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Comparison of Tension Band Wiring Method Applied with K-wire or Cannulated Screw in Mayo 2A Olecranon Fracture Fixation: A Biomechanical Study

Mayo 2A Olecranon Kırık Tespitinde K-teli veya Kanüllü Vida ile Uygulanan Gergi Bantlama Metodunun Karşılaştırması: Biyomekanik Çalışma

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ABSTRACT

Aim: The study aimed to compare the biomechanical stability and strength of the tension band wiring method used to treat mayo 2A olecranon fractures with Kirschner (K)-wire or cannulated screw configurations.
Material and Methods: A total of 24 anatomical ulna models (Sawbones Model 1004, Pacific Research Laboratories, Vashon Island, WA) used in the study were divided into two equal groups of 12, tension band fixation with K-wire (Group 1) and tension band fixation with cannulated screw (Group 2), and groups were compared. The mechanical comparison was performed with a universal measuring machine (Shimadzu Autograph 50 kN; Shimadzu Corp).
Results: Fixation methods comparison (K-wire/cannulated screw) were the main factors that determined the stability and the strength of the internal fixation. The median flexion strength of Group 1 was 107.92 (range, 94.22-121.72) N, and that of Group 2 was 109.67 (range, 105.07-113.86) N. The median varus strength of Group 1 was 100.02 (range, 83.24-102.18) N, and that of Group 2 was 76.32 (range, 68.44-78.43) N. Varus strength and stiffness were significantly higher in the K-wire group than in the cannulated screw group (both p values were <0.001). No significant differences were detected between the groups regarding flexion strength and stiffness (both p values were 0.999).
Conclusion: Although no significant differences were detected between the two fixations in flexion bending cyclic loading, a significantly more stable fixation was achieved in tension banding applied with K-wire in varus bending cyclic loading. No reduction loss was detected during cyclic loading tests in either technique.
Keywords: Olecranon fracture fixation; tension banding; displaced transverse olecranon fracture.

ÖZ

Amaç: Bu çalışmanın amacı mayo 2A olekranon kırıklarının tedavisinde kullanılan gergi bantlama metodunun Kirschner (K)-teli veya kanüllü vida ile konfigürasyonlarının biyomekanik stabilitesini ve gücünü karşılaştırmaktı.
Gereç ve Yöntemler: Çalışmada kullanılan toplam 24 anatomik ulna modeli (Sawbones Model 1004, Pacific Research Laboratories, Vashon Island, WA), K-teli ile gergi bant tespiti (Grup 1) ve kanüllü vida ile gergi bant tespiti (Grup 2) olmak üzere 12'şerli iki eşit gruba ayrıldı ve gruplar karşılaştırıldı. Mekanik karşılaştırma evrensel bir ölçüm makinesi (Shimadzu Autograph 50 kN; Shimadzu Corp) ile uygulandı.
Bulgular: Fiksasyon yöntemleri karşılaştırması (K-teli/kanüllü vida), internal fiksasyonun stabilitesini ve gücünü belirleyen ana faktörlerdi. Grup 1'in ortanca fleksiyon mukavemeti 107,92 (aralık, 94,22-121,72) N ve Grup 2'nin 109,67 (aralık, 105,07-113,86) N idi. Grup 1'in ortanca varus mukavemeti ise 100,02 (aralık, 83,24-102,18) N ve Grup 2'nin 76,32 (aralık, 68,44-78,43) N idi. Varus mukavemeti ve sertliği K-teli grubunda kanüllü vida grubuna göre anlamlı şekilde daha yüksekti (her iki p değeri <0,001). Fleksiyon mukavemeti ve sertliği açısından gruplar arasında anlamlı bir farklılık saptanmadı (her iki p değeri 0,999).
Sonuç: Fleksiyon bending siklik yüklenmede iki tespit arasında anlamlı bir farklılık saptanmazken, varus bending siklik yüklenmede K-teli ile uygulanan gergi bantlamada anlamlı şekilde daha stabil bir tespit sağlandı. Her iki teknikte de siklik yükleme testleri sırasında herhangi bir redüksiyon kaybı görülmedi.
Anahtar kelimeler: Olekranon kırık fiksasyonu; gergi bantlama; deplase transvers olekranon kırığı.

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INTRODUCTION

Olecranon fractures are intra-articular fractures accounting for approximately 10% of all upper extremity fractures (1,2). The impaction of the distal humerus, a direct trauma mechanism, often leads to a comminuted fracture pattern, and triceps traction, which is an indirect mechanism, leads to a simple-transverse fracture pattern (3). Anatomical reduction is necessary for olecranon fractures to prevent the development of post-traumatic arthritis and restore the former functionality of the triceps muscle (4). Also, it is essential to provide a stable fixation in which anatomical reduction is protected from the elbow's early flexion and extension movements.

In olecranon fractures, triceps' re-fixation with interfragmentary screws, Kirschner (K)-wires, or cannulated screw supported tension band wiring method (TBWM), plate-screw fixation, or bone fragment excision are among the fixation methods defined previously (5). TBWM is a reliable and widely used fixation method, especially in displaced transverse olecranon fractures. Although clinical and biomechanical studies regarding standard TBWM report excellent results, problems such as K-wires coming back, loss of reduction, and soft tissue irritation are still observed (6). In recent years, various methods have been proposed to develop TBWM, one of which is the Arbeitsgemeinschaft für Osteosynthesefragen (AO) tension band technique first performed with two K-wires sent intramedullary. Then it was changed to pass the distal volar cortex of the coronoid process. It was reported that the approach made by crossing the coronoid cortex reduces the rates of skin rebound and unsuccessful fixation (7). However, the implantation of K-wires through the anterior cortex of the coronoid process may restrict forearm rotation, increasing the risk of heterotopic ossification and neurovascular damage (8,9). Although there is evidence regarding successful clinical outcomes of different fixation methods used for olecranon fractures, the best fracture fixation technique is still a matter of debate (10).

The present study aimed to compare the biomechanical stability and strength of the TBWM used to treat Mayo 2A olecranon fractures with a K-wire or cannulated screw configuration.

MATERIAL AND METHODS

The approval for the study was obtained from the local Non-Interventional Clinical Studies Ethics Committee of Marmara University. Estimating that a minimum difference of 1 unit and a deviation of 0.5 units in the flexion and varus bending measurements would be clinically meaningful, the effect size was calculated as d=2. To achieve 80% power (β=0.20) at the α=0.05 level, six subjects were required in each group. Power analysis was performed using the G∗Power (v.3.1.9.2) program. A single orthopedic surgeon performed the entire procedure on each model. The osteotomy models and fixations were performed at the Department of Orthopedics and Traumatology of Marmara University. The biomechanical tests were performed at Dokuz Eylül University Biomechanics Laboratory.

A total of 24 anatomical ulna models divided into two equal groups of 12 were used in the study (Sawbones, model #1004 synthetic bone, Pacific Research Laboratories, Vashon Island, Washington, USA). Two groups were compared in the study; Group 1: tension band fixation with K-wire (1.6 mm diameter; TST Medical, Istanbul, Turkey) and Group 2; tension band fixation with a cannulated screw (6.5 mm diameter; TST Medical, Istanbul, Turkey). Two parallel K-wires or one cannulated screw in the same direction were inserted into the ulna distal anterior cortex proximal to the olecranon from previously determined standard locations. Fixation was completed in 8 configurations by passing a flexible cerclage wire (1.2 mm diameter; TST Medical, Istanbul, Turkey) through the tunnel opened in the ulnar dorsal cortex at a distance of 6.5 cm from the tip of the olecranon proximally behind the K-wire or cannulated screw and distally. For the cerclage tension, three full turns of tension were applied with the help of pliers with a knotting technique in the system whose void was taken (7). The schematization of the fracture line modeling and standardized entrance and exit locations to be used in detection in Group 1 were given in Figure 1. The schematization of the fracture line modeling and standardized entrance and exit points to be used in Group 2 were given in Figure 2.

Then, each sawbones was embedded in a plastic template containing liquid epoxy resin designed to hold it rigidly and was allowed to harden. Mechanical analysis was performed by fixing the plastic mold to a cylindrical metal with a mechanical clamping system.

The mechanical comparison was made with a universal measuring machine (Shimadzu® Autograph AG-IS 5 kN, Load Cell: SLBN5KN, Shimadzu Co., Kyoto, Japan; Figure 3). The models were tested in 50 cycles. For each sample, six models were used in ulna bending mechanical loading, and the force required to be applied at 0.5 mm/sec speed and 0-5 mm displacement were calculated for each configuration. The stiffness was calculated based on the slope of the force-displacement curve of five cycles for flexion-varus measurements. The stiffness value was calculated with Microsoft Excel (Microsoft Corp., Redmond, WA) software (N/mm).

Statistical Analysis

The IBM SPSS Statistics v.22 (IBM Corp.; Armonk, NY, USA) program was used for statistical analyses. According to the Shapiro-Wilk test, the quantitative variables were not normally distributed. The data were expressed as medians and interquartile ranges. The Mann-Whitney U test determined the differences in applied displacement force and stiffness between osteotomy groups. A p-value of <0.05 was considered statistically significant.

RESULTS

K-wire or screw application were the main factors that determined the stability and strength of the internal fixation. Mean flexion-varus bending cyclic load values were shown in Table 1. Varus bending cyclic load values in Group 1 were significantly higher than in Group 2 (p<0.001). No significant differences were detected between the groups in flexion bending cyclic load values (p=0.999). The mean stiffness values developed against flexion-varus bending cyclic loading applied in all osteotomy models were shown in Table 2. Stiffness values under varus bending cyclic load in Group 1 were significantly higher than in Group 2 (p<0.001). No significant differences were detected between the groups in stiffness values under flexion bending cyclic load (p=0.999). Neither group detected no pin loosening or reduction loss during cyclic loading tests.

DISCUSSION

The TBWM for olecranon fractures provides a stable fixation allowing early mobilization. Continuous advances in the TBWM technique have significantly reduced failure rates on fixation and postoperative complication rates in olecranon fractures (11). Many authors published reports of various bicortical-localized K-wire or screwed configurations (12,13). This study aimed to determine whether the tension band fixation applied with bicortical K-wire or cannulated screw is equivalent in terms of strength and stability in Mayo 2A olecranon fractures. Although no significant differences were detected between the two fixations in flexion bending cyclic loading, the tension banding applied with K-wire in varus bending cyclic loading provided a significantly more stable fixation.

K-wires can be sent intramedullary-distally along the long axis of the ulna in the tension banding technique or can be sent obliquely-bicortical towards the anterior cortex of the ulna. In their study, Mullett et al. (14) explained the clinical and biomechanical results, and they showed that the bicortical method has a much lower complication rate than the intramedullary method. The need for implant removal is five times less. They showed that the bicortical method was significantly more stable in biomechanics. In the present study, we applied the bicortical method in both fixation techniques in line with the existing literature.

Cerclage in a circular configuration may provide insufficient stabilization in the tension banding technique, which may fail fixation because of early loosening. In their study that compared the fixation methods of olecranon fractures, Wang et al. (15) showed that the circular configuration and fixation had the lowest fixation strength, and eight wirings and screw fixation had similar fixation strength. In the present study, we preferred the Cerclage application in the eight configurations in the tension banding method.

In Jones et al.'s (16) study, the transcortical screw provided a more stable fixation under cyclic loading than the K-wire tension banding method. Hutchinson et al. (17), in another study, compared four olecranon fixation methods. They showed that adding a tension band system to intramedullary cancellous screw fixation increased stability, and intramedullary cancellous fixation supported by this tension band was more stable than tension band fixation with bicortical or intramedullary K-wire. Unlike Hutchinson et al. (17), Carofino et al. (18) simulated the strength of standing up from a chair with a high load and showed that the K-wire tension band system provides better stability than the intramedullary screw tension band system. No significant differences were detected in the present study under flexion bending and cyclic load. We found that the K-wire tension band system was more stable under varus cyclic loading, similar to Carofino et al.'s (18) study.

Biomechanical studies are conducted with materials such as sawbones, cadavers, and animal bones. Although it is possible to make consistent evaluations in biomechanical

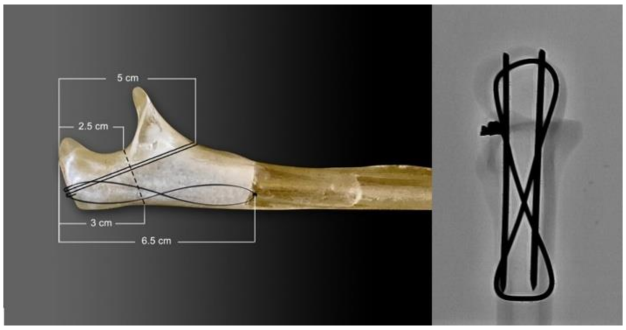

Figure 1. Mayo 2A olecranon fracture fixation with K-wire, a) Diagram view b) Anteroposterior (AP) X-ray view

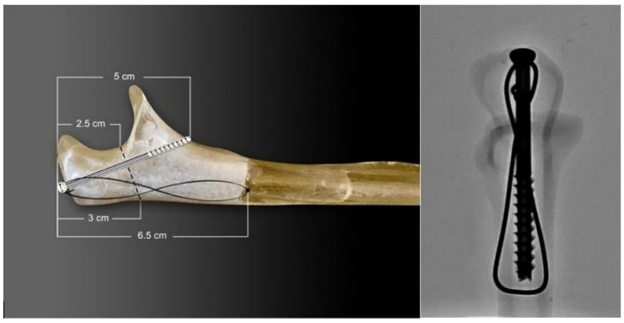

Figure 2. Mayo 2A olecranon fracture fixation with cannulated screw, a) Diagram view b) Anteroposterior (AP) X-ray view

Figure 3. Biomechanical testing of a Sawbone® with Mayo 2A olecranon fracture fixation

Table 1. Comparison of bending cyclic load values

	K-wire	Cannulated Screw	p
Flexion Bending (N)	107.92 (96.52-119.55) [94.22-121.72]	109.67 (107.45-111.18) [105.07-113.86]	0.999
Varus Bending (N)	100.02 (87.44-100.35) [83.24-102.18]	76.32 (72.93-77.22) [68.44-78.43]	<0.001

K-wire: Kirschner wire, descriptive statistics were given as median (25^{th}-75^{th} percentile) [min-max]

Table 2. Comparison of stiffness values against cyclic load

	K-wire	Cannulated Screw	p
Flexion Stiffness (N/mm)	21.58 (19.29-23.93) [18.83-24.51]	21.98 (21.45-22.30) [20.97-22.74]	0.999
Varus Stiffness (N/mm)	19.99 (17.47-20.12) [16.64-20.59]	15.25 (14.60-15.44) [13.83-15.70]	<0.001

K-wire: Kirschner wire, descriptive statistics were given as median (25^{th}-75^{th} percentile) [min-max] studies by using cadavers, the use of cadavers is limited because of the lack of a sufficient number of cadavers, exposure to the effects of a wide age range, body structure, different health conditions, and specimen with no appropriate bone density (19). Although sawbones models do not represent the mechanical properties of cadaver bone, relative mechanical stability can be tested under consistency because all conditions are the same in mechanical testing, except for the fixation technique (20). In the present study, we preferred sawbones for olecranon mayo type 2A fracture modeling.

Our study had some limitations. The combined forces of compression, distraction, bending, and rotation in olecranon fracture could not be simulated at the fracture line, which could be caused by the potential deforming or stabilizing forces of the muscles around the elbow affecting the possible results. Although a natural fracture cannot be accurately reproduced in a single experimental model or biomechanical study, the data obtained can provide new insights into the treatment of fractures in general, especially in metal implants for fixation, to help surgeons make choices when dealing with real situations. Aside from biomechanical evaluations, there may be differences in surgical technique, ease of application, wound healing, surgical time, and fixation difficulty. A clinical study that will evaluate these will contribute to the literature.

CONCLUSION

According to the biomechanical analyses, K-wire configured tension banding provided significantly better stability in varus cyclic loading. However, no significant differences were detected between the two groups in flexion loadings.

Ethics Committee Approval: The study was approved by the Ethics Committee for Non-Invasive Clinical Studies of Marmara University (25.02.2021, 23).

Conflict of Interest: None declared by the authors.

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