Evaluation of insertion, removal and fracture torques of different orthodontic mini-implants in bovine tibia cortex

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Abstract

Objective: Evaluate mini-implants of different sizes for the following factors: (a) insertion torque, (b) removal torque, (c) fracture torque, (d) shear tension, (e) normal tension and (f) type of fracture. M**ethod:** Twenty self-drilling mini-implants were used, 10 manufactured by SIN and 10 by Neodent, measuring 8 and 7 mm in length, respectively and all with 1.6 mm in diameter. Out of these 10 mini-implants, for each brand, 5 did not have a neck and the other 5 had a 2 mm neck, and were separated into 4 groups: SIN without neck (S), SIN with neck (SN), Neodent without neck (N) and Neodent with neck (NN). All mini-implants were inserted into bone cortex and removed with a low speed handpiece connected to a digital torquimeter. The mini-implants were also submitted to a fracture test. The insertion, removal and fracture torques, as well as the calculated shear and normal tensions were compared between all groups using ANOVA. The type of fracture was assessed by a scanning electron microscope. **Results:** The NN group presented a significantly greater insertion torque than all other groups, although all of them fractured during insertion (n=2) or removal (n=3). There were no significant differences between groups for removal torque. For group N, the fracture torque was significantly smaller than all other groups. All mini-implants suffered ductile fracture. **Conclusion:** Since there were no differences in the mechanical resistance of both brands of mini-implants, which varied only in shape, one may conclude that resistance to fracture can be affected by this variable.

Keywords: Dental implants, Material resistance, Torque, Orthodontic anchorage procedures.

INTRODUCTION

Orthodontic anchorage is defined as resistance to undesired tooth movement[20]. Traditionally, groups of teeth are used as anchorage units[1], but can be displaced as a result of unwanted reaction to the applied forces. Appliances that require patient cooperation can also be used as anchorage mechanisms[13,24]. Moreover, the absence of posterior teeth can compromise adequate anchorage.

With the advent of osseointegration,

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orthodontic treatment methods with maximum anchorage control were proposed, especially for adults[21,22]. The use of osseointegrated implants as absolute anchorage devices[7] was indicated for treatment of more complex cases, for the optimization of results with simpler mechanics, or even for the reduction of treatment time. However, conventional osseointegrated implants can only be inserted in specific sites, such as the retromolar area or edentulous spaces[10,21].

Orthodontic mini-implants were developed based on surgical stabilization screws and used as absolute anchorage devices[12]. As well as an efficient anchorage alternative, they are easy to install and remove, and are sufficiently small for placement in various areas of alveolar bone, and even between roots. These features were responsible for the widespread clinical usage of mini-implants[4,19].

Unlike osseointegrated dental implants that are made from pure titanium, mini-implants are made of Ti6Al4V alloy for three main reasons: (a) mini-implants have a small diameter, and this alloy has greater mechanical resistance than the commercially pure titanium; (b) the application of these systems is based upon primary, not secondary stability, which is achieved through osseointegration; and (c) mini-implants must be easily removable. By using the Ti6Al4V alloy, which has inferior bioactive characteristics compared to the commercially pure titanium, the degree of osseointegration is low[9].

Mechanical stability is the most important mini-implant feature for orthodontics. It is achieved by primary stability, which is defined as that obtained immediately after insertion. Bone density at the insertion site, mini-implant shape and width, and the preparation of the area into which the device will be inserted all exert significant impact on mini-implant primary stability. Depending on the insertion site and the bone quality of the area, the orthodontist can choose a combination of type, diameter and length to find the best suited mini-implant for that region[25].

Mini-implant shape should provide mechanical anchorage by means of bone/implant contact surface and should also allow for load distribution so as to not adversely affect bone physiology. Mini-implant design should also limit trauma during the insertion procedure and provide for primary stability[10].

Mini-implant insertion torque reflects the amount of primary stability and is therefore an important factor for the success of the anchorage mechanism[25]. Friberg et al[11] described a statistically significant positive correlation between mini-implant insertion torque and bone density values, and concluded that methods used to measure torque during mini-implant placement should be used routinely.

After using the mini-implant for the desired movement, removal is necessary. There are few studies evaluating maximum removal torque. Generally, removal torques in short term studies are lower than insertion torques[9,16]. On the other hand, when there is a follow-up longer than four weeks, removal torques increase significantly[5,6,8].

Fracture is one of the risk factors and complications that may happen when using mini-implants. It normally occurs during insertion or removal, but can also happen during force application for orthodontic treatments. However, bone quality and density can influence insertion torque resistance, and when associated to sub-perforation can increase incidence of fracture close to the mini-implant head[14].

Melsen[15] associated a smaller diameter to greater fracture risk. Using techniques to measure stress distribution, fracture occurrence is greater during removal than insertion. Fractures usually occur close to the screw neck and the presence of holes can weaken even more the device.

Searching for more efficiency, many types and shapes of mini-implants have been released in the market by different manufacturers. It is known that the selection of the diameter and length of the mini-implant are important factors

for its adequate usage, even though it can be used in various areas of the mouth. Nevertheless, there is no protocol that indicates what type of mini-implant is the most recommended for each situation[2,3]. In spite of the rich literature on the treatment of clinical cases with mini-implants, many doubts still exist regarding how certain morphologic characteristics of these devices may influence their physical properties[25]. Therefore, the purpose of this study was to evaluate the insertion, removal and fracture torques, and the mechanical characteristics of torsion fracture of mini-implants from different manufacturers and with different dimensions.

MATERIALS AND METHODS

Mini-Implant Sample

Twenty commercial self-drilling mini-implants were used, ten manufactured by SIN (Sistema de Implantes Nacional, São Paulo, SP, Brazil) and ten by Neodent (Curitiba, PR, Brazil). All mini-implants had 1.6 mm in diameter, those from SIN measured 8 mm (Fig. 1A, C) in length and those from Neodent measured 7mm (Fig. 1B, D). To create the groups, five mini-implants with neck and five without neck from each manufacturer were used (Fig.1). The sample was divided into four groups which were named as: SIN with neck (SN); SIN without neck (S); Neodent with neck (NN) and Neodent without neck (N). All assays and procedures were performed in the Biomaterial Laboratory of the Military Institute of Engineering of Rio de Janeiro.

Specimen Preparation

Two bovine tibias were obtained from a local abattoir. They were cross-sectionally cut in relation to their long axis, into 15 mm segments. Bone marrow was removed and the cortex width was measured. Segments that had more than 9 mm in width were selected and were cut once again into squared specimens measuring 10 mm per side. These dimensions allowed for adequate

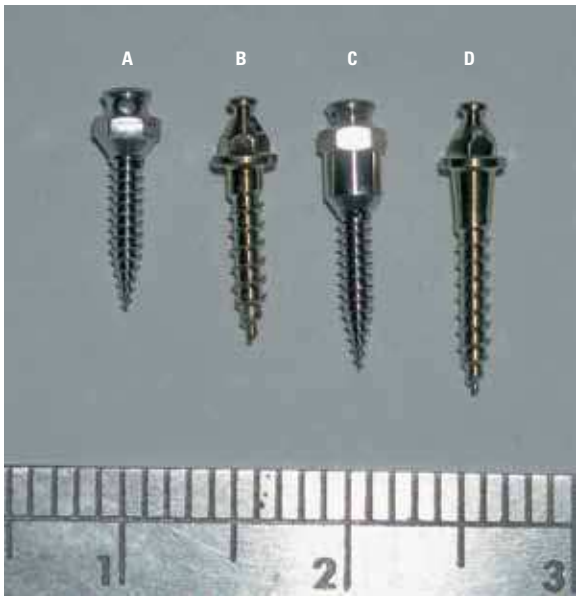


FIGURE 1 - Self-drilling mini-implants with 1.6 mm diameter which was part of the sample: **(A)** Neodent mini-implant with 7mm in length with no neck (group N); **(B)** SIN mini-implant measuring 8 mm in length with no neck (group S); **(C)** Neodent mini-implant measuring 7 mm in length, with a 2mm neck (group NN) and **(D)** SIN mini-implant measuring 8 mm in length, with a 2 mm neck (group SN).

placement of the specimen on the torquimeter and assured complete drill insertion during perforation (Fig. 2) and also that of the mini-implants which were to be evaluated in cortical bone. Twenty bone fragments were obtained in this manner, one for each mini-implant; they were maintained at 4°C for three days, until the day of the experiment.

These bone fragments were placed into a metallic support, which could be adjusted according to their size and shape. This piece was attached to a torquimeter (Lutron torquimeter TQ-8800, Taipei, Taiwan), fixed to a bench lathe, which firmly secured the device during experimentation.

The surgical motor MC-101, Omega.02 (Dentscler, Ribeirão Preto, SP, Brazil), connected to a 20:1 reduction handpiece, with 40000 rpm (Anthogyr Instruments, Saclanches, France) was

FIGURE 2 - Bovine tibia fragment with 10 mm in width and length and 9 mm in height to allow for complete bur insertion during drilling and also for the evaluated mini-implants.

FIGURE 3 - System used to measure mini-implant insertion and removal torques, consisting of a digital torquimeter **(a)** connected to a bench lathe **(b)**, with a bone specimen, where the mini-implants were inserted, attached by a metallic positioner **(c)**.

used for the mini-implant insertion and removal experiments.

To ensure mini-implant insertion into cortical bone alone, a hole was drilled in the center of the bone specimen. A carbide surgical bur, specific for bone perforation, with 1.3 mm in diameter, was used (Neodent, Curitiba, PR, Brazil). It was placed on the handpiece and drilling was performed under manual irrigation with water.

Mechanical assays

The mini-implant placement was performed following perforation with the insertion key attached to the handpiece, and also under manual irrigation. The insertion procedure was interrupted when the handpiece locked and the engine was shut down. A torque key was used in these cases until complete mini-implant insertion to the bone, i.e., no part of the screw could be seen. The mini-implants were removed with the same handpiece using the reverse rotation option, with no need for the manual key.

During insertion and removal assays torque was measured continuously. This data was recorded by a torquimeter connected to a computer, which sent the information to the Lutron Program 101, version V0011TW (Lutron Electronic Enterprise, Taipei, Taiwan). The obtained values were sent to the Origin Pro 7.0 Program (Origin Lab Corporation, Northampton, MA, USA) for developing graphical representations. Maximum insertion and removal torques were obtained from graphic peaks.

During these assays some mini-implants fractured. Those that did not were submitted to mechanical testing for torsion fracture, using a rotation shaft system attached to a universal mechanical testing machine (EMIC, Curitiba, PR, Brazil) with a 500 N load cell.

For torsion fracture the mini-implant was held in place by shafts on both sides. One of these shafts is stationary, where the mini-implant tip was placed. The other shaft turns due to traction by a polymer thread, which is attached to a shaft axis and to the load cell, where the implant head was placed. Since one side rotated and the other was fixed, a torque force was applied to the mini-implant, which was recorded by the Tesc Program,

version 3.04 (EMIC, Curitiba, PR, Brazil) and the maximum force produced fracture (Fig. 4).

Torque fracture was calculated by multiplying the maximum force by the axis radius in which the polymeric thread was wound, according to the following equation:

Torque (T) = Force (F) x 4.

For the mini-implants that fractured during the insertion and removal assays, the torque during fracture was used.

Microscopic evaluation

Mini-implant fracture surfaces were evaluated by scanning electron microscopy (SEM), with a JEOL microscope; model JSM-5800 LV (JEOL, Tokyo, Japan). Since some mini-implants fractured inside the bone, only the upper part could be used for SEM without specific preparation. As such, the upper mini-implant fragments were placed on a metallic plate and held by double-face adhesive tape, to be kept in a vertical position. Using the specific program for the microscope, the mini-implant was found and the fracture region was analyzed and photographed at a x500 magnification. The type of fracture was determined by visual inspection.

To evaluate differences between the mini-implant material resistance the calculated shear tension was used and obtained using the following formula:

$$\text{Shear Tension} = 16.T/\pi.\ D^3,$$

Where T = torque and D = the diameter of the fractured surface of the mini-implant. To measure this diameter an optic Zeiss microscope was used. Stemi 2000-C (Zeiss, Jena, Germany) at a x150 magnification. Surface images were captured to a computer and evaluated using Axio Vision Program (Zeiss, Jena, Germany), where the diameters were calculated. Two perpendicular lines, containing the surface diameter were traced and the mean of these two values was considered the fractured surface diameter. For some mini-implants, these values were confirmed under SEM (Fig. 5).

To confirm shear tension values, normal tension was calculated by the following formula:

$$\text{Normal Tension} = 16.T/\sqrt{}_3.\ \pi.D^3,$$

where T = Torque and D = the diameter of the fractured surface of the mini-implant.

Statistical analysis

All numerical results were presented as means and standard deviations. Insertion, removal and fracture torques, as well as calculated shear tension were compared between all groups by one-way ANOVA. To compare insertion and removal torques for each group a two-way ANOVA was used. Significance level was established at $p < 0.05$.

RESULTS

Mini-implant maximum insertion torques in bovine cortical bone were 25.2 ± 1.9, 23.2 ± 4.9, 26.0 ± 2.4 and 30.6 ± 1.8 Ncm for groups S, SN, N and NN, respectively (Fig. 8). Two mini-implants from group N and two from group NN fractured during insertion procedures. In these cases the recorded value for maximum torque was that obtained during fracture. Insertion torque means were compared by one-way ANOVA (Tab. 1). Statistically significant differences were observed for group NN when compared to all other groups, demonstrating that maximum insertion torque for group NN was significantly greater than all other groups.

Mini-implant maximum removal torques from cortical bone were also measured. Observed means were 17.2 ± 4.9, 17.6 ± 7.6, 16.6 ± 7.5 and 25.0 ± 5.5 Ncm for groups S, SN, N e NN, respectively (Fig. 8). Three mini-implants from group NN fractured during removal, and the value for maximum removal torque was also recorded at the moment of fracture. Maximum insertion torque values were greater than those for removal for all groups, whereas group NN presented greater torque values for these two

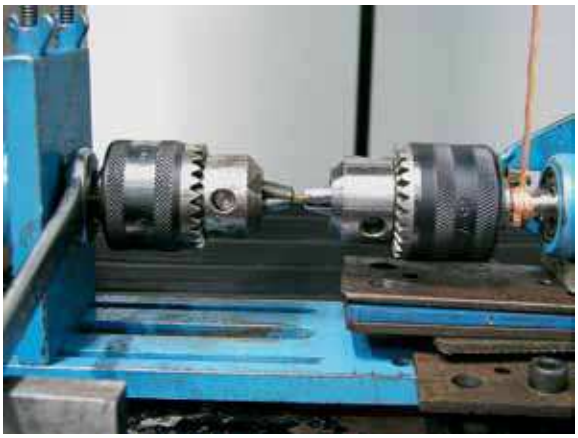


FIGURE 4 - Torsion assay device, performed to determine maximum resistance torque to fracture for the mini-implants, connected to the universal mechanical assay machine with 500N load cell. The right side shaft rotates when the polymer thread is pulled by the assay machine and the left shaft is stationary and holds the mini-implant.

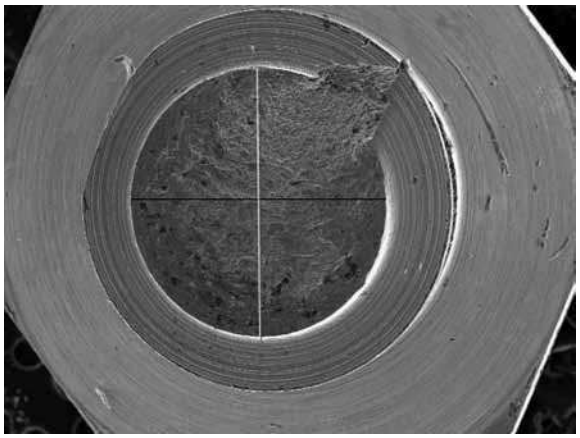
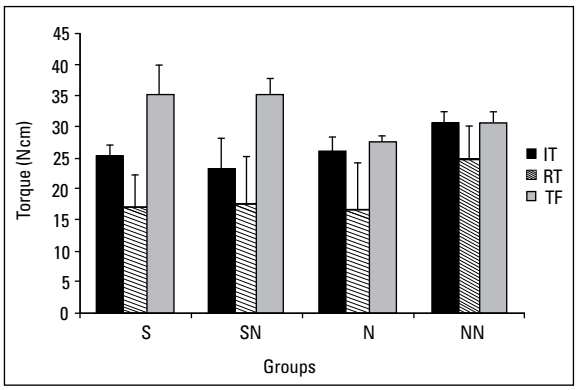


FIGURE 5 - Cross-section of the fractured mini-implant observed under SEM in a x500 magnification. The white and black lines were used to calculate the mean diameter of the fracture area and thereby obtain the calculated shear tension.



GRAPH 1 - Maximum insertion (IT) and removal torques (RT) for all four groups of mini-implants. Columns represent the mean and the error bars represent the standard deviation. The sample size is five for each group, with the exception of groups N and NN for the removal assays, which had sample size of three.

variables. There were no significant differences for maximum removal torques between all groups (Tab. 1).

For each group, means for maximum insertion and removal torques were compared by two-way ANOVA (Tab. 2). Only group S showed significantly statistical difference, demonstrating that, for this group, maximum insertion torque was significantly greater than removal torque, even though all other groups showed the same behavior.

The mean fracture torques for mini-implants were 35.1 ± 4.9, 35.1 ± 2.7, 27.4 ± 1.1 and 30.6 ± 1.8 Ncm, for groups S, SN, N e NN, respectively (Fig. 8). Groups S and SN presented greater values more similar to each other than groups N and NN. When comparing fracture torques between groups (Tab. 1) no differences were found between groups S and SN and between groups S and NN. Group N presented the smallest fracture torque mean and differed significantly from all other groups. SIN mini-implants (groups S and SN) did not present significant differences when compared between themselves, demonstrating a small variation in resistance.

Mini-implant surface fractures for all groups were compared by visual inspection under SEM. All groups presented microporosity and lines of plastic deformation caused by torsion deformation. The direction of the lines indicate that the fractures occurred due to shearing, characterizing a ductile fracture (Fig. 6).

The calculated shear tension was 1123.1 ± 168.3, 1041.9 ± 154.8, 1124.8 ± 123.0, and

Table 1 - Statistical comparison (one-way ANOVA) between means of insertion, removal and fracture torques of all groups. Numbers represent p values and significant differences are indicated with an asterisk.

	groups					
	S x SN	S x N	S x NN	SN x N	SN x NN	N x NN
Insertion	0.421	0.574	0.001*	0.287	0.013*	0.009*
Removal	0.924	0.652	0.372	0.135	0.311	0.191
Fracture	0.992	0.034*	0.160	0.003*	0.036*	0.003*

Table 2 - Statistical comparison (two-way ANOVA) between means of mini-implant insertion and removal torques of the same group. Numbers represent p values and significant differences are indicated with an asterisk.

	groups			
	S	SN	N	NN
p	0.044*	0.287	0.272	0.177

1088.7 ± 128.7 MPa for groups S, SN, N e NN, respectively (Tab. 3). No statistically significant differences were observed between groups, when compared by one-way ANOVA, demonstrating that all mini-implants did not differ in relation to the mechanical resistance of the material of which they were made. These results were also confirmed by the calculated normal tension.

In order to calculate shear tension, mini-implant diameters were measured, without including the thread length, which was called the implant core. It was noticed that an increase in the cross-section diameter of the mini-implant was followed by an increase in torque (Tab. 3).

By macroscopic evaluation, differences were found between the characteristics of mini-implants of different manufacturers used in this study, most specifically in the number of threads and distance between them (Fig. 1). This observation was confirmed in SEM images, demonstrating that mini-implants from groups N and NN presented greater number and closer threads when compared to groups S and SN (Fig. 7).

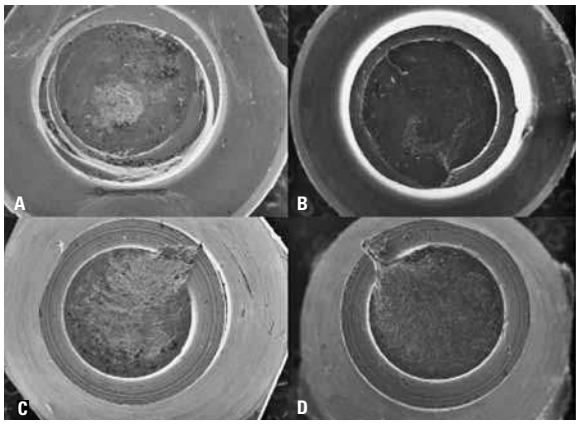


FIGURE 6 - Cross-section of one mini-implant of each group observed under SEM at a magnification of x500: **(a)** mini-implant from group S; **(b)** mini-implant from group SN; **(c)** mini-implant from group N and (d) mini-implant from group NN. These images were used to classify the type of fracture. All were classified as ductile, according to the shearing lines generated by torsion.

DISCUSSION

Although the small dimensions of mini-implants enable their insertion in various areas of the mouth, there is an increased likelihood of deformation during usage and fracture during insertion or removal[9]. In this study, orthodontic mini-implants were analyzed according to resistance during insertion in and removal from bovine bone cortices and then subjected to fracture by torsion.

Mini-implants from two major national manufacturers were selected which shared the most similar dimensions. All mini-implants had the same diameter of 1.6 mm, which was considered a suitable size to be applied in all areas of the mouth[23]. Additionally, the choice of a larger diameter had the purpose of obtaining high torque values. Elias et al.[9] when comparing two types of mini-implants from the same manufacturer with different diameters evaluated that the greater the diameter, the greater is the mini-implant insertion torque, since this is proportional to the contact area between mini-implant and bone.

Table 3 - Values for the diameter (D) of mini-implant fracture regions, fracture force (F), fracture torque (T), calculated shear tension (ST), and calculated normal tension (NT). Results are presented in means and standard deviations of 5 samples in each group.

	groups			
	S	SN	N	NN
Mean D (mm)	1.2 ± 0.0	1.2 ± 0.0	1.1 ± 0.0	1.1 ± 0.0
F (N)	88.0 ± 12.2	88.0 ± 6.8	69.18 ± 2.25	77.5 ± 4.56
Torque (Ncm)	35.1 ± 4.9	35.1 ± 2.7	27.4 ± 1.1	30.6 ± 1.8
ST (MPa)	1123.1 ± 168.3	1041.9 ± 154.8	1124.8 ± 123.0	1088.7 ± 128.7
NT (MPa)	648.5 ± 97.1	601.5 ± 89.4	634.0 ± 70.6	631.1 ± 64.6

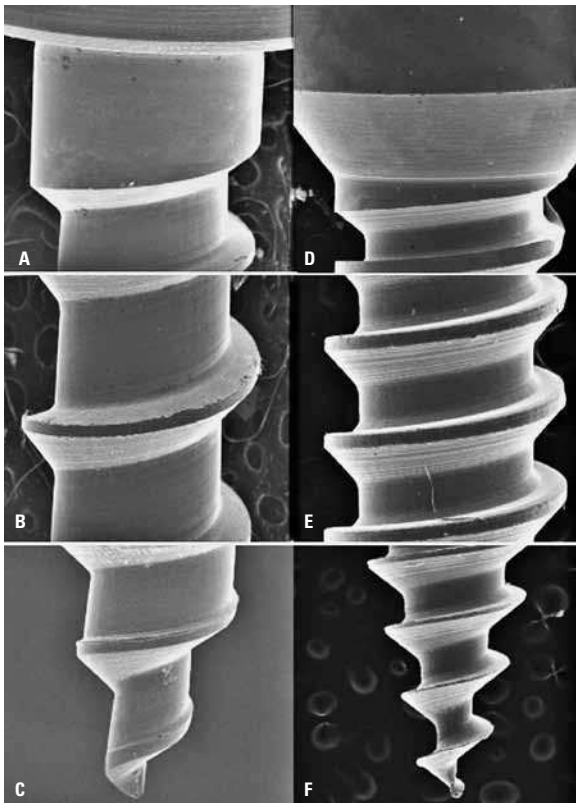


FIGURE 7 - Mini-implant profiles, with 1.6mm in diameter, observed under SEM at a magnification of x500. Figures **(A)**, **(B)** and **(C)** correspond to SIN mini-implants and figures **(D)**, **(E)** and **(F)** to Neodent mini-implants, respectively upper, middle and lower sections of the mini-implant body. All areas present different dimensions even though these mini-implants have the same commercial specifications. The number of threads, the distance between the threads and the active points are different.

The presence and absence of the neck was one of the variables analyzed in this study. The purpose of this structure is to maintain the health of the tissues around the mini-implant, especially in areas with small attached gingiva, since the absence of inflammation is a factor that contributes to improved mini-implant stability[3]. Mini-implants with and without a 2 mm neck were chosen from both brands, for this was the greatest possible variation span in neck size manufactured by SIN and Neodent.

The chosen length was the closest possible between both companies, 7 mm for Neodent and 8 mm for SIN. These companies do not produce mini-implants with the same length.

Success in using mini-implants is related to primary stability after placement. Primary stability mainly depends on implant shape and bone quality of the insertion area. Cortical bone support is essential for primary stability, since the small thickness of bone results in mini-implant failure[3]. Thus, bovine tibia cortex was chosen for the assays due to the quality of cortex bone, which permits full insertion of the mini-implant.

Mean values for maximum insertion torque varied between 30.6 and 23.2 Ncm. These values are compatible with those described by Wilmes et al.[25], that varied from 41.3 to 23.4 Ncm, even though mini-implant insertion was performed in swine pelvic bone, which has a thinner cortex than the one used in this study. Motoyoshi et al. found insertion torque values much lower than those observed in this study, varying from 7.2 to 13.5 Ncm in adults[17] and 7.6 to 9.2 Ncm in adolescents[18]. Elias et al.[9] described insertion torques for mini-implants with 1.5 mm in diameter of 9.6 Ncm in rabbit cortex and 12.6 Ncm in bovine cortex, also much smaller than the values obtained in this study. Mini-implants with 2 mm in diameter when inserted in bovine cortex produced a mean torque of 23.2 Ncm, closer to the values obtained in this investigation.

Mean values for maximum removal torque obtained in this study varied from 25.0 (group NN) to 16.6 Ncm (group N) and there were no significant differences between groups. Elias et al.[9] evaluated commercial mini-implant removal torques with 6.0mm in length and 1.5 to 2.0 mm in diameter and found values of 5.4 ± 0.7 Ncm in rabbit cortex and 6.8 ± 0.8 Ncm in bovine cortex for mini-implants with 1.5 mm diameter. Mini-implants with 2.0 mm diameter were only tested on bovine cortex and presented removal torque of 12.0 ± 1.6 Ncm. These values were smaller than those found in this work, even for the mini-implants with greater diameter. Nevertheless, mini-implants tested by Elias et al.[9] were shorter (6 mm) and were not inserted solely in bone cortex.

As with insertion torque, group NN showed greater removal torques, demonstrating also greater difficulty in removing them from bone. Only the presence or absence of the neck seems not to affect insertion or removal torques, since only group NN had significant differences, whilst group SN did not.

When comparing insertion and removal torque values, Elias et al.[9] observed that removal torque is smaller than insertion torque irrespective of the type of bone or mini-implant diameter, a finding also observed in this study. However, only group S presented significant difference between insertion and removal torques. Dilek et al.[8] reported greater removal torques than insertion torques in a non-vital experiment in bovine femur, which was not in agreement with other studies. Higher removal torques than insertion torques were found in studies in vivo, when there is at least a four week follow-up, allowing for the osseointegration of the device[5,6,16,1718].

During insertion experiments, two mini-implants from groups N and NN fractured and three others from group NN fractured during removal tests. No mini-implants from groups S and SN fractured in these experiments. Groups N and NN presented greater insertion torques, which can explain the fractures. The presence of the neck seems not to affect torque values for the SIN mini-implants, but there seems to be a difference between those made by Neodent. The fact that more mini-implants fractured during removal tests is in accordance to Melsen´s[15] findings, which affirms that this is the moment when mini-implant fractures most often occur.

Fracture torques varied from 35.14 (group S) to 27.42 Ncm (group N). Groups S and SN presented very similar fracture torques, while groups N and NN had very discrepant values. A comparison of fracture torques between groups was also performed. There were no significant differences between SIN mini-implants. However, Neodent mini-implants were different among themselves. Dilek et al.[8] reported that torques between 35 and 50 Ncm can cause mini-implant fracture. Wilmes[25] recommends limiting insertion torque to 20 Ncm in order to avoid fractures.

According to these results, it becomes evident that there are differences between mini-implants from different manufacturers. To ascertain whether the mechanical resistance of the manufacturing material was similar, the mini-implants were subjected to SEM of the fractured surfaces. All groups presented ductile fracture, i.e., plastic deformation. This characteristic shows that, probably, all mini-implants evaluated are made of a compatible material.

The calculated shear tension and the normal tension obtained at the moment of fracture allows one to verify that the mini-implant manufacturing material is similar and represents its mechanical behavior. To calculate these tensions the fracture region diameter of the mini-implant was measured. Values for shear and normal tensions did not show significant differences between groups and therefore, no difference was observed for the mechanical resistance between the manufacturing materials of different mini-implants. Since no differences were observed

either for the mechanical resistance or for the fracture surface morphology, differences in torque resistance can be related to the shape of the mini-implant.

An increase in the cross-section diameter of the mini-implant was followed by an increase in fracture torque. The diameter, which is presented by the manufacturer, represents the full dimension and is the necessary clinical information to know how much space the device will require. However, owing to these results, it was noted that there is a difference in the diameter of the mini-implant core in the different groups evaluated. Thus, the shape of the mini-implant is a variable that should be considered when evaluating the mechanical resistance of this product. A greater number and smaller distance between threads was seen in groups N and NN, which can provide greater mechanical attachment and consequently, greater resistance for mini-implant insertion into bone. The smaller core diameter and the greater insertion torques can explain the smaller resistance to fractures of the mini-implants from these groups.

By evaluating the obtained mechanical analysis results for the mini-implants, there is a need for standardizing all the structures in this product, namely, core diameter, mini-implant size and shape and distance between threads. Mini-implant fractures during insertion or during force application can be a serious problem, and can even restrain a tooth from future movement[14]. Even though the current literature is rich in clinical information on mini-implants, little association of what is known about ideal characteristics of mini-implant morphology has been converted into clinical applications. With the increasing use of these devices, new studies are suggested with the purpose of improving and adapting the shape of mini-implants to its best clinical application in orthodontic treatment.

CONCLUSION

Group NN presented the greatest insertion torque, which was significantly different from all other groups. Mini-implant removal torque did not present statistically significant differences between groups, but was always smaller than the insertion torques. Group NN differed significantly from all other groups presenting the smallest fracture torque. SIN mini-implants (groups S and SN) did not show any differences between themselves, demonstrating a small variation of resistance. All groups presented ductile fracture in SEM inspection, demonstrating compatibility of mini-implant material, even though they were from different manufacturers. This was confirmed because there were no differences for the maximum calculated shear tension.

Neodent mini-implants presented, in general, a different behavior from SIN mini-implants. Since these devices are made from the same material, one may say that the difference in shape, core diameter and number of threads can affect mini-implant physical properties, especially insertion, removal and fracture torques.

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