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Original Article

The effect of insertion angle on orthodontic mini-screw torque

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ABSTRACT

Background: Primary stability is an important factor for the clinical success of orthodontic mini-screws. The present study made an attempt to evaluate the effect of insertion angle changes on the maximum insertion and removal torque of orthodontic mini-screws.

Materials and Methods: In this experimental study, 72 mini-screws (Dual Top Anchor System, Jeil, 1.6 mm diameter, 8 mm length) were used. They were randomly divided into four equal groups and inserted in poly-carbonate plates with 3 mm thickness. Then, their maximum insertion torque (MIT) and maximum removal torque (MRT) were recorded using a digital torque tester/screwdriver. Each group had a different insertion angle (90°, 75°, 60° and 45°). The data were analyzed by SPSS software (version 18) using one-way ANOVA and post-hoc Tukey's tests. The level of significance was set at 0.05.

Results: The maximum MIT was observed in 45° insertion angle (14.84 Ncm) and the minimum MIT was reported in 75° insertion angle (12.66 Ncm). The maximum MRT was observed in 45° insertion angle (23.21 Ncm) and the minimum MRT was reported in the 90° insertion angle (17.43 Ncm).

Conclusion: Oblique insertion of the mini-screws results in higher insertion and removal torques and probably more primary stability compared to the vertical insertion.

Key Words: Insertion torque, orthodontic mini-screw, removal torque, skeletal anchorage

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INTRODUCTION

Anchorage preparation is an important factor in the success of orthodontic treatment. Reducing the need for patient cooperation, increase in the quality and efficiency of treatment, ease of placement and lower costs are the main advantages of mini-screws in comparison to conventional and other skeletal anchorage preparation methods.[1-5]

Further, primary stability is a major element in the success of mini-screws. Factors which affect this stability include:
1. Thickness and quality of bone
2. Mini-screws design (length, diameter, tapering, thread length and pitch), and
3. Placement conditions (pre-drilling, insertion angle, penetration depth and the number of involved cortical plates). Increase in the bone thickness and density, length and diameter of the mini-screws, penetration depth and the number of involved cortical plates increase the primary stability.[3,6-9]

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But, there is no general consensus on the effects of insertion angle changes. Oblique placement of mini-screws is suggested because this method decreases the risk of root injury due to more spaces in the apical parts between the roots. At least, in theory, the oblique placement of mini-screws increases their contact with the bone.[1,10,11] The present study aimed to investigate the effect of insertion angle changes on mini-screw torque values using a different method.

MATERIALS AND METHODS

In this experimental study, 72 mini-screws (Dual Top anchor System, Jeil Medical corporation, Seoul, Korea) with 1.6 mm diameter and 8 mm length (Order No: 16-JA-008H), were randomly divided into four equal groups. The mini-screws were attached to the digital torque tester/screwdriver (Imada Inc., Northbrook, IL, USA) using a customized screw driver. The torque tester/screwdriver handle was mounted on the rotary part of the milling machine (Jamco; CM6241, 2010, China). It was exactly placed in the center to limit the eccentric movements during the rotation. On the opposite side on the non-rotary part of the milling machine, the poly-carbonate plate (Raychung, Taiwan) with 3 mm thickness was fixed inside an aluminum frame [Figure 1].

The rotation speed was 45 rounds per minute. The movement speed of the non-rotary part relative to the rotary part was equal to the mini-screw pitch (0.9 mm/360° rotation). The insertion angles were 90, 75, 60 and 45 degrees in different groups. These angles were adjusted by changing the angle of the non-rotary part and the long axis of the torque tester/screwdriver and mini screws. Pre-drilling was performed using a 0.8 mm bur with the same screw insertion angle in each group to prevent the mini-screw tip from slipping on the poly-carbonate plates. The insertion depths of screws were set at 7.5, 6.9, 6.2 and 5.3 mm in 90, 75, 60 and 45-degree groups, respectively. The maximum insertion torque (MIT) and maximum removal torque (MRT) were recorded in Ncm. Data were analyzed by the SPSS software (version 18, SPSS Inc., Chicago, IL, USA) using one-way ANOVA and post-hoc Tukey's tests. The level of significance was set at 0.05.

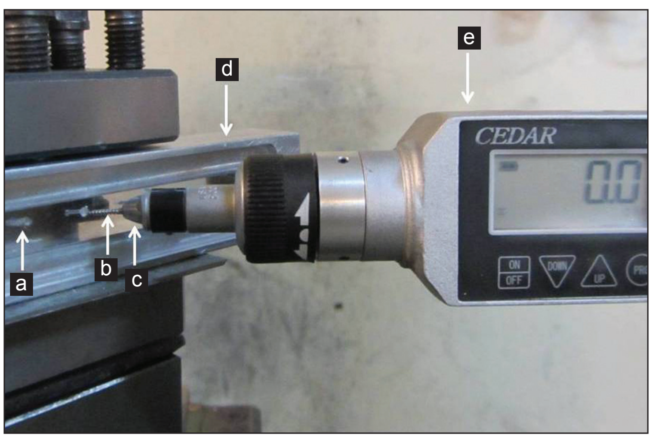

Figure 1: A view of torque testing process and the arrangement of pre-drilled holes (a), mini-screw (b), customized screw driver (c), torque tester/screw driver (e) mounted on the rotating part of the milling machine and poly-carbonate plate fixed in aluminum frame and mounted on the non-rotating part of the milling machine

RESULTS

Table 1 shows the mean of MIT and MRT in each group. The ANOVA test indicated significant differences between the groups, both in MIT and MRI ($P < 0.001$). The post-hoc Tukey's test revealed that changing the insertion angle from 90° to 75° resulted in MIT decrease ($P < 0.001$), but the change from 75° to 60° increased the MIT ($P < 0.001$). The MIT values were higher in 60° compared to 90° insertion angle but the difference was not significant ($P = 0.142$). Decreasing the insertion angle from 60° to 45° also resulted in the increase of MIT ($P = 0.428$). The MIT values were significantly higher in 45° compared to 75° and 90° insertion angles ($P = 0.002$). Decreasing the insertion angle increased MRT values. The difference between 75°, 60° and 45° was not significant but, their difference with 90° was significant ($P < 0.001$).

DISCUSSION

Measurement of MIT and MRT is a method for evaluating the primary stability and predicting the clinical success of mini-screws as skeletal anchorage.[7,8] Using mini-screws with larger diameter, deeper penetration and placement in regions with thicker cortical plates increases the bone-screw contact area, torque values and stability. Oblique placement of mini-screws, at least in theory, increases the bone-screw contact area, but it leads to earlier contact of the collar with mucosa in one side and reduces the penetration depth potential.[6] Most of the mini-screws are tapered, so reducing the penetration depth decreases the bone-screw contact area and can

Table 1: Insertion and removal torque values (N.Cm) in different Insertion angles

Group	Sample size	Insertion angle (degree)	Insertion depth (mm)	Insertion torque (N.Cm)			Removal torque (N.Cm)		
				Mean (SE)	Max	Min	Mean (SE)	Max	Min
1	18	90	7.5	13.8 (0.14)	14.7	12.6	17.43 (0.4)	22.3	15.3
2	18	75	6.9	12.7 (0.12)	13.8	11.8	21.92 (0.4)	24.9	18.9
3	18	60	6.2	14.41 (0.19)	15.9	12.5	22.36 (0.6)	26	17.2
4	18	45	5.3	14.9 (0.3)	17.9	13.1	23.2 (0.3)	24.5	20.2

eliminate some of the positive effects of the oblique placement.

Oblique placement of mini-screws increases the possibility of screw tip slipping, which can lead to difficult handling and decreased clinical accuracy. When mini-screws are placed with an oblique angle, more of the screws remain outside the mucosa, which can lead to a longer lever arm when applying forces on the screw heads. This generates larger moment and induces higher stress on the bone-screw interface.[6] The oblique position of the head and collar may make their hygiene difficult to maintain and increase the chance of food debris and accumulation of microbial plaques and inflammation of soft tissue. These factors may have negative effects on the long-term success of mini-screws.[6]

Wilmes and Drescher[6] proposed placing mini-screws with an oblique angle to use the more available space in the inter-radicular area. Min, *et al*.[1] and Hu, *et al*.[11] stated that the oblique placement of mini-screws increases their contact with the cortical bone, but Woodall, *et al*.[12] reported that placing mini-screws in less than 90 degree in the alveolar bone has no anchorage advantage. Deguchi, *et al*.[13] reported that the cortical bone thickness in 30 degree is 1.5 times thicker than 90 degree. Poggio, *et al*.[14] reported that if a screw is placed perpendicular to the tooth long axis, it enters the inter-radicular area faster than when placed with angle. Therefore, they suggested that placing mini-screws with a 30-40^o angle allows using longer mini-screws and decreases the risk of root injury.

In this study, we made an effort to use a different method to evaluate the effects of mini-screw oblique placement on the torque values. Application of the milling machine for mini-screw placement reduces human errors and eliminates lateral movements during insertion/removal. It also increases the accuracy of penetration depth, rotation speed, insertion/removal linear movement speed and vertical pressure during the testing process. Coordinating the speed of insertion and removal linear movement with the mini-screw pitch reduces the risk of vertical force generation between the threads and bone, which limits the effects of extra friction on the torque values. The penetration depth for each group was calculated separately to simulate the first contact of the collar with the supposed soft tissue with 1 mm thickness. This generates clinical conditions and prevents the contact between the screw collar or screw driver head and the poly-carbonate plates. If this contact occurs, it can lead to severe torque increase and measurement errors.[15] Small values of standard errors in each group confirm the accuracy of this testing method.

Wilmes and Drescher[6,16] reported that pre-drilling reduces the insertion torque and results in initial stability. In this study, pre-drilling was done to prevent the screw tip slippage on the poly-carbonate plates.

This study showed that decreasing the insertion angle from 90^o to 45^o results in higher insertion and removal torques. The only exception was 75^o in which the torque decreased instead of increasing. This could be due to the dominance of the negative effect of the penetration depth decrease compared to the positive effect of the oblique placement. This is not in line with the results of Wilmes, *et al*.[10] Noble, *et al*.[17] reported that cortical bone contact in 45^o was much higher than 90^o. They also stated that removing the mini-screws, which are placed with an oblique angle, induced higher stresses on the bone and produced micro-fractures; therefore, mini-screws should be placed perpendicular as long as root damage can be avoided.

We suggest that when a higher primary stability is needed, mini-screws can be placed with 45^o angle. It should be remembered that a large number of screws and mini-screws with larger diameter can also be used in these conditions.

CONCLUSION

Oblique placement of mini-screws results in higher MRT and MIT. This increase is significant between 90^o and 45^o angles. Further studies are recommended to evaluate the interactions of other factors with the oblique placement of mini-screws and to assess its long-term clinical outcomes.

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