Orthodontic mini-implant diameter does not affect in-situ linear microcrack generation in the mandible or the maxilla

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Introduction: Microdamage reduces bone mechanical properties and thus could contribute to implant failure. The objective of this study was to investigate whether the diameter of mini-implants affects linear microcrack generation and whether this differs between the mandible and the maxilla because of their contrasting cortical thicknesses. Methods: Maxillary and mandibular quadrants of 5 dogs were randomly assigned to receive, in situ, no pilot drilling or mini-implant insertion (control), pilot drilling only without mini-implants, or pilot drilling plus a mini-implant of 1 of 3 diameters: 1.4 mm (n = 18), 1.6 mm (n = 18), and 2.0 mm (n = 18). Linear microcracks were assessed on basic fuchsin-stained sections by using epi-fluorescence microscopy.

Results: Pilot drilling without mini-implant insertion produced significantly higher linear microcrack burdens in the mandible compared with the maxilla. In the both the mandible and the maxilla, all implants produced higher linear microcrack burdens than did the controls, yet there were no differences between the 3 implant diameters. Conclusions: Neither the diameter of the mini-implant nor the site of insertion (mandible vs maxilla) had a significant effect on the amount of linear microdamage adjacent to the implant when the implants were inserted after pilot drilling in situ. (Am J Orthod Dentofacial Orthop 2012;142:768-73)
mini-implants and whether this differs between the sites of insertion (maxilla vs mandible). We hypothesized that mini-implants with greater diameters would generate more linear microdamage compared with smaller-diameter implants, and that the mandible would have higher amounts of linear microdamage than the maxilla for a given implant size.

MATERIAL AND METHODS

We used 5 mongrel dogs (weight, 20–25 kg; age, 1–1.5 years) that were part of an approved study at our university unrelated to the maxillofacial skeleton. Quadrants of each bone were randomly assigned to 1 of 5 implant groups. Each group received mini-implants with diameters of 1.4 mm (n = 18), 1.6 mm (n = 18), and 2.0 mm (n = 18) after pilot drilling, pilot drilling without mini-implant insertion, or no pilot drilling or mini-implant insertion (control). The maxillary and mandibular quadrants received 4 and 5 mini-implants, respectively (Fig 1). All mini-implants (Rocky Mountain Orthodontics, Denver, Colo) were 6 mm long. After the dogs were killed, the mucosa and the periosteum were reflected, and mini-implants were inserted manually after pilot drilling with a 1.0-mm-diameter surgical drill (Dentaurum, Newton, Pa) with a contra-angle hand piece (Aseptico, Woodinville, Wash) with copious saline-solution irrigation.

After the surgical treatment, each mini-implant, pilot hole, or similar region was sectioned with surrounding bone (approximately 2.0 × 2.0 cm) and immediately fixed in 70% ethyl alcohol for 7 days. The blocks were stained en bloc in 1% basic fuchsin hydrochloride in a graded series of alcohols under vacuum according to standard protocols. The blocks were embedded in methyl methacrylate, sectioned along the mini-implant axis by using an IsoMet low-speed saw (Buehler, Lake Bluff, Ill), and ground and polished to approximately 150 to 160 μm by using a grinding system (Exakt Technologies, Oklahoma City, Okla). The use of basic fuchsin staining allows visualization of microdamage with an epifluorescence microscope (Optiphot 2 microscope; Nikon, Tokyo, Japan) and is essential to differentiate cracks caused from the implant (stained) from cracks formed during grinding and polishing of the histologic slides (unstained). Linear microcracks in the cortical bone adjacent to the mini-implant were identified under an epifluorescence microscope with an excitation wavelength of 546 by using Osteo II software (Bioquant Image Analysis, Nashville, Tenn) according to specific parameters. Specifically, the cracks needed to match these criteria: (1) larger than canaliculi but smaller than vascular channels, (2) sharp borders, and (3) upon a change in depth of focus, their edges appeared more deeply stained than the intervening space. Linear microcrack assessment was conducted at 10 times objective magnification (Fig 2) by measuring the crack numbers and lengths and the implant surface length adjacent to the mini-implant (Fig 3). The number of cracks for each implant was summed, and the crack density (number of cracks divided by implant surface length) and the total microdamage burden per surface length (number of cracks × average crack length divided by implant surface length) were calculated. For the group with pilot drilling without mini-implants, microdamage was measured relative to the surface of the pilot hole. For the controls without drilling or mini-implant insertion, microdamage was identified in a general region similar to that of the implants. Cortical bone thickness was also measured by using epifluorescence with 4 times objective magnification. All measurements were made by 1 examiner (E.C.-M.). Intrarater reliability ranged from 0.90 to 0.97 for all parameters based on the intraclass correlation between 2 blinded measurements with a 2-week interval on 10 randomly selected sections.

**Statistical analysis**

Statistical analyses were performed by using SPSS statistical software (version 19; IBM, Armonk, NY). Unpaired t tests were used to compare the cortical thicknesses of the maxilla vs the mandible. The effects of implant size (1.4, 1.6, and 2.0 mm; pilot drilling; and control), insertion site (4 in the maxilla, 5 in the mandible), and jaw (maxilla or mandible) on microdamage were assessed by using a 3-way analysis of variance (ANOVA). When there were no interactions between the jaw and other factors, separate 1-way ANOVA tests were
Parameters of mini-implants in the maxilla produced minimal yet quantifiable level of linear microdamage density (6.94 ± 19.62 µm/µm). Insertion of all 3 diameters of mini-implants in the maxilla produced a significantly higher total linear microcrack burden compared with both pilot drilling and the controls without drilling or mini-implants (Fig 4, A). This was the result of both a greater number of cracks and an increase in mean crack length. There was no significant difference in the total linear microcrack burden among the 3 implant sizes (1.4 mm, 77.28 ± 23.79 µm/µm; 1.6 mm, 69 ± 13.79 µm/µm; and 2.0 mm, 75.69 ± 13.67 µm/µm).

In the mandible, drilling a pilot hole generated a greater linear microcrack burden (76.0 ± 67.47 µm/µm) compared with the no drilling, no mini-implant controls (none) (Fig 4, B). There was no difference in the total linear microcrack burdens between pilot drilling without mini-implants and any of the 3 diameters of mini-implants, or among any of the 3 diameters of implants. Insertion of mini-implants with diameters of 1.4, 1.6, and 2.0 mm produced 74.0 ± 19.98, 109.67 ± 84.89, and 84.62 ± 17.01 µm/µm linear microcrack burdens, respectively. Despite the lack of difference in total microcrack burdens, significantly more microcracks were generated by the 2.0-mm mini-implants compared with pilot drilling without mini-implant insertion (Table).

The cortical thickness was significantly higher (+46%) in the mandible (2325 ± 341 µm) compared with the maxilla (1597 ± 549 µm). There was no significant correlation between cortical thickness and any microdamage parameter.

**DISCUSSION**

Despite increased usage, the mini-implant success rate is lower compared with traditional dental implants. It has been suggested that inserting a larger-diameter mini-implant in the mandible with a thicker cortex causes a greater amount of linear microdamage, potentially contributing to a higher failure rate relative to the maxilla.\(^{19-21}\) Our study documents that, after pilot-hole drilling, the diameter of the mini-implant has no effect on the generation of linear microcracks.

Overall, the amount of linear microcracks in the mandible was significantly higher than in the maxilla. This was due to significantly greater damage in the pilot-drilling group (without mini-implant insertion) between the 2 bones, since there was no significant difference between the bones with any of the 3 mini-implant diameters. The thicker cortex in the mandible is likely to necessitate higher forces during pilot drilling. This might explain why pilot drilling produced few linear microcracks in the maxilla but more in the mandible. The amount of damage in the mandible after pilot drilling was comparable with that in the maxilla after implant insertion. These data indicate...
that most linear microcracking was produced while drilling a pilot hole through the thick mandibular cortex, and only a small amount of additional microdamage was created during implant insertion. This could explain why the 3 diameters of implants yielded similar levels of linear microcracks because the insertion resistance might have been mostly eliminated during pilot drilling.

Differences in tissue-level mineralization could also contribute to the differences in linear microcracks between the 2 bone sites in response to pilot drilling. The higher cortical thickness in the mandible is likely to result in a greater number of highly mineralized interstitial regions. Increased mineralization is known to be associated with greater microdamage. It is therefore possible that, even if the drilling forces were similar between the 2 bones, greater microdamage could be generated in the mandible because of mineralization.

In both the maxilla and the mandible, the mini-implant diameter did not significantly affect linear microcrack production. This is consistent with a large-scale retrospective study in which the authors concluded that mini-implant diameter was not a critical factor in the failure rate. However, it directly contradicts a recent study by Lee and Baek, who reported that larger mini-implants produce more microdamage. They used tibias and assessed microdamage without basic fuchsin staining. The tibia has a significantly slower bone remodeling rate compared with the oral bones, and this will significantly influence the mineralization level and, therefore, the microdamage generation.

All data are presented as means and standard deviations.

**Table.** Cortical thickness and microdamage parameters in the maxilla and the mandible

<table>
<thead>
<tr>
<th></th>
<th>Cortical thickness (µm)</th>
<th>Implant surface length (µm)</th>
<th>Number of cracks</th>
<th>Crack length (µm)</th>
<th>Crack density (number of cracks/µm) × 10⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td></td>
<td></td>
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<tr>
<td>Control</td>
<td>1524 ± 528</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Pilot drilling</td>
<td>1913 ± 496</td>
<td>4118 ± 1111</td>
<td>0.5 ± 1.41</td>
<td>13.99 ± 39.58</td>
<td>0.116 ± 0.327</td>
</tr>
<tr>
<td>1.4-mm MI</td>
<td>1613 ± 751</td>
<td>4595 ± 2274</td>
<td>10.5 ± 4.75</td>
<td>215.62 ± 63.95</td>
<td>2.726 ± 1.915</td>
</tr>
<tr>
<td>1.6-mm MI</td>
<td>1434 ± 512</td>
<td>4422 ± 1852</td>
<td>8.13 ± 4.73</td>
<td>209.3 ± 41.65</td>
<td>2.138 ± 1.613</td>
</tr>
<tr>
<td>2.0-mm MI</td>
<td>1492 ± 378</td>
<td>4847 ± 1015</td>
<td>11 ± 4.5³</td>
<td>248.93 ± 46.79</td>
<td>2.413 ± 1.057</td>
</tr>
<tr>
<td>Mandible</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2437 ± 283</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Pilot drilling</td>
<td>2466 ± 354</td>
<td>5013 ± 964</td>
<td>4.1 ± 5.65</td>
<td>158.4 ± 149.32</td>
<td>0.852 ± 1.192</td>
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<tr>
<td>1.4-mm MI</td>
<td>2172 ± 281</td>
<td>6296 ± 987</td>
<td>10.4 ± 5.38</td>
<td>213.27 ± 55.23</td>
<td>1.650 ± 0.806</td>
</tr>
<tr>
<td>1.6-mm MI</td>
<td>2283 ± 380</td>
<td>6944 ± 1610</td>
<td>11 ± 6.88</td>
<td>267.75 ± 70.82</td>
<td>1.628 ± 0.916</td>
</tr>
<tr>
<td>2.0-mm MI</td>
<td>2269 ± 368</td>
<td>7593 ± 1207</td>
<td>14 ± 6.11</td>
<td>283.09 ± 54.04</td>
<td>1.835 ± 0.749</td>
</tr>
</tbody>
</table>

All data are presented as means and standard deviations.

*P < 0.05 between the mandible and the maxilla when all conditions (control, pilot drilling, and 3 mini-implant diameters) were combined; ^P < 0.05 vs maxilla in treatment (control, pilot drilling, or 1 of 3 mini-implant diameters) condition; \(^P<0.05\) vs control in bone; \(^P<0.05\) vs pilot drilling in bone.
similarly generated during processing across all treatment groups, this should not be assumed to be true.

The balance between linear microcrack formation and removal determines the in-vivo skeletal microdamage burden.42 Our study, with in-situ insertion of implants, was focused on linear microcrack generation and thus cannot address the total influence of damage on mini-implant integration or failure. Differences in implant diameter could influence other aspects of implant integration, such as induction of remodeling. Furthermore, implant diameter could interact with other factors of mini-implants (eg, when the implant is loaded) to influence microdamage. It was also beyond the scope of this study to determine any direct relationship between microdamage and implant failure.

CONCLUSIONS

Neither the diameter of the mini-implant nor the site of insertion (mandible vs maxilla) had a significant effect on the amount of linear microdamage adjacent to the implant when they were inserted after pilot drilling in situ. These data provide a foundation for future work investigating the physiological effects of mini-implants.

REFERENCES


