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FiberWire® is superior in strength to stainless steel wire for tension band fixation of transverse patellar fractures

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ABSTRACT

Background: The metal implants used to achieve fixation of displaced transverse patellar fractures are associated with implant failure, postoperative pain and a significant re-operation rate. Recent studies have examined braided suture as a possible alternative to stainless steel wire to increase patient satisfaction and decrease re-operation rates, but suture has not demonstrated clearly superior fixation strength. FiberWire® is a reinforced braided polyblend suture that has demonstrated superior characteristics to the previous sutures studied and has not to our knowledge been examined as a material for tension band fixation of transverse patellar fractures.
Methods: Materials testing was performed on repeated samples of No. 5 FiberWire suture and 18-gauge stainless steel wire. The strength and stiffness of each material was measured. The two materials were then used for tension band fixation on a novel transverse patellar fracture model and tested to failure by three-point bending. The constructs included a single stainless steel wire, a single-strand FiberWire tied with a sliding knot, double-strand FiberWire tied with sliding knots and double-strand FiberWire tied with a Wagoner's Hitch. The fixation strength and stiffness of the constructs were measured.
Findings: Unlike stainless steel, FiberWire maintained its initial stiffness until failure. Furthermore, during three-point-bend testing, double-strand FiberWire was found to have a significantly higher failure load than stainless steel wire when the suture was tied and locked under the tension produced by a modified Wagoner's Hitch.
Interpretation: FiberWire is a potentially superior alternative to stainless steel wire in tension band fixation of transverse patellar fractures.

Introduction

Internal fixation using metal implants in configurations based on the tension band principle remains the mainstay of treatment for operative transverse patellar fractures.[14] However, metal implants are associated with complications in 18–50% of patients.[2,6,13,16] Hardware may be prominent causing irritation, inhibition of motion and possible sinus formation and, over time, wires may fragment and migrate. Recent investigations[2,4,5,11,12] have examined heavy suture as a possible alternative to conventional metal implants. Heavy suture is easier to place accurately in the soft tissues, conforms more readily to bony structures, is less likely to fragment over time and appears to be associated with greater patient satisfaction and decreased re-operation rates. Should it be determined, therefore, that suture is at least as effective as stainless steel wire in the maintenance of a tension band under deforming forces, the clinical use of the suture is justified to decrease complication rates and increase patient satisfaction.

The No. 5 Ethibond (Ethicon, Somerville, NJ, USA) and No. 5 Ti-Cron (Davis and Geck, Gosport, Hampshire, UK) braided polyester sutures have been studied in patellar fracture models for this purpose. To our knowledge, FiberWire® (Arthrex, Naples, FL, USA) suture has not been studied as a possible substrate for tension band fixation of patellar fractures. FiberWire is a Food and Drug Administration (FDA)-approved, biocompatible, braided polyblend suture consisting of two polyester strings and a polyethylene string. It has demonstrated superior strength compared to braided polyester sutures in experimental studies.[7,15] The present study aims (1) to evaluate differences in stiffness and failure strength between No. 5 FiberWire, with and without a surgical knot, and 18-gauge stainless steel wire, with and without a compression twist; and (2) to evaluate the effectiveness of FiberWire as a tension band construct using a novel three-point-bend model.

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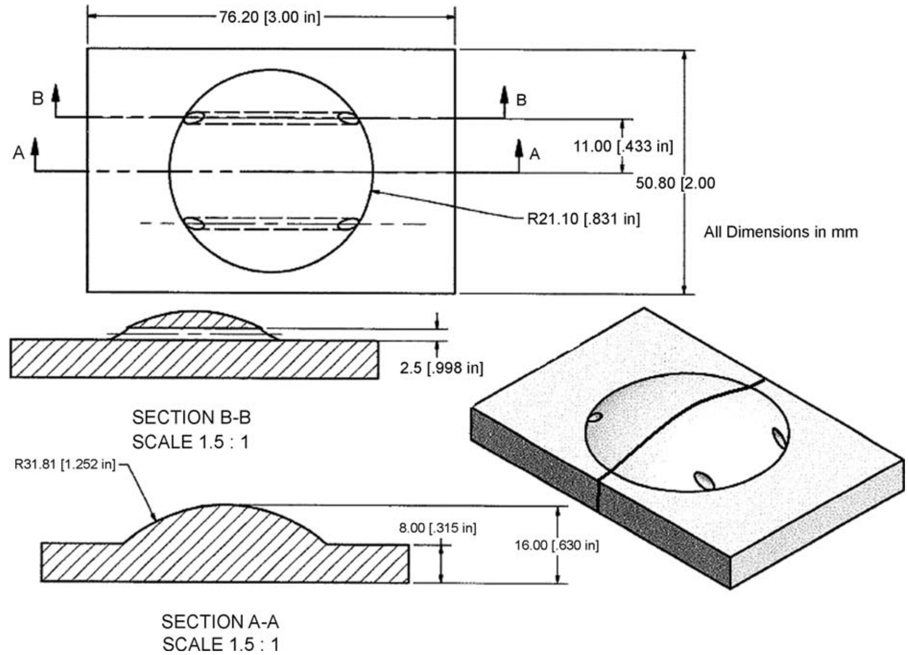

Fig. 1. Schematics of the stainless steel three-point-bend model.

Materials and methods

Repeated samples of No. 5 FiberWire suture and 18-gauge stainless steel wire were tensile tested to failure under displacement control at a rate of 5 mm/min using a materials testing system (Instron, Norwood, MA, USA). To simulate the conditions after uniting opposite ends of the material to secure a tension band construct, tensile tests were then performed with a knot in the centre of a set of new FiberWire samples and a twist in the centre of a set of new 18-gauge stainless steel wires. Specifically, the opposite ends of the FiberWire were tied with a sliding knot followed by three square knots, and the opposite ends of the stainless steel wire were secured with seven visually confirmed symmetric twists. Stiffness and failure strength were calculated for each sample in both of these protocols. Stiffness was calculated as the slope of a best-fit line for the linear portion of the force–deformation curve. Failure strength was determined to be the highest load tolerated by the material. The aforementioned preliminary series of tests, to address the first aim, were performed simply to characterise the suture materials and fastening methods in isolation.

After these preliminary tests, the two materials were used for tension band fixation of a novel three-point-bend model (Fig. 1). The three-point-bend model was machined from stainless steel with an anterior convex surface to mimic a symmetrical patella and flanges superior and inferior to permit placement in a three-point-bend jig (Fig. 2). To reproduce the Lötke figure-of-eight anterior tension band technique, two parallel longitudinal tunnels were drilled in the model to allow the passage of the FiberWire or stainless steel wire.[9] After the suture or wire was secured, the model was loaded in three-point bending at a rate of 5 mm/min using the aforementioned material testing machine (see Fig. 2). The three-point-bending configuration stretches the tension band fixation leading to an anterior fracture gap. An anterior fracture gap of 3 mm was defined as construct failure[14] and was calculated from a start point of zero using the following equation:

$$\text{fracture gap [mm]} = 32\sin\left\{\tan^{-1}\left(\frac{\text{displacement [mm]}}{25.4}\right)\right\}$$

The equation was derived based on the geometry of the three-point-bend model. The gap was also confirmed by the use of a micrometre at the end of each trial. Failure strength for the construct was thus identified at this critical fracture gap. The four constructs tested were: (A) single stainless steel wire with two (bilateral) compression twists; (B) single-strand FiberWire tied with a Müller sliding knot[10]; (C) double-strand FiberWire tied with individual sliding knots; and (D) double-strand FiberWire tied with a modified Wagoner's Hitch[5] (Fig. 3).

Based on the first six repeated samples, power analyses were performed to calculate the needed sample size. To compare and identify significant differences between the four different tension band constructs, a one-way balanced analysis of variance (ANOVA) was employed. To specifically identify which pairs of means (i.e. which of the four conditions) were significantly different, if any,

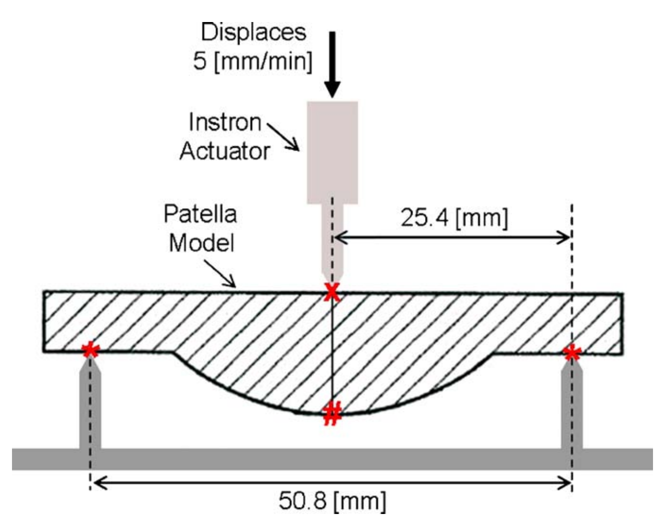

Fig. 2. The patella model in the three-point-bending protocol. In three-point bending, two outer points of the model are supported (shown with an '*'), and as the actuator from the testing machine displaces downwards at a central point (noted with an '×'), the suture begins to stretch and a fracture gap starts to develop at the most anterior point (noted with a '#').