The hybrid fixators, or the fixators that use the thin wire fixation in the perarticular fragment combined with the half-pin fixation in the diaphysis, have made the multiplanar external fixation easier to use and thus growing in popularity. However, the configuration of the ideal hybrid has not been elucidated yet. The purpose of this study was to determine the stiffness characteristics affecting hybrid external fixation.

**MATERIALS AND METHODS**

A prospective laboratory investigation was used to test and compare the mechanical stiffness between the new proposed hybrid fixator (Figure 1) and the more commonly used hybrid external fixators: Ace-Fischer, DePuyACE, Warsaw, IN; Hoffmann II, Stryker Howmedica Osteonics, Rutherford, NJ; Synthes Hybrid, Synthes USA, Paoli, PA; EBI DynaFix®, EBI, Parsippany, NJ; and a custom built “rigid” frame (Figure 2). The test model was a fiberglass composite tibia (Pacific Research Laboratory, Vashon, WA, USA) with a 2 cm proximal metaphyseal gap osteotomy simulating the fracture pattern described by OTA classification 41-A.3.3. The “rigid” frame consisted of five 15 cm diameter aluminum rings having 2.0 cm square cross-sections and four stainless steel longitudinal connecting rods 1.25 cm diameter. A standardized pin and wire configuration was created by using the “rigid” frame as a guide for drilling holes in each test tibia for placement of wires and pins. Proximal loading was through a custom load plate mounted on the tibial plateau and distal loading was through a universal joint mounted at the level of the ankle. Direct compression and torsion loads were applied using a biaxial servohydraulic load frame (Model 858 Bionix, MTS, Eden Prairie, MN). Five loading regimes were used; central compression, medial compression, posterior compression, postero-medial compression, and torsion. The compression load was 100 N in each case. The proximal load plate offset the medial and posterior load by 4 cm resulting in 4 N-m of bending in those loading modes. The postero-medial loading resulted in 5.66 N-m of bending. The torsional loading was 5 N-m. The amount of displacement (mm or deg) of the MTS actuator was recorded for each test. Each of the five fixation types were applied to three separate tibiae. Each tibia construct was loaded and data recorded for three test runs with wires re tensioned between each run. The multiple runs were used to confirm that the testing procedure was consistent. Analysis of Variance (ANOVA) followed by post-hoc t-tests was used to compare the amount of displacement allowed by the four configurations for each loading mode (p<0.05). Separate validation tests were performed on the “rigid” frame to determine its stiffness. A 0.75 cm thick plate was mounted on the top ring of a five ring configuration of the “rigid” frame. The custom load plate was then mounted to the thick plate and loaded and described as described previously. The load developed for very small motions was recorded and the stiffness of the “rigid” frame was calculated.

**RESULTS**

The validation test results showed that the axial stiffness of the frame was 7965 ± 10.8 N/mm and the torsional stiffness was 301 ± 3.1 N/m/deg. This represents a hundred-fold difference in the stiffness behavior when the rigid frame was compared to the motion of the tibia fixated with pins and wires. Thus the displacements observed with the “rigid” reference frame fixation of the tibia model are assumed to occur only within the wires and pins. Motion Allowed In Each Loading Mode, Mean (Std. Dev.) is presented in Table 1. For simulated fracture fixation, the “rigid” frame allowed significantly less motion than each of the commercial frames in every loading mode (Table 1). The new hybrid fixator showed comparable stiffness with commercialized fixators or even was stiffer.

**DISCUSSION**

In general, the four commercially available hybrid external fixation systems performed similarly. The only significant difference was that the Ace-Fischer frame was more stable in pure axial loading, which is probably explained by its symmetry compared to the eccentricity of the other hybrid frames. When a pure axial load is applied, a bending load is generated in these frames. This bending behavior increases the motion at the fracture site. Furthermore, the motion due to bending causes angulation at the fracture site instead of pure axial translation. While it is thought that axial compression helps the fracture healing process, angular deformation is believed to contribute to delayed union, malunion, and non-union. Decreasing the distance of the side bar to the center of the bone effectively shortens the length of the half-pins, which decreases their deflection during bending, and thus increases stiffness. We measured the distance between the bone surface and point of fixation of wires and half-pins (Table 2). We think that a better stiffness of new fixator than of others is due to a shorter distance between the bone surface and points of fixation of wires and half-pins. Adequate distribution of supporting components (Figure 1): box-like configuration of the Ace-Fischer components, triangular configuration of the supporting components in the Hoffmann II, Synthes, and EBI less off axis bending or cantilever bending created by axial loading of hybrid fixators. The obliquely angled connecting bars of the frame reduce the torsional motion, the parallel connecting bars of the frame makes it more stable to axial compression. The posterior bending motion was less due to more posterior connection of obliquely angled bars. The relationship between obliquely angled connecting bars forming the triangular configuration and fracture site is very important with regard to the stiffness of hybrid external fixation.