The one-piece screw-type dental implant has become a popular and convenient alternative in situations where there is a need to restore severely resorbed edentulous ridges, especially in the anterior esthetic zone and in sites with limited proximal space. The main drawback of the one-piece dental implant is the limited ability to angle the abutment. In sites where there is reduced bone availability, the angulation of the implant may not permit the desired contours for the definitive restoration. As a result, the clinician must prepare the abutment to achieve a proper emergence profile and angulation. This procedure may compromise osseointegration through the production of heat, which is potentially damaging to the vitality of the bone, and also may decrease primary stability of the implant.

There is a large variation in the reported success rates of one-piece implants. Some manuscripts reported high survival rates that were comparable to those of regular two-piece implants. In contrast, Ostman et al reported significantly reduced success rates for one-piece implants, which exhibited extensive marginal bone loss and implant failure. Those differences in the success rates may be attributable to factors such as loading, implant design, shape, length, and the abutment reshaping procedure.

Dental implants are exposed to high temperatures during the restoration production process. Even routine activities such as drinking hot beverages may expose the implant-bone interface to very high temperatures. Heat production while preparing teeth for restorations and its effect on the surrounding tissues is well studied and supported in the dental literature. In contrast, heat production during implant abutment preparation has seldom been studied, and it has never been studied in one-piece implants.

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**Heat Production During Prosthetic Preparation of a One-Piece Dental Implant**

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**Purpose:** Preparation of a one-piece dental implant abutment is often needed to achieve a proper emergence profile for a definitive restoration. However, this procedure may compromise osseointegration through the production of heat. The aim of this study was to measure heat production during implant abutment preparation with different volumes of water irrigation using a one-piece implant system.

**Materials and Methods:** Forty-five one-piece dental implants were used in this study. The implants were divided into three groups according to the water flow rate used during abutment preparation: 30 mL/min (G30), 15 mL/min (G15), and without water irrigation (G0). Thermocouples were positioned at the most coronal and most apical threads. The abutments were prepared using a high-speed dental handpiece. Preparation continued for 120 seconds or until the implant temperature reached 47°C.

**Results:** The time needed to reach 47°C in the most coronal thread of group G0 was 5.73 ± 1.16 seconds. After the preparation was stopped at 47°C, the temperature continued to increase until reaching a maximum temperature. None of the implants in the water irrigation groups reached 47°C. The time needed to reach maximum temperature was significantly shorter for group G0 than the groups with water irrigation. A strong positive correlation was found between coronal and apical recordings.

**Conclusion:** Prosthetic preparation of one-piece dental implants without irrigation induced a rapid increase in temperature. Water irrigation reduced heat production during abutment preparation in a dose-dependent manner.

**Key words:** dental abutment, heat production, one-piece dental implant, osseointegration, preparation, water irrigation

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Drs Gabay and Cohen made equal contributions to this study.
As mentioned earlier, the preparation procedure, often required intraoperatively for one-piece implants, is associated with substantial heat production prior to osseointegration. The presence of excessive heat (above 47°C) immediately after implant placement may significantly impair bone formation and compromise osseointegration. To avoid this type of irreversible damage, the clinician should consider protective measures, such as sufficient water irrigation and shorter working intervals, although the effect of water irrigation flow on heat production has not been studied. The aim of this study was to examine heat production during abutment preparation with different volumes of water irrigation using a one-piece implant system.

MATERIALS AND METHODS

Experimental Design
Forty five one-piece dental implants (UNO, MIS Implant Technologies), 3 mm in diameter and 13 mm in length, were used in this study. Implants were divided into three groups of 15 each depending on the water flow rate used during the preparation process: group G30 (preparation with 30 mL/min water spray irrigation), group G15 (preparation with 15 mL/min water spray irrigation), and group G0 (preparation without water irrigation, air cooling only).

Temperature Measurement
The implants were mounted and fixed into 2.7-mm-diameter machined slots in a custom-made acrylic glass apparatus (Faculty of Mechanical Engineering, Technion-Israel Institute of Technology). T-type, copper-constantan, 30-gauge wire thermocouples (TE Wire & Cable) were positioned at the most coronal and most apical threads (Fig 1). The thermocouples were tightened against the implant threads with plastic screws. Thermal changes on the implant surface were recorded continually at 100-ms sampling intervals using a TC-08 thermocouple data logger (Pico Technology) and data acquisition software (PicoLog R5.20.3; Pico Technology). All measurements were made at room temperature (average 24.81°C ± 0.78°C). The tap water used for irrigation had a mean temperature of 24.81°C ± 0.54°C.

Abutment Prosthetic Preparation
The abutment portion of the one-piece implants was prepared in a continuous circular motion using a high-speed dental handpiece at 400,000 RPM (M 8101 model, MTC Industries & Research). A new medium-grit diamond bur (C3, Strauss) was used for each implant. The implant–acrylic glass complex was covered and isolated with rubber dam (Henry Schein), in which a hole was punched to allow the abutment to be exposed for the prosthetic preparation while protecting the implant (Fig 2). Preparation continued for 120 seconds or until the temperature reached 47°C at the coronal or apical thermocouples. All implants were prepared by the same operator.

Data Processing and Statistical Analysis
Temperature measurements at selected time points were extracted: maximum temperatures at the coronal and apical threads (Cmax and Amax, respectively) and the initial temperatures at the coronal and apical threads (C0 and A0, respectively) for all three experimental groups. The time that elapsed until the maximum temperature was reached (CTmax and ATmax) was recorded for all three experimental groups. The amplitudes of the thermal changes (∆C = Cmax – C0 and ∆A = Amax – A0) were calculated separately for the coronal and apical sites in each group. In the G15 and G30 groups, mean plateau temperatures at the
most coronal thread (Cplateau) and the amplitudes of thermal changes to Cplateau (ΔCplateau = Cplateau – C0) were calculated.

Temperature differences at selected time points, maximum temperatures, and plateau averages were analyzed in the three experimental groups using one-way analysis of variance with Scheffé modification at 95% confidence level. The correlations between apical and coronal temperatures and time measurements were tested in a linear regression model. A 5% significance level was used.

RESULTS

Temperature Findings

The time needed to reach 47°C in the most coronal thread in the G0 group was 5.73 ± 1.16 seconds, at which time the preparation was halted. Although the preparation was stopped, a pronounced overshoot was noticed as the temperature continued to rise until reaching a mean Cmax of 61.60°C ± 3.63°C. None of the implants in the other two groups, G15 and G30, reached 47°C (Fig 3). The mean Cmax temperatures recorded differed significantly between all experimental groups: 61.60°C ± 3.63°C, 32.88°C ± 1.37°C, and 28.74°C ± 1.37°C for G0, G15, and G30, respectively (P = .0001; Table 1).

C temperatures were significantly different between all experimental groups, 36.94°C ± 4.13°C, 7.79°C ± 1.54°C, and 4.04°C ± 1.08°C for G0, G15, and G30, respectively (P = .0001). Temperatures recorded at the apical threads were also significantly different between all experimental groups: 4.62°C ± 0.41°C, 3.15°C ± 1.46°C, and 1.47°C ± 0.74°C for G0, G15, and G30, respectively (P = .0001); thus a temperature gradient of approximately 1.6°C between experimental groups resulted from the decreased flow rate of water spray (Table 1).

Table 1  Mean (± SDs) Temperatures and Time Frames of Heat Production During Prosthetic Preparation

<table>
<thead>
<tr>
<th>Group</th>
<th>ATmax (s)</th>
<th>ΔA (°C)</th>
<th>CTmax (s)</th>
<th>ΔC (°C)</th>
<th>Cmax (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G0</td>
<td>42.40 ± 4.05</td>
<td>4.62 ± 0.41</td>
<td>10.80 ± 1.27</td>
<td>36.94 ± 4.13</td>
<td>61.60 ± 3.63</td>
</tr>
<tr>
<td>G15</td>
<td>106.02 ± 19.21</td>
<td>3.15 ± 1.46</td>
<td>90.53 ± 31.19</td>
<td>7.79 ± 1.54</td>
<td>32.88 ± 1.37</td>
</tr>
<tr>
<td>G30</td>
<td>97.20 ± 32.65</td>
<td>1.47 ± 0.74</td>
<td>81.93 ± 34.47</td>
<td>4.04 ± 1.08</td>
<td>28.74 ± 1.37</td>
</tr>
</tbody>
</table>

Cmax = coronal maximum temperature; ΔC = amplitude of coronal thermal changes; CTmax = time to reach coronal maximum temperature; ΔA = amplitude of apical thermal changes; ATmax = time to reach apical maximum temperature. (vertical bars, P = .0001).
positive correlation (r = 0.72, P = .0001). The same pattern was observed for the ΔCplateau values in the G15 and G30 groups: 5.75°C ± 1.07°C and 2.99°C ± 0.69°C, respectively (P = .0001). A strong positive correlation was found between coronal and apical temperatures recorded at 30, 60, 90, and 120 seconds when the three experimental groups were grouped together (r30 = 0.83, P = .0001; r60 = 0.89, P = .0001; r90 = 0.85, P = .0001; r120 = 0.68, P = .0001). Also, ΔC and ΔA values showed a strong positive correlation (r = 0.72, P = .0001). The same pattern was found for CTmax and ATmax time measurements (r = 0.73, P = .0001).

**DISCUSSION**

The present study found that during prosthetic preparation of one-piece dental implants there is a pronounced production of heat, with a temperature increase ranging between 4.04°C ± 1.08°C and 36.94°C ± 4.13°C at the most coronal thread. Eriksson et al.15,16 used vital microscopy to evaluate bone viability after heat trauma and concluded that heat generated in an implant above 47°C may lead to significantly reduced bone formation at the implant-bone interface and may compromise osseointegration. In another study, osteoblast cultures exposed to heat shock (at 42°C) induced activation of apoptosis mechanisms.17 Oral thermal insults may result from daily oral practices, such as drinking hot beverages and eating hot foods,10 or in the dental clinic when using materials with exothermic setting reactions, such as impression plasters8 and acrylic resins.9 The most common implant-related heat-generating procedure that has been studied is the osteotomy preparation, with various outcomes. While some researchers did not find any critical temperature elevation when a strict protocol was followed,19,20 others reported that an increase of more than 10°C in bone temperature was possible as a result of sequential drilling.18 Both procedures (ie, drilling and one-piece prosthetic preparation) are executed at the time of implant placement, and thus their effect on osseointegration may be critical. The importance of water irrigation during osteotomy preparation has been well documented by thermoreactors located at the drilling cavity walls21 and through thermography.22,23 In consideration of those studies, one can conclude that to avoid elevating the implant to an unsafe temperature, water irrigation is crucial.

In the G0 group, thermal changes were excessive to the point that the preparation was discontinued at 47°C in all cases, whereas in the G15 and G30 groups, temperature elevation was attenuated markedly and none of the implants reached 47°C. The water irrigation was apparently effective since, following a short phase of rapid temperature increase, a stable plateau was established. This is in agreement with the findings of Lloyd et al.13 who showed that the presence of water at the cutting bur interface prevents significant increases in temperature. As a result of oral thermal insults, a significant increase in temperature may be found at the implant-bone interface. On the other hand, the results demonstrated that temperature transfer from the abutment apically along the implant decreased markedly; hence, it may be concluded that the tested implants seem to have a limited heat conduction capacity. This is influenced by implant length24 and width10 and the physical characteristics of the implant-specific titanium alloy. According to an earlier report, the generated heat was located at a specific position, directly beneath the bur.14 In the present study, the data recorder was located approximately 3 mm apical to the bur tip; this distance may have attenuated the maximal recorded temperatures in comparison to the actual heat produced, but from a clinical point of view the implant-bone interface is crucial and therefore should be the focus of investigation. However, bone is not a homogenous mass; the thermal conductivity of cortical bone is 0.16 to 0.34 W/m/K, while that of cancellous bone is 0.30 W/m/K.25

<p>| Table 2  Coronal Plateau Temperatures (Means ± SDs) Recorded During Prosthetic Preparation with Water Spray Irrigation |
|----------------------|----------------------|----------------------|</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>ΔCplateau (°C)</th>
<th>Cplateau (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G15</td>
<td>5.75 ± 1.07</td>
<td>30.84 ± 0.96</td>
</tr>
<tr>
<td>G30</td>
<td>2.99 ± 0.69</td>
<td>27.80 ± 0.97</td>
</tr>
</tbody>
</table>

Cplateau = coronal mean plateau temperature; ΔCplateau = amplitude of coronal thermal changes to plateau temperature. (Vertical bars, P = .0001).
This study showed that heat applied at the abutment level may induce significant temperature elevation along the implant, reaching the most apical thread. Although thermal changes were found at both apical and coronal sites, they were more pronounced at the coronal sites. These thermal differences were more obvious in the G0 group. A similar pattern was found when time measurements were considered, as ATmax lagged a few seconds behind CTmax. The positive correlation found between coronal and apical sites in both thermal and time measurements validate the existence of an apically directed heat transfer gradient along the implant axis.24

Because of the need for reproducibility in the experimental setup, implant preparation was set to end at 47°C or 120 seconds (whichever came first), whereas in clinical practice, intraoral abutment preparation is routinely done in interrupted short working intervals with an overall similar or longer duration. However, these methodologic differences seem to be of little significance; rapid thermal changes were seen in all three experimental groups. According to the present findings, the time needed to reach the maximum temperature at the group G0 coronal thread was less than 6 seconds, while in the G15 and G30 groups it took slightly longer, < 10 seconds, to reach the plateau temperature and a temperature of 47°C was never reached.

Finally, although the current research focused on heat production during prosthetic preparation of one-piece implants and the possible adverse effects on osseointegration, other insults associated with this process should not be ignored. These include titanium shavings and microbial contamination of the surrounding tissues, handpiece air infiltration into the open wound, or mechanical insult that may compromise implant primary stability.3 Contamination of the oxidized titanium implant surface may also occur during impression making, fabrication of acrylic resin provisional crowns, or cementation.7 All of these insults may lead to crestal bone resorption and loss of osseointegration.

CONCLUSION

The results demonstrated that prosthetic preparation of a one-piece implant without irrigation induced a rapid increase in temperature. Water irrigation reduced heat production during abutment preparation in a dose-dependent manner. Further research in this area is needed to determine the biologic impact of one-piece dental implant preparation on the surrounding tissues both in vitro and in vivo. An improved understanding of the different elements of one-piece dental implant preparation may help clinicians avoid damage that may put osseointegration at risk and thus achieve better long-term results.

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