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Original Research

Augmentation of cerclage wire strength with a basic knot technique: A biomechanical study

Augmentation of cerclage with a knot

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Abstract

Aim: Loosing of cerclage wire is a common problem in the fixation of fractures and alternative techniques are required to provide more strength cable systems. The aim of this study was to evaluate the benefit of an additional knot to the cable system to increase durability and strength of wire

Material and Methods: Twelve artificial bone fragments were bisected thoroughly in the coronal plane. Two mm diameter CoCr Dall Miles were used in two groups; the first group was the sleeve group (n=6) and the second group was the sleeve + knot group (n=6). All cables were once looped around the saw bone with positioning the sleeve at the beaded end of the cable, and the tensioner knob was used to create tension to 90 lb/in2 (62,05 N/cm2). In the sleeve + knot group, one more simple knot was performed with conventional surgery skill, and the two ends of cerclage wire were put into the tensioner knob to create tension again. Mechanical tension testing was performed at a velocity of 20mm/min. Axial tension force was applied until failure. The maximum force and displacement values were recorded at the failure point.

Results: There was a significant difference in the mean rank of applied force between the sleeve and sleeve + knot groups (p=0,025). However, there was no statistical difference in the amount of displacement between the two groups (p=0,378). The ratio of force/displacement displayed a significant difference between the two groups, it was shown that the sleeve + knot group was more durable than the sleeve only group (p=0,01).

Discussion: Adding a knot to the cable system increases the durability and strength of the cable system by approximately %40. These findings showed that adding a knot to the cable-domino system had decreased the possibility of loosening and fixation failure.

Keywords

Augmentation; Biomechanics; Cerclage wire; Dall miles; Knot; Sawbones

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Introduction

Cerclage wiring, a basic surgical technique, has been used in many areas of orthopedic surgeries, especially to help or support the fixation of fractures mainly long bones and periprosthetic fractures. In the past, many materials such as titanium alloy, chrome-cobalt, stainless steel were used for cable systems [1].

Documentation of the first use of cerclage wire dates back to 1775 [2]. It has become an option in different areas such as fixation of unstable intertrochanteric, acetabular, periprosthetic fractures of femur, humerus, elbow, revision total hip arthroplasties in combination with other implants [3-9]. In recent years, the use of cerclage wire has increased as a result of the increase of periprosthetic fractures, and in this situation there is increasing interest in the cerclage wire techniques, which provide augmentation and make fixation more stable. Surgeons try to overcome the insufficiency and stability of cerclage by using different techniques and adding other implants such as Steinman pins [10], external plaster cast [9]. Since simple cerclage wiring alone is related to high failure rates, fixing the rigidity is very important [11]. Therefore, researchers are focusing on the factors that affect yield and breaking load, fatigue strength because the best way to measure mechanical strength is to evaluate yield and breaking loads. Fatigue strength is also useful for the measurement of the strength of cerclage wire [1].

The multifilament cable was first used for the fixation of the greater trochanter osteotomy in total hip arthroplasty by Dall and Miles [12].The widely used Dall Miles cables are made of stainless steel multifilament and are twice as strong as surgical chrome wire [10,13] . Other beneficial effects of multifilament cables are preventing kinking, which is widely accepted as a risk factor for breakage of cable, making control of tension degree easier [6,13,14]. However, surgeons also encounter failure of multifilament cables because of the patient's biologic factors (bone quality, comorbidities, life qualities), the surgeons' insufficiency about instruments stability, and also wire itself can fail.

In literature, the best cerclage wire configuration is still unclear. This study compared the failure of a load of conventional and our augmentation technique by detecting the strength point value when displacement had occurred.

Material and Methods

Study groups

No animal or human studies were carried for this study so there was no need for ethical approval. Twelve artificial bone fragments (Sawbones, fourth-generation composite, item no: 3403 medium–left) cut from the femur diaphysis model were used. The diameter and length of all sawbones were the same and were approximately 2 cm and 10 cm respectively. These fragments were bisected thoroughly in the coronal plane. Twelve CoCr Dall Miles (Med – Tıp, İzmir, Turkey) 2 mm diameter cable systems were used in two groups; the first group was the sleeve group (n=6) and the second group was the sleeve + knot group (n=6), focusing on 2 different cerclage wiring techniques. All cables were once looped around the saw bone with positioning the sleeve at the beaded end of the cable, and the tensioner knob was used to create tension to 90 lb/in2 (62,05 N/cm2) [15]. The sleeve was crimped with crimp tool. These procedures were the same for the two groups. In the sleeve + knot group, one more simple knot was performed with conventional surgery skill, and the two ends of cerclage wire were put into the

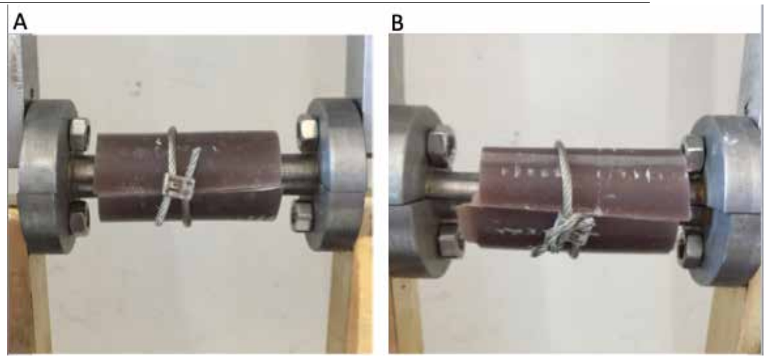

Figure 1. (A) 2 mm Dall Miles cable was looped around saw bone and only sleeve was used for stability; (B) 2 mm Dall Miles cable was looped around saw bone and a knot on the sleeve.

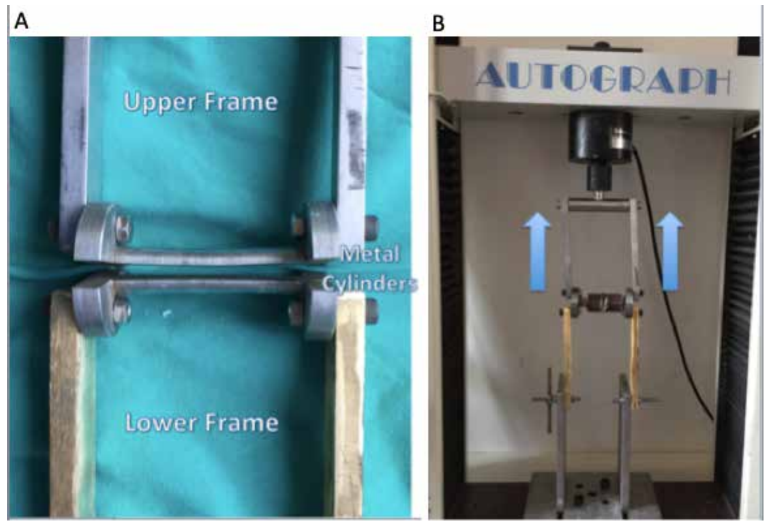

Figure 2. (A) Test setup system. There is no direct connection between upper and lower frames. Saw bone fragments were mounted around metal cylinders with 2 mm Dall Miles cables, and all system was fastened.
(B) Completed test setup. Blue arrows show the direction of distraction force. The lower frame is fixed to the base platform.

Figure 3. Failure of the system: breakage of upper saw bone fragment.

tensioner knob to create tension again. Under tension, the two ends of the cable were cut using a cable cutter (Figure 1).

Mechanical testing

Mechanical testing was performed on a test system (Shimadzu Autograph AG-IS 5kN, Japan) with a 5 kN load-cell. The half of the saw bone fragments were mounted separately on two metallic half-cylinders forming a full cylinder. Each metal half-cylinder was fastened to a frame. The upper frame was fixated to the load cell of the system using a Schanz screw passing through all the holes in the frame and load cell. The lower frame was rigidly fixated to the base platform of the actuator. Both half metal cylinders mediatized and saw bone fragments were put on these cylinders to provide contact to each other (Figure 2). The cables were looped around the two cortical half shells, passed into the sleeve, tensioned and cut and manually pretensioned. Mechanical tension testing was performed at a velocity of 20 mm/min. Axial tension force was applied until failure occurred (Figure 3). The maximum force and displacement values were recorded at the failure point when the applied force suddenly dropped.

Statistical analysis

We used the SPSS software (SPSS 26; SPSS, Chicago, USA) for statistical analysis. The ratio of maximum force and displacement was used to evaluate failure between the groups. In the analytical evaluation, the Mann-Whitney test was applied to evaluate the differences in the mean ranks of the two groups because the comparison of these two groups provided nonparametric conditions. The significance was defined as $p < 0.05$.

Results

All saw bone models were broken at the failure point. The amount of applied force leading to the initiation of the break of the saw bone models and the displacement of half shell pieces at the moment of break are shown in Table 1. There was a significant difference in the mean rank of applied force between the sleeve and the sleeve + knot groups (p=0,025) (Table 2). The Sleeve + knot group needed much more force to catastrophically destroy the cable system than only sleeve group. But no statistical difference in the amount of displacement between the two groups was seen (p=0,378) (Table 2). When we look at the force/displacement ratio, we found a significant difference between two groups: the sleeve + knot group was more durable than the sleeve only group (p=0,01) (Table 3). No failure or loosening of cable in the crimp happened.

Table 1. Values of forces and displacements in sleeve and sleeve + knot groups

n	Maximum Force (N)		Maximum displacement (mm)		Force/Displacement ratio (N/mm)	
	Sleeve	Sleeve + Knot	Sleeve	Sleeve + Knot	Sleeve	Sleeve + Knot
1	2088,75	2604,38	5,84	4,33	357,72	601,75
2	2391,26	2577,03	6,38	3,65	377,95	706,04
3	2702,66	2664,84	6,49	5,99	416,18	444,58
4	1921,41	2717,5	3,74	6,33	513,75	429,51
5	2167,34	2949,53	5,59	5,58	387,72	528,97
6	1534,69	2489,31	4,91	4,73	312,63	526,84

Table 2. Comparison of maximum forces and maximum displacement between two groups

Groups	Maximum Force: Median (minimum – maximum) Mean rank	p*	Maximum displacement: Median (minimum – maximum) Mean rank	p*
Sleeve	2128,05 (1534,69 – 2702,66) 4,17	0,025	5,72 (3,74 – 6,49) 7,42	0,378
Sleeve + Knot	2634,61 (2489,32 – 2949,53)		5,16 (3,65 – 6,33) 5,58	

*: Mann – Withney Test

Table 3. Comparison of ratio of force/displacement between two groups

Groups (n)	Mean rank	p*
Sleeve	3,83	0,01
Sleeve + Knot	9,17	

*: Mann – Withney Test

Discussion

In this study, we investigated that adding a simple knot technique to the standard procedure of the cable system made it more strength and stable biomechanically. In this setup, the saw bone fragments were transformed into half-shells by cutting in the coronal plane, and these pieces were mounted on metal bars to create separation under our control and measure the applied force and the amount of displacement. We defined the failure point as the applied axial loading exceeded the centripetal force of the wire around the saw bone. There may be seen loosening in the cerclage wire system after fixation of the fracture during the postoperative period [16-19]. In this study, we think this problem could be reduced with a simple knot. It was seen that adding a knot to cable – domino fixation system increased the stability by approximately 40% more strength.

The most common places of failure on the wire are usually at stress risers (knots, twists, or kinking areas). The site of failure is usually located at potential stress risers [1]. In our study, we added an extra knot on the sleeve part of the cable. Thus, we think this adding knot spread the stress area to a wider area, and this may help resist more strongly. We cut our wire just near the knot under the tension of the device. Therefore, we might lose our tension after cutting, but even though the sleeve + knot group is superior to only the sleeve group. This study showed us that a device that protects against tension after cutting wire is needed in this area.

We have made knots by hand first and then used a tensioner device to create tension on the knot. This is compatible with other studies. Harnroongroj et al. [20] found that stiffness was related to the tightening of the construct; they found that to achieve the best stability, 200 N tension cerclage wire was needed. Wähnert et al. [21] found that twisting under tension was beneficial for the installation of pre-tension.

Cutting the wire causes a significant loss of tension. Which part of wire is cut, also effects the tension, within the twist at the end of the wire [21]. Rook et al. [22] investigated first the twisted wire and then cutting below the breakage, in addition, without breakage, to reach the precise stable long-term tension, the strength of the wire is as important as fracture reduction and bone-to- bone contact. In this study, we proved that adding a basic knot method significantly enhances the load resistance of the cerclage and improves the cerclage fixation.

The limitation of this study is that, in normal human physiology, the cable system always exposures cyclic loading by dynamic forces. Accordingly, the reason of failure is fatigue. But we perform force from the center to the periphery by increasing continuously until broken down. This shows us strength and durability. We defined failure of the system when it broke. In the literature, Lenz et al. [23] defined more than 3 mm axial displacement, Talbot et al. [24] defined displacement of 10 mm, or the point where applied force suddenly dropped by 10%. The point of only catastrophic failure of each system was determined. We also dealt only with centripetal force with axial loading.

Conclusion

This knot technique is very simple and fast. In our biomechanical study, we showed that only adding a knot to a cable system increases the durability and strength of the cable system by approximately 40%. These findings showed that adding a knot to the cable-domino system decreased the possibility of loosening and failing of fixation. There will be some advantages in clinical use considering the difficulties, especially in fixation of periprosthetic fractures, complex fractures using screws.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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