Assessment of flexural strength and fracture of orthodontic mini-implants

Matheus Melo Pithon*, Lincoln Issamu Nojima**, Matilde Gonçalves Nojima**, Antônio Carlos de Oliveira Ruellas**

Abstract

Objective: This study was designed to assess the deformation and fracture of orthodontic mini-implants of different commercial brands by submitting them to loads perpendicularly applied along their lengths. **Materials and Methods:** A total of 75 mini-implants were divided into five groups (n=15): M (Mondeal, Tuttlingen, Germany), N (Neodent, Curitiba, Brasil), I (INP, São Paulo, Brazil), S (SIN, São Paulo, Brazil), and T (Titanium Fix, São José dos Campos, Brazil). The mini-implants were inserted perpendicularly into swine cortical bones and submitted to mechanical tests using an Emic DL 10.000 universal testing machine at cross-speed of 0.5mm/min. The different forces required to fracture mini-implants after undergoing 0.5mm, 1mm, 1.5mm and 2mm deformation was assessed. The data were assessed using analysis of variance (ANOVA) and Tukey's test. **Results:** Mini-implants in Group S required the greatest forces to deform and fracture. These results were statistically significant in comparison with the other groups (P<.05) which required lower forces to deform and fracture. Group M yielded the lowest distortion values but with no significant statistical difference compared to Group N (P>.05), whereas Group T required the lowest fracture values with statistical difference compared to Groups M, S and I. **Conclusions:** It is possible to conclude, based on the results of the present study, that the shape and flexural strength of mini-implants bear direct correlation with each other. Despite their different flexural strength levels all mini-implants proved effective in clinical use.

Keywords: Anchorage. Mini-implant. Mini-screw. Deformation.

INTRODUCTION

Anchorage in orthodontics plays a paramount role in orthodontic planning. In treatment planning, very important and challenging decisions rely on anchorage, namely: Whether or not to extract permanent teeth, whether or not orthognathic surgery is required, whether or not soft tissues should be altered, the need for patient compliance and the length and streamlining of orthodontic treatment[10].

In the last few years, the dental literature has described a number achievements in the field of Implantology, such as miniplates[5,6], surface implants (onplants)[2], conventional osseointegrated[9,18] implants and mini-implants, with proven efficacy in orthodontic anchorage. One cannot

* Orthodontics specialist at Alfenas Federal University (UNIFAL); currently a Doctor degree student at Rio de Janeiro Federal University (UFRJ).
** Holds a Doctor's degree in Orthodontics from Rio de Janeiro Federal University (UFRJ).

help but note, however, that mini-implants have aroused greater interest than other devices in the last years[15].

The use of mini-implants ushers in a new concept in Orthodontic Anchorage, named skeletal anchorage, which prevents any movement from occurring in the response unit. This is due to the fact that the anchorage unit is unable to move when submitted to orthodontic mechanics[4,12,14,20].

As is the case with conventional dental implant systems, professionals inserting a mini-implant should take special care, both during surgery and in the stages where orthodontic forces are applied, in order to avert mini-implant deformation or even fracture[3,8].

Thanks to a reduction in mini-implant size, today a wider range of insertion sites is available which helps to mitigate the risk of root injury. The down side, however, is that reduced size entails a decrease in the mini-screw's flexural strength. As a result, the maximum force required to permanently deform and fracture mini-implants is also diminished[8].

Based on this premise, the present study was designed to assess the deformation and fracture of orthodontic mini-implants of different commercial brands by submitting them to loads perpendicularly applied along their lengths.

MATERIALS AND METHODS

Altogether, 75 mini-implants were used from 5 different manufacturers and distributed into 5 different groups, as shown in Box 1.

Prior to use, the mini-screws had their dimensions gauged under a profile projector (Nikon, Tokyo, Japan) and were subsequently submitted to a JEOL scanning microscope (2000 FX, Tokyo, Japan) with a 15x magnification for morphological assessment. The purpose was to correlate the values found in the mechanical tests[7] with the mini-implants' morphology.

To aid in carrying out the flexure strength and fracture trials, specimens – with 8mm thickness - were fashioned from swine cortical bones obtained from the mid-segment of a pig's femur bone, which would serve as the mini-implants' insertion sites.

After the pig's femur bones had been obtained they were dissected and sliced into bone blocks with 10cm cortical length and 8mm cortical thickness. The bone blocks were placed into PVC tubes (Tigre, Joinvile, Santa Catarina, Brazil) and bonded to these tubes using self-curing acrylic resin (Clássico, São Paulo, Brazil). To help in properly positioning the bone blocks a glass square was utilized to align the bone surface perpendicularly to the ground.

The specimens were then dipped into a saline solution and kept in a fridge at a temperature of 8° C. After 7 days had elapsed, the specimens were removed from the fridge and left sitting for 12 hours at room temperature awaiting mini-screw insertion.

To insert the mini-implants a manual key was attached to a parallelometer (Humpa, Rio de Janeiro, Brazil), whereby insertion could be made parallel to the ground and perpendicular to the bone tissue.

Groups	Commercial brands	n	Diameter (mm)	Length (mm)	Type	Alloy
M	Mondeal	15	1,5	7	Self-drilling	Ti-6AL-4V
N	Neodent	15	1,6	7		
S	SIN	15	1,6	6		
I	INP	15	1,5	6		
T	Titanium Fix	15	1,5	5	Self-tapping	

Box 1 - Sample distribution with their respective diameters, lengths and alloy.

Immediately following mini-screw insertion, the specimens were tested in the universal testing device (Fig. 1). In order to stabilize the specimens a vise-like device was contrived to keep the specimens steady throughout the trials.

The flexural strength test was conducted using an Emic DL 10.000 universal testing machine (São José dos Pinhais, Paraná, Brazil) operating at a cross-head speed of 0.5mm/min through an active chisel head (Fig. 2). The force was applied to the screw heads with the aim of deforming the mini-screws by 0.5, 1.0, 1.5 and 2.0mm and to the point of fracture (Fig. 2).

Statistical analyses were conducted with the aid of the SPSS 13.0 software program (SPSS Inc., Chicago, Illinois). A descriptive statistical analysis, including mean, standard deviation, median, minimum and maximum values, was performed for the five groups under evaluation. The values for maximum deformation and fracture forces (in N/cm²) were submitted to an analysis of variance (ANOVA) to determine whether there were any statistical differences between the groups, and subsequently to Tukey's test (Tab. 1).

RESULTS

The results have shown deformation in all mini-implants. Group S mini-implants required, on average, greater forces to undergo deformation. The lowest deformation values were achieved by Group M and Group N mini-screws.

After mini-implants had been deformed by 2mm, the same speed was maintained until fracture occurred, whereupon this maximum value was noted.

Groups I and T showed less deformation than the other groups whereas fracture occurred prior to 2mm deformation (Tab. 1).

FIGURE 1 - Flexure strength trial using an Emic DL 10.000 universal testing machine.

FIGURE 2 - A mini-implant undergoing deformation during mechanical testing.

Table 1 - Mean and standard deviation values of forces required to deform mini-implants, and statistical analysis.

Groups	Deformation (mm)							
	0,5mm	sig.*	1,0mm	sig.*	1,5mm	sig.*	2,0mm	sig.*
M	44,54 ± 6,63	A	72,44 ± 9,63	A	87,75 ± 6,61	A	109,06 ± 2,86	A
N	50,46 ± 6,45	A	74,33 ± 7,34	AD	87,83 ± 10,95	A	100,76 ± 8,89	A
S	60,89 ± 8,31	B	183,31 ± 9,85	B	344,41 ± 8,44	B	326,35 ± 9,80	B
I	82,71 ± 7,56	C	142,89 ± 7,60	C	165,48 ± 5,37	C	-------	
T	55,04 ± 2,75	AB	90,90 ± 9,71	D	107,03 ± 9,47	D	-------	

* Identical letters stand for no statistical differences (p > 0,05).

Table 2 - Mean and standard deviation values of forces required to fracture mini-implants, and statistical analysis.

Groups	Fracture	sig.*	Deformation	sig.*
M	261,14 ± 10,74	A	3,48 ± 0,25	A
N	119,52 ± 8,06	B	2,84 ± 0,30	AC
S	476,06 ± 11,19	C	2,56 ± 1,07	ABC
I	174,15 ± 7,81	D	1,59 ± 0,30	BC
T	117,59 ± 10,50	B	1,94 ± 0,49	B

* Identical letters stand for no statistical differences (p > 0,05).

Insofar as fracture force values are concerned, Group S mini-implants had a statistically superior performance compared with the others, followed by Group M. The lowest values were recorded for Groups T and N, between which there were no statistical differences. Group M required greater degree of deformation before fracturing, followed by Groups N and S, respectively. Conversely, Groups I and T fractured prior to reaching the 2mm deformation benchmark proposed in this study (Tab. 2).

DISCUSSION

Knowledge about the deformation of orthodontic anchorage structures is crucial in assessing potential anchorage failure[7,11]. Based on this premise, this study was designed to assess the strength required to deform orthodontic mini-screws and the strength required to fracture these mini-screws when submitted to flexural load.

The need to evaluate mini-implant deformation when applying perpendicular force stems from the fact that this axis is predominantly used when applying mini-implant assisted orthodontic forces. To this end, specimens were fashioned which allowed mini-implants to be placed parallel to the ground, thereby enabling the application of perpendicular forced to their axes, as is the case in the oral cavity.

All mini-implants tested suffered deformation from the onset of force application to the moment of fracture. Group S required greater forces than any other group before deforming and fracturing ($P<0.05$). The lowest deformation values were recorded for Group M and Group N mini-implants ($P>0.05$). These results can be ascribed to a larger diameter of the transmucosal region/screw thread junction of Group S mini-implants versus a smaller diameter in Group M and Group N, whose mini-implant heads and screw threads were slightly disproportionate, which made the mini-implants more prone to deformation even with lower forces.

In light of the findings of this study, the term 'rigid anchorage', as employed by Park et al.[16], should be reconsidered since it conveys the wrong idea that absolute resistance to orthodontic movements is possible. This is corroborated by Liou et al.[13], who also found anchorage loss when using orthodontic mini-implants. This author reports that such drift could be attributed to different factors, such as mini-screw size, bone quality, osseointegration time and magnitude of the orthodontic force.

After mini-implants had been deformed by 2mm, the same speed was maintained until fracture occurred. The only mini-implants which could not be assessed as far as a 2mm deformation were the ones in Groups I and T, since fracture occurred prematurely.

Insofar as fracture force values are concerned, Group S mini-screws had a statistically superior performance ($P<0.05$) compared with the others, followed by Group M. The lowest values were recorded for Groups T and N, between which there were no statistical differences. Group M required a greater degree of deformation prior to fracturing, followed by Groups N and S, respectively.

Fortunately, even when subjected to minor deformations, all orthodontic mini-implants proved strong enough to be an integral part of anchorage systems since none fractured when submitted to orthodontic forces cited in the literature[17].

The deformations found in this study do not preclude the use of these mini-implants in their role of supporting orthodontic treatments since the smallest force capable of causing a 0.5mm deformation was 44.54 N – approximately 4460.00 g/cm^2, much higher than any force currently used in Orthodontics.

In the oral cavity the mini-screws were submerged into bone and soft tissue. The bone-inserted part offers greater resistance in the face of orthodontic forces. However, the moment of force is located flush to the bone surface. After assessing the mini-implant regions deformed in this experiment, the authors recommend that the mini-screw threads remain submerged below the cortical bone since the smallest diameter found on the mini-screws in precisely the region in between the screw threads, which is most susceptible to fracture.

The spot where the mini-implants underwent the most deformation was the region located immediately above the bone tissue. Due to this feature we believe that tapered mini-implants are the best suited for orthodontic purposes in view of the fact that tapered mini-implants combine a slimmer thickness on their cutting edge and a more resistant diameter immediately below the point where orthodontic forces are applied. This trend can be seen in the new mini-implant designs recently launched in the market[4,12,19].

CONCLUSIONS

All mini-implants tested in this study proved adequate for use in orthodontic anchorage.

Mini-implant shape is directly related to the flexural strength afforded by these devices when perpendicular forces are applied along their axes.

Submitted: May 2008
Revised and accepted for publication: July 2008

REFERENCES

1. ARAÚJO, T. M.; NASCIMENTO, M. H. A.; BEZERRA, F.; SOBRAL, M. C. Ancoragem esquelética em Ortodontia com miniimplantes. **Rev. Dental Press Ortodon. Ortop. Facial**, Maringá, v. 11, n. 4, p. 126-156, 2006.
2. BLOCK, M. S.; HOFFMAN, D. R. A new device for absolute anchorage for Orthodontics. **Am. J. Orthod. Dentofacial Orthop.**, St. Louis, v. 107, no. 3, p. 251-258, 1995.
3. CARANO, A.; VELO, S.; LEONE, P.; SICILIANI, G. Clinical applications of the miniscrew anchorage system. **J. Clin. Orthod.**, Boulder, v. 39, no. 1, p. 9-24; 29-30, Jan. 2005.
4. CHADDAD, K.; FERREIRA, A.; GEURS, N.; REDDYD, M. Influence of surface characteristics on survival rates of mini-implants. **Angle Orthod.**, Appleton, v. 78, no. 1, p. 107-113, Jan. 2008.
5. CHUNG, K. R.; KIM, Y. S.; LINTON, J. L.; LEE, Y. J. The miniplate with tube for skeletal anchorage. **J. Clin. Orthod.**, Boulder, v. 36, no. 7, p. 407-412, July 2002.
6. DE CLERCK, H.; GEERINCKX, V.; SICILIANO, S. The zygoma anchorage system. **J. Clin. Orthod.**, Boulder, v. 36, no. 8, p. 455-459, Aug. 2002.
7. ELIAS, C. N.; LOPES, H. P. **Materiais dentários**: ensaios mecânicos. São Paulo: Ed. Santos, 2007.
8. ELIAS, C. N.; SERRA, G. G.; MULLER, C. A. Torque de inserção e remoção de mini-parafusos ortodônticos. **Rev. Bras. Implant.**, Rio de Janeiro, v. 11, p. 5-8, 2005.
9. FAVERO, L.; BROLLO, P.; BRESSAN, E. Orthodontic anchorage with specific fixtures: related study analysis. **Am. J. Orthod. Dentofacial Orthop.**, St. Louis, v. 122, p. 84-94, 2002.
10. FREITAS, J. C.; CASTRO, J. S. Avaliação da frequência do uso de implantes de ancoragem ortodôntica. **J. Bras. Ortodon. Ortop. Facial**, Curitiba, v. 9, no. 2, p. 474-479, 2004.
11. JOLLEY, T. H.; CHUNG, C. H. Peak torque values at fracture of orthodontic miniscrews. **J. Clin. Orthod.**, Boulder, v. 41, no. 6, p. 326-328, June 2007.
12. LIM, S.; CHA, J.; HWANG, C. Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. **Angle Orthod.**, Appleton, v. 78, no. 2, p. 234-240, Mar. 2008.
13. LIOU, E. J.; PAI, B. C.; LIN, J. C. Do miniscrews remain stationary under orthodontic forces? **Am. J. Orthod. Dentofacial Orthop.**, St. Louis, v. 126, no. 1, p. 42-47, July 2004.
14. MOON, C.; LEE, D.; LEE, H.; IM, J.; BAEK, S. Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region. **Angle Orthod.**, Appleton, v. 78, no. 1, p. 101-106, 2008.
15. PAIM, C. B. **Avaliação da utilização de pinos de titânio como auxiliares no tratamento ortodôntico**. Rio de Janeiro: Universidade Federal do Rio de Janeiro, 1996.
16. PARK, H. S.; KWON, O. W.; SUNG, J. H. Micro-implant anchorage for forced eruption of impacted canines. **J. Clin. Orthod.**, Boulder, v. 38, no. 5, p. 261-262, May 2004.
17. REN, Y.; MALTHA, J. C.; KUIJPERS-JAGTMAN, A. M. Optimum force magnitude for orthodontic tooth movement: a systematic literature review. **Angle Orthod.**, Appleton, v. 73, no. 1, p. 86-92, Feb. 2003.
18. ROBERTS, W. E.; SMITH, R. K.; ZILBERMAN, Y.; MOZSARY, P. G.; SMITH, R. S. Osseous adaptation to continuous loading of rigid endosseous implants. **Am. J. Orthod.**, St. Louis, v. 86, no. 2, p. 95-111, 1984.
19. SONG, Y. Y.; CHA, J. Y.; HWANG, C. J. Mechanical characteristics of various orthodontic mini-screws in relation to artificial cortical bone thickness. **Angle Orthod.**, Appleton, v. 77, no. 6, p. 979-985, Nov. 2007.
20. SOUTHARD, T. E.; BUCKLEY, M. J.; SPIVEY, J. D.; KRIZAN, K. E.; CASKO, J. S. Intrusion anchorage potential of teeth versus rigid endosseous implants: a clinical and radiographic evaluation. **Am. J. Orthod. Dentofacial Orthop.**, St. Louis, v. 107, no. 2, p. 115-120, 1995.

Contact address
Matheus Melo Pithon
Rua México 78 - Recreio
ZIP: 45.020-390 - Vitória da Conquista / Bahia
E-mail: matheuspithon@ufrj.br