Torque Measures as Orthodontic Microimplants Stability Indicators

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ABSTRACT

Objectives: To evaluate the effectiveness of multiple torque measures in describing the stability/prognosis of Orthodontic Microimplants (OMIs) and to find the most reliable one to perform from those reported in the literature.

Methods: A total of 84 OMIs (Dentos Inc, Daegu, South Korea, 7mm in length) that had the same design except the diameter were divided into 3 equal groups of 28 (SH1312, SH1413 and SH1514). They were inserted and then removed from custom-made rigid polyurethane foam using a surgical engine and contra-angle handpiece. Multiple torque measures then were analysed and compared according to the relation between the OMI diameter and torque values. The correlation between Maximum Removal Torque (MRT) - which was taken as a reference - and other variables was tested. All statistical tests were performed at $P < 0.05$ level of significance.

Results: All torque measures except one (Torque Ratio, TR) showed statistically significant differences between the 3 OMIs groups with the SH1514 group having comparatively the largest mean torque values then SH1413, and then SH1312 group. The correlation to MRT was significant with only TR, and although it was statistically not significant; the correlation between MRT and Maximum Insertion Torque (MIT) was increasing with the diameter increase.

Conclusion: All of the tested measures showed the same idea at the end from statistical view and that considering any of them is feasible with no superiority of one measure over the other.

Key words: Microimplant, Torque, Stability.

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Introduction

Due to the advantages of minimal need for patient compliance, versatility, and minimal surgical invasiveness,[1,2] Orthodontic Microimplant (OMI) is now used as a routine procedure in orthodontic practice. Yet, the success rate of this bone-borne anchorage device to date being in the range of 70-90%,[3-5] one to three out of 10 OMIs can undergo loosening and become unstable during the course of orthodontic treatment. With this relatively high failure rate, the OMI stability which is a prerequisite to its clinical success has been considered as a central topic of the research in this field.

While the OMI stability might be defined as its ability to resist orthodontic forces, insertion torque has been used as a measure for assessing it. Torque is the product of the resistance an OMI

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Table I: Material properties of the polyurethane foams used in this study.

Density		Compressive		Tensile		Shear	
		Strength	Modulus	Strength	Modulus	Strength	Modulus
pcf	g/cc	MPa	MPa	MPa	MPa	MPa	MPa
10	0.16	2.2	58	2.1	86	1.6	19
40	0.64	31	759	19	1000	11	130

Properties parallel to direction of rise of foam, poission ratio =0.30

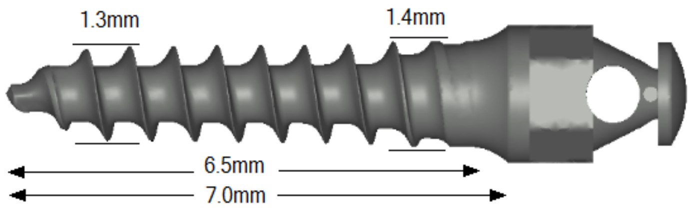

Fig. 1: Orthodontic microimplant design used in the study (SH1413-07 is shown here)

experiences during its insertion or removal, and as this resistance is proportional to the amount of bone compression the OMI impose on the interfacial bone, it is a reference to the biomechanical conditions at the OMI/bone interface. Based on this, many researchers have attempted to find the correlation between insertion torque and the stability or prognosis of the OMI in bone. Motoyoshi and his colleagues[(6-8)] proposed an insertion torque window as a guide line or necessary condition for the success of the microimplants.

Torque is actually a complex quantity that can vary as a function of OMI size, surface condition, thread design, bone quality, insertion technique etc., and as such it cannot be correlated directly to localized biomechanical conditions at OMI/bone interface. Moreover, many previous studies have defined torque in quite different ways. For example, Maximum Removal Torque (MRT), Maximum Insertion Torque (MIT), Average Insertion Torque (AIT), Peak Insertion Torque (PIT), and Torque Ratio (TR) have been used as OMI stability measures and these multiple definitions are a source of confusion among clinicians.

The aim of this study was to evaluate the effectiveness of multiple torque measures in describing the stability/prognosis of OMIs and to find the most reliable one to perform from those reported in the literature.

Methods

In this study we assumed the MRT as the variable which might represent the OMI stability, but because of its destructiveness and irrationality to be performed clinically, we tested its correlation with other variables which will pass the effectiveness test of describing the relation between torque and microimplant diameter.

Three types of OMI that had the same design except the diameter were used in this study- SH1312, SH1413 and SH1514 OMIs (Dentos Inc, Daegu, South Korea, 7mm in length; Fig. 1). According to their diameters, they were divided into 3 equal groups of 28 samples for each.

All microimplants groups were inserted into- and then removed from- a custom-made block (90mm width × 130mm length × 40mm thickness) of rigid polyurethane foam (Sawbones, Pacific Research Laboratories Inc, Vashon, Wash). This bilayer bone block is consisted of 1 mm thick top layer with a density of 40 pounds per cubic foot (pcf) and 39 mm thick bottom layer (10 pcf). The material properties of these foams densities are shown in Table I.

For the OMI insertion and removal, a surgical engine and contra-angle handpiece (SA200C, M&H ELCO Med Burmoos, Salzburg, Austria) which can record the torque at 1/8-second intervals was used. Being calibrated at a speed of 30rpm and torque of 40 Ncm, an average weight of 900g was used to insert the microimplants by

Table II: Definitions of torque measures as reported in literature.

Variable	Definition
Maximum Removal Torque (MRT)	The maximum torque value registered during OMI removal.
Maximum Insertion Torque (MIT)	The maximum torque value registered during OMI insertion.
Average Insertion Torque (AIT)	The mean of insertion torque values from the beginning to the end of insertion procedure.
Peak Insertion Torque (PIT)	The mean torque value recorded during 1 second at the last stage of the insertion procedure.
Torque Ratio (TR)	The MRT divided by MIT.

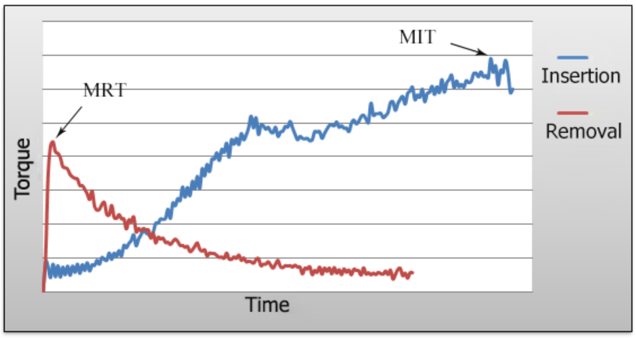

Fig. 2: Insertion and removal torque values in Ncm as plotted with time in seconds.

a self-drilling procedure with equable attempts to drill them in a perpendicular way to the artificial bone block surface until just below the neck collar area.

The torque data were transferred to a computer via a chip card for analysis. Then the torque measures utilized for analyses were those reported in the literature.[9-13] Table II shows these measures with definitions (as reported in the previous studies) and Fig. 2 below shows a general schematic representation of insertion and removal torque values plotted together with relation to time.

Running Levene and Shapiro-Wilk tests showed that the torque data obtained for the 3 OMI groups were found to be homogenous and normally distributed. One-Way Analysis Of Variance (ANOVA) and Tukey post-hoc tests were performed to compare the torque values between the OMIs groups. The correlation between MRT and the other variables was tested by Pearson correlation. All statistical tests were performed at $P < 0.05$ level of significance using the statistical software SPSS version 21 (IBM Corp., Armonk, NY, USA).

Results

For all variables except TR, there were statistically significant differences between the mean torque values of the 3 OMIs groups with the SH1514 group having the largest values then SH1413, and then SH1312 groups. For TR; the statistical difference was only found when comparing the SH1312 group with the other groups, while between these later groups, there was no difference. (Table III)

When testing the correlation between MRT and the other variables, Pearson correlation showed statistically significant correlation to TR for all OMIs groups and also between MRT and AIT and PIT for the 1312 group only. There was no significant correlation to MIT for all OMIs groups and to AIT and PIT for the 1413 and 1514 groups. (Table IV)

Discussion

OMI diameter has been known to correlate positively to the OMI insertion torque.[9-11] This diameter/torque relationship was taken as a base in this study to differentiate between the reported torque variables (Table II). The basic idea beyond this was to check whether each variable will express this relation as it should be in this manner or not. In this study and to signify the impact of diameter on the OMI torque, any other factor rather than the diameter was standardized. Identical OMIs except for the diameter were inserted into solid artificial bone with homogenous density by the same insertion parameters.

Table III: Mean values and significant differences in all variables measured for the 3 OMIs groups

Variables		OMIs Type			Multiple Comparison			
		1312 (N=28)	1413 (N=28)	1514 (N=28)	Sig.*	1312 vs. 1413	1312 vs. 1514	1413 vs. 1514
MRT	Mean	5.17	6.04	6.85	0.000*	0.001*	0.000*	0.002*
	SD	0.74	0.72	1.03				
MIT	Mean	6.73	7.12	7.99	0.000*	0.000*	0.000*	0.000*
	SD	0.36	0.27	0.50				
AIT	Mean	3.25	3.53	3.90	0.000*	0.000*	0.000*	0.000*
	SD	0.13	0.07	0.14				
PIT	Mean	4.82	5.76	6.23	0.000*	0.000*	0.000*	0.000*
	SD	0.32	0.40	0.22				
TR	Mean	0.77	0.84	0.86	0.010*	0.045*	0.012*	0.873
	SD	0.11	0.10	0.12				

SD; Standard deviation , * Indicates Significance at level of P<.05

Table IV: Correlation between MRT and other variables for the 3 OMIs groups.

OMIs groups	MRT C.	MIT C.	AIT C.	PIT C.	TR C.
1312	1	0.059	0.423*	0.410*	0.920**
1413	1	0.278	0.356	0.335	0.949**
1514	1	0.366	0.035	-0.165	0.901**

C.: Pearson Correlation *. Correlation is significant at the 0.05 level (2-tailed).**.Correlation is significant at the 0.01 level (2-tailed).

Although each variable gave different range of torque than the other; we found that all torque variables except TR were shown to increase with OMI diameter which is consistent with the basic reference we relied on in this study as was found by the previous studies. Statistically, utilizing any of these variables was found to lead to the same conclusion at the end without any superiority of one over the other.

However, the proper torque measure to consider as a reliable indicator of OMI success/prognosis can be found by studying the concept of OMI stability which can be evaluated precisely by measuring its resistance to lateral - or rotational- forces while in the potential energy state that is after full insertion in the receipt material. Generally, the potential energy, which is a function of the position of an object within a field, has a direct relationship to the object mass and height. For OMI as pressed by the surrounded bone, there is the elastic potential energy which arises as a consequence of the bone to restore its original state before compression by the microimplant insertion. These consequences define the nature of resistance between the OMI and the bone surface which is expressed as torque.

Physically, torque can be defined as a force applied at a right angle to a lever multiplied by its distance from the lever's fulcrum (the length of the lever arm). Loosely speaking, it is a measure of the turning force on an object. The relationship between torque and energy is expressed as a direct one. Energy equals torque multiplied by the angle the body is moved.[14,15] So that, measuring the unscrewing resistance the OMI encounters during its removal from the receipt material might be a convenient way for describing this resistance or in other words, its stability while in the potential energy state. For this, the MRT could be the most suitable and reliable indicator among all torque measures reported as was proved also by other studies.[13,16,17] As the total potential energy for the OMI is high, the torque needed to remove it will also be high. Then this value of removal torque as affected by the total potential energy depends on size and configuration of the OMI and the receipt material properties.

The problem with MRT as mentioned

previously is a matter of inconvenience to perform clinically. It has the drawbacks of possible damage to the microimplant and bone, adding to that, patient comfort and medico legal issues should not be overridden when performing such procedures. For this we tested the correlation between this variable and the other ones in order to find a suitable measure for clinical purposes.

We found significant correlation between MRT and AIT, PIT and TR for the 1312 group and to only TR for the other groups. The correlation between MRT and TR is simply because the TR is calculated using this variable in relation to MIT. Within the range of OMIs diameters used in this study; there was no correlation between MRT and MIT for all groups in contrast to other studies,[12,13,18,19] but the studies designs should be considered for this. However, we found that the correlation was increasing between these 2 variables with the diameter increase (Table IV) and there might be a significant correlation with the use of larger OMIs diameters. At the same time, the correlation to AIT and PIT although it was significant in the 1312 OMIs group but after that it started to decrease with the diameter increase. For this and if possible, MIT might be considered as the closest variable to coincide well with the MRT.

We recommend adopting the MIT as a reliable measure to be clinically performed and leaving the MRT option for the experimental studies.

Conclusion

The effectiveness of multiple torque measures in evaluating the stability/prognosis of OMIs was tested experimentally with 3 different microimplants diameters. All of the tested measures showed the same idea at the end from statistical view and that considering any of them is feasible with no superiority of one measure over the other.

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