**UCDARTICLE IN PRESS**

**ORIGINAL ARTICLE**

**Primary stability of orthodontic mini-implants inserted into maxilla and mandible of swine**

Matheus Melo Pithon,a Matilde Gonçalves Nojima,b and Lincoln Issamu Nojima,b Bahia and Rio de Janeiro, Brazil

**SOUTHWEST BAHIA UNIVERSITY AND FEDERAL UNIVERSITY OF RIO DE JANEIRO**

**Objective.** The objective of this study was to assess the primary stability of different orthodontic mini-implants inserted into different maxillary and mandibular regions of swine.

**Material and methods.** One hundred eighty orthodontic mini-implants produced by 5 different manufacturers, all presenting several shapes, were divided into 5 groups: Mondeal (M), Neodent (N), SIN (S), INP, and Titanium Fix (T). Fifteen pigs (Sus scrofa piau) were used for study and 12 mini-implants were inserted into 3 mandibular and maxillary regions. After insertion, the animals were killed and osseous blocks containing the mini-implants were obtained for mechanical pullout tests to be performed by a universal test machine at cross-head speed of 0.5 mm/s. Maximum force values (N/cm) for insertion were recorded and submitted to both analysis of variance and Tukey’s test.

**Results.** The primary stability provided by cylindrical mini-implants (groups M and I) was statistically significantly superior to that of conical mini-implants (groups N and S). On the other hand, screw-type mini-implants were shown to be statistically inferior compared with the others \((P < .05)\). Statistical differences between pullout forces at different oral cavity regions were also found \((P < .05)\). The mini-implants inserted into palatal suture had lesser stability, whereas those inserted into upper molar and premolar regions were shown to be more stable.

**Conclusions.** The shape of mini-implants, in association with location of insertion, is directly related to primary stability. (Oral Surg Oral Med Oral Pathol Oral Radiol 2012;xx:xxx)

The use of mini-implants for orthodontic anchorage is well established in the literature.\(^1\)-\(^3\) This approach has revolutionized orthodontics over the years, thus allowing stable anchorage to be reliably achieved.\(^4\)-\(^5\) However, to promote adequate anchorage opposing the reaction forces from the orthodontic movement, it is necessary to insert the mini-implants into bone tissue so that stability can be achieved.\(^6\)

Didactically, mini-implant stability can be either primary or secondary. The former involves direct contact between mini-implant and bone, whereas the latter (or late) occurs following a cicatrization.\(^7\) Primary stability is an important sign of a successful insertion, as most cases of failure involving mini-implants occur during the initial stages following such a procedure.\(^8\),\(^9\) The lack of stability may be related to osseous factors\(^10\) and mini-implant characteristics, including diameter, screw,\(^11\) and dimension of pilot perforation.\(^12\)-\(^14\)

When the stability of a given mini-implant has to be mechanically evaluated, one of the increasingly used methodologies is the pullout test,\(^15\),\(^16\) which is widely used in medical areas, such as orthopedics,\(^17\) neurosurgery,\(^18\),\(^19\) and cosmetic and maxillofacial surgery,\(^20\),\(^21\) for testing the primary stability of several screw devices. The pullout test consists of extracting the mini-implant from osseous tissue at constant speed, thus enabling the assessment of maximum force needed to remove the implanted device.

Because there are few studies that have assessed mini-implant stability in vivo, the objective of the present work was to evaluate the biomechanical behavior of orthodontic mini-implants of different shapes and diameters inserted in different regions of swine maxilla and mandible. The pullout test was used to relate the shape of mini-implants to their stability at different regions of the oral cavity.

**MATERIAL AND METHODS**

A total of 180 mini-implants from 5 different manufacturers (M [Mondeal, Tuttlingen, Germany], N [Neodent, Curitiba, Brazil], S [SIN, São Paulo, Brazil], I [INP, São Paulo, Brazil], and T [Titanium Fix, São Jose dos Campos, Brazil]), all presenting their own characteristics, were divided into 5 groups (n = 36 each...
Before insertion, the animals were deeply anesthe-
tized. First, 0.1 mg/kg of acepromazine maleate (Ace-
pran 1%, São Paulo, Brazil) and 2 mg/kg of meperidine
(Dolosal, São Paulo, Brazil) were administered intra-
muscularly as preanesthetic medications. After 15 min-
utes, vascular access (cephalic vein) was achieved
and 20 mg/kg of sodium ampicillin was immediately
administered. Anesthesia was induced with intrave-
nous propofol (2 to 4 mg/kg) and maintained during
orotracheal intubation using 100% oxygen through
an inhalation anesthetic system. The insertion pro-
cedures were performed with the animals under deep
anesthesia.

Four groups of mini-implants (M, N, S, and I) were
drilling screws, thus not requiring previous cortical
perforation; however, mini-implants from group T re-
quired pilot perforation of 1.1 mm in diameter before
insertion.

The insertion of mini-implants was performed by
using a surgical leader made of thermoactive resin
material and synthetic rubber (CTRBS, Tramontina,
Canoas, Brazil), aimed to mold the occlusal surfaces,
and a rectangular metal wire of 0.19 × 0.024 inch
(Moreli, Sococaba, Brazil), serving to locate and mark
the optimal local insertion. Periapical radiographs were
taken according to the surgical leader so that the central
radius was in parallel to the interproximal area. After
localization, the insertion area was cleaned with a so-
lution of 0.12% chlorhexidine digluconate. After local-
izing and disinfecting the area, a small gingival incision
was made to facilitate the insertion procedure, as pigs
have thicker gingiva.

The mini-implants were inserted by using a torque
screwdriver mounted on a digital calliper, thus allowing
both insertion and torque measurement to be perpen-
dicularly performed in relation to the osseous surface.

Next, all 15 animals were killed under deep general
anesthesia followed by administration of potassium
chloride until cardiorespiratory failure was achieved.
The animals’ maxillas and mandibles were dissected so

---

### Table I. Main characteristics and dimensions of mini-implants used in the present study

<table>
<thead>
<tr>
<th>Type</th>
<th>Screw design</th>
<th>Corporation</th>
<th>Length, mm</th>
<th>Body length, mm</th>
<th>Screw length, mm</th>
<th>Screw diameter, mm</th>
<th>Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Self-drilling</td>
<td>Mondeal</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>1.5</td>
<td>Ti-6Al-4V</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>Neodent</td>
<td>10</td>
<td>7</td>
<td>7</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>SIN</td>
<td>10</td>
<td>7</td>
<td>6</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>INP</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td></td>
<td>Titanium Fix</td>
<td>10</td>
<td>5</td>
<td>4.5</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Screw diameter, mm</th>
<th>Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>Ti-6Al-4V</td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

---

The mini-implants were inserted by using a torque
screwdriver mounted on a digital calliper, thus allowing
both insertion and torque measurement to be perpen-
dicularly performed in relation to the osseous surface.

Next, all 15 animals were killed under deep general
anesthesia followed by administration of potassium
chloride until cardiorespiratory failure was achieved.
The animals’ maxillas and mandibles were dissected so

---

**Figure 1.** A, Microphotograph of mini-implants after me-
chanical assay (magnification ×15). B, Mini-implants evalu-
ated. Images are available in color at www.ooooe.net.

---

The mini-implants were inserted by using a torque
screwdriver mounted on a digital calliper, thus allowing
both insertion and torque measurement to be perpen-
dicularly performed in relation to the osseous surface.

Next, all 15 animals were killed under deep general
anesthesia followed by administration of potassium
chloride until cardiorespiratory failure was achieved.
The animals’ maxillas and mandibles were dissected so
that bone blocks containing the mini-implant could be obtained. The samples were immersed in saline solution and then stored at −15°C for 15 days. After this period of time, the bone blocks were left at room temperature for mechanical assay.

The test was performed using a universal test machine (Emic DL 10.000, São José dos Pinhais, Brazil). A claw-shaped device was confected and mounted on the upper part of the machine so that the mini-implant could be removed. Another device served as a base for both fixing the bone block and keeping the mini-implant in a perpendicular position during the tests, thus avoiding momentum creation (Figure 3). Mechanical assay was performed at a crosshead speed of 0.5 mm/s for removing the mini-implant from osseous bone. Load and displacement values were recorded, as well as the maximum force (F_{max}) for posterior evaluation.

Following mechanical assays, the bone blocks were stained with eosin so as to differentiate the cortical medullar bone and then covered with acrylic resin (Clássico, São Paulo, Brazil). The blocks were sectioned by using a diamond disk and the cortical bone thickness was measured with a digital calliper (Starlet, São Paulo, Brazil) and ×16 magnifying stereoscopic glass (Carl Zeiss, Göttingen, Germany). In this way, the mean cortical values for the 6 regions containing mini-implants could be obtained in vivo, thus allowing a correlation between pullout test and cortical thickness values.

Experimental data from pullout tests were statistically analyzed using SPSS software v13.0 (SPSS Inc., Chicago, IL). Maximum force values (in N/cm²) were submitted to analysis of variance and Tukey’s test, wherein the former was applied to determine any statistical difference among the groups. The results were found to be statistically significant at \( P < 0.05 \).

RESULTS

The highest pullout values were achieved in group M, involving almost all combinations except for the lower incisor region, whereas group I had the highest mean values (\( P = 0.835 \)). The lowest values, on the other hand, were obtained in group T in all regions evaluated (Tables II and III).

With regard to those regions containing mini-implants, the highest pullout values were observed in the upper molar and lower molar, in the median palatal suture, which had the lowest values (Tables II and III).

The mean values of cortical thickness were 1.58 ± 0.14 (between incisors and upper canines), 2.56 ± 0.08 (premolars and upper molars), 0.92 ± 0.13 (median palatal suture), 1.4 ± 0.1 (lower incisor and canine), 2.44 ± 0.167 (lower premolars and molars), and 2.24 ± 0.08 (lower retro-molar) (Figure 4).

DISCUSSION

The objective of the present study was to evaluate the biomechanical behavior of orthodontic mini-implants of different shapes inserted in various regions of maxilla and mandible for the pullout test. Such information provided preliminary data to the practitioner regarding
the choice of specific mini-implant based on the region for insertion.

The pullout test consists of extracting the mini-implant from osseous tissue perpendicularly and at constant speed. This method, which is extensively used in several areas of medicine, has been increasingly used in orthodontics since an article by Huja et al. was published.

Despite the nontraction force being applied to mini-implants, the values obtained during mechanical assay show “imbrication” between the screw-part of mini-implants and the osseous tissue in which they are inserted.

Piau pigs (Sus scropha) were the experimental animal model used in the present study. This choice was based on the similarity between humans and swine in terms of maxillary bone, a fact that is well known and well established in the literature.

The present study assessed the force exerted on mini-implants inserted into different osseous regions of the oral cavity of swine. The animals were killed after the mini-implant insertion and consequently no healing

<table>
<thead>
<tr>
<th>Groups</th>
<th>Incisor/Canine</th>
<th>Tukey*</th>
<th>Pre/Molars</th>
<th>Tukey*</th>
<th>Suture</th>
<th>Tukey*</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>249.54 ± 9.56</td>
<td>A</td>
<td>285.03 ± 14.65</td>
<td>A</td>
<td>180.40 ± 5.09</td>
<td>A</td>
</tr>
<tr>
<td>N</td>
<td>172.94 ± 8.07</td>
<td>B</td>
<td>253.74 ± 13.40</td>
<td>BC</td>
<td>95.144 ± 2.93</td>
<td>C</td>
</tr>
<tr>
<td>S</td>
<td>161.26 ± 10.1</td>
<td>B</td>
<td>227.78 ± 14.34</td>
<td>B</td>
<td>86.47 ± 2.63</td>
<td>C</td>
</tr>
<tr>
<td>I</td>
<td>178.79 ± 15.7</td>
<td>B</td>
<td>264.88 ± 13.42</td>
<td>AC</td>
<td>114.63 ± 17.66</td>
<td>B</td>
</tr>
<tr>
<td>T</td>
<td>86.91 ± 20.03</td>
<td>C</td>
<td>180.94 ± 15.73</td>
<td>D</td>
<td>79.62 ± 5.78</td>
<td>C</td>
</tr>
</tbody>
</table>

M, Mondeal; N, Neodent; S, SIN; I, INP; T, Titanium Fix.

*Statistical analysis in which equal letters correspond to absence of statistical differences (P < .05).

the choice of specific mini-implant based on the region for insertion.

The pullout test consists of extracting the mini-implant from osseous tissue perpendicularly and at constant speed. This method, which is extensively used in several areas of medicine, has been increasingly used in orthodontics since an article by Huja et al. was published.

Despite the nontraction force being applied to mini-implants, the values obtained during mechanical assay show “imbrication” between the screw-part of mini-implants and the osseous tissue in which they are inserted.

Piau pigs (Sus scropha) were the experimental animal model used in the present study. This choice was based on the similarity between humans and swine in terms of maxillary bone, a fact that is well known and well established in the literature.

The present study assessed the force exerted on mini-implants inserted into different osseous regions of the oral cavity of swine. The animals were killed after the mini-implant insertion and consequently no healing

<table>
<thead>
<tr>
<th>Groups</th>
<th>Incisor/Canine</th>
<th>Tukey*</th>
<th>Pre/Molars</th>
<th>Tukey*</th>
<th>Retromolar</th>
<th>Tukey*</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>169.64 ± 14.62</td>
<td>AC</td>
<td>271.06 ± 10.91</td>
<td>A</td>
<td>250.91 ± 12.48</td>
<td>A</td>
</tr>
<tr>
<td>N</td>
<td>159.56 ± 21.32</td>
<td>AC</td>
<td>238.47 ± 10.54</td>
<td>B</td>
<td>247.30 ± 12.25</td>
<td>A</td>
</tr>
<tr>
<td>S</td>
<td>148.01 ± 21.83</td>
<td>AC</td>
<td>221.096 ± 16.77</td>
<td>BC</td>
<td>221.8 ± 10.21</td>
<td>B</td>
</tr>
<tr>
<td>I</td>
<td>182.57 ± 17.00</td>
<td>A</td>
<td>252.87 ± 19.2</td>
<td>AB</td>
<td>250.15 ± 8.57</td>
<td>A</td>
</tr>
<tr>
<td>T</td>
<td>136.54 ± 22.44</td>
<td>C</td>
<td>204.82 ± 22.00</td>
<td>C</td>
<td>180.76 ± 19.90</td>
<td>C</td>
</tr>
</tbody>
</table>

M, Mondeal; N, Neodent; S, SIN; I, INP; T, Titanium Fix.

*Statistical analysis in which equal letters correspond to absence of statistical differences (P < .05).
process could change the results. Therefore, the initial stability between different mini-implants in different areas of oral cavity was reliably achieved.

Groups S and N showed mean values smaller than groups M and I for all regions evaluated, although no statistical differences were observed. The shape of mini-implants had enormous influence on such differences. Conical-shaped mini-implants, for instance, had smaller values because of the displacement toward a broader region, thus resulting in a lower resistance. On the other hand, mini-implants from groups M and I had the highest pullout values for all insertion regions, a finding certainly related to their format. The cylindrical shape enabled the same bone area to be in contact with the screw part of the mini-implant during the mechanical test; that is, there was greater osseous contact.

The diameter of mini-implants did not have a decisive influence on primary stability, as groups M and I had mean values greater than those of groups N and S, although the former had a small diameter (1.5 mm) compared with the latter (1.6 mm).

Group T was included to evaluate the behavior of self-tapping in comparison with self-drilling. Compared with other groups, one can observe that primary stability was inferior in all regions containing these mini-implants. Because self-tapping mini-implants do not have self-drilling characteristics (e.g., small thread width), the osseous contact is rather unstable. Another factor possibly contributing to these differences would be pilot perforation. These results are in accordance with findings by Yano et al., who assessed histologically the osseous contact with both self-drilling and self-tapping mini-implants. According to the authors, there should be a healing period before using self-tapping mini-implants for anchorage.

The mean pullout force values between the mini-implants inserted in all the regions of the oral cavity ranged from 79.62 to 295.03 N. The lowest mean values were observed in group T, which had mini-implants inserted in the region of median palatal suture, whereas the highest mean values were observed in group M, which had mini-implants inserted between the upper molar and premolars. Other authors, who also evaluated in vivo the primary stability by using the pullout test, corroborate the values found in the present work.

As the pullout test was initially performed in vivo and then in vitro, a concern exists regarding storage of the samples and time elapsed between when the pigs were killed and the mechanical test. Earlier studies on pullout force demonstrated force variation over time; that is, between insertion and pullout assay. Roe et al., who tested 1-week samples stored at −20°C, reported lack of statistical differences when the test was carried out immediately after the animals were killed. Other works report a decrease in pullout force as storage time was extended from 4 to 8 weeks. In the present work, the samples were dissected immediately after the animals were killed, and then stored in saline solution for 15 days at −15°C. The procedures followed were in accordance with other studies on orthodontic mini-
implants.\textsuperscript{15,16} On the 15th day, the samples were left at room temperature to gradually unfreeze. To fix the bone fragment during the mechanical test, a metallic device was confectioned that was mounted on a universal test machine. The inferior part of the device was made to keep the mini-implant perpendicularly positioned on the base without having to apply resin to the osseous block, as suggested elsewhere.\textsuperscript{15,16} This decision was made because of the reduced size of the sample and the possibility of resin penetration into the osseous tissue, which might mask the results.

Studies evaluating screw pullout performed immediately following insertion and 8 weeks later found no statistical differences.\textsuperscript{26} In another study on titanium implants inserted in facial bones, only a modest gain in the pullout strength was measured after comparing the healing periods of 1, 2, 3, 4, 6, 9, 12, and 32 weeks. Based on these works, the secondary stability required during the treatment is directly related to the primary stability achieved during insertion of mini-implants. However, further studies are needed to evaluate the primary and secondary stability of mini-implants without force application.

In general, the optimal forces required for orthodontic movement range from 0.3 to 4.0 N. The pullout forces found in the present study were significantly greater than those for clinical purposes, which validates the oral cavity regions studied as well as the different types of mini-implants. Because cortical thickness is recognizably important in terms of primary stability of mini-implants, it was necessary to measure it so as to qualify and quantify the regions chosen for insertion. The median palatal suture had the least thickness, with mean value of 2.56 ± 0.08. These results are directly related to the primary stability achieved by using different types of mini-implants and are also supported in the literature.\textsuperscript{16,27}

**CONCLUSIONS**

- Cylindrical mini-implants were found to have greater primary stability compared with the conical mini-implants.
- The primary stability of mini-implants is directly related to their shape and the regions of the oral cavity in which they will be inserted.
- The thicker the alveolar cortical bone, the greater the stability of mini-implants.

**REFERENCES**

21. Heidemann W, Gerlach KL, Grøbel KH, Köllner HG. Influence of different pilot hole sizes on torque measurements and pullout


Reprint requests:
Matheus Melo Pithon
Southwest Bahia University, UESB
Av. Otávio Santos, 395, Sala 705
Centro Odontomédico Dr. Altamirando da Costa Lima.
Vitória da Conquista, Bahia, Brazil
matheuspithon@bol.com.br