The use of three types of suture and stainless steel wire tension banding for the fixation of simulated olecranon fractures

A COMPARISON STUDY IN CADAVER ELBOWS

S. J. Lalliss, J. G. Branstetter
From The United States Army Institute of Surgical Research, Fort Sam, United States

Using an osteotomy of the olecranon as a model of a transverse fracture in 22 cadaver elbows we determined the ability of three different types of suture and stainless steel wire to maintain reduction when using a tension-band technique to stabilise the bone.

Physiological cyclical loading simulating passive elbow movement (15 N) and using the arms to push up from a chair (450 N) were applied using an Instron materials testing machine whilst monitoring the osteotomy site with a video extensometer. Each osteotomy was repaired by one of four materials, namely, Stainless Steel Wire (7), No 2 Ethibond (3), No 5 Ethibond (5), or No 2 FiberWire (7).

There were no failures (movement of > 2 mm) with stainless steel wire or FiberWire and no significant difference in the movements measured across the site of the osteotomy (p = 0.99). The No. 2 Ethibond failed at 450 N and two of the five of No. 5 Ethibond sutures had a separation of > 2 mm at 450 N.

FiberWire as the tension band in this model held the reduction as effectively as stainless steel wire and may reduce the incidence of discomfort from the hardware. On the basis of our findings we suggest that a clinical trial should be undertaken.

Fractures of the olecranon with displacement exceeding 2 mm require open reduction and internal fixation. In 1873, Lister undertook this treatment using a wire loop. In 1963 the technique was modified by Weber and Vasey, using Kirschner (K-) wires and a stainless steel wire loop. This continues to be the most common method of fixation of transverse fractures and osteotomies of the olecranon with generally good results. However, a common complication of this technique is discomfort from the wires because of the limited subcutaneous tissue in this region and this requires their removal in 42% to 82% of cases. One study reported an incidence of 94% of such discomfort requiring removal in patients under 60 years of age treated by stainless steel wire. The development of a material which maintains enough strength and stiffness to allow healing of the fracture but without requiring subsequent removal would present obvious advantages over traditional tension-band wiring.

Biomechanical testing of different forms of suture compared with stainless steel wire has been reported. The main concern in replacing stainless steel wire, with suture material for tension-band fixation, is the ability of the material to maintain sufficient stability to allow healing without malunion. Harrell et al raised concern about the use of the Ethibond suture (Ethicon Inc, Somerville, New Jersey) for the fixation of fractures. They reported that despite good tensile strength being obtained, poor stiffness was found. In a cadaver model, fixation of an olecranon osteotomy with various absorbable sutures identified that No. 2 Panacryl (Ethicon Inc. Somerville, New Jersey) suture was equivalent to stainless steel wire in maintaining reduction after 600 cycles in a continuous-passive motion machine. This study only examined passive movement and not the higher forces acting on the fracture post-operatively as would be found with active movement of the elbow.

A new development has been the introduction of sutures manufactured using ultrahigh-molecular-weight polyethylene (UHMWPE), one of which is FiberWire (Arthrex, Naples, Florida). It has a diameter of 0.5 mm and consists of a core of multiple filaments of UHMWPE surrounded by braided polyester. In biomechanical testing, it was more than twice as strong in load to failure as a similarly-sized Ethibond suture. Our aim was to compare the ability of Ethibond and FiberWire sutures with that of stainless steel wire to maintain the reduction of a transverse fracture of the olecranon in a tension-band construct in a cadaver model. Our hypothesis was that...
No. 2 FiberWire and No. 5 Ethibond sutures would be equal to stainless steel wire in stabilisation of the fracture.

Materials and Methods
A total of 11 paired fresh-frozen human cadaver elbows were obtained and kept frozen at -50°C. The mean age of the donors was 42 years (19 to 60). All the specimens were thawed at room temperature for 24 hours before testing and kept moist throughout the testing procedure. The paired elbows were assigned to one of three different groups with each elbow from the same donor being assigned to a different group. Initially, we tested 1.02 mm stainless steel wire, No. 2 Ethibond and No. 2 FiberWire. The first three specimens in the No. 2 Ethibond group all failed. Therefore No. 5 Ethibond was used for the remaining five specimens. All soft tissue was removed from the specimens except for the triceps muscle and its tendon, the medial and lateral collateral ligaments, the annular ligament and the joint capsule. A small medial arthrotomy was made in order to ensure complete reduction of the osteotomy. A microsagittal saw was used to create an osteotomy in the mid-portion of the semilunar notch to simulate a fracture of the olecranon. The saw was taken to the subarticular bone, and the osteotomy completed using an osteotome. The osteotomy was reduced with reduction forceps and two K-wires 1.6 mm in diameter were then passed from the tip of the olecranon across the site of the fracture into the anterior cortex of the proximal ulna just distal to the coronoid process. A 2 mm drill hole was placed 2 cm distal to the osteotomy and either stainless steel wire or suture was passed through the drill hole and around the ends of the K-wires (Fig. 1). The stainless steel wire was tightened by a two-knot technique placing four twists in each knot which was shown on an Instron 85215 servohydraulic materials testing machine (Instron Corporation, Canton, Massachusetts) to create 30 N of tension in the wire. The sutures were tied in a single knot after practising on the tensiometer to achieve a similar tension in the suture. The K-wires were then bent and buried in the proximal ulna. The humerus and ulna of the specimens were potted into polyvinylchloride pipes with plaster-of-Paris for attachment into an Instron 8521S servohydraulic materials testing machine (Instron Corporation). The musculotendinous portion of the triceps was sutured to a nylon strap for placement in the hydraulic grip.

Biomechanical testing. The testing protocol was based on a study performed by Hutchinson et al.16 The elbow was positioned at 90° of flexion. The nylon strap which was sutured to the triceps tendon was placed into the hydraulic grip which was attached to a 1000 N load cell with the distal humerus and proximal ulna embedded in polyvinylchloride pipes with plaster-of-Paris for attachment into an Instron 8521S servohydraulic materials testing machine (Instron Corporation). The musculotendinous portion of the triceps was sutured to a nylon strap for placement in the hydraulic grip.
extensometer which can detect displacement within SD 2.5 μm with a 200 mm field of view. Displacement was measured at the surface of the joint since it is clinically relevant at this location. Next, 500 cycles at 0 N to 450 N were applied to the triceps tendon while recording displacement at the joint surface. The same method of attachment and testing parameters were used for all specimens.

**Statistical analysis.** The data were analysed using two-way analysis of variance with repeated measures with statistical significance set at p ≤ 0.05. All analyses were performed using SAS version 9.1 software (SAS Institute Inc., Cary, North Carolina). All the data were reported as the mean and SEM. A sample size of seven was chosen to detect a difference of 2 mm with a power of 80%.

**Results**

**Simulated active elbow movement.** All the specimens had displacement of less than 2 mm after completion of the cycle of active elbow movement. The No. 2 Ethibond specimens had a mean movement of 180 μm (SEM 108) during testing. The FiberWire, stainless steel wire and No. 5 Ethibond groups all had a mean movement of < 30 μm during testing (Fig. 3). At the beginning of the simulated active elbow movement (15 N) testing, four of the seven specimens in the stainless steel wire group showed compression at the articular surface compared to two of the seven in the FiberWire group and one of the five in the No. 5 Ethibond group. None of the No. 2 Ethibond specimens showed compression at the beginning of the 15 N testing. At the completion of the 1000 cycles of loading at 15 N, five of the seven specimens in the stainless steel wire group showed compression at the articular surface compared to three of the seven specimens in the FiberWire group and two of the five specimens in the No. 5 Ethibond group. Two of the three specimens in the No. 2 Ethibond group showed articular surface compression at the completion of the 1000 cycles at 15 N. There was no significant difference between the stainless steel wire, FiberWire and No. 5 Ethibond groups in terms of separation of the site of the osteotomy during testing at 15 N (p = 0.735).

**Pushing up from a chair.** The data for simulated pushing up from a chair are reported in Figure 4. There were three failures in the first three specimens of the No. 2 Ethibond suture group. The suture broke in the first No. 2 Ethibond specimen at 200 N and the remaining two specimens had displacement of more than 4 mm after 500 cycles at 450 N. Because of these failures, No. 5 Ethibond was substituted for No. 2 Ethibond. None of the stainless steel wire or FiberWire specimens had a displacement of 2 mm or more at the site of the osteotomy. Two of the five No. 5 Ethibond specimens had a displacement of 2 mm or more after 500 cycles at 450 N of tension. The mean displacement of the stainless steel wire construct was 0.24 mm (SEM 0.04) and that of the FiberWire construct 0.1 mm (SEM 0.14). These two groups did not differ significantly (p = 0.994). The No. 5 Ethibond group had a mean displacement of 1.2 mm (SEM 0.14) after 500 cycles. This difference was
significant when compared with both the stainless steel wire and FiberWire groups (p = 0.0296 and p = 0.0279, respectively).

Discussion
A material which offers the strength and durability of a stainless steel wire tension band, but without the problems sometimes associated with the hardware could be useful in treating these fractures. A study of various sutures including absorbable material found that absorbable. No. 2 Panacryle performed as well as stainless steel wire but only with the limited forces associated with a passive range of movement when tested in a continuous passive-motion machine. A comparison of stainless steel wire with the braided polyethylene cable (Secure-Strand) showed no difference in separation at the site of the fracture between the two groups but only three cycles of testing were carried out and fatigue testing was not undertaken. A clinical report on the use of biodegradable screw and wire fixation in 15 fractures of the olecranon found an outcome similar to that of the use of stainless steel wire.

Our study compared the use of a commonly-used braided polyester suture (Ethibond) with stainless steel wire and a suture comprised of polyester and UHMWPE (FiberWire) in conjunction with K-wires to secure an olecranon osteotomy using the tension-band wire technique. The No. 2 Ethibond failed to maintain reduction of the fracture in the first three specimens and was therefore changed to No. 5 Ethibond but this was also unable to maintain reduction as well as stainless steel wire. The FiberWire was able to maintain reduction as well as the latter both in simulated active movement and simulated pushing up from a chair. Early movement is required in the treatment of fractures to prevent post-operative stiffness. The ability to resist forces of up to 15 N for 1000 cycles without catastrophic failure was seen in all configurations, but it is likely that without external splinting a fracture would be subjected to forces greater than 15 N. The Ethibond suture group had a mean displacement of 180 μm which might prevent healing of the fracture and lead to nonunion.

While a force of 450 N may be excessive to impose on a healing fracture, it does represent the maximum force likely to be applied to an unprotected elbow fracture. Any material seen as a potential replacement for stainless steel wire in tension-band fixation should be able to tolerate forces to the same extent and have the same resistance to fatigue failure. Only the stainless steel wire and FiberWire constructs were able to maintain reduction of the osteotomy against simulated pushing up from a chair for 500 cycles. Our results are similar to those reported by Carofino et al who compared stainless steel wire and FiberWire tension-band techniques with the use of K-wires and cannulated screws in similar loading parameters. FiberWire performed as well as stainless steel wire at 10 N and 500 N with cyclical loading. They did not test Ethibond and used only ten cycles for active range of movement. We used 1000 cycles as this would mimic the activities of a post-operative patient more closely. From these combined results, we feel that FiberWire can be used as an alternative to stainless steel wire in tension-band fixation of transverse fractures and osteotomies of the olecranon.

Hutchinson et al questioned whether tension-band wiring of the olecranon produced compression at the articular surface. In a similar model with K-wire and screw fixation and tension-band wiring they measured displacement of the anterior and posterior olecranon without finding any compression at the anterior olecranon. Our investigation did show compressive movement at the articular site of the osteotomy with all configurations. The discrepancy between these studies may be related to differences in the testing apparatus. In the study by Hutchinson et al the triceps tendon was attached to the load cell through a pulley system which may not have applied a tensile force to the posterior olecranon. Also, only ten range-of-movement cycles were performed which possibly did not allow the compressive force of the construct to be seen because of stiffness of the wire, suture or tissues. In our study seven of the 22 specimens showed compression at the articular surface at the beginning of the 15 N cycles whereas 12 showed compression at completion of 1000 cycles loading at 15 N.

We recognise that we used a wide range of ages of cadaver bone and that all the specimens were < 60 years of age at the time of death without gross evidence of osteopenia. This might be perceived as a weakness in the study. However, our results were similar to those obtained in other studies testing stainless steel wire for tension-band fixation of olecranon fractures. Hutchinson et al found a mean displacement of 0.6 mm (± 0.6) in the stainless steel wire fixation group which is similar to our findings using specimens of a similar age range. Carofino et al found a mean displacement of 0.3 mm (± 0.3) in the stainless steel wire fixation group and of 0.3 mm (± 0.3) in the FiberWire group which are also similar to our findings. Additionally, the results obtained using cadaver tissue to represent fracture fixation must be interpreted with caution. Furthermore, we were unable to ascertain whether FiberWire produces similar complications to those of stainless steel wire when used subcutaneously at the olecranon. We also accept that our study did not address the problem of K-wires backing out after fixation which is another potential source of symptoms. Despite these limitations, the use of fresh-frozen cadaver material from donors representing the typical age range seen in patients presenting with these injuries has shown that FiberWire is equivalent to stainless steel wire in maintaining reduction of a simulated transverse fracture of the olecranon. On the basis of our findings we suggest that a clinical trial should be undertaken.

We wish to thank J. Jones and W. Wade for their assistance in this project. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References