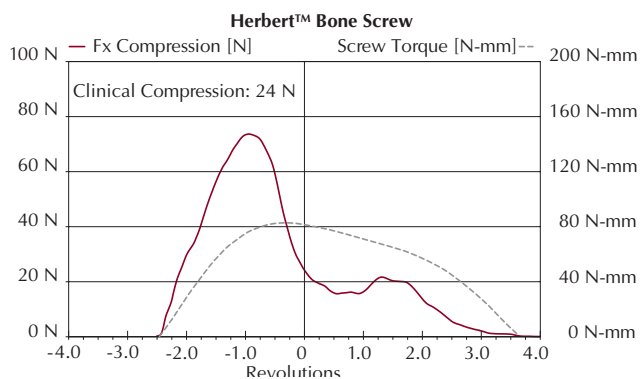
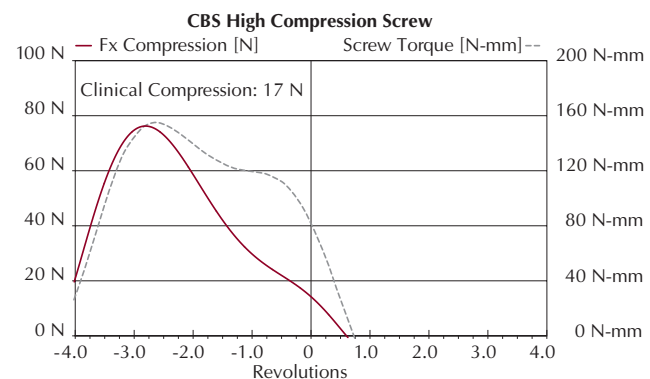
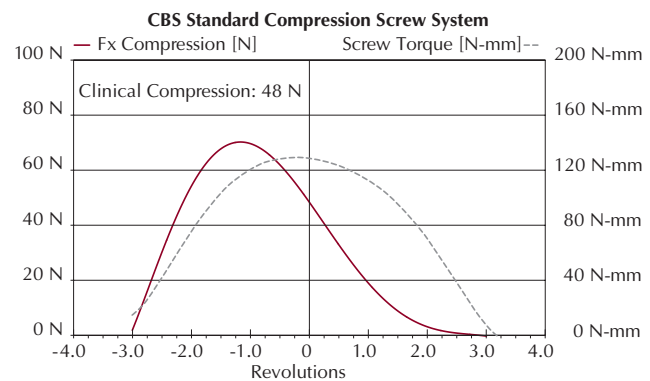
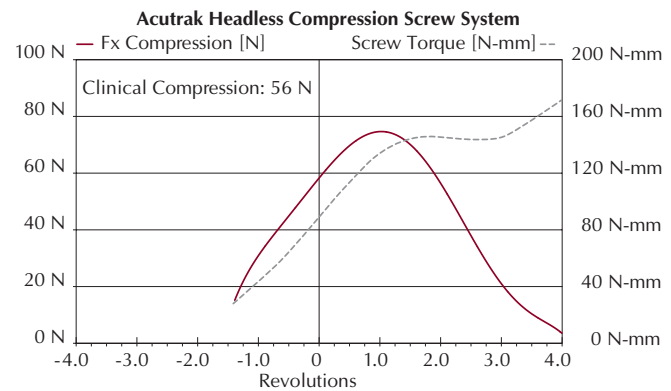
Each surgeon inserted four screws of each design into the foam blocks, measuring compression at the insertion endpoint, (n=8). The mean clinical compression was then calculated for each screw system. For comparison, an additional specimen for each screw system was then assembled using the Instron testing machine with torque and compression being recorded for the entire screw insertion.

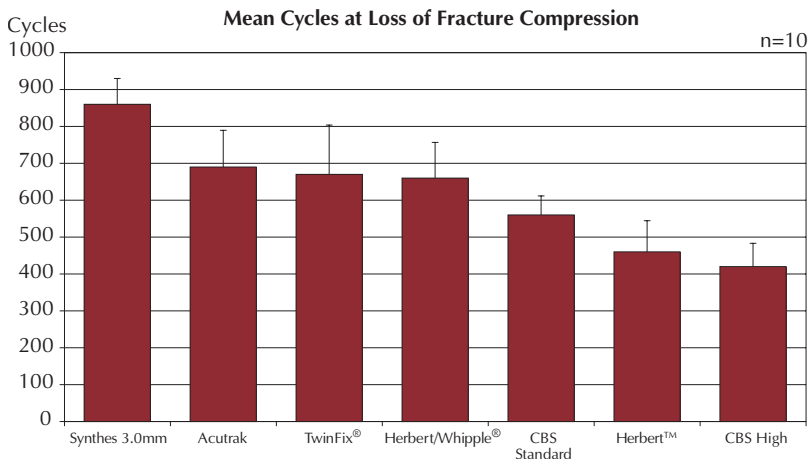
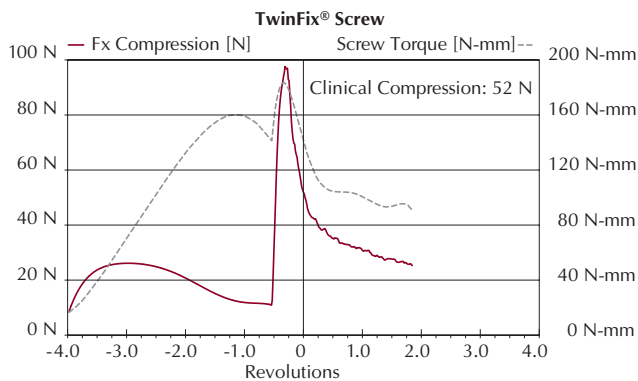
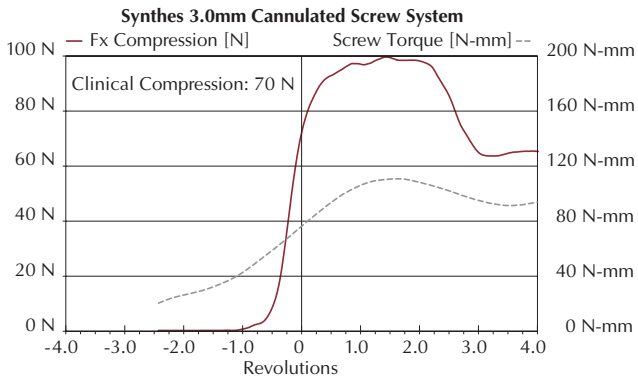
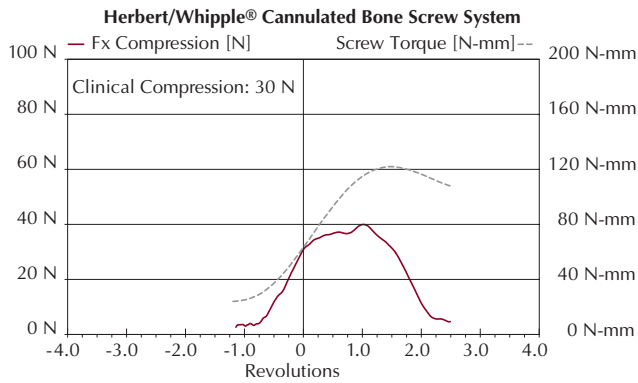
Short-Cycle Fatigue Testing

Utilizing fully reversing, four-point bending, ten specimens for each screw design were subjected to a stepped fatigue protocol for 1,100 cycles in the MTS testing machine, where after every 100 cycles the bending angle was increased 0.45 degrees (n=10). Compression measurements were continuously recorded. The mean number of cycles prior to loss of fracture compression was then calculated for each screw system.

Long-Term Fatigue Testing

After completing the short-cycle fatigue, the mean bending angle for which all screw systems survived the stepped fatigue protocol was determined. One specimen for each screw design was then subjected to this bending angle in fully reversing four-point bending for 46,000 cycles at 1 Hz with the fracture site compression measured throughout the testing.





RESULTS

Clinical Seating Compression

The graphs depicted compare the compression at the fracture site with the driving torque derived by the Instron. The vertical line indicates the location of the mean clinical compression value measured at the endpoint of the surgeon assembly of the test specimens and has been normalized to correspond with zero revolutions for each screw design. From these graphs one can appreciate the variability between the designs in terms of clinical and peak compression values as well as the number of screw revolutions required to achieve these conditions. Additionally, it is of note that the tactile sense of surgeon-applied torque can be misleading and in several of these systems, does not directly relate to fracture compression.

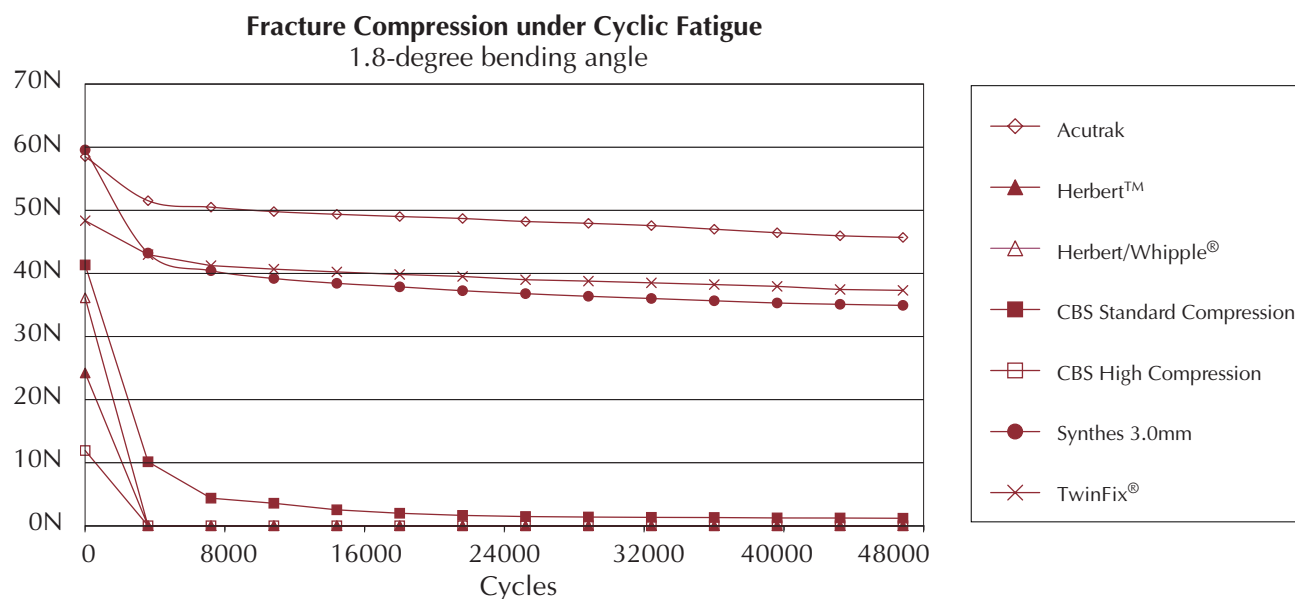
Short-Cycle Fatigue Testing

The graph below summarizes the mean number of cycles prior to loss of fracture compression for each screw design studied along with one standard deviation. The table defines the bending angle for each 100-cycle segment of the fatigue test.

Cycles	Bending Angle [degrees]
0 - 100	0.45
101 - 200	0.90
201 - 300	1.35
301 - 400	1.80
401 - 500	2.26
501 - 600	2.71
601 - 700	3.16
701 - 800	3.61
801 - 900	4.06
901 - 1000	4.51
1001 - 1100	4.97

Long-Term Fatigue Testing

From the short-cycle fatigue testing, a bending angle of 1.8 degrees was chosen. It is of note that while all of these systems maintained this bending angle during the short-cycle fatigue testing, only three of the designs were able to retain fracture compression past 7,200 cycles.



TAKE HOME MESSAGE

- This study determined that contemporary, cancellous bone screw designs advocated for scaphoid fracture repair differ dramatically in their ability to generate and retain compression under physiologic loading. These findings suggest that device selection plays an important part in promoting fracture healing and the avoidance of delayed or nonunion.
- A secondary finding of clinical interest is that a surgeon's tactile sense of applied torque may lag or lead fracture compression, which is strongly influenced by individual screw design.
- Because some scaphoid fractures are oblique and/or comminuted, less rather than more compression may be required. Thus, the screw of choice will vary with the fracture pattern and designs with adjustable fracture compression may represent an advantage. Regardless, fragment stabilization during the healing phase remains paramount.
- Within the 1.8-degree bending limit, all screws maintain fracture compression with short-cycle fatigue loading. Beyond 1.8 degrees of bending, increased failure was noted.
- Loss of fracture compression increases with the number of cycles in many screw designs, as indicated by the long-term fatigue data.
- Extrapolated to the clinical setting - regardless of the screw chosen for a particular fracture pattern, this data suggests caution be employed in allowing motion (with resistance) until bone union has been achieved.

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