In vitro flexural strength evaluation of a mini-implant prototype designed for Herbst appliance anchorage

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Abstract

Aim: The purpose of this study was to evaluate the limit of flexural strength of a mini-implant prototype designed for Herbst appliance anchorage. **Methods:** After sample size calculation, four specimens with the new mini-implant were submitted to a single cantilever flexure test using a universal testing machine. The limit of flexural force strength was calculated. **Results:** The mini-implant prototype showed a limit of flexural force strength of 98.2 kgf (982 N), that was the lowest value found. **Conclusion:** The mini-implant prototype designed for Herbst appliance anchorage can withstand flexural forces higher than the maximum human bite forces reported in the literature.

Keywords: Orthodontic appliances. Orthodontics. Herbst appliance. Mini-implant.

INTRODUCTION AND LITERATURE REVIEW

Mini-implants were conceived based on decreasing the length and diameter of existing implants, allowing new areas to be used as orthodontic anchorage according to the bone thickness.[5] Thus, mini-implants could be used for lower incisors intrusion, when inserted in the mandibular symphysis; for horizontal traction, when inserted in the alveolar crest; for molars intrusion, when inserted between its

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roots; or for molar distalization, when inserted in the palate.[11,12,13]

Other authors have suggested the use of implants as orthopedic anchorage in animals[7,19] and in Class III treatment due to a retrusive maxilla in humans.[8] On the other hand, in Class II treatments, the Herbst appliance[18] has been used frequently because of its efficiency[3] and also because of its positive effects in orthodontic and orthopedic correction.[10,14,15,16] However, some investigators have stated that there is certain lack of control in orthodontic movement (specially exaggerated lower incisor proclination), which could be associated with and increase in mandibular incisor crowding and gingival recession.[2,6]

In view of these problems and with the intention of solving them, a mini-implant was created for Herbst appliance anchorage. However, the first doubt was if this new mini-implant would be capable of resisting maximum bite forces (mean of approximately 756 N or 75.6 kgf).[1]

So, the purpose of this study was to evaluate, in vitro, the limit of flexural forces strength of a mini-implant prototype designed for Herbst appliance anchorage.

MATERIALS AND METHODS

Four specimens were used in this experiment and each one had three parts: the mini-implant prototype, a brass block which acted as a support for the setting, and a straight shaft from the telescopic tube (Dentaurum) of the Herbst appliance (Figs 1 and 2).

The brass blocks were machined to a rectangular section of 18 mm in width and 20 mm in length. A perforation was performed at the center of the squared section of the block in its long axis with a 1.9 mm diameter drill. A beveller was used on the perforation edge to permit the full adaptation of the conic profile of the mini-implant when it was inserted. For insertion torque standardization of the mini-implant in the brass block, a calibrated

FIGURE 1 - Mini-implant prototype with suitable screw, in lateral view.

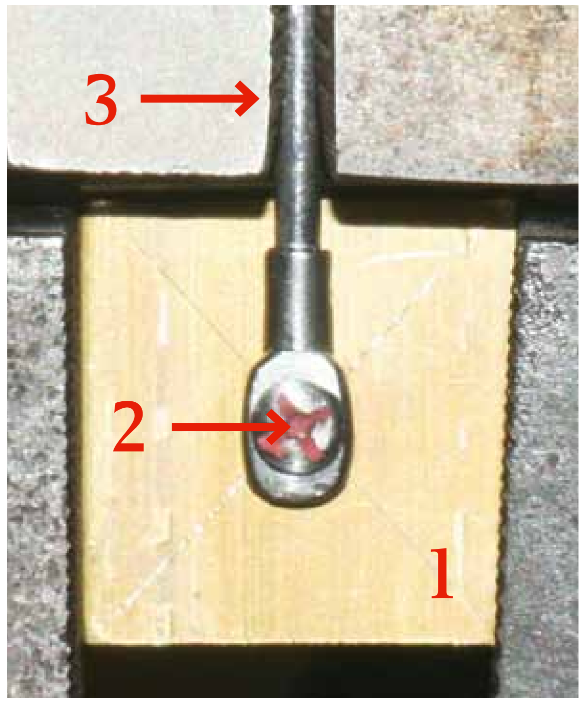

FIGURE 2 - Specimen used: (1) brass block, (2) mini-implant prototype with screw attached to the telescopic tube, (3) shaft of the telescopic tube of the Herbst appliance.

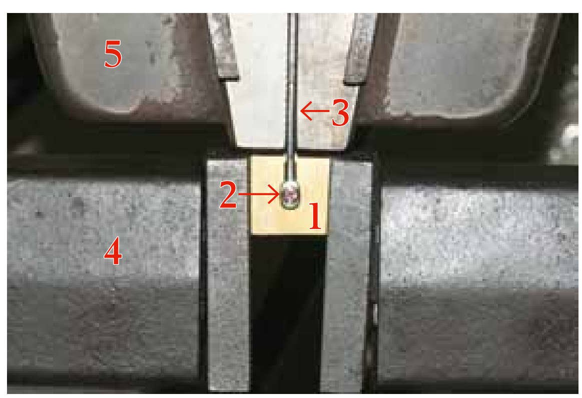

FIGURE 3 - Specimen in the test machine prior to the mechanical testing: (1) brass block, (2) mini-implant prototype, (3) shaft of the telescopic tube of the Herbst appliance, (4) and (5) clasps used during the tests.

torquimeter was used, not exceeding 30 cN.m. The mini-implant prototype was then carefully inserted with the torque key attached to the torquimeter, so that only the mini-implant head was exposed with the screw with 4.0 mm in length. Then, the shaft of the appliance was attached to the mini-implant prototype with a screw.

The mechanical test

The mechanical tests were performed in the IPEN (Nuclear and Energetic Research Institute) in the CCTM (Materials Technologic Research Center) located at USP (University of São Paulo). To perform the mechanical tests, the specimens were placed in the Instron 4400 R test machine, with the brass block attached to the lower clasp and the telescopic tube to the upper clasp, which were connected to a load cell of 100,000 N (Fig 3).

TABLE 1 - Maximum strength to flexure force recorded for each specimen, as well as the mean and standard deviation for the pilot study.

Specimens	Maximum strength to flexure force (N)
A	982
B	998
C	990
Mean	990
SD	08

TABLE 2 - Maximum strength to flexure force recorded for each specimen, as well as the mean and standard deviation found in this study.

Specimens	Maximum strength to flexure force (N)
A	982
B	998
C	990
D	988
Mean	989
SD	06

A single cantilever flexure test was performed, in which the flexure force application occurs with a distance from the brass block, generating a momentum. Flexural traction was applied at 0.5 mm per minute until the maximum strength was reached. The values were recorded, generating a strength x dislocation graph using a specific software provided by the equipment manufacturer (Fig 4).

Statistical analysis

Initially, a sample size calculation was carried out using a pilot study with three mechanical tests. The mean maximum resistance strength and standard deviation of the mini-implant prototype was calculated for each specimen using the software Instron Series IX (Table 1). Then, the following statistical[20] formula was used:

$$n = \frac{(Z \times s)^2}{D^2}$$

where n = number of specimens, Z = number of standard deviations from normal distribution, s = standard deviation and D = difference between a variable value and the average of values from this variable. As Z = 1.96 (95% of confidence interval), s = 8 and D = 8 (998 – 990). Calculating, n = 3.84 ≅ 4. The number of specimens needed for the study was 4.

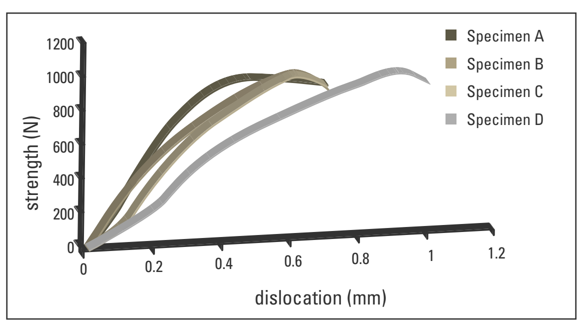

FIGURE 4 - Strength x Dislocation graph presenting the flexure test curves for the four specimens tested.

RESULTS

After the maximum flexure resistance tests performed on the specimens, a mean of 989 N was found, with a standard deviation of 6, a minimum value of 982 N and a maximum value of 998 N (Table 2).

Figure 4 shows the performance of the four specimens tested. It can be observed that there was a constant dislocation until the peak was reached. At this moment, the mini-implant started to be pulled out of the brass block or the telescopic tube had fractured.

DISCUSSION

Figure 5 shows a specimen in lateral view after the test, depicting the bending of the mini-implant and the telescopic tube of the Herbst appliance. The maximum force criteria used in this study is based on the indication that when plastic deformation occurs on the mini-implant or on the telescopic tube they are incapable of maintaining the loads, resulting in lower force levels. None of the tested mini-implants fractured, but all of them suffered permanent deformation.

Some modifications were done in the mini-implant prototype in relation to the mini-implants mostly used nowadays, which measure approximately 1.6 mm in diameter and 6 mm in length. These changes had the purpose of increasing the contact of the mini-implant prototype to the bone and, consequently, its resistance. So, the diameter was increased to 2.0 mm which is compatible with the mesio-distal distance between the roots of the upper first molars and second premolars and between the lower canines and first premolars (suggested location for the insertion of the mini-implant prototypes for Herbst appliance anchorage), which is 3-8 mm of distance from the alveolar crest.[17]

Although Miyawaki et al[12] did not find a significant association between the success rate and the mini-implant length, Brettin et al[4] concluded that bicortical mini-implants provide superior anchorage resistance, reduced cortical bone stress, and superior stability when compared with monocortical mini-implants. Therefore, in order to achieve bicortical anchorage, the length was increased to 10 mm.

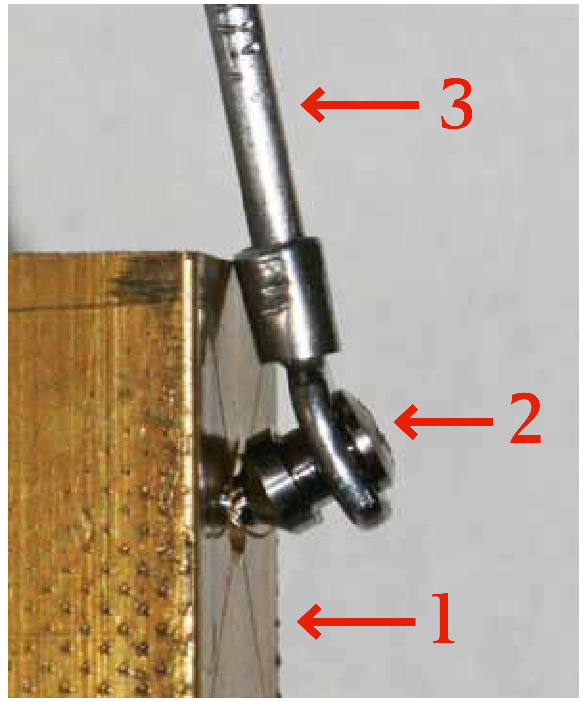

FIGURE 5 - Specimen after traction: (1) Brass block, (2) deformed mini-implant, and (3) deformed telescopic tube of the Herbst appliance.

In relation to the sample, it could be questioned the few specimens used in this study that is not common in Orthodontics. However, this number is common in other areas, such as Engineering and Physics, because of the smaller difference among the studied variables. So, a pilot study with three specimens allowed a sample size calculation.[20] This calculation showed that the number of specimens needed was four. In this case just one other mechanical essay was necessary.

Another issue to be discussed regarding the sample could be on its selection. Due to the fact that the mini-implant prototype was machined by a company specifically to be used as anchorage for the Herbst appliance and it is not commercially available, no random sample selection was performed, by selecting different mini-implants from different manufacturing batches, as is recommended for in vitro studies. Only one batch existed and this could explain why maximum force values found is this study were so similar, since different batches could present differences in titanium alloy composition or in dimensions, which could lead to slighter different results.

Another question that could arise would be the use of a brass block, rather than bone, to attach the mini-implant, which would be the material in which the mini-implants would regularly be inserted. It should be emphasized that the mechanical tests performed were technological essays, where the results are valid only for the specimen tested. Therefore, this study aimed only to test the mini-implant prototype resistance. It was necessary to insert the mini-implant into a rigid material, so as to evaluate only the performance of the mini-implant prototype. The brass was the better metal to be used, because the aluminium was not sufficiently resistant (an essay with a aluminium block showed 750 N of maximal mini-implant resistance and the hole of the block deformed). The steel was considered too resistant (three mini-implants fractured when inserted to steel blocks).

In relation to the mechanical essay performed, it was necessary to submit the mini-implant to a force perpendicular to its long axis, simulating the force received when it is used as Herbst appliance anchorage. Because there was a distance of 4 mm between the block base and the point of force application, the shear force test was not indicated because in this test this distance should not exist. The traction test also was not indicated because in this test the force is loaded parallel to the mini-implant long axis, not reproducing the force perpendicular to the long axis applied when the mini-implant is used as anchorage to the Herbst appliance. Therefore the single cantilever flexure test was the one which best simulated the usage conditions of the mini-implant, taking into consideration the momentum created by the distance between the point of force application and the brass block.

The mean maximum resistance strength of 989 N found in the present study and even the minimum strength of 982 N, that would be the resistance limit, were higher than the highest value found in the literature for human bite maximum force mean of 756 N[1]. It suggests that the mini-implant prototype could resist the maximum bite forces when used as a Herbst appliance anchorage. However, questions about mini-implant failure as Herbst anchorage are related to bone/mini-implant interface suggesting that, before clinical studies, other in vitro tests should be performed to evaluate the resistance of the mini-implant prototype when it is inserted in bone.

CONCLUSION

The mini-implants prototypes designed for Herbst appliance anchorage are capable to withstand single cantilever flexure forces of 982 N when fixed in a brass block and can withstand higher forces than the maximum human bite forces found in the literature.

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