DOI: 10.34108/eujhs.1433626

SAĞLIK BİLİMLERİ DERGİSİ
JOURNAL OF HEALTH SCIENCES
Erciyes Üniversitesi Sağlık Bilimleri Enstitüsü Yayın Organıdır

Araştırma 2025; 34(1): 113-120

EFFECTS OF INSERTION ANGLE AND BODY SHAPE ON THE PRIMARY STABILITY OF ORTHODONTIC MINISCREWS*

ORTODONTİK MİNİ VİDALARIN YERLEŞTİRME ANGULASYONUNUN VE GÖVDE YAPISININ PRİMER STABİLİTEYE ETKİSİ

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ABSTRACT

In this study, we aimed to analyze the maximum insertion torque (MIT), pull-out and shear strength of the samebrand miniscrews with different body structures that were inserted at 30°,45°,60°and, 90° in order to compare their stability. The study consisted of 144 self-drilling, 1.4×8 mm titanium alloy miniscrews (Abso-Anchor conical, Abso-Anchor cylindrical). Each group of miniscrews were inserted in fresh male bovine hip bone segments at four different angles and the MIT was recorded. Pull-out and shear force resistance values were measured and recorded until 1.5 mm displacement occurred. The data was analyzed with the use of the IBM SPSS program. Statistical analyses were conducted with Shapiro-Wilk, One-Way ANOVA, Tukey HSD and Student's t-test. It was determined that the maximum insertion torque and force resistance values of the conical miniscrews and an insertion angle of 45° were significantly higher than those of the other groups. The Abso-Anchor conical group was the most resistant to failure. To achieve the best primary stability, the use of a conical shape is advisable. The insertion angle of 45° is more favorable than excessive oblique or vertical angles.

Keywords: Miniscrew, primary stability, pull-out test, shear test.

ÖZ

Çalışmanın amacı 30°, 45°, 60° ve 90° de yerleştirilmiş, aynı markanın farklı gövde yapısına sahip mini vidalarının maksimum yerleştirme torkunu, pull-out ve shear kuvvet dayanımını ölçmek ve stabilitelerini karşılaştırmaktır. Çalışmada 1.4×8 mm ebatlarında toplamda 144 tane titanyum alaşım, self-drilling mini vida (Abso-Anchor konik, Abso-Anchor silindirik) kullanılmıştır. Her iki grup dört farklı açıda yerleştirilmiş ve maksimum yerleştirme torkları kaydedilmiştir. Daha sonra vidalara pull-out ve shear kuvvet testleri, vida başı 1.5 mm yer değiştirinceye kadar uygulanmış ve gösterdikleri kuvvet dayanımları Ncm cinsinden kaydedilmiştir. Veriler IBM SPSS programıyla analiz edilmiştir. İstatistiksel analizler; Shapiro-Wilk, tek yönlü Anova, Tukey HDS ve Student t testleriyle yapılmıştır. En fazla maksimum yerleştirme tork değeri ve kuvvet dayanımı, konik gövde yapısı ve 45° yerleştirme açısında görülmüştür. Abso-Anchor konik grubu primer stabilite yönünden diğer gruptan daha başarılı bulunmuştur. En yüksek primer stabilite için konik gövde yapısı tavsiye edilmektedir. 45° yerleştirme açısı, aşırı eğimli veya dik açılara göre daha uygundur.

Anahtar kelimeler: Minivida, primer stabilite, pull-out test, shear test.

*Effects of insertion angle and body shape on the primary stability of orthodontic (poster presentation), Annual Session of American Association of Orthodontists, Washington DC, USA, May 2018. It is a specialist thesis.

Makale Geliş Tarihi : 18.02.2024
Makale Kabul Tarihi: 28.11.2024

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INTRODUCTION

The growing need for orthodontic treatment methods requiring minimal patient cooperation and maximum anchorage has led to the development of implant technology. Miniscrews have advantages such as small size, easy implementation, non-comprehensive surgical procedures, of use in many parts of the alveolar bone, immediate post-insertion force.[1,2]

Many studies reported in the literature have evaluated the factors affecting miniscrew success, with primary stability being the most common.[3-6] The mechanical lock obtained immediately after the insertion of the miniscrew into the bone is referred to as primary stabilization. Factors such as miniscrew size and design, quality and quantity of cortical bone, insertion torque, placement angle, application technique, screw thread characteristics, and soft tissue health all affect the initial stability.[7-9]

The body of the mini screw can be cylindrical or conical, with conical screws having 20% -30% less surface area than cylindrical ones.[10] This reduces the surface area contact with the total bone and may adversely affect the stability.[11] However, with conical screws, tighter cortical bone contact is obtained and better primary stability is provided.[7,12] There are also studies that indicate that cylindrical miniscrews are superior to conical ones.[13] However, in the literature there is no definite information about which body shape is better.

can be placed at various angles to increase support from the cortical bone and to prevent damage to biological formations such as teeth roots, nerves and veins.[14,15] In the literature, while many studies[16-18]advocate angled placement, there are some which argue that angular placement does not provide an additional advantage.[19,20]

There is no gold standard for measuring primary stability. A number of methods are considered in the literature.[21,22] However, measurements of insertion and removal torque, resonance frequency analysis and force resistance tests are considered to be the most reliable methods and ones that are commonly used.[23] In addition, there are a few studies in the literature on pull -out and shear tests.[6,9] When the use of in a clinical situation is evaluated, it is seen that anteroposterior force such as space closure is generally applied. However, there is a need for more information and study about the use of shear test. Although the number of studies involving the use of pull-out test is greater than those involving shear test, the number of studies is still insufficient.

The purpose of our study is to analyze the insertion torque, pull-out and shear test results of of the same brand with different body structures in order to compare the stability usingdifferent insertion angles and body type in an in-vitro environment.

MATERIALS AND METHODS

Study Design

The width and height of the bone models were 15 mm. The cortical portion of these bones was between 1.5 and 2 mm (Figure 1).

Figure 1. Cortical part of the bones

The models were stored in a locked bag with damp cloths and frozen at -5°C until the test was completed. Freezing does not adversely affect the elastic properties of the bone.[24] The bones were embedded in a cold acrylic from a liquid consistency prepared in metal templates and the upper surface of the bones was completely outside (Figure 2).

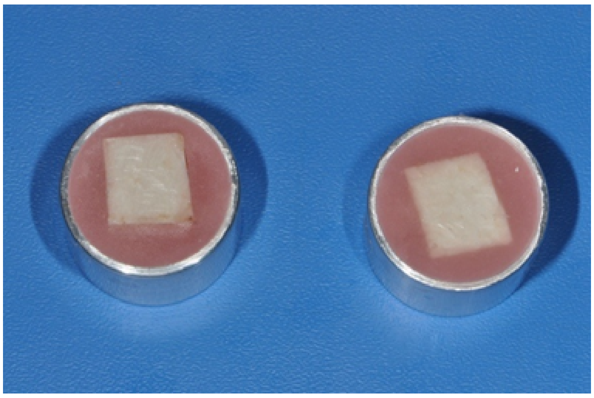

Figure 2. Preparation of the bone samples

A mechanism similar that used by Uyar[25] was created in order to fix the bone models and ensure the correct screw driver angle when placing miniscrews in the bone models (Figure 3).

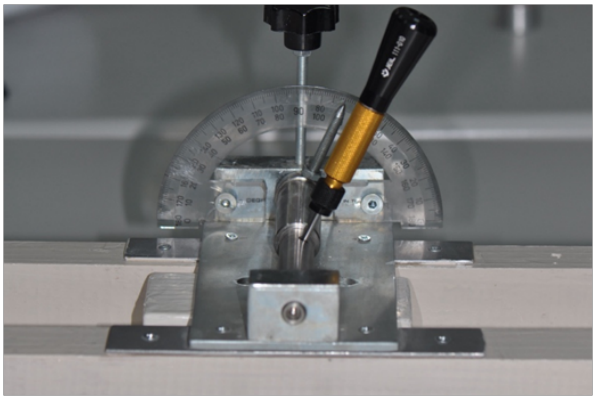

Figure 3. Mini screw application stand and angular apparatus

A gauge was placed on a wooden scaffold and was combined with a screw driver carrier system. In the pilot study, it was determined that the MIT at the first entrance of the miniscrews by drilling the bones was always less than the ones emerged in the last tours. So the application made until the final few turns of the mini screw were carried out with a screwdriver. The mini screw is less tightened than the last application distance so that the torque measurement test can be performed (up to 2 mm) (Figure 4).

Figure 4. Maximum insertion torque measurement

The torque measuring screw driver (Checkline TSD 50,USA) was used up to 1mm and the MIT was recorded. The last 1 mm distance represented gingiva. The force resistance test was performed using the Testometric device (M500, 25kN, Testometric, Rochdale, Lancashire, England) (Figure 5).

Figure 5. Testometric device

The device has two parts, one of which is fixed while the other is movable. The samples to be tested were placed on the fixed part with the aid of a metal adapter. By means of the force transmitters which are movable and distance-adjustable, aforce was applied to each screw up to 1.5 mm displacement and the maximum resistance they showed in a pull-out test was recorded in Ncm (Figures 5,6).

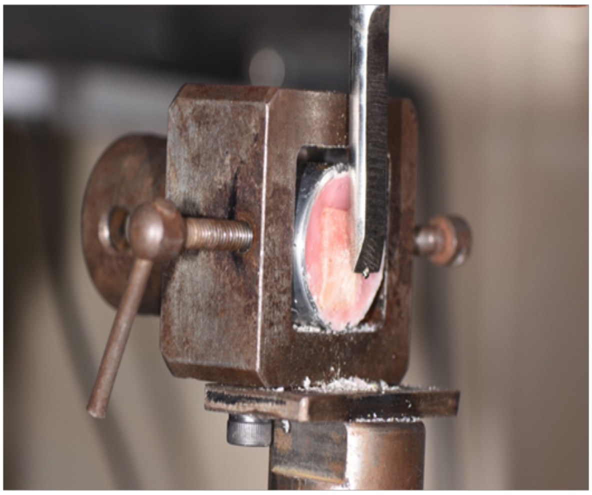

Figure 6. Testometric device and pull-out resistance test

The shear test was applied when the sample was rotated 90 degrees with out changing the direction of the force arm in the device. In our study, a total of 144 miniscrews were used. 72 were Abso Anchor cylindrical and 72 were Abso Anchor conical. Each miniscrew group was placed at 30°, 45°, 60°, and 90° angles to the bone. Therefore 8 groups were created, each with18 screws. To measure the force resistance of the miniscrews, two different forces were applied using pull -out and shear tests. The force applied in the shear test is in an antero-posterior direction, parallel to the alveo-lar surface and has a different orientation according to the mini screw angulation (occluso-gingival direction). The force applied in the pull-out test is on the same plane as the mini screw angulation. In the smallest group of 18 miniscrews, each test was applied to 9 miniscrews (Figure 7).

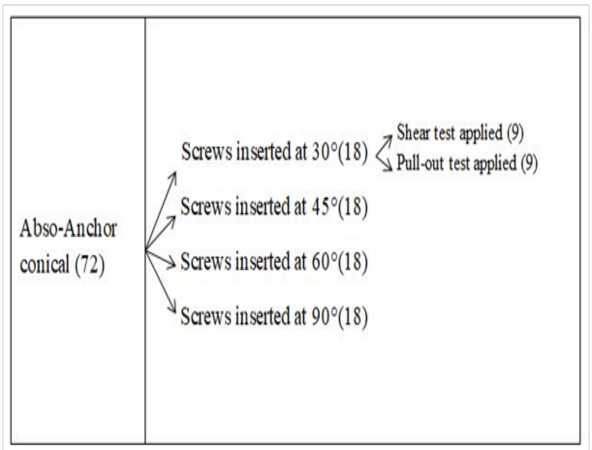

Figure 7. Distribution of the miniscrews that applied the force resistance test

Statistical Analysis

The sample calculation was performed by using the data of a previous study[6] and the effect size in the present study was established.[6,15] The alpha-type error of 0.05, a power of 0.80 and a ratio N2/N1 of 1 were also stipulated. A total of 9 samples per group were indicated as the ideal size required for noting significant differences.

To evaluate the findings obtained in this study, the IBM SPSS Statistics 22(IBM SPSS, Chicago, IL, USA) program was used for statistical analysis**.** To assess whether the data were normally distributed, the Shapiro-Wilk test was performed. The One-Way ANOVA test was used for comparison of angle groups, the post-hoc Tukey HSD test was used in determining the group that caused the difference. The student t-test was used to compare the two groups of parameters. Significance was assessed at the $p<0.05$ level.

RESULTS

Table 1 shows that the seperate evaluation of the insertion torque, pull-out and shear test according to the angles of the miniscrews in groups. Table 2 shows that the post-hoc evaluation of the angle groups in terms of insertion torque measurement pull out and shear tests. Table 3 shows a comparison of the Abso-Anchor conical and Abso-Anchor cylindrical groups.

In the case of the Abso-Anchor conical group, the highest MIT was at 45° and the lowest MIT was at 90° (Table 1). Both values were statistically significant compared to the 30° and 60° groups (Table 2). In the case of the Abso-Anchor cylindrical group, the highest MIT was at 30° (Table 1). This was statistically significant compared to 45°, 60°and, 90° (Table 2). The lowest MIT was at 45° (Table 1) and there was no statistically significant difference between 45°, 60° and 90° (Table 2). In the Abso-Anchor conical group, the highest pull-out strength was at 45° (Table 1). This was statistically significant compared to 30°, 60° and, 90° (Table 2). The lowest value was at 30° (Table 1) and there was no statistically significant difference between 30°,60° and 90° (Table 2). In the Abso-Anchor cylindrical group, the highest pull-out strength was at 45° (Table 1) and there was no statistically significant difference between 30°,45° and 60° (Table 2). The lowest pull-out strength was at 90° (Table 1) and this was statistically significant compared to 30°,45° and 60° (Table 2).

In the Abso-Anchor conical group, the highest shear strength was at 45° (Table 1) and there was no statistically significant difference between 45°,60° and, 90° (Table 2). The lowest shear strength was at 30° (Table 1) and this was statistically significant compared to 45°, 60° and 90° (Table 2). In the Abso-Anchor cylindrical group, the highest shear strength was at 60° (Table 1) and there was no statistically significant difference between 45°, 60° and 90° (Table 2). The lowest shear strength was at 30° (Table 1) and this was statistically significant compared to 45°,60° and, 90° (Table 2).

DISCUSSION

Looking at recent studies, few researchers appear to be working on the biomechanical properties of different types of miniscrews.[26-28] Studies have focused more on comparing the biomechanical properties for clinical use of the same miniscrew. In addition, there is no definite information in the literature about which body shape is better. Abso-Anchor conical and Abso-Anchor cylindrical groups were used to compare body shape differences and all other features were kept the same.

The screws with the highest insertion torque are the Abso-Anchor conical group placed at 45°. There are other studies in the literature that show that conical screws have more MIT than cylindrical ones.[11,22] Lim et al. found that cylindrical screws have much higher insertion torque at the incomplete screw thread, while taper screws show a much higher insertion torque at the final inclination part of the screw thread.[35] Our study was based on values at the end of screw driving. Consequently these results are similar to those found in our study.

Cha et al. placed ninety-six cylindrical and tapered miniscrews in 6 beagle dogs to determine the effect of bone mineral density (BMD), cortical bone thickness (CBT), screw position, and screw design on the stability of the miniscrews.[12] They measured both insertion and removal torque. It was reported that the tapered miniscrews had a higher placement torque than did the cylindrical type (P\0.001). However, the removal torque was similar in both groups. Our study also measured the insertion torque. There fore, the situation that conical

Table 1. Evaluation of the insertion torque, pull-out and shear test according to the angles of the miniscrews separately in groups

			Insertion Torque		
	30°	45°	60°	90°	p
Abso-Anchor conical	8.46±0.46	8.91±0.47	7.54±0.33	6.72±0.33	<0.001*
Abso-Anchor cylindrical	7.22±0.25	6.69±0.21	6.81±0.22	6.83±0.43	<0.001*
			Pull-out test		
	30°	45°	60°	90°	p
Abso-Anchor conical	100.200±7.759	170.840±8.412	131.377±13.500	106.888±20.310	<0.001*
Abso-Anchor cylindrical	136.500±20.500	139.877±35.155	124.588±30.914	83.111±21.525	<0.001*
			Shear test		
	30°	45°	60°	90°	p
Abso-Anchor conical	59.544±13.215	100.560±15.203	87.300±8.675	99.711±33.855	<0.001*
Abso-Anchor cylindrical	62.311±4.536	90.933±10.396	98.388±6.594	97.244±15.415	<0.001*

1-way ANOVA Test * p<0.05

Table 2 Post-hoc evaluation of the angle groups in insertion torque measurement, pull-out and shear tests.

Insertion torque		Abso-Anchor conical	Abso-Anchor cylindrical
30°	45°	0.007*	<0.001*
	60°	<0.001*	<0.001*
	90°	<0.001*	0.001*
45°	60°	<0.001*	0.591
	90°	<0.001*	0.450
60°	90°	<0.001*	0.996
Pull-out test		Abso-Anchor conical	Abso-Anchor cylindrical
30°	45°	<0.001*	0.994
	60°	<0.001*	0.799
	90°	0.720	0.002*
45°	60°	<0.001*	0.650
	90°	<0.001*	0.001*
60°	90°	0.003*	0.017*
Shear test		Abso-Anchor conical	Abso-Anchor cylindrical
30°	45°	0.001*	<0.001*
	60°	0.031*	<0.001*
	90°	0.001*	<0.001*
45°	60°	0.512	0.414
	90°	>0.999	0.556
60°	90°	0.566	0.995

* p<0.05

Tukey HSD Test

Table 3. Comparison of Abso-Anchor conical and Abso-Anchor cylindrical groups

		Abso-Anchor conical	Abso-Anchor cylindrical	p
		Mean±SD	Mean±SD	
30°	Insertion torque	8.46±0.46	7.22±0.25	<0.001*
	Pull-out	100.200±7.759	136.500±20.500	<0.001*
	Shear	59.544±13.215	62.311±4.536	0.561
45°	Insertion torque	8.91±0.47	6.69±0.21	<0.001*
	Pull-out	170.840±8.412	139.877±35.155	0.030*
	Shear	100.560±15.203	90.933±10.396	0.136
60°	Insertion torque	7.54±0.33	6.81±0.22	<0.001*
	Pull-out	131.377±13.500	124.588±30.914	0.554
	Shear	87.300±8.675	98.388±6.594	0.008*
90°	Insertion torque	6.72±0.33	6.83±0.43	0.364
	Pull-out	106.888±20.310	83.111±21.525	0.028*
	Shear	99.711±33.855	97.244±15.415	0.845

Student's t-test * p<0.05

screws have higher insertion torque is consistent with our findings.

In their study using three different miniscrews, Carano et al. compared screws with a diameter of 1.5 mm and a length of 11 mm, in terms of their resistance to bending, torque, and pull-out strength (Leone, Firenze, Italy; M.A.S. Micerium, Avegno, Italy; Dentos, Korea).[13] Looking at the mechanical properties evaluated in this study, they found the cylindric shape of the screws to be better than the conical ones. They recommended the use of the conical shape in the event that the site of insertion is interradicular and therefore limited to 2.5-3.5 millimetres. The miniscrews used in this study were of different sizes than those in our study and were selected as self-tapping.

The highest MIT are at angled positions (45°) and the lowest MIT are at 90°. This finding is in line with those studies advocating the angular positioning of the miniscrews.[16,30,36] It has been reported that miniscrews have significant advantages in terms of angled placement, such as increasing the amount of contact with the cortical bone, thereby reducing the likelihood of contact with tooth roots.[37-40]

The screws with the maximum pull-out strength are those in the Abso-Anchor conical group placed at 45°. Xu et al. suggest placing the screws at an angle for better primary stability.[41] Araghbidikashani et al. compared four angles (30°, 45°, 60°, 90°) and found the highest

pull-out strength at 90°.[6] In this study, fresh sheep bones were used, the diameter and length of the screw were used different (1.6×6 mm) and force was applied until the screw completely failed. The thickness of the cortical part of the bone was not initially standardized and was determined by radiography after the screws had been inserted. The resulting difference may be due to these reasons.
Apart from the primary stability and force resistance, there are some factors that may affect the stability and success of miniscrews. These factors include the intensity and form of the orthodontic force applied, the age of the patient, oral hygiene and soft tissue inflammation. In laboratory conditions these factors are disabled but should not be ignored in a clinical setting. The bone models used in our study do not fully reflect human bone tissue. The rates of bone thickness in the maxilla and mandible differ in humans, but in this study no such distinction was made, and only one type of bone was used. These are weaknesses associated with our work.

CONCLUSIONS

Within the limitations of this in-vitro study, the body shape of the miniscrews was evaluated and the conical screws were found to be superior to the cylindrical ones. The angle with the highest primary stability is 45°. The insertion angle and body structure of the miniscrews are important in terms of MIT and force resistance. Since many factors are involved in primary stability, there is a need for more extensive studies.

Ethics Committee Approval: Ethics committee approval was received for this study from the Review Committee of the Research Foundation of Medical Sciences of Çukurova University (Date: 10/02/2017, Number: 2017/61).
Informed Consent: Not applicable.
Peer-review: Externally peer-reviewed.
Author Contributions: Concept-CD; Design-CD,MST; Supervision-MST; Resources-CD; Materials-CD; Data Collection and/or Processing-CD; Analysis and/or Interpretation-CD; Literature Search-CD; Writing Manuscript-CD; Critical Review-MST; Other-CD
Declaration of Interests: The authors declare that there is no conflict of interest.
Funding: This study was supported by Çukurova University Scientific Research Projects Department with project number THD-2017-8555.

Etik Kurul Onayı: Bu çalışma için Çukurova Üniversitesi Tıp Fakültesi Etik Kurulundan (Tarih: 10/02/2017, Sayı: 2017/61) onay alınmıştır.
Katılımcı onamı: Gerekli değildi.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir-CD; Tasarım-CD,MST; Denetim-MST; Kaynaklar-CD; Malzemeler-CD; Veri Toplama ve/veya İşleme-CD; Analiz ve/veya Yorum-CD; Literatür Taraması-CD; Yazma-CD; Eleştirel İnceleme-MST; Diğer-CD
Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.
Finansal Destek: Bu çalışma Çukurova Üniversitesi Bilimsel Araştırma Projeleri Bölümü tarafından THD-2017-8555 numaralı proje ile desteklenmiştir.

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