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Comparing the Primary Stability of Three Different Orthodontic Mini-Implants with Various Dimensions on Artificial Bone

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ABSTRACT

Background/Purpose: *The Development of mini-implant as a mean of maximum anchorage achieved outspread scope for enhancing better orthodontic outcomes, and their success is highly influenced by their primary stability. The aims of this study were the evaluation and comparison the primary stability of three various companies with different shapes and dimensions and to evaluate the effect of the dimensions of the miniscrew on the primary stability.* ***Methods:*** *The study sample of this study consisted of sixty orthodontic mini-implants (self-drilling) from three various manufactures (KJ Meditech, Hubit, and Dentos), each sort of these mini-implants was presented in two different lengths, 8 mm and 10 mm, and two different diameters, 1.4 mm and 1.6 mm. All the orthodontic mini-implants were inserted into simulated artificial bone of anterior region of the maxilla manually. Insertion torque (IT), and the pullout strength values were recorded and compared using ANOVA and Tukey honestly significant difference tests.* ***Results:*** *The results showed that the mean values of the pullout strength of KJ Meditech mini-implants were greater than those of Hubit and Dentos mini-implants respectively, and there was highly significant difference among these various manufactures. Furthermore, the mean values of pull out test were higher for mini-implants with dimensions 1.6 mm × 10 mm, and then followed by 1.6 mm × 8 mm, 1.4 mm × 10 mm, and 1.4 mm × 8 mm.* ***Conclusion:*** *The primary stability was greater in KJ Meditech mini-implants than Hubit and Dentos mini-implants respectively. Moreover, the length and the diameter had direct relation with the primary stability, and the diameter achieved higher effect on the primary stability than the length.*

Keywords: Miniscrew, Primary stability, Pullout strength, Orthodontic anchorage

INTRODUCTION

Anchorage is the resistance to undesired movement of the teeth, and it is essential for treatment of dental and skeletal malocclusions [1]. Furthermore, anchorage regarded as one of the most critical factors that determines the treatment outcome [2].

The term temporary anchorage devices (TAD) are any sort of implant, screw, pin, or implant that are placed to enhance skeletal anchorage and then removed after the completion of the treatment. The mini-screws belong to the (TAD) and the modern ones are usually made of bio-inert titanium compounds (Ti_6Al_4V), their diameter range between 1.2 mm to 2.3 mm, and are between 4 mm and 15 mm in length [3,4].

Primary stability is necessary for the miniscrews, because of immediate loading on them, and differs according to various patient, the design of the miniscrew, and clinical technique factors, also it is considered as clinical condition of mini-implant immobility and ability to resist loads in different directions [5,6].

In the *in vitro* studies, using the double layer artificial bone is mandatory to simulate the human cortical and cancellous bone with appropriate thickness and mechanical properties corresponding the specific areas of the jaws [7].

The insertion of the orthodontic miniscrew can be done either manually or motorized, and the manual insertion method is usually simpler and can achieve better tactile sensation than the motorized one [8]. It is recommended that mini-implant should be inserted at a slow speed, with low and continuous forces so that the load on both the mini-implant and the surrounding bone is kept low [9].

There is no gold standard for evaluating primary stability, but histological evaluation of the implant-bone interface, Periotest (device to measure the initial stability of dental implants) and resonance frequency (RF) analysis have all been used to measure primary stability [10]. In the literature, the most common methods to evaluate the primary stability were measurements of insertion and removal torque, as well as behavior in pullout tests [11-16].

Since the miniscrews exist to improve the anchorage during the orthodontic treatment, and there are many commercially available brands of miniscrews, so that there is a need for a method to assess the primary stability of various miniscrews from different manufactures and compare among them, and there are no previous Iraqi studies presented to assess the primary stability.

MATERIALS AND METHODS

Sample

The sample consisted of sixty self-drilling mini-screws from three different manufactures twenty from each company Abso Anchor mini-implant (power head type, Dentos, Daegu, Korea), Neo Anchor Plus mini-implant (type III, KJ Meditech, Bukgu, Gwangju, Korea), and Hubit mini-implant (Hubir, Gyeonggi-do, Korea). Each type of mini-implant was available in two different lengths (8 mm and 10 mm), and each length was available in two different diameters (1.4 mm and 1.6 mm) (Figure 1).

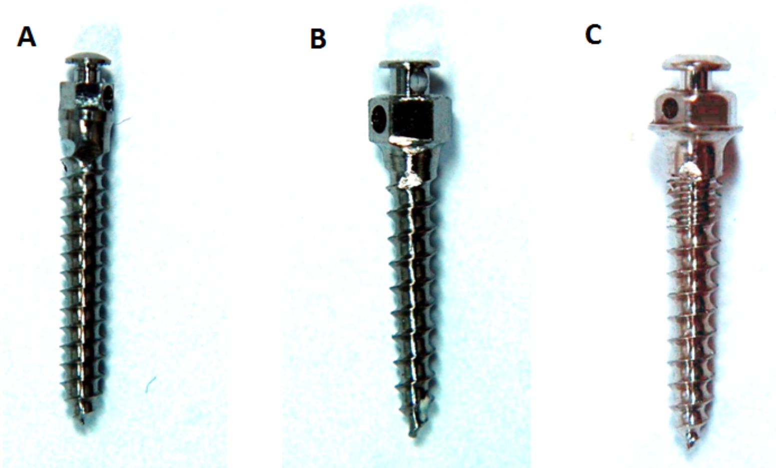

Figure 1 (A) Dentos Mini-implant (B) Hubit mini-implant (C) KJ Meditech mini-implant

Test Medium

Custom-made polyurethane foam artificial bone block with two layers were used as an alternative test medium for human cortical and cancellous bone (Sawbones Pacific Research Laboratories Inc. Krossverksgatan, Malmö, Sweden) [17-19]. Block with density 0.48 g/cm^3 (30 pcf) and height 18.5 mm was selected to simulated cancellous bone of anterior maxilla, which is in line with clinical norms [20], and Misch classification [21], and Short fibre-filled epoxy sheet with 1.5 mm thickness was used to simulate human cortical bone of anterior maxilla [22,23]. The dimensions of the block (length × width × height) were 170 mm × 120 mm × 20 mm respectively.

Insertion Procedure

After loading of the artificial bone in the stand, that was customized to secure the bone block and stabilize the digital torque meter torque meter (Lutron Electronic Enterprise Co., Ltd., Taipei, Taiwan) during the insertion, mini-implants were loaded to the probe of the digital torque meter, which was lowered until contacting the bone block [24-26].

All the mini-screws were inserted perpendicular to the surface of the synthetic bone block for standardization [27,28], and the insertion was performed manually by rotating the probe of the digital torque meter clockwise at speed 3 rpm until full insertion was enhanced [29].

Pullout Strength (POS) Test

The test was performed by extracting the mini-implants from the artificial bone in axial direction at a constant velocity by using a universal tensile testing machine, which is connected to a Pentium IV computer using QMAT test zone software version 4.4.40 [26,29,30].

Two F clamps were served to secure the bone block in place and to keep the miniscrew in a perpendicular position during the test; moreover, A clamp like head was customized to connect the head of the miniscrew to the testing machine.

The machine's displacement control setting was used to extract the miniscrew at a crosshead speed of 2 mm/min from the bone, and the maximum pull out force was recorded for each type of company and each length and diameter [19,30,31].

Statistical Analysis

Data were analyzed using SPSS software (IBM Corporation, Armonk, NY, USA). In this study the following statistics were used:

1. **Descriptive statistics:** mean, standard deviation, minimum and maximum values and statistical tables and figures.
2. **Inferential statistics:**
   a) **One-way ANOVA test:** to compare the primary stability among different companies and miniscrew dimensions.
   b) **Tukey's HSD test:** to test any statistically significant difference between each two companies and miniscrew dimensions.

RESULTS

The mean values of the pullout strength (POS) for every brand were greater in the miniscrews with dimensions 1.6 mm × 10 mm, followed by 1.6 mm × 8 mm, 1.4 mm × 10 mm, and 1.4 mm × 8 mm respectively. Moreover, one-way ANOVA test showed high significant differences among various mini-implants dimensions, and Tukey's HSD test showed that there was a high significant difference between each mini-implant dimension as demonstrated in Table 1.

Table 1 Descriptive statistics of pull out test and comparison among different mini-implants dimensions of various companies

Manufacturing	Miniscrew	Descriptive statistics				ANOVA test		Tukey's HSD test			
Company	dimension	Mean	SD	Min	Max	F-test	p-value	Dimension	p-value	Dimension	p-value
Dentos	1	419.6	6.46	412	430	600.4	0.00***	1-2	0.00	2-3	0.00
	2	522.8	5.44	515	530			1-3	0.00	2-4	0.00
	3	452.1	8.64	443	466			1-4	0.00	3-4	0.00
	4	597	7.83	587	605			-	-	-	-
Hubit	1	443.1	6.02	435	450	926.192	0.00***	1-2	0.00	2-3	0.00
	2	538.2	6.04	530	545			1-3	0.00	2-4	0.00
	3	496	6.54	489	503			1-4	0.00	3-4	0.00
	4	634.7	5.11	627	640			-	-	-	-
KJ Meditech	1	445.6	6.22	439.5	454	1710.329	0.00***	1-2	0.00	2-3	0.00
	2	553	4.11	548.5	559			1-3	0.00	2-4	0.00
	3	511.8	7.5	500.5	520			1-4	0.00	3-4	0.00
	4	726.8	7.54	719.5	737			-	-	-	-

*** Highly significant at P ≤ 0.01; 1=1.4 mm × 8 mm; 2=1.6 mm × 8 mm; 3=1.4 mm × 10 mm; 4=1.6 mm × 10 mm

The mean values of the POS is greater in the miniscrews of KJ Meditech company followed by Hubit company and then by Dentos company; moreover, One-way ANOVA test showed that there was a high significant difference among the various companies, and Tukey's HSD test showed that there was a high significant difference between each company for each miniscrew dimension except in size (1.4 × 8) there was no significant difference between KJ

Meditech and Hubit companies, and in size (1.4 × 10) there was a significant difference between KJ Meditech and Hubit companies as demonstrated in Table 2.

Table 2 Descriptive statistics of POS and comparison among different companies for each miniscrews dimension

Miniscrew dimensions (mm)	Manufacturer	Descriptive statistics				Comparison			
						ANOVA test		Tukey HSD test	
		Mean	SD	Min.	Max.	F-test	p-value	Manufacturer	p-value
1.4 × 8	I	419.6	6.46	417	430	24.163	0.00	I-II	0.000***
	II	443.1	6.02	435	450			I-III	0.000***
	III	445.6	6.22	439.5	454			II-III	1.000 #
1.6 × 8	I	522.8	5.44	515.5	530	41.2	0.00	I-II	0.002***
	II	538.2	6.05	530	545			I-III	0.000***
	III	553	4.11	548.5	559			II-III	0.002***
1.4 × 10	I	452.1	8.64	443.5	466.5	82.544	0.00	I-II	0.000***
	II	496	6.55	489.5	503.5			I-III	0.000***
	III	511.8	7.51	500.5	520			II-III	0.017*
1.6 × 10	I	597	7.83	587.5	605	463.153	0.00	I-II	0.000***
	II	634.7	5.12	627	640			I-III	0.000***
	III	726.8	7.54	719.5	737			II-III	0.000***
I=Dentos; II= Hubit; III= KJ Meditech; *** Highly significant; # Non-significant; * Significant									

DISCUSSION

Mini-implants enhance adequate skeletal anchorage and decrease the requirement of dental anchorage, leading to predictable treatment outcomes, and can provide different tooth movement with less dependence on patient cooperation [17,32].

Since mini-implant may be immediately loaded, they need sufficient primary stability, which provides the ideal environment for tissue healing followed by secondary stability increasing the chances of a successful treatment [33,34]. This is the main cause that the parameters of the primary stability like pullout values is used extensively as stability predictors [25,35].

By comparing the POS values of the mini-screws, we were able to assess the primary stability of the miniscrews of different manufacturers, and assess the effect of the length and the diameter of the miniscrews on the primary stability.

It was difficult to test the POS values *in vivo*, and it was problematic to extract the sample from animal cadavers, this challenge occurs because of the variation in the thickness and the density of the bone from the extraction site, so the POS values cannot be compared easily. Therefore, the artificial bone block was chosen in this study, which has been widely used in *in vitro* studies [36-38].

It is apparent from the previously mentioned results that the mean values of the pullout strength (POS) is higher in 10 mm miniscrews than the 8-mm miniscrews, and the pullout force increases significantly with increasing the length of the mini-screws, this outcome is congruent with the findings noted by Chang, et al. [39], and Shah, et al. [40]. Moreover, a study by Tseng, et al. [16] showed that longer anchor length exerts greater pull out strength and higher primary stability, likewise this outcome is consistent with Hitchon, et al. [41] who found that longer orthopedic screws produce higher pull out force than shorter screws do. Conversely, these outcomes disagree with studies by Lim, et al. [17], Park, et al. [42], and Wu, et al. [43], which showed that the primary stability is independent on the length of the miniscrew.

Since the POS values increased with increasing the diameter of the miniscrew, so that the higher miniscrew diameter, the greater the bone is compressed, thus enhancing better primary stability. Similar results are reported in previous studies by Holmgren, et al. [44], Miyawaki, et al. [45], Walter, et al. [46], and Tseng, et al. [47]. However, some studies have suggested that higher failure rate may be associated with greater diameters of miniscrews, as there is more chance to hit the neighboring roots [43,48].

The results of our study showed that the three brands of the miniscrews differed significantly in the POS. Furthermore, the KJ Meditech mini-screws had the higher primary stability presented by the greatest values of POS followed by

Hubit and Dentos miniscrews respectively. The explanation for these outcomes could be attributed to the variations in the screw body design, and as KJ Meditech miniscrews have a conical dual-threaded body design, so they produced the highest values of POS than the other types of mini-implants which have a single-threaded body design, which is may be due to the highly surface area embedded in cortical bone with dual threaded design than with a single-threaded design as described in study by Hong, et al. [49] Also, this outcome is consistent with findings by Yu, et al. [50], who observed that the body design of the miniscrew affected the POS values, since dual threaded mini-screws achieved higher POS values than single-threaded ones.

Regarding the values of the POS, they are in conformity with those of Florvaag, et al. [27], and Yu, et al. [50] but they are higher than those reported in other studies using synthetic bone [16,51]. These differences in the POS values between different studies are probable caused by variations in the thickness and the density of the artificial bone used in each experiment and this is agreed with Mutaz and Habal [52].

CONCLUSION

According to the outcomes of this experimental *in vitro* study, it can be concluded that KJ Meditech miniscrews have greater primary stability than Hubit and Dentos mini-implants respectively. And the primary stability of the miniscrew is directly related to their lengths. Moreover, the primary stability increased significantly with increasing the diameters of the mini-implants, likewise the diameter of the miniscrew has a higher effect on the primary stability than the length. Finally, the knowledge of the effect of the length and the diameter on the primary stability may help the orthodontists in selecting the most suitable size of the miniscrews.

DECLARATIONS

Conflict of Interest

The authors and planners have disclosed no potential conflicts of interest, personal, financial, or otherwise with this work.

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