INTRODUCTION: Distal radius fractures are among the most common fractures, constituting approximately 10% of all fractures. It is becoming popular to use non-bridging type external fixators to treat these fractures. The devices can provide proper anatomical reduction and alignment to fix fracture fragments directly, while allowing easy management of the soft tissue injuries during fracture healing, and provide better results than bridging-type fixators [1]. To date, no consensus has been reached on the optimal indications for the use of a non-bridging fixator to manage distal radius fractures, because the biomechanical characteristics of the fixators are not fully known. This study evaluated the relative stiffness of currently used non-bridging external fixators under axial compression, torsion, and bending moment.

MATERIALS AND METHODS: Three currently used non-bridging external fixators were tested: F-Wrist (Arata, Saitama, Japan), Hoffman II Compact (Stryker, NJ, USA), and Pennig Wrist Fixator (Orthofix, Verona, Italy). Their structural characteristics are shown in Table 1. With F-Wrist, three small-diameter distal pins (4.2 mm) are generally used and inserted from radial to ulnar to fix the fracture fragments securely. By contrast, in the Hoffman and Pennig fixators, two slightly larger distal pins (3.0 mm in diameter) are inserted from dorsal to volar.

Figure 1 shows the experimental set-up. All the fixators were equipped with a standardized distal radius model, which was based on geometric characteristics. The distal radius was modeled as a cylinder 25 mm in diameter, made of ABS resin. A 10-mm fracture gap was made 20 mm proximal to the articular surface to simulate a distal radius fracture. In assembling each fixator, the span of the two inner side pins was kept constant at 90 mm. The free pin distance (bone surface to pin-frame junction) was held constant at 16 mm. Distal radius models equipped with each fixator were mounted securely on the mechanical testing machine (858Mini Bionix II, MTS). The proximal end of the distal radius model was fixed. The load or moment was applied from the joint surface quasi-statically. For the bending moment test, the loading plate was placed on the joint surface and the load was applied 40 mm from the long axis of the distal radius model. Dorsal, volar, radial, and ulnar aspects were tested. Each fixator was tested seven times for each type of load and the stiffness was calculated from the slope of the linear portion of the load versus the displacement curve. All data obtained were compared using 1-factor ANOVA. Multiple comparison tests (Fisher’s PLSD) were performed whenever significant differences were identified (p<0.05).

RESULTS: The results are shown in Figure 2. With axial compression (Fig. 2A), the Pennig was the stiffest fixator, while F-Wrist was the least stiff. As with axial compression, in terms of torsion, the Pennig was the stiffest fixator and F-Wrist was the least stiff (Fig. 2B). In terms of the bending moment (Fig. 2C), the stiffness on the radial side was greater than that on the other sides for F-Wrist, while for the Hoffman and Pennig fixators, the stiffness of the dorsal side was greater.

DISCUSSION: To our knowledge, we are the first to document the biomechanical characteristics of non-bridging external fixators, although many biomechanical studies of bridging-type external fixators have been reported [2]. We found that there is variation in the stiffness of existing devices, and that the Pennig is the stiffest external fixator, while F-Wrist is the least rigid. Since three distal pins are inserted from radial to ulnar using F-Wrist, the bending stiffness on the radial side is greater. By contrast, using the Hoffman or Pennig fixators, two distal pins are inserted from dorsal to volar, so the bending stiffness on the dorsal side is greater than on the other sides. The most influential factor during the initial phase of bone and soft tissue healing is the initial rigid fixation [3]. Consequently, the most rigid fixator would be optimal. Therefore, our results suggest that initial fixation is best achieved using the Pennig wrist fixator. Conversely, it has also been reported that rigid fixation delays bone healing, while micro-movement and mechanical stimuli promote secondary bone healing [4]. Micro-movement would be likely to occur using F-Wrist, which is the least rigid device. In addition, it is easier to insert multiple the smaller pins with a severely comminuted fracture or when insufficient space exists in the distal fragment. In conclusion, we determined the biomechanical characteristics of non-bridging external fixators. Understanding the characteristics of the non-bridging fixators expands the indications for their use in distal radius fractures.

REFERENCES:

** Ishii Orthopaedic and Rehabilitation Clinic

Table 1 The structural characteristics of the three external fixators

<table>
<thead>
<tr>
<th></th>
<th>F-Wrist</th>
<th>Hoffman</th>
<th>Pennig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame weight</td>
<td>38 g</td>
<td>125 g</td>
<td>115 g</td>
</tr>
<tr>
<td>Distal pin direction</td>
<td>radial to ulnar</td>
<td>dorsal to volar</td>
<td>dorsal to volar</td>
</tr>
<tr>
<td>Distal pin diameter</td>
<td>Ø 1.8 or 2 mm x3 or 4 pins</td>
<td>Ø 3 mm x 2 pins</td>
<td>Ø 3 mm x 2 pins</td>
</tr>
<tr>
<td>Proximal pin diameter</td>
<td>Ø 3 mm x 2 pins</td>
<td>Ø 3 mm x 2 pins</td>
<td>Ø 3 mm x 2 pins</td>
</tr>
</tbody>
</table>

Figure 1 Experimental construct used to evaluate relative stiffness

Figure 2 Fixator stiffness (A) axial compression (N/mm); (B) torsion (N-mm/deg.); (C) bending moment (N-mm/mm).