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Short Paper

Biomechanical comparison of metal wire and FiberWire as tension band techniques: an *ex vivo* study

Hwang, B. M.[1] **and Kim, M. S.**[2*]

[1]Department of Veterinary Surgery, College of Veterinary Medicine, Chonbuk National University, 79, Gobong-ro, Iksan-si, 54596, Jeollabuk-do, South Korea; [2]Department of Veterinary Clinical Science, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University, Seoul 08826, South Korea

[*]***Correspondence:*** *M. S. Kim, Department of Veterinary Clinical Science, College of Veterinary Medicine and Research Institute for Veterinary Science, Seoul National University, Seoul 08826, South Korea. E-mail: minsukim@snu.ac.kr*

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Abstract

Background: The pin and tension band wire (PTBW) technique is used to convert the tensile force at the olecranon fracture site. Although metal wire can be used for the tension band technique, it has side effects such as skin irritation or infection. Other fixation materials like a high-strength polyester and polyethylene suture that do not cause skin irritation and pain, provide similar mechanical strength. **Aims:** The aim of this study was to compare olecranon fragment stability by applying tension bands using metal wire and FiberWire of identical tensile strength. **Methods:** This study was designed as *ex vivo* biomechanical test on canine cadaveric elbows. We biomechanically analyzed the following two fixation methods in cadaveric elbows with olecranon osteotomies: (1) Kirschner (K) wire with 0.76 mm metal wire tension band, (2) K-wires with No. 2 FiberWire tension band. A tensile testing machine was used to measure displacement. **Results:** It was measured that the mean maximum load (MML) value and mean yield load (MYL) were higher using No. 2 FiberWire as a tension band than 0.76 mm metal wire. **Conclusion:** Biomechanical strength of No. 2 FiberWire was significantly different from 0.76 mm metal wire in a canine model of olecranon osteotomy. So, FiberWire is applicable instead of metal wire that has a similar strength.

Key words: Canine, FiberWire, Metal wire, Olecranon osteotomy, Tension band

Introduction

Olecranon osteotomy may be performed in dogs for better surgical access to treat complex distal humeral fractures or to facilitate open reduction of elbow luxation (Caron and Fitzpatrick, 2016; Lai *et al*., 2017). Simple extra-articular transverse fractures are typically caused by trauma in human medicine, but rarely in veterinary medicine (Carofino *et al*., 2007; Grafinger *et al*., 2007). Displacement of the fracture fragment in simple olecranon fractures is caused by the tensile force of the triceps mechanism (Fournet *et al*., 2018). In human medicine, pin and metal wire tension bands are most commonly used in the Association for the Study of Osteosynthesis (AO) method to stabilize olecranon fractures (Lai *et al*., 2017; Powell *et al*., 2017). The pin and tension band wire (PTBW) technique was used to convert the tensile force of the triceps mechanism into a compressive force at the fracture site (Halling *et al*., 2003; Kim *et al*., 2014). As a result, the primary bone healing process is facilitated by the narrow fracture line and increased inter-fragmentary stability (Wiegand *et al*., 2012; Sivolella *et al*., 2014). Although the PTBW technique produces good clinical results, it is associated with numerous complications such as osteomyelitis, delayed union, nonunion, and implant failure in human and veterinary medicines (Halling *et al*., 2002; Ren *et al*., 2016). Symptoms such as skin irritation, pain, seroma are caused by the rigidity of an implanted hardware, specifically due to the protrusion of the proximal ends of pins or particularly twisted knots of the metal wire tension band (Camarda *et al*., 2016; Fournet *et al*., 2018). A study on human medicine reported that a combination of intra-medullary screws and metal wire tension bands lowered skin irritation and pain compared to the traditional AO method; however, 30% of the patients had to undergo a second surgical procedure to address the pain caused by the implanted hardware (Georgiadis and White, 1995; Downey *et al*., 2016). Although the animal study has been an infrequent problem on soft tissue damages, it is imperative to develop a fixation method that does not cause skin irritation and pain and provides a mechanical strength. One method to reduce these symptoms is to use a high-strength polyester and polyethylene suture, such as FiberWire (Arthrex, Naples, FL), instead of a metal wire (Nimura *et al*., 2010). We aimed to compare the strength of metal wire and FiberWire, and to evaluate their biomechanical integrity and stability by applying tension bands made by the two materials having identical strength (Paremain *et al*., 1997). We hypothesized that using a FiberWire, with a similar mechanical strength to a metal wire, as a tension band would not significantly affect its biomechanical integrity and stability.

Materials and Methods

Biomechanical comparison of metal wire and FiberWire tension band techniques were conducted in a canine olecranon osteotomy model. For the modelling, 20 ulna bones were obtained from 10 mature German shepherd dogs, weighing 20 kg or more. All dogs were dead or euthanized at local shelter centers and local animal hospitals due to some reasons unrelated to this study. Both forelimbs were collected from each dog and were frozen until the entire required bones were collected for this study. All forelimbs were defrosted and all tissues were removed except the ulna, triceps tendon, and a small amount of muscle (Fig. 1). Olecranon osteotomies were performed using a thin-bladed saw, perpendicular to the long axis of the ulna and immediately proximal to the anconeal process.

Fig. 1: The ulna and triceps tendon of the dogs prepared for the olecranon osteotomy after removing all tissues

Fixation method

Two 1.4 mm Kirschner (K) wires were inserted normograde in each ulna, through the caudoproximal region of the olecranon. The pins were inserted parallel to each other and directed obliquely on the lateral and medial surfaces. They were placed through the cranial cortex of the ulna, which was distal to the trochlear notch. A transverse 1.2 mm hole was drilled in the caudal cortex of the ulna at the level of the distal point of the trochlear notch. The figure-of-eight-wiring technique was used to create tension bands using the 0.76 mm metal wire or No. 2 FiberWire. A 0.76 mm metal wire was applied on every left ulna and was knotted on both sides according to the traditional AO method. Alternatively, a No. 2 FiberWire was applied on every right ulna and a sliding knot was tied using a half hitch to strengthen the tension of the FiberWire (Figs. 2A and B). Furthermore, two or more additional square knots were applied to increase the knot stability. All implanted hardware was bent to be in a position of least resistance. X-ray analyses of all specimens were performed to verify implant position (Fig. 3).

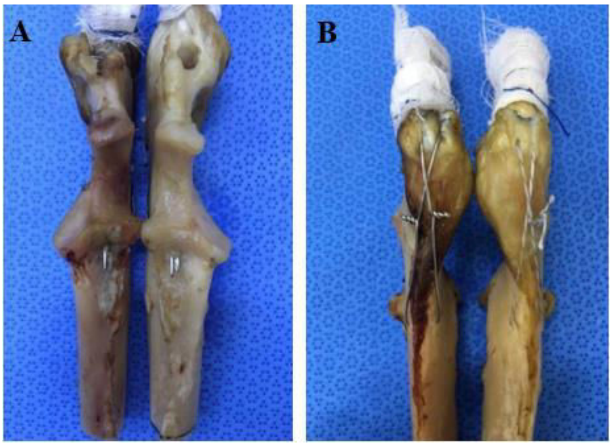

Fig. 2: Tension band fixation via Association for the Study of Osteosynthesis (AO) method by placing two pins and metal wires through the cranial cortex of the ulna distal to the trochlear notch. **A**: Caudal view, and **B**: Cranial view

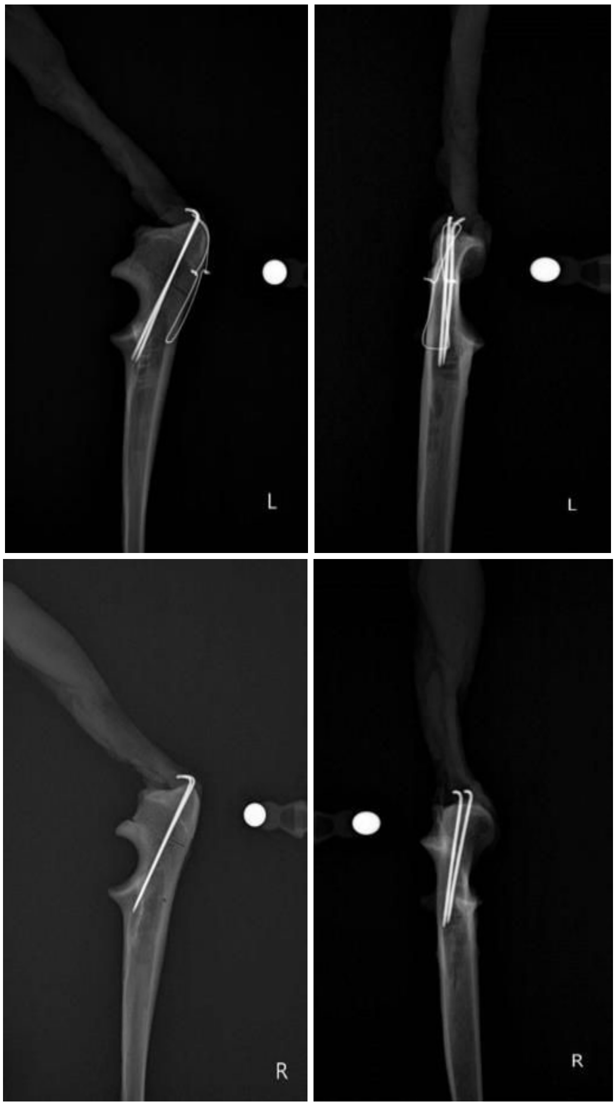

Fig. 3: Lateral and craniocaudal views of metal wire and FiberWire applications in both ulnas. L: left ulna with metal wire, and R: right ulna with FiberWire

Biomechanical testing

The triceps muscle of every ulna was wound by gauze and was tightly sealed using the transfixation suture method. Additionally, cast and cement were distally applied to the trochlear notch of every ulna to prevent slips between the bone or muscle. All specimens were fixed in a frame that positioned the long axis of the ulna at an angle of 135° to the vertically aligned triceps tendon, by vise grip pliers and a specialized gripping apparatus with universal test machine (Fig. 4). Furthermore, the graphs generated after using the data from the previous step were transformed into a trend line, containing the maximum value of each trend line.

Statistical analysis

The data were statistically analyzed for significant differences between the two groups using the Statistical Package for the Social Sciences (SPSS) software with a Student's t-test. A p-value of <0.05 was considered statistically significant.

Results

It was confirmed that all 20 ulnas had matured bone density without pathologic abnormalities before proceeding with fixation and biomechanical testing. In most, but not all ulnas, two pins were placed parallel and were directed to the cranial cortex of the ulna, distal to the trochlear notch. However, every pin was placed through the cranial cortex of the ulna. The test was executed at a speed of 100 mm/min until the metal wire or FiberWire broke due to the tension. The mean maximum load (MML) of the No. 2 FiberWire, as the tension band, was significantly higher than the 0.76 mm metal wire (54.330 kgf and 43.365 kgf, respectively; P=0.018, Fig. 5). The mean yield load (MYL) was not significantly higher while using the No. 2 FiberWire compared to the 0.76 mm metal wire (31.345 kgf and 27.070 kgf, respectively, Fig. 6).

Fig. 4: Fixation of the specimen in a frame that the long axis of the ulna positions at an angle of 135° from the vertically aligned triceps tendon. The parameters are based on the mean and standard deviation

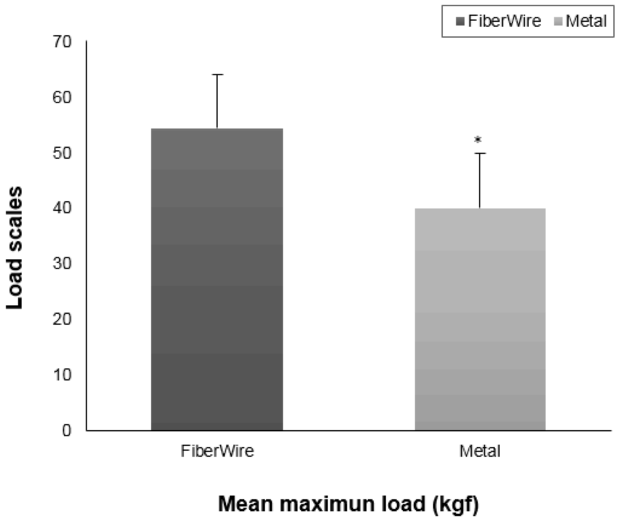

Fig. 5: The mean maximum load (MML) is significantly higher when using No. 2 FiberWire (54.330 kgf) as tension bands than when using 0.76 mm metal wire (43.365 kgf). * P<0.05

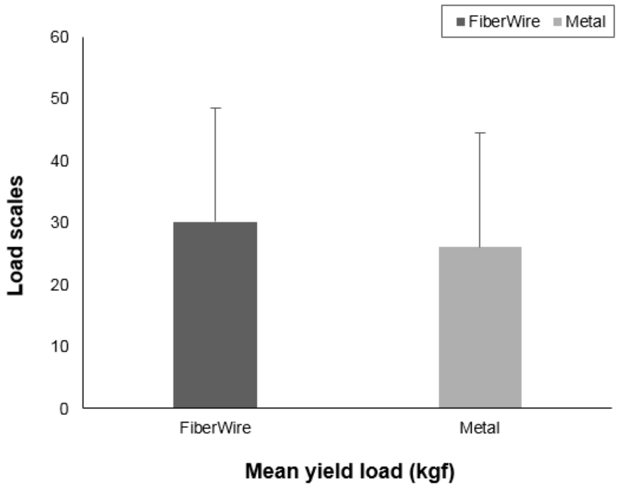

Fig. 6: No significant difference was observed, but the mean yield load (MYL) is higher when using No. 2 FiberWire (31.345 kgf) is used as tension bands than when 0.76 mm metal wire (27.070 kgf) is used

Discussion

Typically, two pins and a tension band, placed appropriately, would successfully maintain good bone fragment stability against the distracting forces of the triceps mechanism in an olecranon fracture (Petraco *et al*., 1996; Zderic *et al*., 2017). Although the clinical results are generally good, implants demonstrate poor results in the post-operative radiographic assessment (Fournet *et al*., 2018). Common errors have been previously described for example losing the two pins to insert perpendicular to the osteotomy line, no connection between the orthopedic flexible wire and the two pins and/or the proximal bone fragment, high distance between the distal bicortical ulna hole and the osteotomy line, and bending over the two twist knots leading to lower tension on the wire (Neat *et al*., 2006; Grafinger *et al*., 2007). The structure and nature of a metal wire and

FiberWire are quite different. A metal wire is rigid and characterized by its monofilamentous shape, while FiberWire is soft and is designed in the form of a braid (Wright *et al*., 2009). Furthermore, in this study, the metal wire and FiberWire appeared visually different from each other after being broken. The problem was the rigidity of the metal wire as a tension band. Romero *et al*. (2000) reported 55 patients with olecranon fracture having metal implantations as tension bands of whom 31 required reoperation since they were "bothered" by the metal wire (Romero *et al*., 2000). FiberWire was evaluated for *ex vivo* use in human medicine in the 2000s. Shoaib *et al*. (2006) excreted two-gauge FiberWire as tension bands to treat olecranon fractures (Shoaib *et al*., 2006). The fracture gap was maintained at 0.5 mm or less, even after applying a load of 100 N; therefore, it was considered suitable for clinical practice as a tension band. Furthermore, in 2009, Wright *et al*. reported that No. 5 FiberWire is a potentially superior alternative to stainless steel wire. In this study, MYL and MML values of the trend line were higher when using No. 2 FiberWire than a 0.76 mm metal wire. Recently, using FiberWire may effectively overcome the problems associated with the metal wire (Camarda *et al*., 2016). This study revealed that the strength of No. 2 FiberWire was better than that of 0.76 mm metal wire.

This study has several limitations. First, all soft tissues were removed except the triceps tendon and a small amount of muscle, Therefore, the biomechanical force and stability from most removed tissues were ignored. Second, due to the repeated freezing and defrosting of the tissues, the strength of bones and other tissues may have reduced. Third, this study was only conducted using a biomechanical testing machine without additional equipment or machines such as a video-based tracking system and cyclic testing, due to which there were no data of load associated with length of the inter fragmentary gap. Lastly, the sample size was small.

In conclusion, biomechanical strength of No. 2 FiberWire was significantly different from 0.76 mm metal wire in a canine model of olecranon osteotomy. No. 2 FiberWire was more stable at greater load. Therefore, showing similar strength, FiberWire can apply in place of a metal wire.

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Conflict of interest

The authors declare no conflict of interest.

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