Tensioned olive wires are commonly employed in ring (1, 2, 3, 4) and hybrid (6) external fixation. Traditionally, the olive wires are used for fragment reduction and stabilization (1, 2, 5, 6). The effect of the olive wire on the stiffness of external fixation was studied previously (4, 6), but there is limited data on the effect of the olive wire positioning and tensioning characteristics on the mechanical stiffness of fine wire external fixation. The purpose of this study was to evaluate the influence of wire design (smooth and olive), olive wire positioning (medially, laterally, posteriorly, and anteriorly) and tensioning characteristics (tensioning one end or both ends) on the stiffness of fine wire external fixation.

MATERIALS AND METHODS
The test model was a fiberglas composite tibia (Pacific Research Laboratories, Vashon Island, WA, USA) fixed into an idealized fixator, composed of four aluminum rings with an outer diameter of 20 cm, an inner diameter of 16 cm, and a thickness of 2 cm. Four 1.3 cm in diameter threaded rods connected the rings assembling a 30 cm vertical frame. This fixator was used as a test rig, which allowed testing the wires maximally avoiding ring deformation. The fiberglass tibia was fixated in the most proximal ring of the idealized fixator using two 1.8 mm smooth wires and two 1.8 mm olive wires (Smith and Nephew, Memphis, TN) crossed at 60° angle (most appropriate angle for periarticular fixation), which were inserted 18 mm below the articular surface. The wires crossed in the center of the tibia, with the tibia centered in the ring. Loads were applied through a load plate using a servo-hydraulic load frame (MTS Biomin 858, Minneapolis, MN, USA). Load-deformation behavior was compared among different wire design (smooth and olive wires), olive wire positioning (medially, laterally, posteriorly, and anteriorly) and tensioning characteristics (tensioning one end or both ends) under identical conditions of central axial compression, medial compression-bending, posterior compression-bending, postero-medial compression-bending and torsion. Five separate bones were tested and five repetitions were performed for each testing setup in each loading pattern for each bone. Stiffness values were calculated from the load-deformation and torque-angle curves. The differences between tension values on opposite ends of the wire during different modalities of olive wire tensioning were investigated. The difference between tension values on both ends of the olive wire was calculated from MTS load cell data and data provided by the calibrated Ilizarov tensioner (Smith and Nephew, Memphis, TN) for all five repetitions on five separate bones. ANOVA followed by post-hoc t-tests with an alpha level of p<0.05 was applied to compare the stiffness corresponding to different wire design, olive wire positioning and tensioning characteristics. A t-test: paired two sample for means was used to compare the difference between tension values on both ends of the olive wire during tensioning.

RESULTS
Olive wires tensioned on both ends provided significantly greater bending stiffness compared to the samples with smooth wires and the samples with olive wires tensioned only on the end opposite to the olive (p<0.05); and the same axial stiffness as the samples with smooth wires (p>0.05). There was significantly less axial stiffness when olive wires were tensioned only at the ends opposite the olive compared to olive wires with both ends tensioned. Tensioning both ends of the olive wires provided similar axial stiffness as the samples with smooth wires, but tensioning only the end opposite the olive provided 30% less axial stiffness compared to smooth wires. Morandi and Pearse (3), describing the insertion of the olive wires into the proximal tibia, recommended tensioning of both ends of the olive wire. First is tensioned the end of the wire opposite the olive and it is secured. Subsequently, the tension is applied to the other end of the wire where the olive is located. This allows all the different portions of the wires to be under tension. In our study, when only the ends opposite the olive were tensioned, the tension on the olive end of the wire was only 45% with the bone fixed and 84% with the bone free compared to wire tension on the end opposite the olive.

DISCUSSION
Green (1), describing the Ilizarov system, mentioned that when used for stabilization the olive end of the wire is secured first, thereafter, the end of the wire opposite the olive is tensioned to the ring. Our study found that there was 26% less axial stiffness, 68% less medial bending stiffness, 17% less posterior bending stiffness, 37% less postero-medial bending stiffness, and 56% less torsional stiffness when only the olive wire ends opposite the olive were tensioned compared to olive wires with both ends tensioned. Tensioning both ends of the olive wires provided similar axial stiffness as the samples with smooth wires, but tensioning only the end opposite the olive provided 30% less axial stiffness compared to smooth wires. Morandi and Pearse (3), describing the insertion of the olive wires into the proximal tibia, recommended tensioning of both ends of the olive wire. First is tensioned the end of the wire opposite the olive and it is secured. Subsequently, the tension is applied to the other end of the wire where the olive is located. This allows all the different portions of the wires to be under tension. In our study, when only the ends opposite the olive were tensioned, the tension on the olive end of the wire was only 45% with the bone fixed and 84% with the bone free compared to wire tension on the end opposite the olive.

Many authors mentioned that the use of olive wires reduces translation and increases bending stiffness (2, 4, 6). Hutson (2), describing surgical technique in periarticular fractures of proximal tibia, mentioned that an olive wire is always used to increase fixation stiffness. The use of opposing or “dueling” olive wires increases shear stiffness (4), Watson et al. (5, 6) also advocated for the use of tensioned olive wires to increase fixation stiffness. Our study found also that olive wires increases bending stiffness, but mostly when olives were positioned properly and both ends of the olive wires were tensioned. For example, positioning olives medially and tensioning both ends of the olive wire resulted in more than a twofold increase in medial and postero-medial bending stiffness compared to smooth wires. Positioning olives posteriorly resulted in 30% increase in posterior bending stiffness and 72% increase in postero-medial bending stiffness compared to smooth wires.

For the reason that tensioning both ends of the olive wires and positioning the olives on the side of bending (compression side of the bone) significantly increases bending stiffness, this approach to olive wire usage should be considered in most cases of fine wire external fixation.

REFERENCES