TEMPERATURE CHANGES OF ONE-PIECE IMPLANTS DURING THE SETTING OF ACRYLIC RESIN TEMPORARY CROWN. THE EFFECT OF IMPLANT DIAMETER. AN *IN VITRO* STUDY

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The purpose of this work is to evaluate changes in temperature of one-piece titanium implant surface during the setting of acrylic resin temporary crowns and to correlate thermal changes to implant diameter. Thirty-three one-piece implants (ARRP, Alpha-Biotec) were divided into 3 groups according to diameter size (G1=3 mm, G2=3.3 mm, G3=3.6 mm). Implants were mounted on an acrylic glass apparatus. Thermocouples were positioned at the most coronal thread. Lower incisor temporary polycarbonate crowns were filled with 80 μL of self-curing acrylic resin and positioned immediately on the implant abutment. Thermal changes of the implant surface were recorded continuously for 10 min. Data were statistically analyzed using one-way analysis of variance. The mean initial temperature (C0) of groups G1, G2 and G3 was similar (24.79±0.78ºC, 25.26±0.63ºC, 24.97±1.06ºC, respectively). The setting of the acrylic resin temporary crown resulted in a significant increase in the implant surface temperature of all groups. The mean thermal amplitude (ΔC) for groups G1, G2 and G3 were 6.79±1.02ºC, 6.61±0.94ºC, 6.65±1.26ºC, respectively. The mean time to maximum temperature (Tmax) for groups G1, G2 and G3 were 337.38±42.91 sec, 324.69±41.46 sec and 317.98±37.91 sec respectively (P>0.05). Direct application of auto-polymerizing resin to the titanium abutment of one-piece implants significantly increased the cervical implant surface temperature. Implant diameter did not influence the temperature changes.

One-piece implants have been designed to minimize marginal bone resorption by eliminating the submucosal microgap (1-11). For immediate function of one-piece implants with interim prosthesis, an insertion torque of 35 to 45 N-cm is recommended (12, 13). Unlike two-piece implants, one-piece implants lack complications associated with microleakage, micro-movement and screw-loosening (14). Furthermore, the structure and strength of one-piece implants enable the safe use of relatively small diameters. One-piece implants are entirely suitable for the aesthetic zone, allowing sufficient distance from adjacent teeth and preservation of the interproximal bone and the gingival papillae (15, 16).

Several studies have reported favorable results with one-piece implants and an immediate loading treatment approach in terms of implant stability,

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overall survival rate and bone changes over time (17-27). However evidence suggests that one-piece implants have low success rates, with cumulative survival rates of 89.3% (average 1-year follow-up for 550 implants), 94.8% (2-year follow up for 115 implants) and 94.9% (average 10.2 month follow up for 117 implants reported in 3 studies (19, 20).

One limitation of one-piece implants is that they must be prepared *in situ* to achieve proper emergence profile and angulation and be restored with a crown or partial denture (20). This intraoral procedure, which is performed immediately after implant placement, might compromise osseointegration via heat production and by impairing initial stability (28, 29).

Primary implant stability is a prerequisite for achieving osseointegration and is related to the implants micromotion (30). Animal studies indicated that micromotion above a threshold of 50-100 um result in fibrous union instead of osseointegration (31, 32). Primary stability depends on several factors; these include bone density and dimension, the implant geometry and the surgical technique. Primary stability following abutment preparation of one-piece dental implant was previously investigated by our group with a special "external fixation device" (7). Implants inserted with insertion torque of 15 N-cm lost primary stability after abutment preparation even though they had ISQ value of 57.3 (70.5 adjusted) while implant inserted at a torque of 30 N-cm did not lose primary stability during abutment preparation. It was concluded that insertion torque seems to be a more important factor than ISQ value in predicting primary stability of one-piece implant system (7).

Heat production during provisionalization of one-piece implants stem from the implant abutment preparation and during the setting of the interim restoration material. It has been shown that osteoblast cultures exposed to heat shock at 42ºC, induced activation of apoptosis mechanisms (33). Serial studies of intravital microscopy of heated bone have shown that rabbit tibiae heated to 50ºC for 1 min and to 47ºC for 5 min showed up to 40% bone resorption and replacement by fat cells at the heated site after 40 days (33-35). Furthermore, even the heating of bone to 47ºC for 1 min resulted in fat cell injury and inconsistent bone injury.

Recently it was reported that abutment preparation of one-piece implant with turbine water spray irrigation of 15 ml/min and 30 ml/min were associated with mean increase in crestal bone temperature of 8±1.5oC and 4±1.1oC respectively; while abutment preparation without water irrigation resulted in extensive heat generation exceeding 56oC in few seconds (36). Similar results were reported by Gronkiewicz et al who found that critical temperature threshold of 47°C was always surpassed during abutment preparation of one-piece implants when only air coolant was used (37).

Limited number of studies investigated heat production during provisional restoration of implant abutment, and in those studies, the temperature rise was observed on two-piece implant systems (38, 39). In one study, the implants were embedded in an acrylic resin model of a human mandible and the mean temperature rise reported was 4ºC to 5ºC at the cervical region (38). In a second study, the implants were embedded in a sheep iliac bone in a 37ºC water bath and the mean temperature rise found was only 0.5ºC to 1.04ºC, depending on the type of acrylic resin (39). To the best of our knowledge, heat production during provisional restoration of one-piece implants has never been studied.

The aim of this study is to evaluate thermal changes of one-piece implant neck during the setting of acrylic resin temporary crown and to investigate the effect of implant diameter.

MATERIALS AND METHODS

Experimental design

Thirty-three implants (ARRP, Alpha-Biotec) were equally divided into 3 groups according to implant diameter: G1 (3 mm implant), G2 (3.3 mm implant) and G3 (3.6 mm implant). The supracrestal abutment of all 3 groups of implants had the same dimensions: a width of 3.25 mm at bone level, a width of 2.5 mm at the coronal end, and a length of 9.5 mm.

Temperature measurement

The implants were mounted and fixed into machined slots in a custom-made acrylic glass apparatus (Fig. 1). K-type copper-constantan (Pico Technology, St Neots, Cambrigshire, UK) 30-gauge wire thermocouples were positioned at the most coronal thread. The thermocouples were tightened against the implant threads with plastic screws (Fig. 1). Thermal changes on the implant surface were recorded continuously at 100-ms sampling intervals using a TC-08 thermocouple data logger (Pico Technology, St Neots, Cambrigshire, UK) and data acquisition software (Picolog, Pico Technology, St Neots, Cambrigshire, UK). All measurements were recorded at room temperature.

Provisional crown preparation

Lower incisor temporary polycarbonate crowns (#62, 3MTMESPETM) were filled with 80 µL of self-curing acrylic resin (UNIFASTTM Trad, GC). The acrylic resin was mixed thoroughly for 10-15 seconds in a powder/liquid ratio of 0.4 gr/400 µl. The crowns were filled after the acrylic resin reached a dough-state (after approximately 20-30 sec, according to manufacturer instructions), and were then put on the implant abutment while ensuring that no resin flowed on the implant surface (Fig. 2). The acrylic resin was left to set on the implant abutment for 10 min.

Data processing and statistical analysis

Initial (C0) and maximum (Cmax) temperature measurements were extracted for the 3 groups (Fig. 3). The time elapsed until Cmax was reached (Tmax) was measured. The thermal amplitude (ΔC=Cmax-C0) was calculated, and temperature differences (C0 and Cmax), time differences (Tmax) and amplitude differences (ΔC) were analyzed for the 3 groups using the one way analysis of variance at a 95% confidence level (IBM SPSS Statistics 22.0, Armonk, NY, USA).

RESULTS

The mean initial temperature (C0) for groups G1, G2 and G3 was 24.79±0.78ºC, 25.26±0.63ºC and 24.97±1.06ºC, respectively (Table I), with no significant difference between the groups (P=.420). During the setting of the acrylic resin temporary crown there was a significant increase from baseline temperature (C0) in all groups (P<0.05) (Fig. 4). Mean maximal temperature (Cmax) for groups G1, G2 and G3 was 31.58±1.39ºC, 31.88±1.25ºC and 31.63±1.93ºC, respectively (Table I), with no significant difference between them (P=.893). The mean amplitude of thermal changes (ΔC) for groups G1, G2 and G3 was 6.79±1.02ºC, 6.61±0.94ºC and 6.65±1.26ºC, respectively. The mean Tmax (time to maximum temperature) for groups G1, G2 and G3 was 337.38±42.91 sec, 324.69±41.46 sec and 317.98±37.91 sec, respectively (Table I), with no significant difference between them (P=.534).

DISCUSSION

The results of the present study demonstrated that direct application of a polycarbonate crown filled with self-polymerizing resin on a one-piece implant abutment resulted in pronounced heating of the cervical implant area, with a mean temperature increase of 6.6ºC.

In a study by Li et al. (33), a heat shock of 42ºC induced activation of apoptosis mechanisms in osteoblast cultures, while heat shock of 48ºC resulted in irreversible damage. Taking into consideration a baseline temperature of 37ºC, a change of 6.6ºC found in our study may induce *in vivo* damage to the surrounding bone resulting in impaired osseointegration.

Our results are comparable with those of Ormianer et al (38) who used an intermediate volume of acrylic resin and reported a mean temperature rise of 4ºC to 5ºC at the cervical region. However Kazemi et al (39), who used implants embedded in fresh sheep iliac bone in a 37ºC water bath, found a mean temperature rise of only 0.5ºC to 1.04ºC, depending on the type of acrylic resin. These differences in mean temperature rise between the studies may be explained by the location of the thermocouple that was used to measure the temperature in the cervical area of the implant.

Preparation Results from different studies suggest that implants have a limited heat conduction capacity and that temperature conduction decreases markedly from the abutment apically along the implant (38-40). In the current study, the thermocouple was placed approximately 0.5 mm apical to the abutment-implant junction, compared with 2 mm apically described by Kazemi et al (39). Another explanation for the differences between the studies may be due

Table I. *Temperatures and time frames of heat production during acrylic resin setting*.

Implant Group (n= 11 each)	C0 (°C)	Cmax (°C)	ΔC (°C)	Tmax (sec)
G1[a]	24.79±0.78	31.58±1.39	6.79±1.02	337.38±42.91
G2[b]	25.26±0.63	31.88±1.25	6.61±0.94	324.69±41.46
G3[c]	24.97±1.06	31.63±1.93	6.65±1.26	317.98±37.91

Values are presented as mean±standard deviation.
***C0**: Initial temperature measurement; Cmax- maximum temperature measurement;*
***ΔC**: Thermal amplitude; **Tmax**: - time elapsed until Cmax; **sec**: seconds.*
[a]:3 mm diameter; [b]:3.3 mm diameter; [c]:3.6 mm diameter.

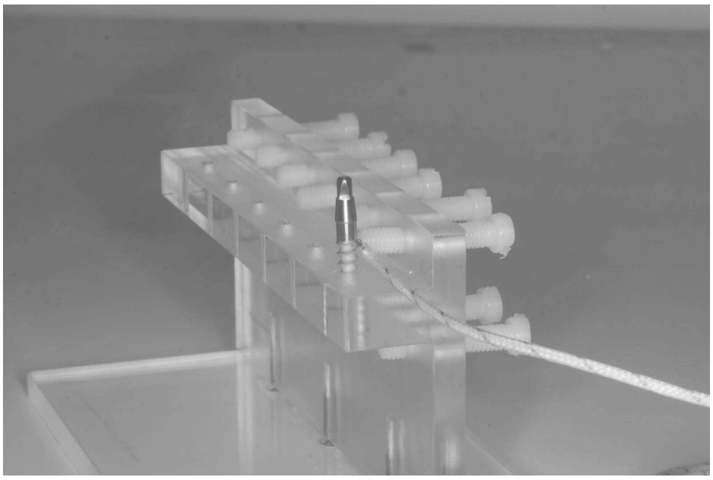

Fig. 1. *Mounting and fixing of an implant into machined slots in a custom-made acrylic glass apparatus.*

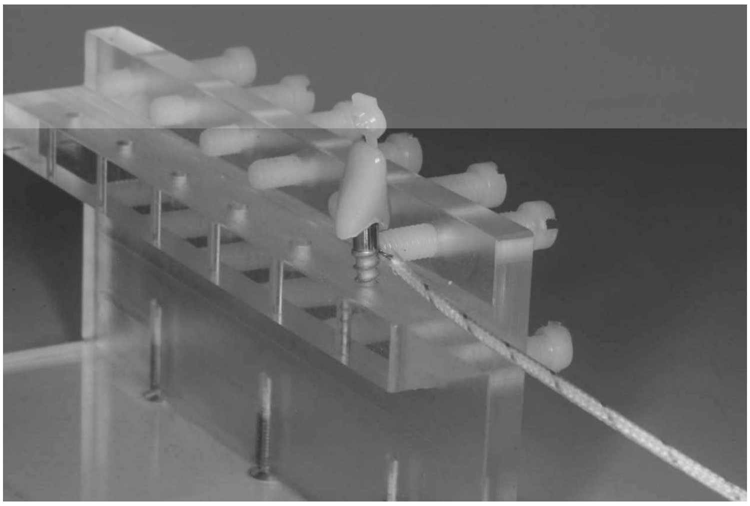

Fig. 2. *Placement of the filled crown on the implant abutment while ensuring that no resin flows on the implant surface.*

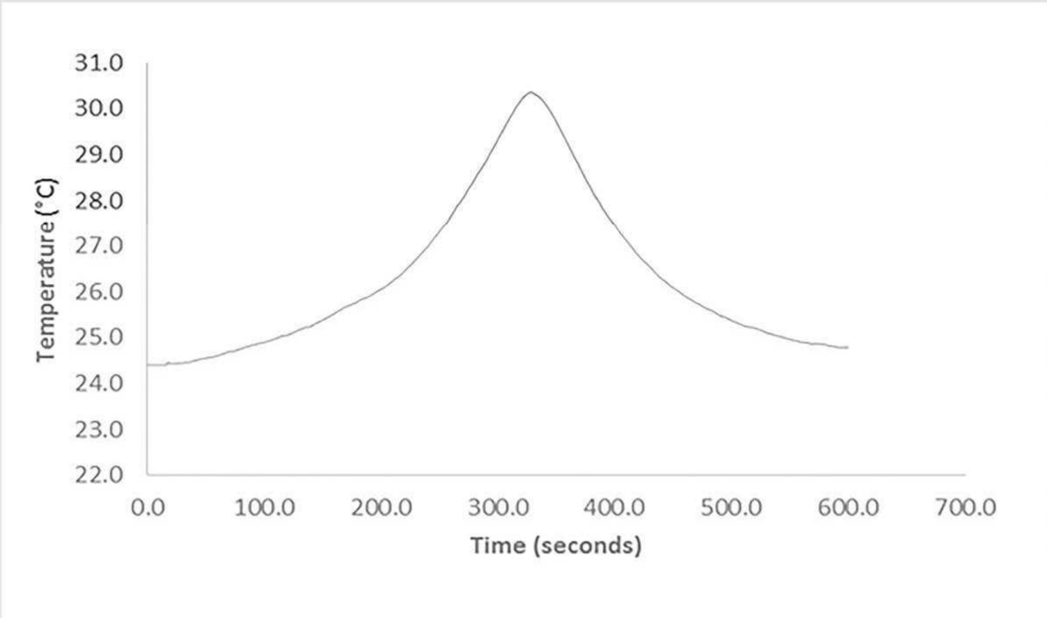

Fig. 3. *An example of recorded temperature over time. The thermal amplitude (ΔC) was calculated by subtracting the initial change (C0) from the maximum change (Cmax).*

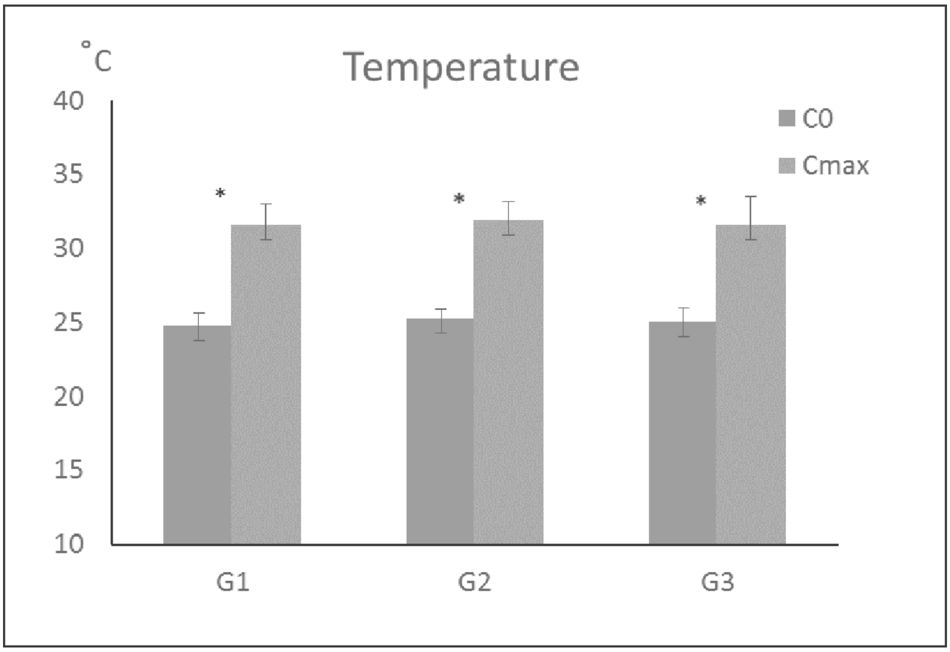

Fig. 4. *Baseline (C0) and maximal temperature (Cmax) recorded in groups.* ***G1****: (3.0 mm-implants);* ***G2****: (3.3 mm- implants);* ***G3****: (3.6 mm-implants). Data presented in Celsius degrees as mean value and standard deviation.* *******: denotes p<0.05.*

different jaw models. An acrylic glass apparatus which held only a small part of the implant body was used in this work, and most of the implant was in contact with air, which has low thermal conductivity (0.02 W/km), while Ormianer et al. (38) and Kazemi et al. (39) used an implant body that was embedded in a jaw model which probably absorbed a significant portion of the heat, having a 30 times higher thermal conductivity than air (0.54 to 0.58 W/km).

Thermal changes create a considerable thermal increase at the implant-cortical bone interface. On the other hand, previous studies demonstrated that implants have a limited heat conduction capacity, and that this is influenced by implant length, width and the physical characteristics of the implant specific to type of titanium alloy (41-43). This study is believed to be the first one to assess the correlation between implant diameter and temperature increase during provisional crown preparation in a reproducible experimental setup, and no influence of the 3 different evaluated implant diameters was found on any of the tested parameters.

One of the limiting factors of this study was that the acrylic resin was left to set exothermally on the implant abutments with no attempt to cool the abutment or provisional crown. Even so, the mean temperature increase, which was 6.6ºC, may induce osteoblast apoptosis *in vivo* (29). In addition, in the present study a small standard volume of 80 µL of acrylic resin was used in the polycarbonate crowns. In the clinical setting, however, the amount of self-polymerizing acrylic used in: impression abutment connection, the soldering index connection , the lining of provisional restorations and provisionalization of large temporary crowns, is expected be higher than the contents of the small polycarbonate crown used in the current study and therefore may result in a greater temperature rise.

Within the limitations of this in vitro study, direct application of auto-polymerizing resin to the abutment of one-piece implants resulted in increased cervical implant temperature. Implant diameter did not influence the temperature changes. To avoid thermal injury to the surrounding bone, it is recommended to constantly cool the implant with water spray, during the setting of the provisional restoration. Further studies using other restoration materials and implant systems should be conducted to confirm these results.

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