Research Article

Stability Comparison Of The Screwed And Unscrewed Kirschner Wire Used In Supracondylar Humerus Fractures In Children: ANSYS 16.0 Finite Element Analysis

Çocuklarda Suprakondiler Humerus Kırıklarında Kullanılan Yivli ve Yivsiz Kirschner Telinin Kararlılık Karşılaştırması: Ansys 16.0 Sonlu Eleman Analizi

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Abstract

Objective: Supracondylar humerus fractures are the most common surgery requiring upper extremity fractures among children. Kirschner Wire (KW) is one of the important surgical method that is smooth stainless steel pins, and is widely used in orthopedics. The aim of this study is to evaluate the stability difference in supracondylar humerus fractures of children by unscrewed and screwed KW by finite element analysis method.

Material and Methods: In this study, the computerized images of patients who were admitted to the Orthopedics and Traumatology department of a Training and Research Hospital with a diagnosis of pediatric supracondylar humerus fracture were used. A bone model was created using a layer created in the 3D Slicer program version 4.10.2. On this model, osteo-synthesis fixation was performed with Solid Works, with screwed and unscrewed K-wire mounting, divergent and crossed. Afterwards, this model was analyzed in ANSYS 16.0 finite element analysis program.

Results: All KW configuration measurements for screwed forces were found higher than unscrewed forces in both crossed and divergent torques.

Conclusion: The use of screwed K wire was found to be superior to unscrewed wire due to the more stable fixation. During surgery, the configuration of the K wire varies according to the surgeon's experience, fracture type, ulnar nerve damage risk analysis.

Keywords: Kirschner wire, supracondylar humerus fractures, finite element analysis, bone modelling

Özet

Amaç: Suprakondiler humerus kırıkları çocuklarda en sık cerrahi tedavi gerektiren üst ekstremite kırık tipidir. Kirschner Wires (KW), ortopedide yaygın olarak kullanılan, pürüzsüz paslanmaz çelik pinler olan önemli fiksasyon yöntemlerden biridir. Bu çalışmanın amacı, çocuklarda suprakondiler humerus kırıklarında sonlu eleman analizi yöntemi ile yivli ve yivsiz KW ile stabilite farkını değerlendirmektir.

Gereç ve Yöntemler: Bu çalışmada bir Eğitim ve Araştırma Hastanesi Ortopedi ve Travmatoloji kliniğine suprakondiler humerus kırığı tanısıyla başvuran çocuk hastaların bilgisayarlı görüntüleri kullanıldı. 3D Slicer programının 4.10.2 sürümünde oluşturulan katman ile bir kemik modeli oluşturuldu. Bu modelde, osteo-sentez fiksasyonu, Solid Works ile yivli ve yivsiz K-teli montajı, diverjan ve çapraz olarak gerçekleştirildi. Daha sonra bu model ANSYS 16.0 sonlu elemanlar analiz programında analiz edildi.

Bulgular: Kirschner teli ile yapılan fiksasyonlariçin tüm KW konfigürasyon ölçümleri, hem çapraz hem de diverjan torklarda yivsiz kirschner teli ile yapılan fiksasyon sonuçlarından daha yüksek bulundu.

Sonuç: Yivli K teli kullanımı daha stabil fiksasyon sağlaması nedeniyle yivsiz tele göre daha üstün bulunmaktadır. Ameliyat sırasında K telinin konfigürasyonu cerrahın tecrübesine, kırık tipine, ulnar sinir hasarı risk analizine göre değişmektedir.

Anahtar Kelimeler: Kirschner teli, suprakondiler humerus kırıkları, sonlu eleman analizi, kemik modelleme

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1.Introduction

Supracondylar humerus fractures are the most common surgery requiring upper extremity fractures among children (1). The lower end of the humerus is the most common fracture site in trauma, due to its unique anatomy and thinning in the area close to the condyles (2). The type of fracture is determined by the severity of the trauma to which the patient is exposed and the bone quality. However, Kirschner wire (K wire) type and placement configuration are determined by the surgeon during osteofixation (3, 4).

Supracondylar humerus fractures in children can be classified according to the injury mechanism. Flexion type humerus fractures occur when the elbow joint falls on the elbow while it is in the flexion. Extension-type fractures, on the other hand, occur when the elbow joint is open and falls on the elbow. Extension-type fractures constitute 96% of supracondylar humerus fractures and are divided into subregions according to the displacement of the distal part. Fracture types are made according to the Gartland classification system. Gartland Type-I fractures have no or minimal displacement. Type-II fractures have displacement, but the integrity of the posterior cortex is intact. In type-III fractures, it is directly displaced to the posterior region, the integrity of the posterior cortex is impaired (5).

It is still controversial that the Kirschner wire (KW) placed in the medial region in children with supracondylar humerus fractures damages the ulnar nerve. Although KW placed in the medial region has a positive effect on stability, the incidence of postoperative ulnar nerve damage varies between 0-15% (4, 6, 7). It has been found that fixation with a crossed KW increases ulnar nerve injury (8). It has been observed that the crossed KW has a significant positive effect on stability, especially when torsional forces are applied (9). Likewise, in another study conducted on an adult cadaver, it was observed that the crossed KW provided optimal stability (4). While loss of reduction was observed in fixations with a divergent KW, no reduction was observed in cross-placed KW fixations (10). Based on intra-op observations, it is recommended to place a KW medially (11). Although there are many studies, the mechanism of reduction loss after osteo-synthesis has not been fully explained (2).

Although much work has been done on the stability, it is observed that the screwed Kirschner wire and the unscrewed KW are not compared. In this study, it was aimed to evaluate the stability difference in supracondylar humerus fractures of children by unscrewed and screwed KW by finite element analysis method.

2.Materials and Methods

In this study, the computerized images of patients who were admitted to the Orthopedics and Traumatology department of a Training and Research Hospital with a diagnosis of pediatric supracondylar humerus fracture were used. A bone model was created using a layer created in the 3D Slicer program version 4.10.2. On this model, osteo-synthesis fixation was performed with Solid Works, with screwed and unscrewed K-wire mounting, divergent and crossed. Afterwards, this model was analyzed in ANSYS 16.0 finite element analysis program. As the analysis conditions, a moment of 1.5 Nm in the clockwise and reverse direction and a 30 Nm compressive force in the axis of the shear and bone parallel to the fracture surface were applied.

The solid models used in the creation of the three-dimensional (3D) finite element model were obtained from the computed tomography (CT) scan of a 6-year-old child. The CT scans were performed on the device with brand "Toshiba Alexion" belonging to the Training and Research Hospital, using 16 Slice CT Scanner parameters. 3D Slicer program version 4.10.2 was used to obtain a solid surface models of CT scans. Since it is not possible to analyze the surface model, this model was re-created as a solid model with the SolidWorks 2018 program. K-wire models used in surgery were modeled and used in the same program. On the obtained solid bone model, the fracture was simulated throughout the entire section at the patient's fracture distance. Then, the K-wire, modeled as screwed and unscrewed, was assembled with two parts of bone created after fracture simulation.

The assembly model was carried out as divergent and cross. The bone and K-wire structure, whose assembly was completed, was subjected to finite element analysis against mechanical stresses with ANSYS 16.0 (2020) program. In the analysis, the structure was subjected to 1.5 Nm torque in clockwise and reverse, 30 Nm shear force parallel to the fracture surface and 30 Nm compression forces on the bone axis.

Unscrewed and screwed K wires were placed from the fracture model created using the SolidWorks 2018 program (Figure 1-2).

A separate configuration was applied for each application. Young's modulus was selected as E: 16 GPa for cancellous bone, E: 80 GPa for cortical bone, and E: 210 GPa for the K wires used.

ANSYS 16.0 Analysis Results

In the study, in the prepared illumination, 1 Nm moment in clockwise and reverse direction, 30 Nm of shear and 30 Nm of pull-out force in the bone axis were applied parallel to the fracture surfaces. This has been applied to all screwed and unscrewed parameters.

Ethical Approval

In this study, there was no need to take an ethical approval since the study was not conducted on animals or patients. The bone modelling was performed by a software using computerized images.

3.Results

The results are summarized in Tables 1 & 2. As can be seen, stability in supracondylar humerus fractures fixed with a screwed K-wire was found to be more stable than fixations made with a unscrewed K-wire

Table 1. Torque and force of unscrewed K-Wire Configuration

KW configuration	μ=0		μ>0,2	
	Torque +	Torque -	Torque +	Torque -
Cross	0.9	0.9	0.75	0.8
Divergent	4.9	4.1	2.0	2.0
	Shear		Pull-out	
	μ = 0	μ >0.2	μ = 0	μ >0.5
Cross	0.9	0.87	0.9	0.5
Divergent	10.0	0.87	15.0	0.5

Table 2. Torque and force of screwed K-Wire Configuration

KW configuration	μ=0		μ>0,2	
	Tork +	Tork -	Tork +	Tork -
Cross	1.3	1.3	1.0	1.2
Divergent	5.2	4.2	2.2	2.2
	Shear		Pull-out	
	μ =0	μ >0.2	μ =0	μ >0.2
Cross	1.3	1.0	1.3	0.8
Divergent	13.0	1.0	16.5	0.8

4.Discussion

There are several studies on the use of K wire in supracondylar humerus fractures or upper extremity fractures. For supracondylar humerus fracture in infants, there are two kinds of treatment strategies widely used. These therapies include the installation of two K-wire or parallel K-wire fixation techniques by crossing. The crossing technique of K-wire fixation is beneficial for the top fracture position, whereas the parallel technique of K-wire fixation is beneficial for the bottom fracture position (12-15). An exceptionally low rate of complications following closed reduction and percutaneous pinning in this study, the largest recorded series of type 2 supracondylar humerus fractures in children; secondary operations were also rare (0.5 percent). Compared to previous studies of children treated with closed reduction without pinning, the study demonstrates a high likelihood of successful outcome following surgical treatment of type-II supracondylar fractures (16, 17). After open reduction and K-wire fixation via an anterior approach, the functional results were poorer with longer surgery time and Gartland type (18). Operative reduction and pin fixing is the latest approved treatment for Gartland type-II and III fractures. Lateral entry pins alone have ample fixation stability when the correct technique is used, eliminating the risk of iatrogenic ulnar nerve injury.

A supracondylar fracture in a pulseless limb should be treated with an immediate reduction, which should not be postponed if an angiogram is awaited, as the reduction of the fracture typically restores perfusion (19). In a prospective and surgeon-randomized study, it was found that no statistical difference in the radiographic findings between lateral-entry and medial and lateral pine strategies for the treatment of Type-III supracondylar fractures in children when examined, but two cases of iatrogenic ulnar nerve injury occurred with medially positioned pins (20, 21). The pick of KW configuration historically provides the clinician with a choice between a more robust build and the greater potential for nerve injury. The outcome of a study suggested that the stability of the two diverging lateral KW configurations is similar to that of the crossed KW configuration when KW-bone soldering status is optimal. The relative stability of the crossed configuration is superior when bending is compromised. As KW-implant bonding conditions in the clinical setting are not currently measurable, further studies are needed to compare KW insertion techniques with bone-implant bonding conditions (2). Secure, reliable, immobilization for children after closed reduction and pinning of supracondylar distal humerus fractures was supported by a frame cast immobilization. Children with preoperative neurovascular compromise should be watched closely for signs of excessive swelling and consideration should be given to separating the cast before leaving the operating room (22, 23).

It can be seen that, conforming to the studies in the literature, K wires placed as divergent are found to be equal or superior to K wires placed as crossed in supracondylar humerus fractures (19, 22). However, ulnar nerve damage in the K wire put in the medial is a deterrent factor in terms of putting the K wire here by the surgeon. Another study demonstrated the positive effect on K wire stability placed in medial using computer analysis (2). The findings of the study show that the fixation with K wire from medial contributes positively to stability (10). At the same time, it provides reliable results that fixation with screwed

K wire increases stability. Stabilization with plaster splints after surgery is recommended, as seen in other studies, and contributes positively to stability (23). During surgery, repeatedly entering through the same hole may have a negative effect on clinical stability (2). However, the least possible input during fracture fixation has a positive effect on stability.

During surgery, the configuration of the K wire varies according to the surgeon's experience, fracture type, ulnar nerve damage risk analysis. In this study, the use of screwed K wire was found to be superior due to the more stable fixation. However, the fixation through lateral 3K wire is excluded from this study. Better results can be obtained with this method, but further studies are needed to clarify the advantages on this subject.

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