RESEARCH

Cooling Profile Following Prosthetic Preparation of 1-Piece Dental Implants

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The aim of this study was to evaluate the effect of water irrigation on heat dissipation kinetics following abutment preparation of 1-piece dental implants. UNO 1-piece dental implants were mounted on Plexiglas apparatus clamping the implant at the collar. T-type thermocouple was attached to the first thread of the implant and recorded thermal changes at 100 millisecond intervals. Implants were prepared using highspeed dental turbine at 400 000 RPM with a coarse diamond bur. Once temperature reached 47°C, abutment preparation was discontinued. Thirty implants were divided into 2 groups. Group A: Passive cooling without water irrigation. Group B: Cooling with turbine's water spray adjacent to the implant (30 mL/min). The following parameters were measured: T47 (time from peak temperature to 47°C), T50%, T75% (time until the temperature amplitude decayed by 50% and 75%, respectively), dTemp50%/dt decay, and dTemp75%/dt decay (cooling rate measured at 50% and 75% of amplitude decay, respectively). Water spray irrigation significantly reduced T47 (1.37 ± 0.29 seconds vs 19.97 ± 3.06 seconds, $P < 0.0001$), T50% (3.04 ± 0.34 seconds vs 27.37 ± 2.56 seconds, $P < 0.0001$), and T75% (5.71 ± 0.57 seconds vs 57.61 ± 5.47 seconds, $P < 0.0001$). Water spray irrigation also increased cooling capacity ninefold: dTemp50%/dt decay (4.14 ± 0.61°C/s vs 0.48 ± 0.06°C/s, $P < 0.0001$), and dTemp50%/dt decay (1.70 ± 0.29°C/s vs 0.19 ± 0.03°C/s, $P < 0.0001$). The continuous use of water spray adjacent to the abutment following the cessation of implant preparation might prove beneficial for rapid cooling of the implant.

Key Words: 1-piece implant, heat, water irrigation, abutment preparation

INTRODUCTION

In recent years, the use of immediate restoration of dental implants has gained popularity. One-piece implants are most suited for this purpose as they require minimal interdental space that is often an issue in the anterior region.

The main drawback in the 1-piece dental implant is its limited abutment angulation. In many cases, because of poor bone availability, the implant is not placed in an optimal angulation and the clinician has to reshape the abutment to achieve proper emergence profile and angulation of the abutment. This procedure might compromise osseointegration by heat production and by impairing initial implant stability.[1]

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The success rate of 1-piece implants varies in different reports. Some articles reported high survival rates similar to those of traditional 2-piece implants,[2–4] while others reported significantly lower success rates of 1-piece implants, with extensive marginal bone loss and greater implant failure.[5] Those differences in success rates may be attributable to factors such as implant design, implant shape, insertion length, and the intraoral abutment preparation.

As mentioned before, abutment preparation is associated with heat production. Excessive heat production greater than 47°C may cause impaired bone formation around implants.[6] To avoid irreversible thermal damage, the clinician is required to exercise protective measures, including sufficient water irrigation and short working intervals.

Early studies investigated the importance of water irrigation for the prevention of thermal damage during cavity preparation in teeth. Water irrigation was found to be essential in preventing pulp exposure to excessive temperature.[7] Others advocated that air coolant alone is sufficient.[8] Woods and Dilts[9] reported that pulp temperature increased by 5.8°C with no coolant, 0.6°C using air coolant, and 0.5°C using water spray. In a study measuring heat dissipation during cavity preparation with air water spray, Carson et al[10] reported a 0.48°C drop in temperature at the dentino-enamel junction with a preparation depth of 0.5 mm into dentin with the use of air water spray compared with a 1°C increase with air coolant alone.

Lloyd et al[11] reported that the use of a handheld syringe or hollow bur with water flow rate as low as 10 mL/min provided excellent cooling capacity as long as the water stream was directed into the cutting region.

Heat generation during preparation of titanium abutment mounted onto a titanium implant (2-piece implant) using diamond and tungsten burs with standard turbine and water irrigation resulted in a mean temperature increase of 1°C with diamond burs and 2°C with tungsten burs. The maximum temperature increase during preparation with diamond burs was 2°C compared with 4.7°C with tungsten burs.[1]

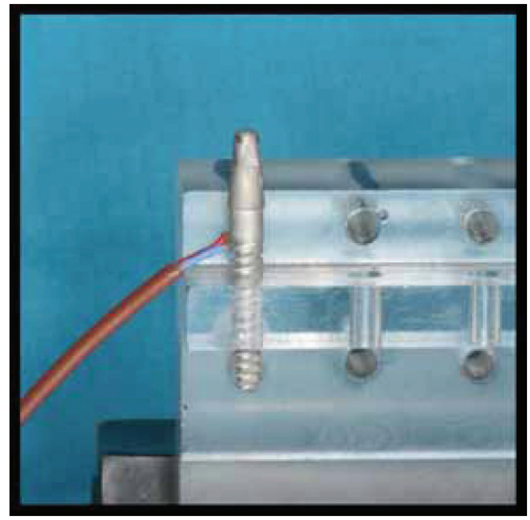

Figure 1. UNO implant mounted on a Plexiglas apparatus with T type thermocouples attached at first thread.

The 1-piece dental implant system differs from the 2-piece implant system in its solid implant abutment interphase.

To date, the cooling capacity of water irrigation during abutment preparation of a 1-piece implant has not been investigated. The aim of this study was to evaluate the effect of water irrigation on heat dissipation kinetics following abutment preparation of 1-piece dental implants.

Materials and Methods

UNO 1-piece dental implants (MIS, Shlomi, Israel) were mounted on a Plexiglas apparatus clamping the implant at the collar. A T-type thermocouple (TC-08 thermocouple data logger, Pico Technology, Cambridgeshire, UK), which was attached to the first thread of the implant, recorded thermal changes every 100 milliseconds for 90 seconds (Figure 1). Implants were prepared in a continuous circular motion using a high-speed dental turbine with a medium-coarse

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diamond bur (C3, Struass, Nahariya, Israel). At a temperature of 47°C, abutment preparation was discontinued. Thirty implants were divided into 2 groups: group A, passive cooling without water spray irrigation, and group B, cooling with turbine water spray placed adjacent to the implant (with a flow rate of 30 mL/min) without contacting it.

The following parameters were measured and recorded: Amp, thermal amplitude calculated by subtracting baseline temperature from peak temperature (the calculated thermal amplitude was used for normalizing all recordings); Temp Bl, baseline temperature; Temp Max, maximal temperature recorded; Temp50% and Temp75%, temperature recorded at 50% and 75% of temperature amplitude decay, respectively; T to 47, time until temperature reached 47°C; T to Max, time interval to peak temperature; T47, time until peak temperature decayed to 47°C; T50% and T75%, time until the temperature amplitude decayed by 50% and 75%, respectively; dTemp50%/dt, heat generation rate measured at 50% of amplitude; and dTemp50%/dt decay, dTemp75%/dt decay, cooling rate measured at 50% and 75% of amplitude decay, respectively (Figure 2). The above model enabled us to isolate and investigate cooling capacity without the interference of heat production during active abutment preparation.

Data analysis

Temperature changes in the 2 groups at each time interval were compared using a *t* test for unpaired observations. Statistical significance was set at $P < .05$.

Results

Figure 2 depicts typical thermal changes recorded during preparation of the UNO implant for each treatment group. Baseline temperatures in group A and group B were similar. Temperature increased during abutment preparation and reached 47°C in group A after 7.8 seconds and in group B after 8 seconds. Once the recorded temperature reached 47°C (during the rising phase), abutment preparation was discontinued. At that moment, cooling with turbine air water spray (30 mL/min) adjacent to the implant commenced. Nonetheless, the temperature continued to rise: both the time interval to peak temperature and peak temperature value in group A were significantly higher than in group B. To the contrary, the heat generation rate measured at 50% of amplitude was the same (Table). Recorded Temp50% and Temp75% were significantly greater in group A than in group B: 42.82°C ± 1.35°C vs 38.88°C ± 1.04°C ($P < .001$) and 33.92°C ± 0.9°C vs 32.12°C ± 0.7°C ($P < .001$), respectively (Figure 3).

Cooling time to 47°C was 19.97 ± 3.06 seconds in group A vs 1.37 ± 0.29 seconds in group B ($P < .001$). Likewise, T50% and T75% were significantly greater in group A compared with group B (Figure 4). Overall, the time in which the temperature remained greater than 47°C was 9.3 times greater in group A than in group B (26.23 ± 3.16 seconds vs 2.81 ± 0.55 seconds ($P < .001$), respectively.

The cooling rate measured at 50% of amplitude decay was 8.7 times greater with water irrigation, 4.14 ± 0.61°C/s vs 0.48 ± 0.06°C/s without water irrigation ($P < .001$). The cooling rate measured at 75% of amplitude decay was 9.1 times greater with water irrigation 1.70 ± 0.29°C/s vs 0.19 ± 0.03°C/s ($P < .001$).

Discussion

Our results indicate that heat dissipation following preparation of UNO 1-piece dental implants with the use of water irrigation (30 mL/min) is ninefold greater than passive cooling. To the best of our knowledge, this is the first study to address this issue in dental implants.

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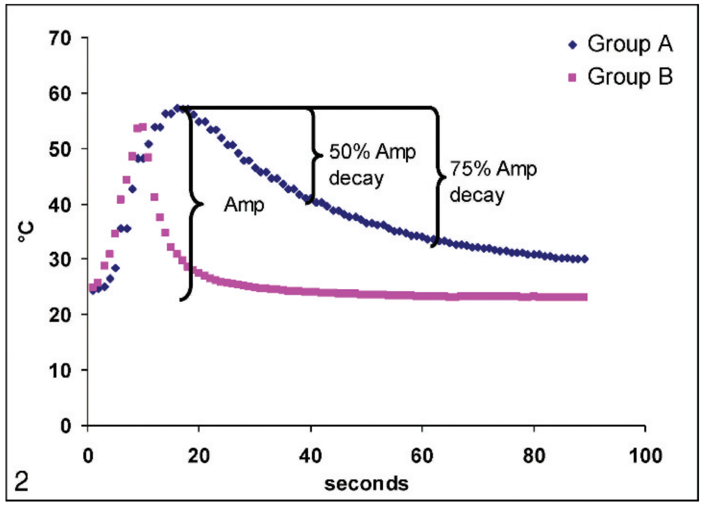

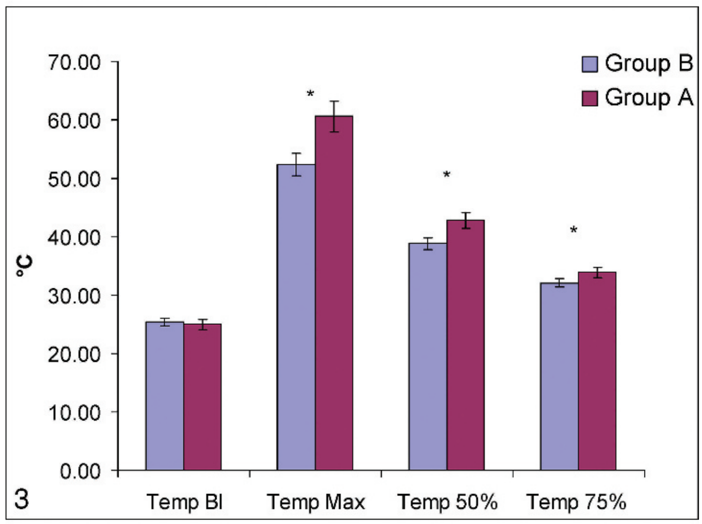

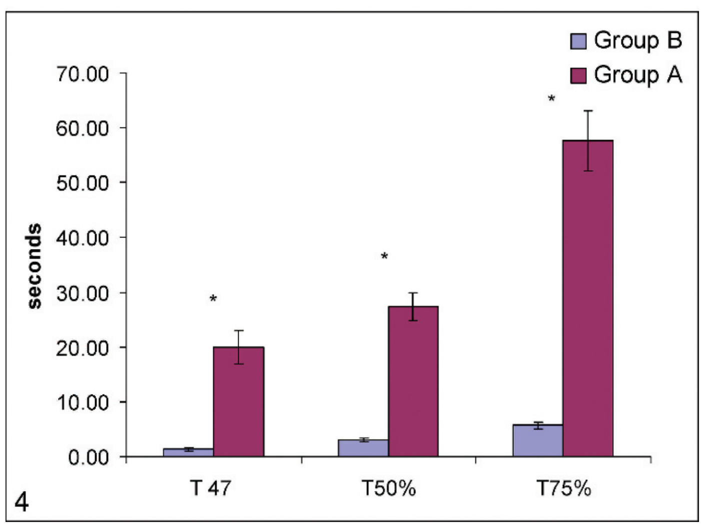

Figures 2–4. Figure 2. Typical thermal changes recording. Group A, without water irrigation; group B, with turbine water spray (30 mL/min). Amp indicates thermal amplitude calculated by subtracting baseline temperature from peak temperature; Amp 50% decay and Amp 75% decay, thermal amplitude decay of 50% and 75%, respectively. **Figure 3.** Comparison of temperatures in both groups. Note that the temperature in group A is significantly higher at all points except baseline. Temp Bl indicates baseline temperature; Temp Max, maximal temperature recorded; Temp50% and Temp75%, temperature recorded at 50% and 75% of thermal amplitude decay, respectively. Data are presented as mean ± SD.

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TABLE

Temporal and thermal differences between groups from baseline to peak temperature*

	Group A	Group B	P value
Temp Bl, °C	25.01 ± 0.88	25.35 ± 0.63	.23611
Temp Max, °C	60.62 ± 2.61	52.40 ± 1.92	.00000
T to 47, °C/s	7.83 ± 2.50	8.00 ± 1.68	.83185
T to Max, s	9.45 ± 1.61	14.10 ± 2.61	.00000
dTemp50%/dt, °C/s	4.29 ± 1.01	4.36 ± 1.22	.88224

*Temp Bl indicates baseline temperature; Temp Max, maximal recorded temperature; T to 47, time until temperature reached 47°C; T to Max, time interval to peak temperature; dTemp50%/dt, heat generation rate measured at 50% of thermal amplitude.

Lloyd et al[11] measured the effectiveness of different cooling techniques in maintaining low tooth temperature. These included air, air water spray from a handpiece water stream, and water supplied through a hollow bur (internal cooling). After 5 seconds of tooth preparation, the temperature reached 100°C without water irrigation, approximately 35°C with air water spray (9–12 mL/min), and approximately 13°C with hollow bur water flow 10 mL/min. Thus, the cooling capacity of the turbine water spray (9–12 mL/min) and hollow bur water flow (10 mL/min) were approximately 3 to 8 times greater than without irrigation. The hollow bur water flow of 10 mL/min was found to be equally effective as air water spray of 35 to 50 mL/min. Hence, with water irrigation at 35 to 50 mL/min, heat generation is 8 times lower. Cavalcanti et al[12] evaluated the cooling efficiency of water flow during cavity and tooth preparation. With a low-load tooth preparation technique, a 9.54°C rise in pulpal temperature was recorded with no cooling and 1.56°C increase with 30 mL/min air water spray. Hence, water spray at 30 mL/min diminished the generated heat by approximately sevenfold.

Overall time in which the temperature remained greater than 47°C was 9.3 times greater in group A compared with group B. Heat generation during drilling is one of the main reasons for failure of implant osseointegration. The alkaline phosphatase denaturation point reported to occur at 56°C; at temperatures greater than that, irreversible bone damage can be expected.[13] Eriksson et al[14] investigated heat trauma using a thermal chamber inserted in rabbit tibia. Heating the chamber for 53°C for 1 minute resulted in an irreversible bone injury, after which healing occurred from the surrounding tissues.[14] In rabbit tibia, heat-induced cortical bone necrosis occurred after 1 minute of exposure to a temperature greater than 47°C.[6,15]

Heat shock of 42°C for 10 minutes caused reversible injury in osteoblast cell culture, while heat shock of 48°C for 10 minutes resulted in irreversible damage.[16]

Recently, Sener and coworkers studied thermal changes in fresh bovine mandible during osteotom preparation. They reported significantly greater temperature 3 mm subcrestally (50.9°C) in the groups where drilling was performed without water coolant compared with $<$37°C in sites where saline irrigation was used during cavitation.[17]

Clinical success of 1-piece implants varies considerably. In a consensus report, Cochran[18] reported that Strauman implants,

←
*$P < .001$ between groups. **FIGURE 4.** Time intervals measured in both groups. The time interval in group A was significantly higher at all points. T47 indicates time until peak temperature decayed to 47°C; T50% and T75%, time until the temperature amplitude decayed by 50% and 75%, respectively. Data are presented as mean ± SD. *$P < .001$ between groups.

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including 1-piece transgingival implant, can be used predictably with a high success rate. A single-center investigation of 47 consecutively placed 21-piece implants (NobelDirect and NobelPerfect) in 30 subjects demonstrated favorable marginal bone levels and a good survival rate of 97.9% after up to 3 years of loading.[4] Other studies reported lower success rates. The survival and success rate of 115 immediately loaded 1-piece implants (NobelDirect and NobelPerfect) followed for at least 12 months with clinical and radiographic examinations was lower than that of 2-stage implants: 5.2% of 1-piece implants failed during the follow-up period due to extensive bone loss. After 1 year, 49% of the 1-piece implants showed 2 mm or more of bone loss compared with only 7.7% for 2-stage implants; 20% showed more than 3 mm of bone loss compared with only 0.6% for 2-stage implants. With success criteria defined as an implant with no clinical or radiographic signs of pathology showing $<$2 mm of bone resorption at 1 year of follow-up, the measured success rate was 46.1% compared with 85% of 2-stage implants. With success criteria defined as an implant with no clinical or radiographic signs of pathology showing $<$3 mm of bone resorption at 1 year follow-up, the measured success rate was 72.2% compared with 91.6% in the 2-stage implant.[5] A follow-up study of 17 NobelPerfect implants demonstrated marginal bone loss of about 4 mm down to the first thread after 18 months.[19] It was speculated that factors such as implant design, insertion depth, in situ preparation, and immediate loading may have had an influence on the clinical outcome.[5] In the present and previous studies, we demonstrated that abutment preparation results in significant heat production at the first thread, which correlates with the crestal bone. The greater marginal bone loss previously reported in 1-piece implants might be due to thermal injury to the marginal bone during abutment preparation.

The maximal recorded temperature was achieved after abutment preparation was ceased. That may stem from the fact that abutment preparation discontinued when the temperature recorded at the first thread reached 47°C during the uprising phase. However, because of delayed thermal conduction and because the thermocouple was connected to the first thread, which is about 3 mm apical to the abutment preparation, the recorded temperature lagged behind the temperature of the prepared abutment; therefore, the maximal temperature was recorded only after abutment preparation was ceased.

Turbine water spray was set to 30 mL/s. Lloyd et al[11] stated that in common dental use, the flow rate of the turbine water spray ranges from 30 to 50 mL/min. Cavalcanti et al[12] reported a slight difference between heat generation during cavity preparation with water spray of 30 mL/min compared with 45 mL/min (1.56°C increase vs 0.04°C decrease, respectively), using a low-load technique. Later on, Cavalcanti et al[20] measured the water flow of various high-speed hand pieces. The average reported water flow rate of 137 samples was 29.48 mL/min.[20] Hence, setting the water flow to 30 mL/min simulated the normal flow rate used in routine dental practice.

Conclusions

Water irrigation (30 mL/min) increased the cooling capacity of a prepared 1-piece implant by ninefold. The use of water spray following the cessation of 1-piece implant preparation might prove beneficial for rapid cooling of the implant, preventing heat dissemination to the underlying tissues.

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