Biomechanical Comparison between Volar Plate Fixator (VPF) and Non-Bridge External Wrist Fixator System (NBX)

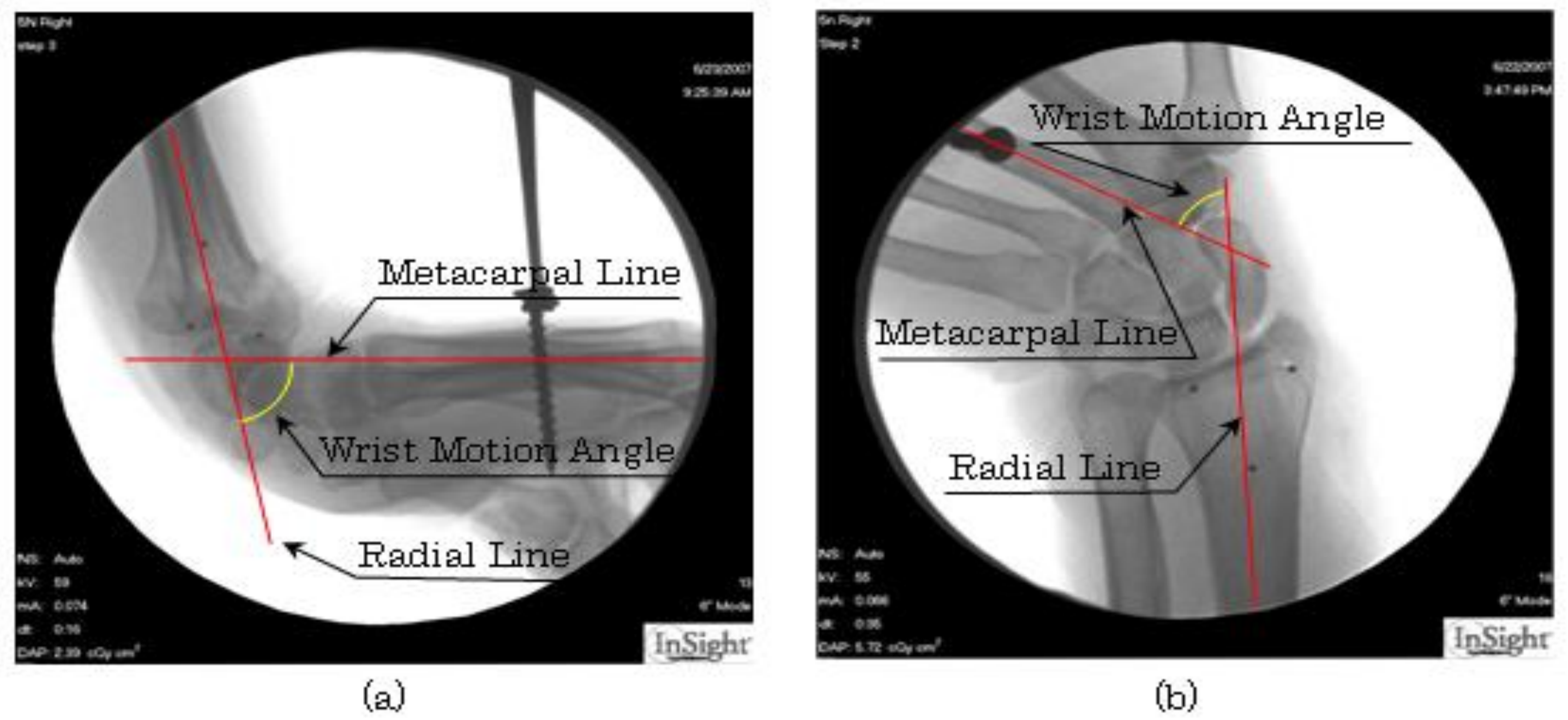
[1]Diaz, V; [2]Sano, T.; [3]Hajianpour M.A; [4]Ouellette, EA; [5]Milne, E.L.; [5]Kaimrajh, D.K.; [1, 5]Latta, L.L.
Univ. Miami, [1]Orthop. Dept., [2]Biomed. Engr. Dept.,
[3]Total Orthop. Care,
[4]The Hand Place, [5] MBI at Mt. Sinai Medical Center[1]

M.B.I. Max-Biedermann-Institute for Biomechanics

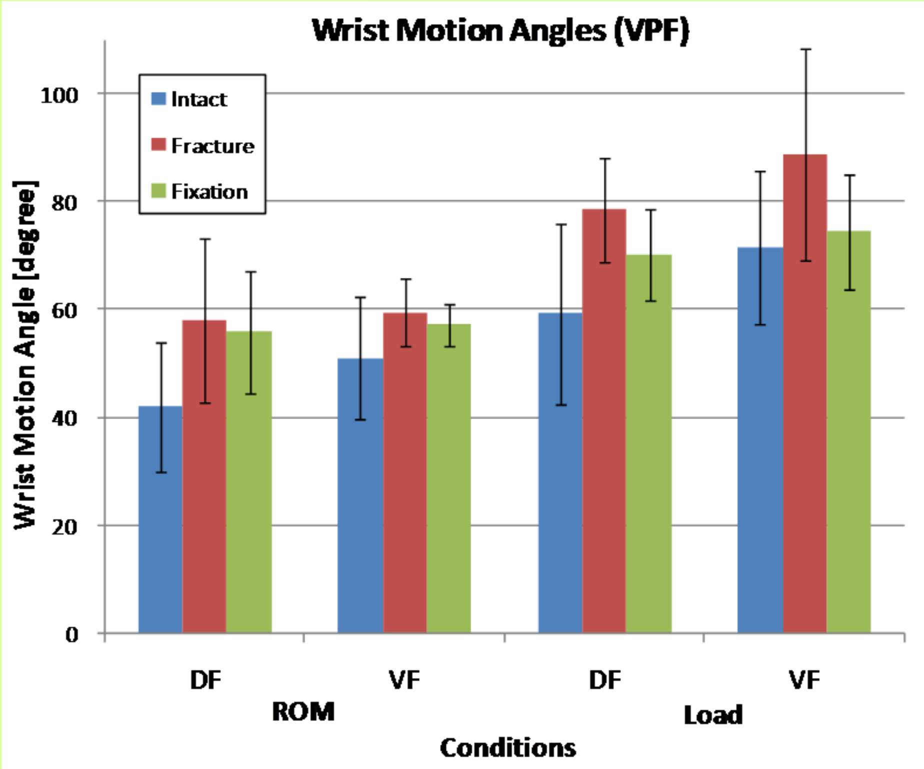
INTRODUCTION: Comminuted distal radius fractures with 5 or more bone fragments are difficult to reduce and stabilize with current ORIF techniques because screw placement and purchase is difficult in the small intra-articular fragments of often osteoporotic bone.1 External fixation can provide stability through ligamentum taxis but immobilization of the wrist joint is required.2 Non-bridging external fixation which allows for precise, multiplanar pin placement provides an alternative to volar plate fixation.
Hypothesis: Because of the ability to provide multiplane fixation and accurate pin placement, the NBX fixator should provide better reduction and comparable rigidity of fixation to a volar plate for a 5-fragment distal radius fracture.
Universal Distal Radius System (Volar Plate Fixator or VPF: Stryker Co.) and Non-Bridge External Wrist Fixator System (NBX, NUTEK) are chosen and tested to compare the effect of the fixations by measuring the angle of the wrist.

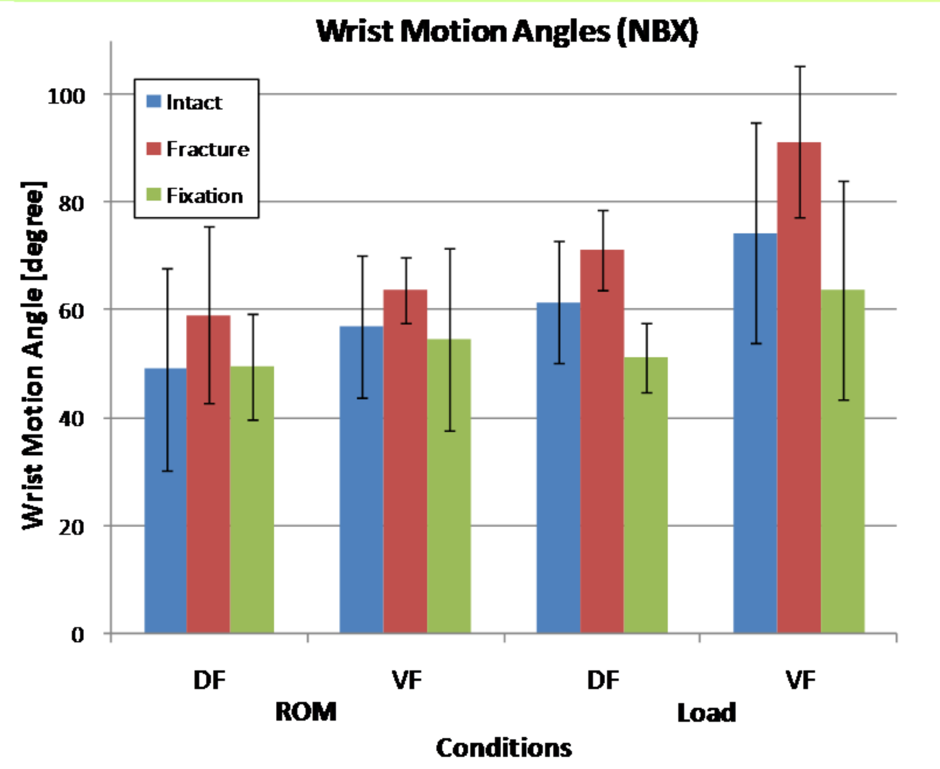
METHODS:
Using a biopsy needle, 1.5 mm stainless steel balls were implanted in the distal radius of 5 fresh pairs of human cadaveric upper limbs to track bone fragments by radiographic images. A simulated 5-part distal radius fracture was created with an osteotome, guided by a fixture to produce consistent size and shape fragments to simulate an OTA . One arm was randomly fixed with the NBX fixator, the matched pair was fixed with a volar plate and screws (VPS). Fluoroscopic images were recorded at the extremes of passive volar-dorsiflexion range of motion (ROM) and radial-ulnar deviation. Finally, each arm was loaded with an axial force at a constant displacement rate until failure. Five pairs of fresh human cadaver arms, from distal phalanx up to elbow, from 57 to 86 years old males and females, were used. A titanium bar (φ4[mm]×250[mm]) was screwed in the cavity of the radius parallel to the bone so that a vise could hold the specimen rigidly. A percutaneous screw (φ4[mm]×50[mm]) was fixed in the third metacarpal at 50mm from the head of radius so that an applied force perpendicular to the bone would apply a specific torque to the wrist. The arm was set in a vise horizontally in 4 positions so that the hand hung by gravity in four directions for each specimen: in the direction of the palm (volar flexion), the back of hand (dorsiflexion), the thumb (radial deviation), and the little finger (ulnar deviation).
Assuming the accidental force to the wrist, the torque of 0.5[N·m] is applied to the wrist in the direction of the four positions: volar flexion, dorsiflexion, radial deviation, and ulnar deviation, by holding the screw at metacarpal and using a force transducer (Chatillou E-DFE-100, AMETEK). These positions are imaged by using fluoroscope (Insight, HOLOGIC Inc.), and the images are analyzed by image analysis software (Image-Pro, Media Cybernetics Inc.) to measure the angle between the extension line of metacarpal bone of the middle finger and that of radius.

Assuming the injury of wrist, the fracture of distal radius is created, and the same procedures and measurements as the test of intact are performed to get the angle. In order to see the effect, the VPF and NBX are set for the artificially created fracture of right arms and left arms, respectively. In the same way, the angle is measured.



(a) (b)





RESULTS:
According to the formula1, the fracture created more rotation than intact at the ratio of 28.0%∓24.2 in the case of dorsiflexion, 26.0%∓21.4 in volar flexion, 25.4%∓17.8 in ulnar deviation, and 95.7%∓102.1 in radial deviation. In comparison between fracture and fixation, VPF performed -10.7%∓3.38 of angle change in dorsiflexion; -14.2%∓13.6 in volar flexion; -14.1%∓14.2 in ulnar deviation; -22.4%∓25.9 in radial deviation. On the other hand, NBX showed -27.6%∓7.2 of change in angle from fracture to fixation in the case of dorsiflexion; -31.1%∓15.6 in volar flexion; -25.2%∓8.5 in ulnar deviation; -34.6%∓12.6 in radial deviation. Moreover, to see the difference between intact and fixation, in the case of VPF, the angle of the wrist increase at 23.8%∓25.4 in dorsiflexion; 5.0%∓5.4 in volar flexion; 6.6%∓8.5 in ulnar deviation; 37%∓95.8 in radial deviation from intact to fixation. In the case of NBX, the change of angle is -15.3%∓10.2 in dorsiflexion; -15.3%∓6.5 in volar flexion; -7.4%∓12.5 in ulnar deviation; -14.2%∓29.6 in radial deviation. As a summary of the result, the wrist angle increase comparing with intact when the fracture is created at distal radius; the angle decrease when the fracture is fixed by either VPF or NBX; the angle when NBX is introduced is smaller than that of intact; the angle when VPF is introduced is greater than that of intact.

DISCUSSION:
According to the result that the ratio of the angle change from intact to fracture is positive, it can be said that the wrist angle increase because of the fracture. Comparing VPF with NBX, both methods are effective to fix the loosen wrist because the ratio of the angle change after fixation of the fracture is negative; however, in the case of NBX, the change of the angle from intact to fixation is negative, which means that NBX can make the wrist stiffer than intact under the limited condition which the applied force to the wrist is not so strong (0.5[N·m]). On the other hand, the ratio of VPF is positive, which means volar plate cannot sustain the wrist as strong as a healthy wrist can, although the method can make the wrist stiffer than fractured wrist.
The fact that the standard deviation of the radial deviation data is comparatively larger than others can be explained by the range of motion of the wrist. As you can try to know, wrist cannot tilt to the direction of radius very much. Thus, the angle can be very small. In terms of the use of biological materials which have various parameters to determine the biomechanical features, the influence of the error of the date should be greater if the target value is too small.
Comprehensively, both methods can stabilize the injured wrist. NBX is more effective than VPF in terms of stabilization of injured wrist under the condition of low torque application. However, the discussion is not only about the stabilization but also about the time to complete all the procedures, accuracy, risk of infections, and so on. Even if NBX is more effective to stabilize the injured wrist than volar plate, it may not mean that the prognosis is better in the case of NBX more than volar plate fixator.

Conclusions:
- Angle increase or wrists become loosen after fracture of the distal radius
- Both NBX and VPF can stabilize the injured wrist
- NBX is stiffer than intact
- VP is not stiffer than intact but more stabilized than injured wrist
- NBX is more effective than VPF in terms of stabilization of injured wrist against relatively low torque application to the wrist.

ACKNOWLEGEMENTS:
This study was performed at the University of Miami's Orthopaedic Biomechanics Lab at Mount Sinai Medical Center, Miami Beach, FL.