BIOMECHANICAL COMPARISON OF PROXIMAL RADIUS LOCKING PLATES UNDER DYNAMIC LOADING

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INTRODUCTION

Proximal radius fractures are commonly encountered in general orthopaedic and upper extremity subspecialty practices (Figure 1). The surgical treatment of these fractures includes the anatomical reconstruction and stable fixation of the proximal radius to achieve early recovery of elbow function, reducing the complication rate. These goals are often obtained in cases showing no or minimal comminution. However, due to high complication rates in the management of complex and highly comminuted fractures,[1] locked plating systems are being utilized with increasing frequency. Specifically, 20% of all elbow trauma is associated with radial head/neck fractures, which historically has been treated with excision or prosthetic replacement. Further, recent literature advocates radial head preservation whenever possible in young, active patients.[2,3]

This study compares the biomechanical properties of two proximal radius locking plate designs under dynamic loading to determine their ability to withstand the forces which occur during fracture healing and early postoperative rehabilitation. The **Acumed**® Locking Radial Head Plate System (Acumed, Hillsboro, OR) and **SBi**® rHead™ Plating System (Small Bone Innovations, Morrisville, PA) were evaluated.

Figure 1: Radiographs of an angulated radial neck fracture and subsequent intra-operative plating.

MATERIALS AND METHODS

Plate Application

For each of the two plate designs, nine third-generation synthetic composite bone radii (Pacific Research Laboratories, Inc., Vashon, WA) were fitted with plates according to the manufacturers' recommended techniques (Figure 2).

Acumed

SBi

Figure 2: Proximal radius locking plate designs evaluated.

The **Acumed**® Locking Radial Head Plate (Titanium Alloy) utilizes five locking and one non-locking screw for fixation. The non-locking screw is placed through a slotted hole in the shaft which permits slight adjustment in the positioning of the plate. Four locking screws are placed in the proximal radial segment with the remaining one placed distal to the non-locking screw. The **SBi**® rHead™ Plating System (Stainless Steel) utilizes two locking and four non-locking screws for fracture stabilization. The locking screws are placed in the distal shaft and used proximally as a tripod stabilizing buttress, while the remaining screws are placed in the radial segment and in a slotted hole in the shaft.

The placement of all plates and screws for each device is shown and was guided by the desire to maximize support of the radial fragment.

Figure 3: Custom osteotomy with radial plate applied.

Osteotomy and Specimen Preparation

To gain optimal plate placement, the screw holes were pre-drilled on each synthetic composite bone radius prior to the creation of the osteotomy. Care was taken to not compromise the mechanical structure of the synthetic bone. After the osteotomies were performed, the plates and screws were applied and the constructs inspected (Figure 3). A fine permanent marker was used to orient all screws, both locking and non-locking, to the plate. This was done to help establish if the screws loosened after cyclic testing.

Biomechanical Testing

Each construct was tested on a Materials Testing System (MTS, Eden Prairie, MN) (Figure 4). The distal ends were potted in acrylic. An axial load was applied through a threaded cylinder with a rubber disc interposed between it and the proximal radius to simulate elbow contact points and load transfer.

Figure 4: Plate-synthetic composite bone construct on MTS.

Three separate testing phases were performed on each specimen to simulate both the number of cycles and magnitudes of force that the plate-bone construct would experience over a 6-week period of fracture healing. The specimen was preloaded to 10 Newtons (N) during each phase and then loaded to 100N, 200N and 300N in Phases 1, 2 and 3, respectively, at a rate of 2N/s. Each construct was then dynamically loaded for 2000 cycles at a frequency of 2Hz in each phase, for a total of 6000 cycles (R=10). Each specimen was then loaded to failure at 2N/s.

Measurements

The following measurements and observations were made:

- Load-deformation curves were determined for each of the three phases in all specimens.
- The distances between the edges of the osteotomy sites were measured between each phase to establish if settling had occurred.
- Each screw/hole marker was inspected to see if screw loosening had occurred. A screwdriver was not placed into the screws to check for loosening.

RESULTS

Figures 5 and 6 graphically illustrate the stiffness for each plate design. All constructs were stiffer after each cyclic loading. Both plate designs tested had an initial stiffness on the order of 190N/mm at 100N. This increased to almost 300N/mm after cyclic loading at 300N. No plates failed during any aspect of the testing for either design. However, three of the SBi® rHead™ constructs had a locking screw unlock during the 200N fatigue loading phase and one further during the 300N testing. Further, the fracture margin distances gradually decreased for all of the plate constructs evaluated with increasing axial load.

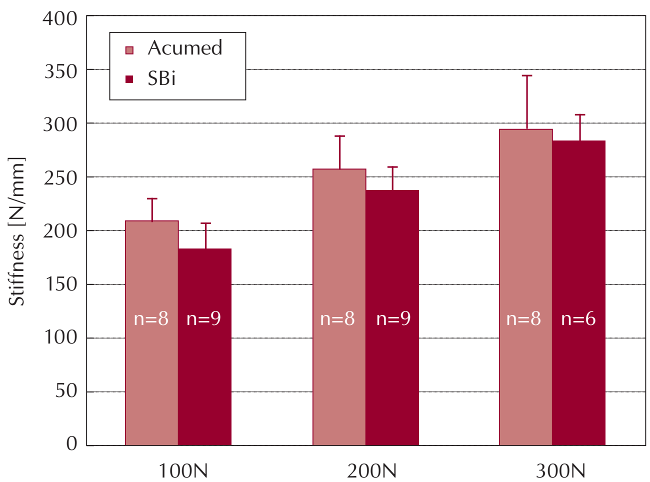

Figure 5: Graph of average proximal radial locking plate stiffness with standard deviations at 100N, 200N and 300N load levels that demonstrates an increase in stiffness with increasing cycles of loading. Differences in average stiffness between plate designs was investigated at each load level and no significant differences were found.

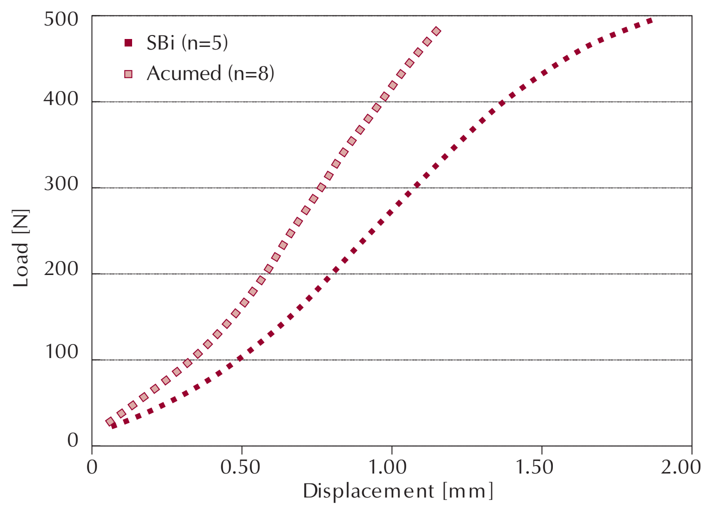

Figure 6: Graph of the average displacement response of the two plate designs after 6000 cycles demonstrating stiffness differences in the range of expected postoperative loading.

DISCUSSION

Restoring the original morphology of the proximal radius following a radial head and neck fracture without jeopardizing the proximal radio-ulnar joint[4] is required to gain a successful clinical outcome.[1,5-9] However, in complex and highly comminuted fractures, this reconstitution may be challenging since limited anatomical landmarks are available during surgery. To address this problem, anatomical plates with a precontoured shape resembling the bone profile of the proximal radius have recently been introduced. These devices should provide greater stability than screws alone[10,11] while guiding the surgeon in the optimal fixation of the radial head and neck fracture.

This study provides quantitative, comparative and descriptive biomechanical data for two locking plate systems used to treat proximal radius fractures under dynamic testing designed to simulate the early *in vivo* postoperative rehabilitation forces.

Several cadaveric studies have been conducted to measure the force distribution across the radius and ulna when applying a static load through the hand.[12-16] While the methodologies have varied, the results concur that between 60% and 100% of the load applied through the wrist is carried by the proximal radius for different forearm positions.

For this current study, cyclic loading of 100N, 200N and 300N across the proximal radius would correspond with load applications between 100N and 500N at the wrist. Further, the results show that these plates fail in a range from 500N to 800N after cyclic testing. Morrey et al. measured forces across the elbow during a push-up activity as being 45% body weight.[17] If one assumes a 100/0 distribution of forces across the radius and ulna, respectively, then these plate designs can support body weights exceeding 110kg.

The current data show that these plates can withstand forces encountered at the elbow during the initial weeks of rehabilitation as well as physically demanding activities. One would also expect that the plate would be progressively offloaded by the healing fracture by the time patients are capable of generating greater forces.

TAKE HOME MESSAGE

- No significant difference in construct stiffness was measured between the plate designs evaluated.
- All plates tested failed at loads above what is considered physiologic during the postoperative healing phase through fracture union.
- Locking screw loosening occurred prior to bone-plate construct failure in four of the nine SBi® rHead™ constructs evaluated.
- Fracture pattern and screw configuration may be more important than biomechanical differences between plates and should guide plate selection for fracture fixation.
- All factors being equal, ease of use, physician comfort with technique, hardware availability, and cost may be the most important factors when choosing a locking plate system for complex and highly comminuted proximal radius fractures.

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