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ORIGINAL ARTICLE

Complications and Solution Suggestions in Situations When Implant Removal is Required After Osteosynthesis with the Plate Screw System: Solidworks Analysis

Plak Vida Sistemi ile Osteosentez Sonrası, İmplant Çıkartlıması Gereken Durumlarda Yaşanılan Komlikasyonlar ve Çözüm Önerileri: Solidworks Analiz

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ABSTRACT

Aim: Extremity fractures are common in orthopedic trauma. Internal fixation with plate screw, which is among the types of osteosynthesis, is frequently preferred because it provides sufficient stabilization and fixation between bone fragments and is easy to apply. In our study, we aimed to analyze the conditions that may occur during the placement and removal of the plate-screw system for any reason with solidworks-based analysis programs and to offer solutions.
Material and Method: When it is necessary to remove the screw, more torque is needed than when it is tightened, and as a result, screw deformations and stripping are encountered. For this reason, it would be more appropriate to use a torque screwdriver during screw placement. We investigated the plate-screw relationship in the locked and unlocked plate screw system with Solidworks 2020 finite element analysis method.
Discussion and Conclusion: Our analysis revealed that the most important factor in the plate-screw relationship, which is as important as the surgical approach and anatomical reduction, is compliance with the AO principles. It has been observed that if the screw is placed at the appropriate torque and place, the removal of the screw is also done at the same torque during primary surgery.

Key words: finite element analysis, bone screws, osteosynthesis

ÖZ

Amaç: Ortopedik travmada, ekstremite kırıkları sıklıkla görülmektedir. Plak vida ile internal tespit, kemik fragmanları arasında yeterli stabilizasyon ve fiksasyon sağlaması ve kolay uygulanabilir olması nedeniyle sıklıkla tercih edilmektedir. Çalışmamızda plak vida sisteminin yerleştirilmesi ve herhangi bir sebeple çıkarılması sırasında yaşanabilecek durumları solidworks tabanlı analiz programları ile analiz etmek ve çözüm önerileri sunmayı amaçladık.
Materyal ve Metod: Plak vida sisteminin çıkarılması gerektiği durumlarda, yerleştirildiği zamankinden daha fazla torka ihtiyaç duyulmaktadır. Bunun sonucunda vida deformasyonları ve sıyırmaları ile karşılaşılmaktadır. Çalışmamızda kilitli ve kilitsiz plak-vida sisteminde, plak-vida ilişkisini Solidworks 2020 sonlu elemanlar analiz yöntemi ile araştırdık.
Tartışma ve Sonuç: Analizimizin sonucunda, cerrahi yaklaşım, anatomik redüksiyon kadar önemli bir etken olan plak vida ilişkisinde, en önemli faktörün AO prensiplerine uymanın olduğunu gözlemlendi. Primer cerrahi esnasında uygun tork ve yerleşimde vida konulduğunda; vidanın çıkartılması esnasında da aynı torkta kuvvet uygulandığı görülmüştür.

Anahtar kelimeler: sınırlı eleman analizi, kemik vidaları, osteosentez

Introduction

Extremity fractures are common in orthopedic trauma. Depending on the severity of the trauma, the injury mechanism, its relationship with the joint, and whether it is open or closed, the classification of fracture is made and treatment is planned accordingly. Among the treatment options are plaster treatment with closed reduction; closed reduction with Kirschner wire, external fixator, and plate-screw system, and intramedullary osteosynthesis (1). Müller et al. established the AO group in the early 1960s and set forth the aims of fracture treatment. The aims were determined as anatomical reduction, the rigid fixation of fracture fragments, the preservation of bone blood circulation, and the initiation of early joint movements (2). Internal fixation with plate screw, which is among the types of osteosynthesis, is frequently preferred because it provides sufficient stabilization and fixation between bone fragments and is easy to apply (3).

The plate screw system is divided into two groups as locked plates and unlocked plates (1). Since the pressure between the bone and the plate is less in locked plates than in unlocked plates, it has been found to have a positive effect on fracture union and bone blood circulation (4). In locked plates, the screw is threaded into the plate by means of the threads of the screw head. In this way, an advantage is gained in terms of fixation, especially in osteoporotic bones (3). Figure 1 and 2 show the relationship between locked plate and bone, and unlocked plate and bone, respectively.

When situations such as infection, non-union, and implant failure occur in patients who underwent osteosynthesis with the plate screw system, the previously placed plate screw system should be removed for both infection treatment and revision surgery (5).

Our aim in this study is to analyze the screw stripping situations that may occur while the plate screw system is being removed, with the Solidworks finite analysis programs and to offer solutions.

Material and Method

The plate-screw system is often used in the surgical treatment of fractures as it produces successful results. The stability of the plate screw system depends on the compression of the plate to the bone with the screw applied. In upper extremity surgery and lower extremity surgery, it is recommended to screw with at least 6-8 cortices and 8-10 cortices respectively, in order to control the torsional forces while performing osteosynthesis with the plate-screw system (6). While using the unlocked plate screw system, which is called the conventional system, circulatory deterioration and eventually bone loss may occur due to the pressure exerted on the bone under the plate. This results in the loosening of the screws. In order to prevent this, Perren et al. produced the LC-DCP (Limited Contact Dynamic Compression Plates) locked plate screw system in the early 1990s. This system ensures more limited contact between the bone cortex and the plate (7). Thus, the pressure on the bone is reduced and positive effects are achieved in terms of the blood circulation of the bone (8).

Symptoms and Findings:

When a traumatized patient comes to the emergency room, he usually has the symptoms of pain, swelling, abnormal movement and deformityif there is a fracture. In all cases, a careful neurovascular examination should be performed. Attention should be paid to the compartments in the relevant place. In open fractures, intravenous fluid and antibiotic therapy should be given after the first intervention in the fracture (9).

Classification:

Fractures are classified according to the fracture type, mechanism of formation, degree of fragmentation of the bone, and the accompanying injuries. Since there may be adjacent joint injuries that may accompany fractures, radiographs that will also include adjacent joints must be performed (10). Müller AO (Arbeitsgemeinschaft für Osteosynthesenfragen) classification is frequently used in the classification of fractures. Making a classification is important in terms of guiding the surgery, the selection of the necessary implants, and the correct choice of fixation methods (11).

Surgical Technique Plate Placement:

Ensuring compression between the fracture ends in fracture fixation has positive effects on clinical outcomes. Locked plate applications have been popular from a biological approach. In particular, having the option of multiple holes, having a dynamic hole that provides compression, and having a locked hole should be among the primary choices (6).

During surgery, after the provision of the appropriate surgical field and the anatomical reduction of the fracture, the plate to be applied is temporarily placed on the bone with bone clamps. Preferably, the screw to be inserted first is placed bicortically into the distal hole. In the second stage, the screw should be placed on the opposite side of the fracture. During the tightening of this screw, the bone clamps are loosened and compression is provided between the fracture ends. Depending on the type of fracture, a pulling screw should be placed (6). Then, depending on the upper and lower extremity bone regions, 8-10 cortices or the minimum number of screws possible depending on the quality of the bone are placed.

Technical Analysis of the Interaction Between Plate and Screw:

If a torque force greater than the safety torque value is used during screw placement on the plate, the friction coefficient increases as the pressure between the screw and the plate increases. As a result, heat occurs, which causes expansion in the screw and the plate. When this metal interaction cools, that is, when it comes down to body temperature, the tension increases. When it is necessary to remove the screw, more torque is needed than when it is tightened, and as a result, screw deformations and stripping are encountered. For this reason, it would be more appropriate to use a torque screwdriver during screw placement. Figure 3 shows the plate screw A: tightened with excessive torque and B: tightened with appropriate torque, using the appropriate hole.

Another important issue is that the pressure distributions displayed in Figure 3 between the plate and screw both in conventional plates and in more biological plates show the relationship between the screw and the plate before the screw is placed and the relationship after the screwing is made using the drill hole. Figure 4 shows (A) the abnormal pressure distribution on the plate when screwing is done without using a drill hole and (B) the abnormal pressure distribution between the plate and the screw when screwing is done without using the drill hole (B).

As can be seen in Figures 3 and 4, abnormal interaction occurs between the plate and screw with the finite element analysis method in Solidworks 2020 program, because the torque of 3 NM is exceeded. As a result, metallic deformation occurs. When the heat generated as a result of over-tightening the screw comes down to body temperature (cools down), bone union increases andthe stretching of shrinking metals increases. As a result, if it is necessary to remove the screw, more torque force is needed than the torque force with which the screw is tightened.

At the same time, weakening occurs on the plate because the load distribution on the plate exceeds the linear ground after drilling and screwing without using a drill hole (Figure 4A). As a result, when tensile, load and torsional forces arising from extremity movements are added, implant failure may occur in the future.

In patients who have undergone osteosynthesis in extremity fractures with the plate screw system, there may be cases for whom revision surgery or removal of the plate is required. In such situations, the metal-to-metal interaction between the plate and the screw and the torque forces at the time of primary surgery are important. The forces used to remove the screw, which is placed using the appropriate drill hole and torque forces in Figure 3 and without using the drill hole in Figure 4, and using a torque force exceeding the screwdriver torque force, were examined using the Solidworks 2020 finite element analysis method. As seen in Figure 3A, to remove the screw placed using 3.5NM torque, 4.203 NM torque force is required, whereas to remove the 3NM screw in Figure 3B, 3.05 NM torque force is needed. On the other hand, in Figure 4B, 4.165 NM torque force is required to remove the screw that was inserted using 3.5 NM torque force without using the hole (Table 1).

As seen in Figure 3 and Table 1, the screws placed in the appropriate hole and screwdriver torque force are removed with the same torque force. However, it is observed that more torque force is required to remove the screws when drilling is done without using the hole and when the screws are placed in a way that exceeds the torque force. As a result of this, during surgery, we may encounter screw stripping that we do not desire to happen at all.

Discussion and Conclusion

Screw removal complications are less when a phillips screwdriver is used to fix the plate screw system. Since the effective surface area of the Phillips head screw is larger, the torque effect of the screwdriver and the stripping of the screw are less. At the same time, applying torque above the normal force during fixing also shortens the material life (12). The most common screw removal complications occur in hexagonal screws. For this reason in this study, we examined the hexagonal screw design in the Solidwork 2020 finite analysis program.

We investigated the plate-screw relationship in the locked and unlocked plate screw system with Solidworks 2020 finite element analysis method. During the analysis, the angular value of the screw plate was assumed to be 90 degrees. Our analysis revealed that the most important factor in the plate-screw relationship, which is as important as the surgical approach and anatomical reduction, is compliance with the AO principles. If the appropriate plate-screw placement technique is not followed, screw stripping may occur due to plate-screw interaction in cases when the plate-screw system needs to be removed. As a result, the surgery time is prolonged, the infection rate increases, it becomes impossible to remove an infected material, or the bone structure is damaged (12). Our analyses revealed the importance of using an appropriate technique during plate and screw placement. It has been observed that if the screw is placed at the appropriate torque and place, the removal of the screw is also done at the same torque during primary surgery. As a result, it is predicted that the complications of screw stripping will decrease. In this regard, investigating the negative effects of the heat emitted during screw placement on the bone may be another research topic.

Table 1: Torque configuration

Torque Configuration	μ>0,2		μ=0	
	Torque close(NM)	Torque open(NM)	Torque +	Torque -
Drill hole+	3=	3.05≤	0.75	0 .8
Drill hole-	3.5=	4.203≤	2 .0	2 .0
Drill hole-	3.5=	4.165≤	2.0	2.01

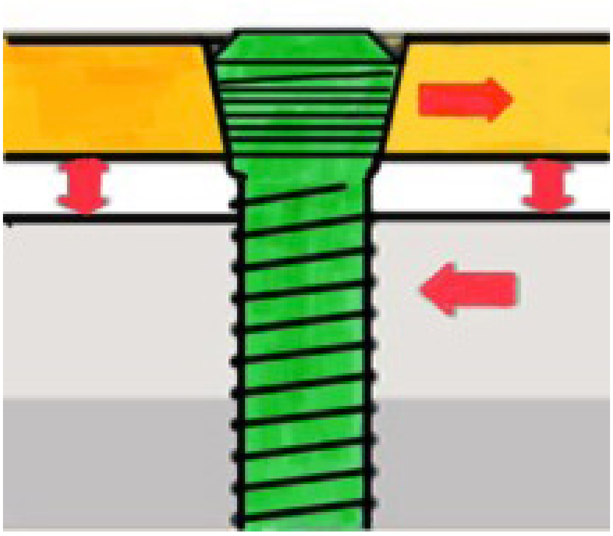

Figure 1: The relationship between locked plate and bone

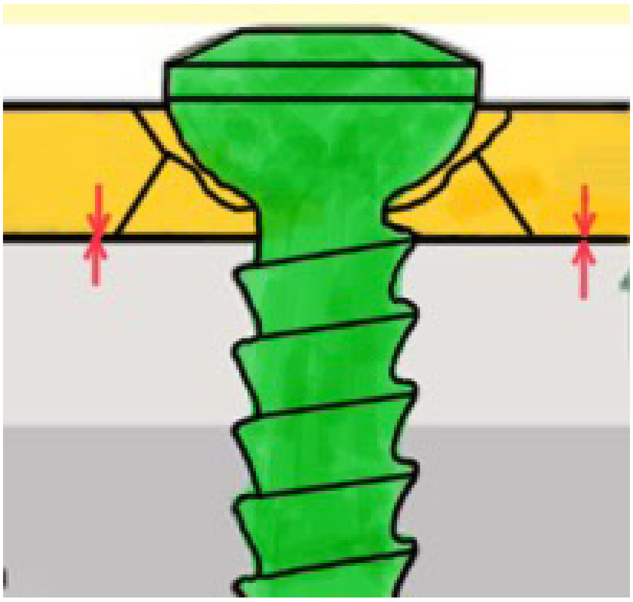

Figure 2: The relationship between unlocked plate and bone

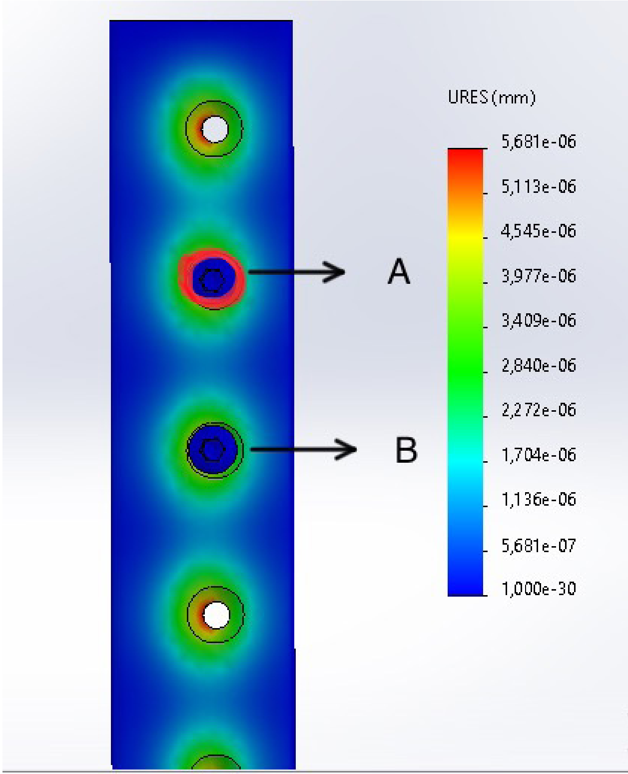

Figure 3: A: Plate screw tightened with excessive torque (more than 3 NM), B: Plate screw tightened with safety torque (3 NM)

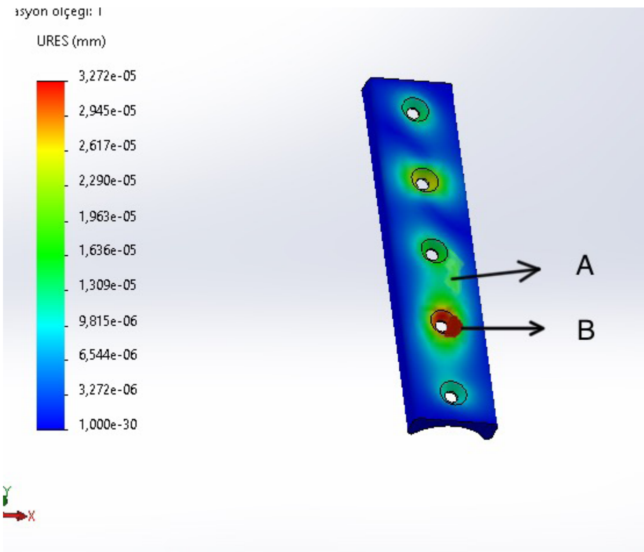

Figure 4: A: Abnormal pressure on the plate when screwing is done without using a drill hole, B: Abnormal pressure distribution between the plate and screw when screwing is done without using a drill hole

References

1.Hojjat A, Kovacı H, Alsaran A ve ark. Tibia kırıklarında kullanılan kilitli ve kilitsiz plak fiksasyon sistemlerinin sonlu elemanlar yöntemiyle incelenmesi. J APPL SCI 2014;18(3):167-74.

2.Müller ME, Perren SM, Allgöwer M et al. Manual of internal fixation: Techniques recommended by the AO-ASIF group. 3rd ed. JBJS 1992; 74(2):315-16.

3.Szypryt P, Forward D. The use and abuse of locking plates. J Orthop Trauma. 2009;23(4):281-90.

4.Haas N, Hauke C, Schütz M et al. Treatment of diaphyseal fractures of the forearm using the point contact fixator (PC-Fix): Results of 387 fractures of a prospective multicentric study (PC-Fix II). Injury. 2001;32:51-62.

5.Şener N. Ekstremite açık kırıklarında komplikasyon ve morbidite oranları. Acıbadem Üniversitesi Sağlık Bilimleri Dergisi. 2010;1(1):9-12.

6.Çağlar Ö, Leblebicioğlu G. Erişkin önkol kırıklarında kilitli plak ile temel tespit prensipleri. TOTBİD Dergisi 2012;11(1):34-40.

7.Perren S, Mane K, Pohler O et al. The limited contact dynamic compression plate (LC-DCP). Arch Orthop Trauma Surg 1990;109(6):304-10.

8.Leung F, Chow S-P. A prospective, randomized trial comparing the limited contact dynamic compression plate with the point contact fixator for forearm fractures. JBJS 2003;85(12):2343-8.

9.Ünlü S, Ersan Ö. Çocuklarda açık kırıklar ve ateşli silah yaralanmalarına yaklaşım. TOTBİD Dergisi 2019; 18:320–326.

10.Kılıç E, Çevik E, Soylu K. Ortopedik acillerde radyolojik incelemeler. TOTBİD Dergisi 2013;12(1):35-46.

11.Gönç U, Teker KK, Tandoğan R et al. Minimal invaziv osteosentez temel prensipleri, cerrahi planlama ve redüksiyon yöntemleri. TOTBİD Dergisi 2012;11(1):1-14.

12.Özbakış Y, Erzincanlı F, Şahin A. Plastik esaslı kompozit malzemelerde kullanılan bağlantı elemanlarının malzeme ömrü üzerine etkisi. International Journal of Advances in Engineering and Pure Sciences 2020;32(3):279-86.

13.Uzunköy A. Cerrahi alan enfeksiyonları: Risk faktörleri ve önleme yöntemleri. Ulusal Travma Dergisi 2005;11(4):269-81.