An in vitro study of temperature changes in type 4 bone during implant placement: bone condensing versus bone drilling

Tijana Misic, DDS, a Aleksa Markovic, DDS, PhD,b Aleksandar Todorovic, DDS, PhD,c Snjezana Colic, DDS, PhD,b Scepanovic Miodrag, DDS, MSc,d and Biljana Milicic, MD, PhD,e Belgrade, Serbia

FACULTY OF STOMATOLOGY, UNIVERSITY OF BELGRADE

Objective. The aim of this study was to compare changes in temperature of the surrounding bone at various osteotomy depths during implant site preparation by bone condensing and by bone drilling as well as the dynamics of their change.

Study design. In the present “in vitro” study, pig ribs with uniform thickness of cortical bone of 2 mm were used. Lateral bone-condensing (experimental group) and bone-drilling techniques (control group) were performed. Temperature changes were recorded at a distance of 0.5 mm from the final test osteotomy by 3 thermocouples at the depths of 1, 5, and 10 mm in tripod configuration. Data were collected from 48 measurements, 24 for each group.

Results. Significantly higher mean temperature increase at the depth of 5 mm was observed during bone drilling compared with bone condensing, whereas for the depths of 1 and 10 mm differences were not significant between the 2 surgical techniques. During bone condensing, the mean temperature rise was continuously decreasing with increasing depth of osteotomies, whereas during bone drilling the mean temperature rise was first increased and reached a peak at the depth of 5 mm and then began to decrease with increasing depth of the osteotomies.

Conclusions. The bone-condensing technique applied in the jaw bone class D4 offers an advantage over bone drilling because it generates a significantly smaller amount of heat. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:28-33)

Jaw bone quality and quantity are of utmost importance for successful dental implant therapy.1 The lower success rates, which vary from 50% to 94% in D4 class of bone, were recorded because of a lack of primary stability.2 This type of bone is often present in the molar region of the upper jaw.3 Several therapeutic protocols related to surgical preparation, implant design, and implant surface texture are suggested for increasing success rates in low-density bone.2 Summers4 recommended the use of bone condensing instead of the conventional (bone drilling) technique for implant site preparation in D4 class of bone to increase primary stability of implant by bone trabeculae condensing.

During bone drilling, no matter how careful the preparatory technique, a necrotic border zone will inevitably appear around any surgically created implant site. The width of this necrotic zone will primarily depend on the generated frictional heat at surgery. This frictional heat causes necrosis of surrounding differentiated and undifferentiated cells and impairs osseointegration.5

Heat generated during implant site preparation is a result of energy released during breaking intermolecular bonds by a drill bit and also a result of friction between the noncutting surfaces of a drill and the bone.6 The temperature and duration of exposure determine the bone tissue response to heat.7 Eriksson and Albrektsson8 established that the threshold level for bone survival during implant site preparation is 47°C keeping drilling time to less than 1 minute. Bone necrosis occurs as a result of the following intracellular changes: protein denaturation, i.e., inactivation of enzymes for cell metabolism, and alterations in protoplasmic lipids, also cell dehydration, membrane rupture and finally carbonization.9 Generated heat causes dislocation in the hydroxyapatite mineral lattice structure and microscopic creeps of compact bone.10 Iyer and Mehta11 established that a temperature increase of only...
4.3°C during implant site preparation causes a significant difference in the quality of “de novo” formed bone.

Surgical technique factors that influence the change in temperature during the implant site preparation include applied force, speed of drill rotation, drill diameter and design, drill wear, the effect of different temperature of saline used for irrigation and the effect of surgical drill guide were investigated in several studies owing to their great importance.11-17

The aim of the present study was to compare changes in temperature of the surrounding bone formed during implant site preparation by bone condensing and by bone drilling. The authors also aimed to investigate changes in temperature increase at various depths of the osteotomies within the same surgical technique and to compare dynamics of temperature increase for both surgical techniques.

MATERIAL AND METHODS

In the present “in vitro” study, pig ribs with uniform thickness of cortical bone of 2 mm were used to simulate class D3 and D4 (by Carl Misch) of human jaw bone.3,18 All specimens were obtained from male animals, 6 months old and 120 kg weight. To minimize changes in bone physical properties, specimens were prepared according to the guidelines established by Sedlin and Hirsch, that is, the bone was kept wet at all times, stored frozen in saline at –10°C, and used within 3 to 4 weeks.

According to the surgical technique for implant site preparation, bone specimens were randomly divided into 2 groups: lateral bone-condensing (experimental group) and conventional bone-drilling technique (control group).

The temperature was measured by 3 thermocouples (Energyx, Nis, Serbia), with temperature range 0 to 90°C and sensitivity ±0.1°C. Thermocouples were calibrated by comparative method and a relative humidity–temperature (RHT) sensor (Sensirion, StaeFa, Switzerland) was used as a referent. Each of 3 thermocouples was connected to the data-acquisition system EUROtherm Mt-02-4T (Energyx, Serbia) with data measurement frequency 3 second−1, which allowed constant, real-time temperature readings. Data were sent to a personal computer (PC). PC-applicative software created in Visual Pascal was used to generate temperature reports.

Thermocouples were vertically positioned around every future implant site at distance of 0.5 mm from the final drill/condenser periphery (ø3.5 mm, Straumann, Waldenburg, Switzerland). The radial position of thermocouples was chosen to minimize interference between them. Thermocouples were placed in their canals in the bone: 1 in corticalis at the depth of 1 mm and 2 in cancellous bone at depths of 5 and 10 mm.

Constant distances between thermocouples and final bone condenser/surgical drill were secured by a drill guide template. A metal, rectangular template with dimensions of 70 × 15 × 3 mm was constructed to guide the preparation of thermocouple canals and to mark the center of the future implant site. The template had the following perforations: 4 central holes ø 3.5 mm for test osteotomies; 12 holes for thermocouple canals, that is, 3 around every central hole at the distance of 0.5 mm; and, finally, 2 screw holes at the ends for fixing the template to a specimen (Fig. 1).

The experimental procedure was conducted in the following manner. The specimen was fixed with the inferior half submerged in the thermostat-controlled water bath at 37 ± 1°C. The superior half of the specimen was at room temperature (26°C). The template was fixed to the specimen (Fig. 2), canals for...
Thermocouples were prepared, centers of the future implant sites were marked, and the template was removed. Three thermocouples were placed in their canals around the place for the first future implant site. The entrance of each thermocouple’s canal was sealed with bone wax to isolate the probes from influences from the outer environment. The samples were heated in a water bath and implant site preparation began when the specimen, as measured by the implanted thermocouples, reached a temperature of 29 ± 1°C to simulate human jaw bone temperature. In the experimental group, the bone-condensing technique was used for implant site preparation. An implant site 10 mm deep was prepared into the specimen using marker burs ø 1.4 mm and ø 2.3 mm, pilot drill ø 2.2 mm, and a series of increasing diameter bone condensers ø 2.8 mm and ø 3.5 mm (Straumann) without irrigation. The condensation procedure was performed in an intermittent manner, by lightly tapping bone condensers with a surgical mallet (Fig. 3). The condenser was removed by a simultaneous pulling and rotating motion. In this study, all preparations were made by the same experienced operator for standardizing the operational procedure, especially applied force. In the control group, conventional bone drilling was used. Drilling procedures were undertaken with the use of a conventional dental handpiece with a physio-dispenser (W&H, Burmoos, Austria). A series of burs of increasing diameters (Straumann): round burs ø 1.4 mm and ø 2.3 mm, pilot drills ø 2.2 mm and ø 2.8 mm, and twist drill ø 3.5 mm were used at a speed of 500 to 600 rpm to simulate clinical conditions (Fig. 4). Irrigation was conducted by saline solution at 5°C, at a rate of 50 mL/min according to the manufacturer’s instructions (control group). Constant level of water in a water bath was secured by aspirating the saline near the site of preparation. Initial bone
Table I. The bone temperature increase (°C) during implant site preparation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-mm depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling</td>
<td>2.17</td>
<td>2.20</td>
<td>0.71</td>
<td>0.6</td>
<td>3.4</td>
<td>1.83-2.51</td>
</tr>
<tr>
<td>Condensing</td>
<td>2.08</td>
<td>2.02</td>
<td>0.68</td>
<td>1.2</td>
<td>3.5</td>
<td>1.74-2.41</td>
</tr>
<tr>
<td>5-mm depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling</td>
<td>2.82</td>
<td>2.80</td>
<td>0.76</td>
<td>1.6</td>
<td>4.4</td>
<td>2.43-3.20</td>
</tr>
<tr>
<td>Condensing</td>
<td>1.93</td>
<td>1.89</td>
<td>0.58</td>
<td>1.0</td>
<td>2.9</td>
<td>1.62-2.24</td>
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<tr>
<td>10-mm depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling</td>
<td>1.74</td>
<td>1.85</td>
<td>0.54</td>
<td>1.0</td>
<td>2.9</td>
<td>1.45-2.03</td>
</tr>
<tr>
<td>Condensing</td>
<td>1.78</td>
<td>1.67</td>
<td>0.53</td>
<td>1.2</td>
<td>2.9</td>
<td>1.46-2.10</td>
</tr>
</tbody>
</table>

Table II. Differences in the bone temperature increases (°C) between 2 surgical techniques

<table>
<thead>
<tr>
<th>Bone drilling</th>
<th>Bone condensing</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-mm depth</td>
<td>2.17 ± 0.71</td>
<td>2.08 ± 0.68</td>
</tr>
<tr>
<td>5-mm depth</td>
<td>2.82 ± 0.76</td>
<td>1.93 ± 0.58</td>
</tr>
<tr>
<td>10-mm depth</td>
<td>1.74 ± 0.54</td>
<td>1.78 ± 0.53</td>
</tr>
</tbody>
</table>

Values are given as mean ± standard deviation of the mean.

* t test.
† Not statistically significant.
‡ Statistically significant.

There is a significant difference in the dynamics of the mean maximum temperature rise at given depths of the osteotomies between the compared surgical techniques (2-way ANOVA with repeated measurements, P = .0320). During bone condensing, the mean temperature rise was continuously decreasing with increasing depth of osteotomies, whereas during bone drilling the mean temperature rise first increased and reached a peak at the depth of 5 mm and then began to decrease with increasing depth of the osteotomies (Fig. 5).

DISCUSSION

Previous studies have shown that bone-condensing technique significantly improves the success rate of endosseous implants placed in bone type D4 compared with conventional technique. Nkenke et al.\textsuperscript{21} announced that the percentage of the bone-to-implant contact during the first 8 weeks of healing significantly increased after the application of bone condensation in relation to bone drilling. They have also shown that bone condensation leads to increased new bone formation and enhanced osseointegration of dental implants in spongy bone.

Heat generated during drilling is an important factor for achieving osseointegration.\textsuperscript{5} There is a lack of studies that compare the amount of heat generated during the bone-condensing to bone-drilling technique. To
achieve this, we applied thermocouple technology that involves setting up of heat-sensitive elements in the previously drilled canals in the bones. Application of this traumatic method in “in vivo” studies is not suitable from an ethical point of view. We chose “in vitro” study design using specimens of dead bone, which might have certain limitations. In the “in vivo” conditions, blood flow could dissipate some heat generated during the implant site preparation. Also, during the preparation of bone, coagulation and occlusion of small blood vessels is likely to occur quickly, which questions the cooling effect that blood flow could have. Because of bone condensation, broken trabeculae could disrupt the vascular network in the surrounding bone and impair fluid flow processes. Matthews and Hirsch compared temperatures when drilling human femoral cortices in vivo and in vitro and obtained similar values.

In the current study, temperature changes with final condenser/drift were recorded because this instrument should theoretically exert maximal friction heat owing to its large diameter and high peripheral velocity. The chosen depth of implant site preparation in our study was only 10 mm. This is because the bone-condensing procedure is indicated in class D4 bone that is present in the molar region of the upper jaw where the bone density is reduced as well as subantral dimension. In this region, because of the previously mentioned limitations, the most widely used implant is 10-mm long. This is confirmed by the study of Rocuzzo and Wilson in which the authors evaluated a 10-mm long. This is confirmed by the study of Rocuzzo and Wilson in which the authors evaluated a protocol for 6-weeks’ loading of SLA (sand blasted and acid etched) implants in the posterior maxilla and of a total of 36 implants used, as many as 27 were 10 mm in length. Mean maximum temperature rise in the surrounding bone during its condensation did not exceed the critical level for thermal necrosis. When the bone condensing technique was performed, the largest increase in temperature was observed at the depth of the osteotomy of 1 mm. This result was expected because of the present compact bone and occurred due to differences in texture and blood supply to cortical bone compared with spongy bone. Then, to compress the bone cortex it is necessary to apply a stronger force, which increases the temperature of the surrounding bone. Also, during the preparation of the implant site in the bone, the condenser gradually progresses from the entrance to the bottom, so the bone at the opening of the site is exposed to friction for a longer time than the one in the deeper parts. In spongy bone, bone temperature decreases with increasing depth of the implant site. The lowest temperature rise was observed in implant site at a depth of 10 mm, probably because this part of the osteotomy was exposed to friction for the least amount of time and spongy bone was present. Yacker and Klein showed that the instrument was most heated when passing through the dense cortical bone and in soft spongy bone its temperature decreased, even though the osteotomy depth increased.

The findings of our study are limited by the osteotomy depth of 10 mm. New research is needed to prove the assumption that during the bone-condensing procedure, the trend of continuously decreasing temperature with increasing depth of the osteotomies could be extrapolated to the osteotomies deeper than 10 mm.

During implant site preparation by bone condensation, the bone tissue is not removed but only compressed laterally as opposed to bone drilling. In bone drilling, part of the bone is removed and with the friction of the noncutting parts of the drill additional energy is released because of breaking of the intermolecular bonds. However, the results of our study indicate that there is no significant difference in temperature rise in the corticalis between the 2 surgical techniques. This observation confirms the assertion of Sener et al that although the superficial part of an osteotomy is more prone to thermal damage, external irrigation is capable of cooling the temperature at this level. Also, irrigation with cooled saline is more effective in cooling the heat generated during drilling.

The only significant difference in temperature increase of the surrounding bone compared between these 2 surgical techniques was observed at the osteotomy depth of 5 mm in the spongy bone. At this osteotomy depth, temperature rise was less during the bone-condensing technique. When the conventional preparation technique is used, the significant increase in bone temperature could be explained by drill bit design. For twist drills, the efficacy of irrigation in reducing frictional heat is evident only at a shallow depth.

Dynamics of temperature increase observed in the control group differed from previous research. Cordioli and Majzoub have recorded a significant rise in temperature at a depth of 8 mm over a depth of 4 mm during bone drilling for dental implant placement with a twist drill of 3-mm diameter. This difference can be attributed to the fact that all drilling procedures in the previous study were carried out in the cortical bone and also continuous drilling was used. It prevents escape of cut bone chips and access for the irrigation fluid, thus causing clogging of the twist drill bit and increase in generated temperature.

Strietzel et al recorded peri-implant alveolar bone loss of 0.4 mm 6 months after installation of implants in bone class D3 by bone condensing. This amount of resorption is acceptable to the radiographic success criteria proposed by Albrektsson et al. Future research needs to examine whether the peri-implant alveolar bone resorption de-
creases if bone temperature is reduced by external irrigation of the corticalis during condensation.

An operator can confirm bone density during the initial drilling procedure that precedes the condensing. If the bone is very soft, only pushing and rotating motions are sufficient to insert the condenser to the desired depth of a pilot osteotomy, but sometimes gentle tapping with a mallet may be necessary. The osteocytes of the spongy bone remain intact when the force of compression does not exceed 10 to 20 MPa.\(^2\)\(^1\) In this study, light, intermittent force was applied by a surgical mallet and further studies are needed to examine the influence of intensity of force applied by the operator during condensation on the surrounding bone temperature changes.

According to the present study, the bone-condensing technique applied for the preparation of the implant site in the bone class D4 offers an advantage over bone drilling because it generates significantly less heat. In this way, bone condensing reduces the degree of thermal damage to bone and creates conditions for improved osseointegration.

**CONCLUSIONS**

The bone-condensing technique applied in the jaw bone class D4 offers an advantage over bone drilling because it generates significantly less heat.

**REFERENCES**


Reprint requests:
Aleksa Markovic, DDS, PhD
Clinic of Oral Surgery
Faculty of Stomatology
University of Belgrade
Dr Subotica 4
11000 Belgrade, Serbia
maleksa@sbb.rs