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Biomechanical Evaluation of a Non-Bridging Half-pin Fixator in a Distal Metacarpal Intra-articular Fracture Model

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INTRODUCTION: Intraarticular fractures of the metacarpals and phalanges have few options for adequate fixation to assure healing in good alignment. Non-operative methods can only control the bone fragments by immobilizing the joints, which results in poor function, lengthy rehabilitation and a high incidence of arthritic changes. Internal fixation with plates and screws provides little options for fixation of the intraarticular fragments. The intracondylar plate for the phalanges has a single spike in a single plane to hold the distal fragments. Previous studies have shown that the mini Hoffmann external fixator and crossed K-wire fixation of metacarpal fractures can provide comparable stability to plate and screw fixation for a diaphyseal osteotomy in a cadaver if the soft tissues are left in place.

PURPOSE: The purpose of this study was to evaluate the biomechanics of a distal, intraarticular fracture of the metacarpal fixed with the NBX external fixation frame, which provides for pin fixation in multiple planes with a fixation system that does not bridge the joint.

METHODS: Ten adult cadaveric metacarpals had a simulated, OTA 77-C3.1 fracture pattern created by making a transverse cut with an osteotome about 80% through the base of the distal condyle and then breaking the bone fragment from the diaphysis by prying. Next the articular fragment was cut in the sagittal plane with an osteotome to split the condyle into two, approximately equal parts.

The fixation strategy was to include at least two pins in different planes of fixation in each fragment. The first pin was driven across the intraarticular fragments in the ML plane to hold them in place while the NBX frame was applied. Next one pin was driven through the diaphyseal fragment to lock the construct together with all three fragments. Two pins were driven through the two remaining ball joints at the distal end of the NBX frame, and through the intraarticular fragments. Finally, two more pins were driven through the proximal diaphysis, see Figure 1. Thus there were three pins at three different angles and three different planes through the intra-articular fragments and three pins at slightly different angles, but almost in the same plane in the diaphysis. The balls were kept from rotating through the locking nuts in the NBX frame.

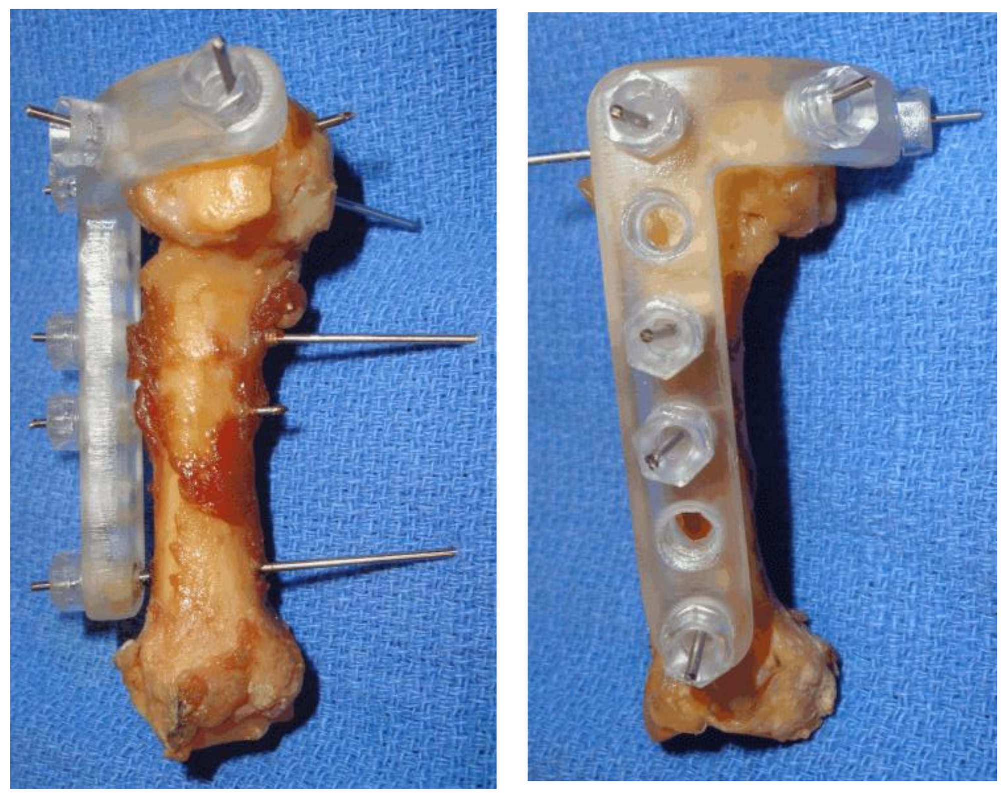

Figure 1 - The NBX configuration for the OTA 77-C3.1 fracture. Note 3 pins are in the diaphyseal fragment only and 3 are in the intraarticular fragments only.

A second group of five metacarpals was fixed with the Mini-Hoffmann external fixator so that two parallel pins were driven through the diaphyseal fragment, and two more parallel pins were driven through the intra-articular fragments, see Figure 2.

The bone was aligned vertically along the axis of the diaphysis and a concave fixture applied load on the distal condyle .A sinusoidal vertical force at 0.25 Hz, was applied in load control, from -10 N to -400 N compression load along the diaphyseal axis. This load level provided movement of the bone fragments within the elastic region of each construct. The stiffness of each construct was calculated from the slope of the load-deflection recording on the MTS machine.

A fluoroscopic video image in the ML plane was also recorded for 2-3 cycles of loading, after steady state was established with the peak load in the cycle at 400 N. Relative movement between bone fragments in the ML plane were measured on the fluoro images with ImagePro® software, see Figure 3. Because each bone was so small, the target screen of the fluoroscope was placed as far from the bone as possible to magnify the bone in the image and maximize the accuracy of the image measurements. The average number of pixels in the diameter of each pin was 10 in the images captured from the fluoroscopic videos, and each pin was 1.1 mm. So the resolution of measurements was 0.11 mm/pixel.

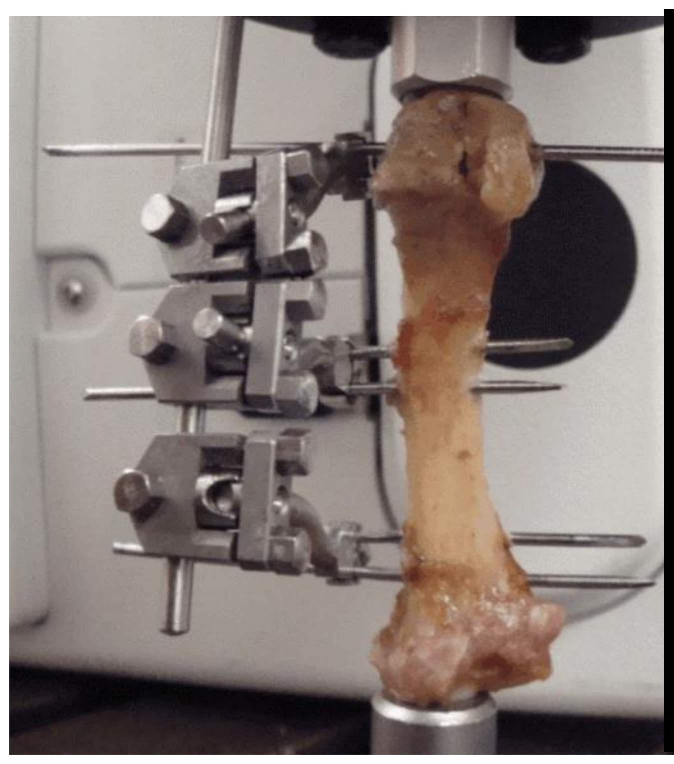

Figure 2 - The Mini Hoffmann configuration for an OTA 77-C3.1 fracture.

Figure 3 - A single frame from the fluoroscopy video of testing.

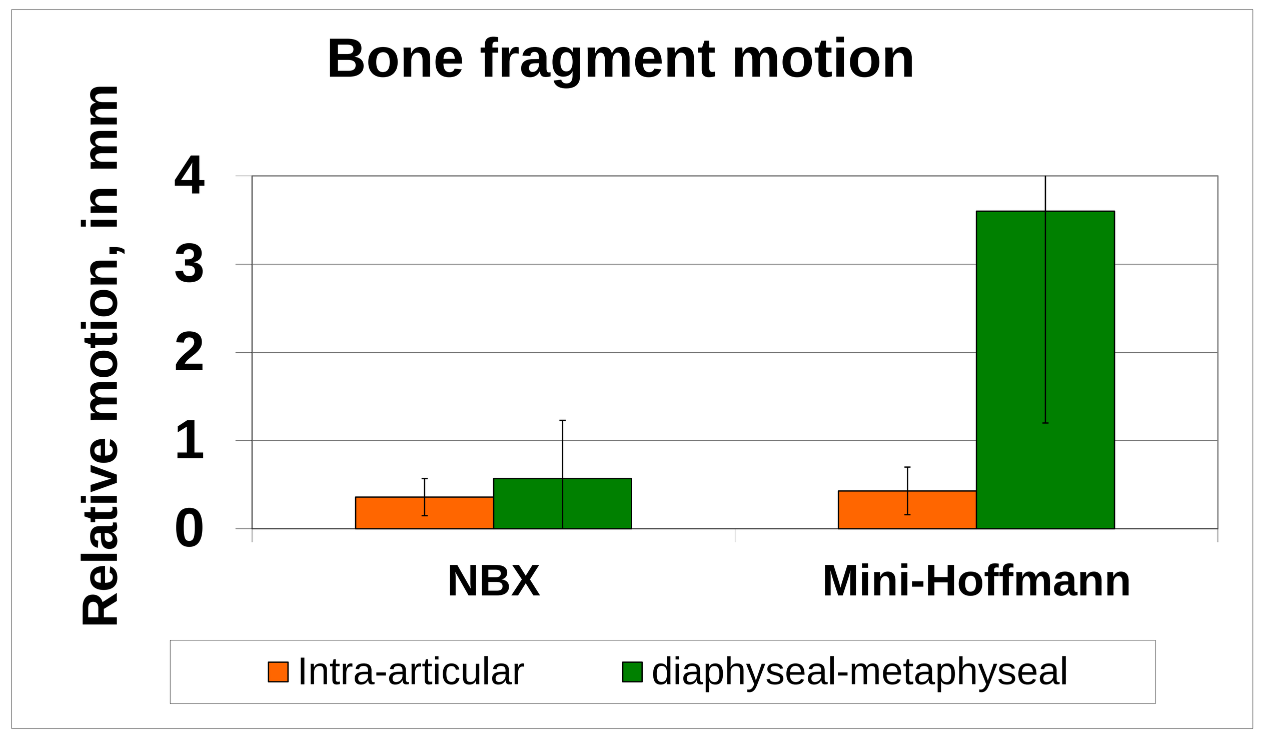

Figure 4 – Interfragmentary movements measured

RESULTS: The linear regression slopes of the compression side of the load displacement cycle for the NBX fixed metacarpal averaged 598.7 ± 229.1 N/mm and 402.9 ± 175.0 N/mm for the Mini-Hoffman. Since the maximum load reached per cycle was 400 N, and the minimum load was 10 N, this means that the average cycle created a total displacement of only about 0.7 mm. Note the large deviations in values for these bones. This is directly attributable to the variations of size of the bones as well as the variation of cancellous bone strength. Some of the bones were more osteoporotic than others.

Measurements of the relative motion of each bone fragment to each other bone fragment in the plane of the fluoroscopic image showed a range from 0.0 to 5.0 mm in the vertical direction and 0.0 to 0.9 mm in the horizontal direction. The average movement between intraarticular fragments was 0.36 mm ± 0.21 in the horizontal direction for the NBX fixation, and 0.43 ± 0.27 mm for the Mini-Hoffmann. Most of the interfragmentary movements were between the proximal fragment and the distal group of fragments. The NBX averaged 0.57 ± 0.66 mm and the Mini-Hoffman averaged 3.6 ± 2.4 mm between the proximal fragment and the intraarticular fragments in the vertical direction, Figure 4.

CONCLUSIONS: Multiple pin fixation in multiple planes of fixation for small intraarticular fragments with the NBX system provided fixation strong enough and rigid enough to hold those fragments together with loading up to 400 N on the joint. The loading was enough to cause some movement of the diaphyseal fragment relative to the intraarticular fragments, and to cause some visible distortion of the diaphyseal pins in the frame, but the movement was less than a mm at even 400 N of load.

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