Implant Fixture Heat Transfer During Abutment Preparation

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The purpose of the study was to evaluate the effect of water flow rate on the heat transmission in implants during abutment preparation using a diamond bur in a high-speed dental turbine. Titanium-alloy abutments (n = 32) were connected to a titanium-alloy implant embedded in an acrylic resin within a water bath at a controlled temperature of 37°C. The specimens were equally distributed into 2 groups (16 each) according to the water flow rate used during the preparation phase. Group 1 had a water flow rate of 24 mL/min, and group 2 had a water flow rate of 40 mL/min. Each abutment was prepared in the axial plane for 1 minute and in the occlusal plane for 1 minute with a coarse tapered diamond bur using a high-speed dental handpiece. Thermocouples embedded at the cervix of the implant surface were used to record the temperature of heat transmission from the abutment preparation. Heat generation was measured at 3 distinct times (immediately and 30 seconds and 60 seconds after the end of preparation). Statistical analyses were carried out using 2-way analysis of variance and the Student t-test. Water flow rates (24 mL vs 40 mL) and time interval had no statistically significant effect on the implant’s temperature change during the abutment preparation stage (P = .431 and P = .064, respectively). Increasing the water flow rate from 24 to 40 mL/min had no influence on the temperature of the implant fixture recorded during preparation of the abutment.

Key Words: implant abutment, abutment preparation, water flow rate, heat transfer

INTRODUCTION

Ossseointegration is one of the fundamental factors for the long-term success of implant restorations. Excessive surgical trauma is an important cause of formation of a soft tissue layer between the installed dental implant and surrounding bone tissue. In addition, preventing excessive heat generation during the bone drilling procedure or osteotomy preparation is one of the factors that influence successful osseointegration. The extent of surgically induced bone necrosis at implant installation is primarily due to the frictional heat generated by bone cutting, although additional tissue trauma may be caused by compression or vibration. Ideally, heat generation should not exceed 39°C. However, to maintain its vitality it has been stated that bone should not be heated beyond 43°C and when the temperature exceeds 43°C, alkaline phosphatase begins to break down. Furthermore, heating the bone to 47°C or 50°C for 5 minutes significantly reduced bone formation around the implants.

There is no doubt that thermal damage to the bone may occur in the preparation of an implant bed (osteotomy). The extent of this damage depends on the nature and quality of the cutting tools, the speed of rotation, and whether internal or external irrigation was used during the process.

Intraoral preparation of implant abutments, shortening the occlusal height of implant abutments, subgingival preparation of the abutment margins, preparation of abutment grooves for resistance and retention of the final crown or bridge, shortening of impression coping screws, or occlusal adjustment of metal or porcelain restorations could carry a risk of heat transfer to the bone-implant interface. Therefore, to maintain the accuracy of preparation, it has been recommended that implant abutment preparation should be carried out extraorally.

Excessive heat generation at the bone-implant interface during preparation of the implant abutment may cause irreversible bone damage and loss of osseointegration. Bragger et al found that preparation of implant abutments did not lead to detrimental effects on peri-implant tissues so long as adequate cooling with spray was provided. Furthermore, in vitro study evaluated the effects of heat generation at the implant surface caused by diamond and tungsten burs in a high-speed handpiece during implant abutment preparation. Their results showed that the abutment preparation with a diamond bur using normal handpiece coolant did not cause a temperature increase on the implant surface.

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Labortechnik mbH, Burgwedel, Germany) with a thermostatic resin block were immersed in a water bath (GFL Gesellschaft für dimensions The implant and its Teflon mount in the acrylic-
neering Inc). The implant and thermocouple were embedded in a special acrylic block (Hydroplastic, Wareham, Mass).
regard regular and effective water flow on the heat transmission in implants caused during abutment preparation using a diamond bur in a high-speed dental handpiece. The null hypothesis was that increasing the water flow in the high-speed handpieces from 24 to 40 mL/min would have no effect on heat generation at the implant surface during abutment preparation.

**MATERIALS AND METHODS**

Four cylindrical solid implants (Straumann Standard implant, Institute Straumann AG, Basel, Switzerland) 4.1 mm in diameter and 12 mm in length were used for this study. The J-type thermocouple electrodes (Omega Engineering Inc, Stamford, Conn) in the temperature recording system were attached to a relatively flattened peripheral surface of the implant at the cervical facial aspect of its body. The tip of the thermocouple was wired tightly around the implant with another J-type thermocouple wire. The other end of the thermocouple was fixed to a connector (J-type, Omega Engineering Inc) that was used to connect the end of the thermocouple to the temperature monitor (Thermocouple transducer, Omega Engineering Inc). The implant and thermocouple were embedded in a Teflon casing (Hengshui Jinggong Rubber & Plastic Products Co, Ltd, Hengshui, China). The implant and the thermocouple tip within the Teflon casing were sealed with silicone sealant material (GE Construction Sealants, General Electric Co, Huntersville, NC) so that the recording system and the implant were totally isolated from any contact with water or the acrylic block to prevent dissipation of the heat that could have been transmitted through the implant body during the preparation procedures.

The implant, thermocouple, and Teflon casing were then placed in a special acrylic block (Hydroplastic, Wareham, Mass). The cube-shaped acrylic-resin block was 80 mm in each of the 3 dimensions The implant and its Teflon mount in the acrylic-resin block were immersed in a water bath (GFL Gesellschaft für Labortechnik mbH, Burgwedel, Germany) with a thermostatic temperature-controlled mechanism with a starting water temperature of 37°C. A solid abutment (5.5 mm height) (048.541, Institute Straumann AG) was inserted into the implant and torqued to 35 NCM. The abutment was isolated from the water level by a rubber dam tied around the implant at the cervix of the abutment (Figure).

The temperature recording system was calibrated by a computer program and board (Data Acquisition Systems, Omega Engineering Inc). The abutment of each specimen was heated to a specific temperature and connected to the board of the computer program (Data Acquisition System, Model TCIC-USB-ENC, Omega Engineering Inc) and the temperature was recorded. In addition, the recording accuracy of the monitor (thermocouple transducer) was calibrated by connecting the same specimen of each implant at the same time to this monitor. The monitor recorded the same temperature that was recorded by the computer program and the same known temperature of the abutment.

**Preparation of the abutments**

A high-speed turbine handpiece (W&H Dentalwerke Bürmoos GmbH, Bürmoos, Austria) with a rotation speed of 390 000 rpm was used at maximum free running-speed (air pressure of 20 psi and a water coolant temperature of 20°C ± 1°C). The abutments were prepared using a coarse, tapered diamond instrument (No. 6836.314.014, Komet GmbH & Co. KG, Lemgo, Germany). A new diamond instrument was used for each specimen, and one operator performed all preparations freehand. Each abutment was prepared axially for 1 minute and occlusally for 1 minute. Occlusal preparation was done with a continuous force for 60 seconds and was intended to cut through the abutment and reduce its height (from the most superior aspect) by 1 mm. Axial preparation was carried out with a continuous force for 60 seconds and was intended to simulate abutment contouring. Abutments were replaced after each successive occlusal and axial preparation. A high-velocity suction tip was held 2 cm from the abutment to remove the water-coolant spray that collected on the rubber dam. In addition, a 15-minute interval was required after abutment preparation to allow the implant temperature to return to the starting temperature of 37°C.

Thirty-two abutments were used in this study. The specimens were equally distributed into 2 groups (n = 16 each). Group 1 had a water flow rate of 24 mL/min; and group 2 had a water flow rate of 40 mL/min. The temperature increase during abutment preparation was measured at 3 distinct times: (1) the temperature was recorded immediately after the end of abutment preparation (zero second), (2) the temperature was recorded 30 seconds after the end of preparation (30 seconds), and (3) the temperature was recorded 60 seconds after the end of preparation (60 seconds).

**Statistical analyses**

Statistical analyses of the data were performed using two-way analysis of variance and a Student t test. All statistical analyses were performed at a .05 level of significance using statistical software (Statistical Package for Social Sciences version 16.0, SPSS Inc, Chicago, Ill).
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TABLE 1
Summary of 2-way analysis of variance of main factors (water flow rate and different time intervals) and their interaction for the implant’s temperature change*

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Square</th>
<th>df</th>
<th>MS</th>
<th>F Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water flow</td>
<td>1.190</td>
<td>1</td>
<td>1.190</td>
<td>.626</td>
<td>.431</td>
</tr>
<tr>
<td>Time</td>
<td>10.762</td>
<td>2</td>
<td>5.381</td>
<td>2.830</td>
<td>.064</td>
</tr>
<tr>
<td>Water flow × time</td>
<td>1.023</td>
<td>2</td>
<td>.512</td>
<td>.269</td>
<td>.765</td>
</tr>
<tr>
<td>Error</td>
<td>171.101</td>
<td>90</td>
<td>1.901</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>105167.437</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*df indicates degrees of freedom; MS, mean square.

RESULTS

As shown in Table 1, there was no significant difference between the 2 water flow rates (24 mL vs 40 mL) on the implant’s temperature change during preparation of the abutment (P = .431). In addition, there was no significant difference among the 3 time intervals (P = .064). The mean temperature recorded immediately after using the 24-mL water flow rate was 33.77°C, whereas the mean temperature recorded with 40-mL water flow was 33.31°C. This indicated no statistically significant difference (P = .395) (Table 2).

DISCUSSION

Avoidance of heat damage, or thermal damage, appears to be a shared prerequisite to achieve primary bone healing and success in immediate implant loading. This kind of damage occurs when bone temperature exceeds 47°C (protein denaturation threshold). The effect of overheating the bone at the interface may cause cell death, vascular stasis and tissue necrosis and may compromise the bone’s ability to survive as a differentiated tissue. During surgical and prosthetic procedures in implant treatment, temperature can increase as a result of the mechanical heating—that is, when using cutting instruments for bone or titanium drilling—or chemical heating—that is, from exothermic setting reactions of autopolymerizing acrylic resins used to adapt provisional restorations. Previous studies on heat generation during abutment preparation using a 2-piece implant system (implant + abutment) showed that the temperature increase in the implant body at the cervix and apex varied according to the grinding conditions, the type of bur, and the type of coolant used. It should be noted, however, that the implant-abutment interface of the 2-piece implant system has different boundary conditions than 1-piece implant designs. The boundary condition posed by an implant-abutment connection may alter the heat transfer characteristics of the implant system compared with the solid transition from the abutment to implant regions of a 1-piece implant. Currently, however, it is not known how variations in abutment geometry may also affect the creation and transference of thermal energy in dental implants. In this in vitro study there were no statistically significant differences between low and high water flow rates even though the high water flow always caused slightly lower temperatures. Therefore, the null hypothesis has been accepted. It can be reasoned therefore that the greater the rate of water flow, the lower the temperature recorded in the implant fixture but to a limit. The limit is the amount of water flow, which can cause an effective reduction in the temperature recorded. The low water flow used in this study (24 mL/minute) seems to have been effective enough to absorb most of the heat generated during abutment preparation. Any increase in water flow beyond that effective level caused only slight increase in the dissipation of the total amount of heat generated.

Gross et al reported that the maximum temperature after reducing 1 mm of height from the most superior aspect of a titanium-alloy abutment with a high-speed handpiece with a coolant for 1 minute was less than 41.7°C. Bragger et al also reported that the maximum temperature after reducing the titanium abutment for 10 seconds with a low-speed handpiece with a coolant was 39°C. In contrast, the preparation of a titanium abutment for 30 seconds with a low-speed headpiece without any coolant provoked a maximum temperature of 155°C, a temperature that is much higher than 47°C and described as critical for irreversible bone damage. Therefore, regardless of the headpiece type, preparation of a titanium abutment and a titanium-alloy abutment without coolant could cause irreversible damage to bone and osseointegration.

In contrast, the current study demonstrated a maximum temperature of 33.77°C that is lower than the critical level of 47°C. The current study was performed in such a way as to decrease interoperator variability, as all preparations were performed by a single operator.

The amount and duration of abutment preparation in this study was determined to be in keeping with previously described methods. Although preparation of the axial walls of the abutment may provide a better simulation of the clinical

TABLE 2
Implant temperature changes as influenced by the water flow rate when recorded at different time intervals after the end of cutting (n = 16).

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Water flow rate</th>
<th>Mean*</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>24 mL</td>
<td>33.77a</td>
<td>1.60</td>
</tr>
<tr>
<td>0</td>
<td>40 mL</td>
<td>33.31a</td>
<td>1.40</td>
</tr>
<tr>
<td>30</td>
<td>24 mL</td>
<td>32.98a</td>
<td>1.31</td>
</tr>
<tr>
<td>30</td>
<td>40 mL</td>
<td>32.73a</td>
<td>1.34</td>
</tr>
<tr>
<td>60</td>
<td>24 mL</td>
<td>32.79a</td>
<td>1.25</td>
</tr>
<tr>
<td>60</td>
<td>40 mL</td>
<td>32.83a</td>
<td>1.34</td>
</tr>
</tbody>
</table>

*Mean values designated with the same superscript are not significantly different (P > .05).
situations, this approach may not lend itself to standardization, thereby resulting in increased variability of results. Given the results of the current study, it appears that the risks to the bone-implant interface through thermal insult are minimal when coolants are properly used.

Continuous cutting caused temperature increases that ranged from 0.6°C to 1.9°C, excluding the tests without cooling. Temperature increase is in fact proportional to application time. These results show that continuous cutting for 30 and 60 seconds should keep temperature in a safe range to avoid heat damage to bone.

Thermocouples and infrared thermography are both used in temperature studies. Thermocouples have been the traditional gold standard of temperature measurement. The limitation of thermocouples is that they measure temperature only at the point it contacts on the surface. On the other hand, infrared thermography shows temperatures over larger surface areas by means of color representation. However, in a study on heat generation on root surfaces during thermal condensation, McCullagh et al confirmed that the use of thermocouples was the most accurate method.

**Conclusions**

Within the limitations of this in vitro study, it can be concluded that increasing the water flow rate had no effect on the temperature recorded at the implant surface during abutment preparation using high-speed handpieces.

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**References**