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Mini-Implants Orthodontics – Relationship Between the Design Characteristics and the Mechanical Properties

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ABSTRACT

The objective of the present work was to evaluate the influence of self-drilling thread and compaction tread on primary stability of orthodontic mini-implants (MI). Forty mini-implants with dual-thread design (compaction and self-drilling) were initially observed using a scanning electron microscopy. After, the mini-implants were inserted in artificial bone to measure the insertion and removal torques. The results shows that the contact area amongst the compact tread and bone is higher than the normal thread, due to the smaller thread pitch. The compact thread showed a slight increase of insertion and removal torque in contrast to the self-drilling shape. The highest value of insertion and removal torque obtained by compact thread translate better primary stability, however it may cause micro damages in the bone, which should be considered regarding osseointegration.

KEYWORDS mini-implants, insertion torque, threads.

Introduction

The mini-implant (MI) primary stability is an important factor for their mechanical retention. It is related to the surgical technique, the bone type, diameter, length and shape of the threads of the device (Lim, Cha & Hwang, 2008). The cylindrical MI shape is more effective, since the higher compaction tension is introduced in the tapered bone crest region, having smaller surface contact area (Kim, Baek, Kim & Chang, 2008). The compacting threads had better distribute stress, because the screw threads in the cervical portion present greater surface contact with the cortical bone. The devices that have self-tapping and compacting threads have a higher mechanical stability, however the tension in the adjacent bone tissue is more intense and may cause microfractures. The design may contribute to higher stability insertion sites that have low bone density. Cho et al. (2012).analyzed four types of mini-implants with different designs in artificial bone and mentioned that devices with greater thread depth, lower pitch and smaller taper generated increased tension between the bone and the screw. There was a higher removal torque with increased thread depth measuring up to 0.32 µm. The removal torque decreased when the measure exceeded 0.32 µm. The removal opposition was reduced by decreasing the taper and the length of the MI.

The causes for losses of MI are several: the poor osseointegration, inflammation of the gingival tissue, excessive insertion torque, which is responsible for increased heat and micro fractures, bone degeneration, may occur in the device interface with bone tissue (Lim, Cha & Hwang, 2008).

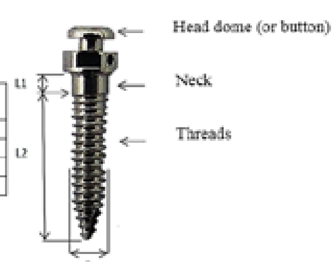
The aim of this study was to investigate the influence of self-drilling and compacting threads on primary stability by insertion torque and removal of the mini-implant in artificial bone.

Experimental

The mini-implants used in the present work had general shape and dimensions as showed in Figure 1, as well as the several types used in the present work. It consisted of a head dome, a perforated hexagonal, a neck portion and the threads.

Figure 1. Description of the mini-implants regarding threads type and principal dimensions (Conexão, 2013).

Dimensions (mm)	D	L2	L1
Group 1	1.8	8	1
Group 2	1.8	8	2
Group 3	1.5	6	1
Group 4	1.5	6	2



The mini-implants produced Ti6Al4V, ASTM Grade V. This alloy has higher hardness and lower biocompatibility than pure titanium (Muguruma et al., 2011). The alloy chemical composition showed 86.1% titanium, 9.8% of aluminum and 4.1% vanadium in mass % as shown in the spectrum of Figure 2a. This data were obtained using energy dispersion spectroscopy (EDS) in a scanning electron microscopy (SEM). The machined surface of threads internal part of the mini-implants is shown

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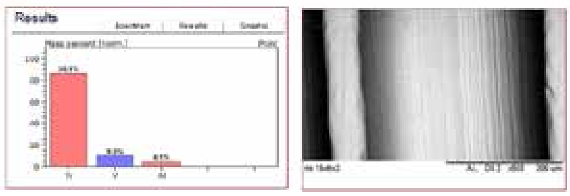
in Figure 2b. The surface machining finishing was very homogeneous and it was not observed any contaminations but few machining shavings.

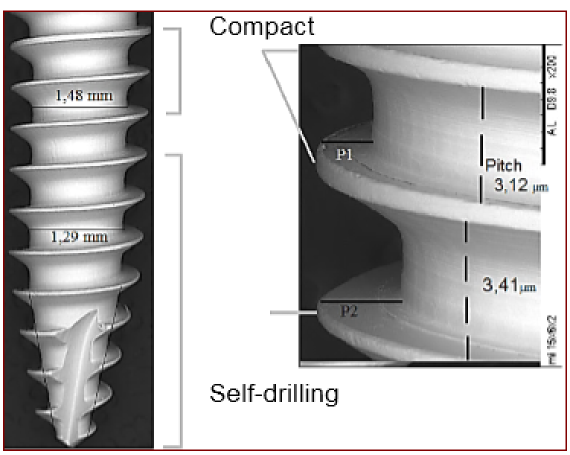
Figure 2. a) Semi-quantitative chemical analysis of the implants as obtained by EDS. b) Back-scattered electron micrograph of the internal surface of threads region of the MI showing a very homogeneous finishing.

Figure 2a Figure 2b



The used MI had threads with three types of design: compacting threads (CT), normal threads (NT) and self-drilling (SDT). The first three threads near the neck had CT design, showing less deep and shorter distance between the threads (pitch) than the NT that comprised the design of the remaining MI threads, besides the self-drilling portion that had a conical shape. The mini-implant typical shape is showed in Figure 3.

Figure 3. Measurements obtained using back-scattered electrons SEM micrograph. The CT thread had a pitch of 3.12 µm, the SDT 3.41 µm. The inner diameter was 1.48 µm. The depth of the CT (P1) is smaller than the depth of the SDT (P2).



The internal diameter of the CT is greater than the internal diameter of the NT due to the depth of the compacting screw be smaller. The internal diameter is also called the minor diameter of the MI. The external design of the threads showed a taper from the apex to the fifth thread and the taper bore followed this as it increases toward the compacting screw. The outer diameter is what characterizes the diameter of the MI as 1.5 mm and 1.8 mm used in this study. It was inserted 40 mini-implants at 90° inclination to bone samples prepared with artificial bones from Sawbones (S) - (Sawbones, 2013) and Nacional Ossos (NO) - (Nacional, 2013), which are described in Table 1. Surface analysis was performed using scanning electron microscopy - SEM before insertion testing. The measured insertion and removal torques was undertaken using a digital torque meter, the data were captured and analyzed.

The artificial bones used were trabecular and cortical with artificial densities and thicknesses similar to human ones from regions of maximum densities such as mandible as specified in Table 1 (Misch, Qu & Bidez, 1999).

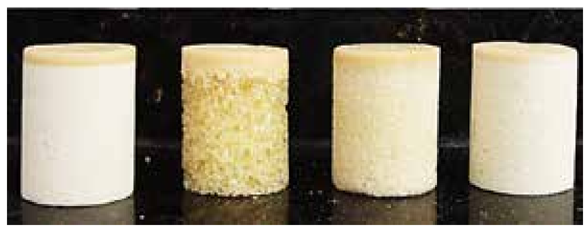
Table 1. Description of mini-implants and bone samples with different densities of artificial trabecular bone and cortical thicknesses.

Materials				
Mini-implants		**Artificial bone**		
Groups	Dimensions (mm)	Density of the trabecular artificial bone g/cm³ (PCF)	Thickness of the cortical artificial bone	Region
1	1.8 x 8 x 1	0.64 (40,0)	1.5 mm	Mandible median
2	1.8 x 8 x 2	0.20 (12.5)	2.0 mm	Jaw posterior
3	1.5 x 6 x 1	0.32 (20.0)	1.5 mm	Jaw median
4	1.5 x 6 x 2	0.64 (40.0)	1.0 mm	Mandible anterior

PCF: pound cubic feet

It specimens were trepanned into cylindrical blocks 20 mm in diameter (Figure 4). A device was developed in the CCTM / IPEN laboratory to hold the cylindrical blocks in front the torque meter.

Figure 4. Trepanned 20 mm in diameter cylindrical blocks and specifications. 1) Density of 0.64 g/cm³ trabecular and 1.5 mm cortical. 2) Density of 0.20 g/cm ³ trabecular and 2.0 mm cortical. 3. Density 0.32 g/cm³ trabecular and 1.5 mm cortical. 4) Density 0.64 g/cm³ trabecular and 1mm cortical.



Results and discussion

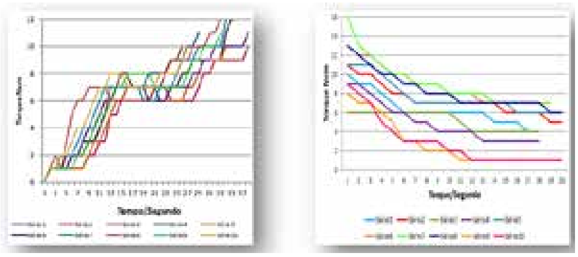
There was a gradual and smooth increase in insertion torque in all groups. The insertion torque (IT) was used to compare the dynamic mechanical insertion of two types of threads. In the region of self-drilling thread (SDT) the time for the torque increase was greater than the compacting thread. The insertion torques in the last four seconds of each test, corresponding to the insertion of compacting threads time were compared between groups. Group 1 showed an increase from 4 Ncm to 8 Ncm, the group 2 from 1 Ncm to 4 Ncm, the group 3 from 1 to 4 Ncm and group 4 from 3 Ncm to 6 Ncm.

The maximum insertion torque (MIT) and the maximum removal torque (MRT) were used to evaluate the pattern of attachment between each group. The MIT and MRT were higher in the group with the highest density of trabecular bone, even compared with the MI group 2 formed with the same length and diameter.

The average value of insertion torques for each group was calculated. The highest average value of insertion torque was 21.4 Ncm in-group 1 and the lowest in-group 2 was 9.5 Ncm. Both groups were used MI measuring 1.8 mm in diameter and 8 mm in length. The density of the artificial trabecular bone in group 1 was larger than that in group 2, but the artificial bone cortical thickness was greater in group 2. The MIT for group 1 was 24 Ncm and for group 2 it was 10 Ncm. The time interval was greater in the insertion of self-drilling screws, taking 4 to 6 seconds to 1 Ncm increase, however the compacting screw insertion of the interval was lower in average of 1 to 2 seconds.

The MRT of group 3 had a progressive decrease, however presented a shorter time span in the two thread types when compared the MIT. The MRT is higher than in most MRI test groups 1 and 4, which have the higher trabecular bone density of (40 PCF). The third group is greater than the MTR group 4, most probably due to the thickness of the cortical bone. In Figure 5, it is show a typical torque in Ncm versus time in seconds response for insertion and removal of the MI. The MRT of group 3 had a progressive decrease, however it presented a shorter time span in the two thread types when compared to its MIT. The MRT for group 3 is higher than in most MRT test groups 1 and 4, which has the higher trabecular bone density of 0.64 g/cm^3 (40 PCF). The group MRT in group 3 is greater than the MRT of group 4, most probably due to the thickness of the cortical bone.

Figure 5. a) Typical insertion torque curve for 10 tests from group 3 with MI of 1.5 mm diameter x 6 mm long. b) Typical removal torque of the 10 tests of group 3.



The SEM analysis revealed slight distortions practically rounding the edges of fillets MI and the edges of the active tip and there was no fracture, as shown in Figure 6. It was also observe a cleaning of small machining shavings still adhered to MI surface.

Figure. 6. Back-scattered electron micrograph of the self-drilling tip of the mini-implants before insertion (6a) and after removal (6b) showing some edges have been rounded and the machining shavings have been removed.

Figure 6a

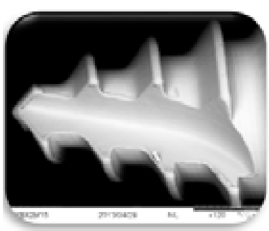
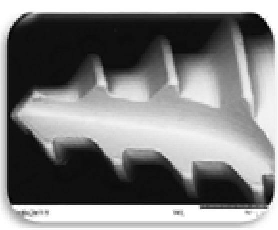


Figure 6b



The torque test in vivo has become a challenge due to variations in thickness and bone density. All MIT values increased with increasing thickness of the cortical bone, but the screw diameter was the most influential factor in determining the torque and concluded that MIT increased with the outer diameter of MI (Lim, Cha & Hwang, 2008). In insertion torque trials values from the present research, the MI with 1.5 mm in length in artificial bone with a density of 0.20 g/cm^3 (12.5 PCF), 0.32 g/cm^3 (20.0 PCF) and 0.64 g/cm^3 (40.0 PCF). The average values of MIT increased from 10.5 Ncm and 12.2 Ncm, respectively, above the optimum torque of 5 Ncm to 10 Ncm (Motoyoshi, Hirabayashi, Uemura & Shimizu, 2006).

Wei et al. (2011) compared the result of osseointegration at different times installed 64 screws in the femur bone from 8 beagle dogs. There was a better primary stability in bone thicker than the thin bone, but the difference became insignificant over time and concluded that more time may be needed to stabilize MI inserted into thin cortical. In the present study the MI group 1 were installed in cortical bone, 1.5 mm and group 2 with 2 mm thickness. The value of the MTI group 1 was 25 Ncm and 10 Ncm for group 2, but the marked discrepancy presumably occurred due to difference in density of the trabecular bone of 0.64 g/cm³ (40.0 PCF), similar to the anterior mandible bone and 0.32 g/cm³ (20.0 PCF) similar to the posterior maxilla bone. The MI of groups 3 and 4 with trabecular bone density of 0.32 g/cm^3 (20.0 PCF) and 0.64 g/cm^3 (40 PCF), respectively showed the value of the MIT of 12 Ncm and 14 Ncm.

The removal torques of the present tests was decreasing discreetly. All groups in the first four seconds had a decrease in the torque range of 1 s to 2 s, except for group 2 that had a longer interval to decrease the torque, even though the long and thick cortical MI, this occurred because the trabecular bone has a lower density of all groups. The RT of group 1 and 3 had a 50 % greater decrease after the test. Groups 2 and group 4 with the lowest bone density this decrease was less pronounced with time, which means less risk and lower risk of bone fracture damage. One of the features to reduce the risk of damage to bone fractures and MI is the drilling before mini-implant installation, particularly in bone with very high-density thick cortical insertion site (Gupta, Kotrashetti & Naik, 2012).

AlSamak, Bitsanis, Makou & Eliade (2012) analyzed the composition of the alloys and the surfaces of MI and marginal defects detected. The results obtained in this study by analyzing surface of the MI before and after insertion, showed discrete rounding the edges of fillets and active tip; however, there was no fracture to the MI during the tests.

Conclusion
The design of the threads, the diameter and length of the mini-implants influence the torque value insertion and removal.

The thread pitch and depth of influence on the time interval and increased insertion torque and removal.

The insertion torque and removal torque increased decreased in shortest time interval in the region of compacting threads making the mini-implant thread to double favorable regions with low bone density.

The maximum insertion torque and removal were higher in groups with higher trabecular bone density.

The thickness of the cortical has less influence on the increase in torque than the density of the trabecular bone.

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