An Investigation of Heat Transfer to the Implant-Bone Interface Related to Exothermic Heat Generation During Setting of Autopolymerizing Acrylic Resins Applied Directly to an Implant Abutment

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Excessive heat generation at the implant-bone interface may cause bone damage and compromise osseointegration. Autopolymerizing acrylic resins are commonly used intraorally to join impression copings and suprastructure components for soldering. The effect of heat generation at the implant surface related to the exothermic setting reaction of autopolymerizing acrylic resins applied to an attached abutment was examined in vitro. Two brands of autopolymerizing acrylic resin, Duralay and GC Pattern Resin, were compared. Acrylic resin was applied to a titanium alloy abutment connected to a titanium alloy cylindric implant in varying controlled volumes, with both bulk application and brush paint-on techniques. The implant was embedded in an acrylic resin mandible in a 37°C water bath. Temperature changes were recorded via embedded thermocouples at the cervical and apical of the implant surface. Analysis of variance for repeated measures was used to compare treatment groups. A mean maximum increase in temperature of 4 to 5°C was seen at the implant cervical for both materials, with a maximum temperature increase of 6°C. No difference between Duralay and GC Pattern Resin was seen, except for bulk application to medium-sized copper bands at the implant cervical ($P < .05$). No difference between the bulk and brush techniques was seen for all options, except for GC, where bulk application to medium-sized copper bands produced higher temperatures than the brush technique ($P < .05$). Spray coolant reduced temperatures for bulk application of both Duralay and GC ($P < .05$). (Int J Oral Maxillofac Implants 2000;15:837–842)

Key words: *autopolymerizing resins, dental implants, heat generation, impression, irrigation*

Autopolymerizing acrylic resin is commonly used intraorally to join impression copings in an implant impression technique (Fig 1), as a soldering index to join superstructure components, and to reline or adapt provisional restorations in conventional and implant prosthodontics.[1–5] These acrylic resins generate significant thermal energy during setting.[6,7] When applied directly to implant impression copings or abutments, they pose a risk of potentially damaging heat transfer to the bone-implant interface. The exothermic setting temperature of 4 autopolymerizing interim resin materials was between 33 and 50°C, with polymethyl methacrylate showing the highest setting temperatures (48 to 54°C).[8] Measurements of heat transfer from 4 resins through dentin on prepared teeth to tooth pulp showed intrapulpal temperature increases from a low of 4.2°C to a high of 7.2°C from methylmethacrylate.[6]

The effect of overheating the tissues at the bone-implant interface can cause bone necrosis and compromise the bone's ability to survive as a differentiated tissue.[9–11] Studies have shown that bone tissues become sensitive to heating at 47°C, where intravital microscopy of heated bone was used. Rabbit tibiae

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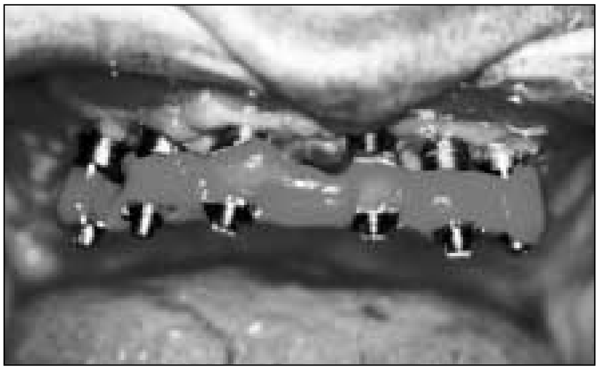

Fig 1 *(Above)* Acrylic resin is applied to impression copings for implant impression.

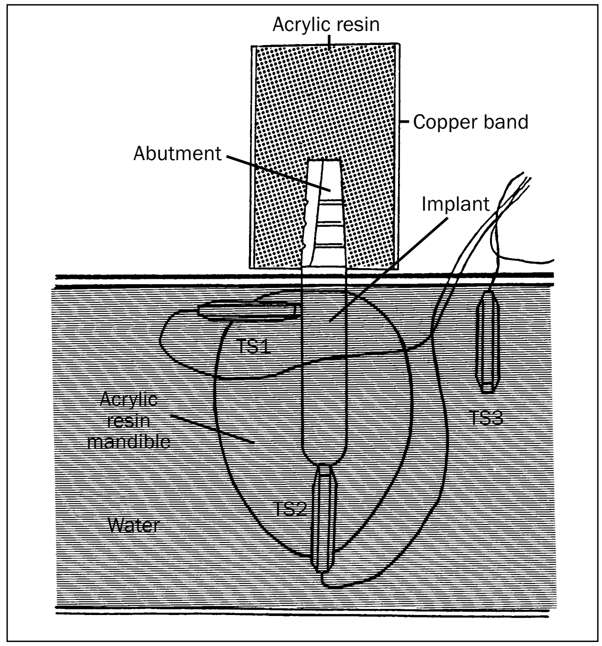

Fig 2 *(Right)* Illustration of experimental setup. TS1 = cervical temperature sensor; TS2 = apical temperature sensor; TS3 = water temperature sensor.

heated to 50°C for 1 minute and 47°C for 5 minutes showed 30 to 40% bone resorption in the observation fields after 40 days, with bone tissue replaced by tissue dominated by fat cells. When the bone was heated to 47°C for 1 minute, fat cell injury and inconsistent bone injury were observed. Endothelial cells of vascular tissue were more resistant to heating than bone and fat cells. Greater injury was reported after tissue was heated to 53°C for 1 minute, and temperatures of 60°C or more resulted in permanent vascular stasis and irreparable necrosis of the bone tissue.[11]

Although there is no direct evidence that heat from autopolymerizing acrylic resin causes a significant clinical problem, the temperature resulting from the exothermic setting reaction can reach as high as 54°C.[8] An increase of this magnitude can cause adverse tissue reactions at the bone-implant interface.

This in vitro study was designed to evaluate heat generation at the surface of a titanium alloy implant caused by the setting of autopolymerizing acrylic resin applied directly to the overlying abutment. Two commercially available resins were used in varying bulk and with different application techniques.

MATERIALS AND METHODS

A previously described in vitro model design was used.[12] An uncoated cylindric Integral titanium alloy implant body, 4 mm in diameter and 10 mm in length (Sulzer Calcitek, Carlsbad, CA), was embedded in an acrylic resin model of a human mandible (Fig 2). The mandible was immersed in a water bath (Hanau, Buffalo, NY) equipped with a thermostatic temperature control mechanism that maintained the initial water temperature at 37°C. A titanium alloy fixed abutment (Sulzer Calcitek) with a 2-mm gingival cuff length was screwed into the implant body and isolated from the water level by a rubber dam tied with dental floss at the cervical of the abutment and at distal peripheral abutments (Fig 2).

Temperature Recording System

Thermocouple electrodes were attached to a flattened peripheral surface of the embedded implant at the cervical and apical-facial aspects of the implant body. The connecting electrode wires were insulated with silicone. An additional electrode remained immersed in the water bath to measure the water temperature, and one more electrode was suspended in the air to measure the ambient room temperature to ensure its stability (Fig 2). Solid-state temperature sensors of 1 μA/K (Analogue Devices, Boston, MA) capable of measuring temperature changes of 0.1°C were connected to a monitoring system (Atlas 8600 Physiolos, Tel Aviv, Israel) and to a personal computer, with 4 bands recording real-time temperature. Data were recorded at a rate of 1 sample per 0.55 second.

Individual Student *t* tests were carried out between all treatment groups for the implant cervical. One-factor analysis of variance (ANOVA) for repeated measures was used, and Fisher protected least significant difference post hoc test was used to detect and locate differences between test groups.

Resin Application

Two commercially available autopolymerizing acrylic resins were used: Duralay (Bosworth, Chicago, IL) and GC Pattern Resin (GC Corporation, Tokyo, Japan). Resin was applied to 2 different sizes of copper bands: small (height 12.3 mm, diameter 8.9 mm) and medium (height 12.3 mm, diameter 11.0 mm) (Hahnenkratt, Eisingen, Germany). Resin was prepared using either a bulk technique or a paint-on brush technique. The paint-on brush technique used alternate liquid and powder-liquid mix applied at a rate of 15 drops over 2 minutes with a fine no. 2 brush (Berlia, Tel Aviv, Israel). Bulk application was carried out by mixing standard amounts of liquid and powder to a doughlike consistency and inserting the resin into the copper band, which was then placed over the abutment and held in position by thumb pressure until the resin had completely set.

Two groups of Duralay and GC acrylic resin in medium copper bands were tested using the bulk technique, with and without spray coolant. Spray coolant was applied at the rate of 88 mL for 40 seconds. The abutment height was 10.0 mm, cervix diameter was 3.9 mm, and occlusal diameter was 2.67 mm.

Ten separate trials were carried out for each test group. Measurements recorded for each sample were of the temperature change at the implant cervical and apical.

RESULTS

Cervical Changes

1. The temperature increase in medium-sized bands was always higher than in small-sized bands when the same application technique was used ($P < .05$), except for Duralay when the bulk technique was used (Fig 3, Table 1).
2. The temperature increase of GC on the medium band with bulk application was significantly larger than for Duralay on the medium band with bulk application ($P < .05$), but not for the small band with bulk application (Fig 3, Table 1).
3. The addition of spray coolant to medium bands with bulk application for both Duralay and GC reduced the temperature increase significantly ($P < .05$), ie, to less than that of the small band without coolant (Fig 3, Table 1).
4. For the same band size, the difference between the bulk and brush techniques was not significant ($P > .05$), except for GC applied to the medium band (Fig 3, Table 1).

Apical Changes

For all sizes and techniques, the mean changes at the apical were half of those at the cervical (Fig 3), reaching a maximum increase of 2°C, compared to a 6°C increase at the cervical (Fig 4).

Maximum Temperature Change

Maximum changes registered for bulk and brush applications for both materials with both band sizes ranged between 2 and 6°C. The addition of spray coolant reduced the change to less than 1°C (Fig 5).

DISCUSSION

Direct application of autopolymerizing acrylic resin in a medium-sized copper band to an implant abutment can cause heating of the implant cervical of up to 6°C. Large, uncontrolled quantities of acrylic resin applied to implant impression posts or metal superstructures can pass potentially significant levels of thermal energy to the implant neck and cervical/bone interface. These can be sufficient in degree and duration to cause tissue changes, as described by Eriksson and coworkers.[9–11] These changes are both temperature- and time-dependent. For example, heating of the implant complex would be rapid and transient while a patient drank a hot beverage. Application of heat over a longer period with a large bulk of autopolymerizing acrylic resin would cause a more substantial heating effect.[8]

The maximum mean increase in temperature (4 to 5°C) was seen at the implant cervical for both materials tested; the greatest temperature increase (6°C) would be sufficient to cause cervical bone damage. The temperature increase was similar for Duralay and GC for both bulk and paint-on techniques. The most influential variable in temperature increase was the amount of material used. Temperature changes ranged from 2.5 to 4.5°C on the medium band, and temperature changes on small bands ranged from 1 to 1.5°C. This indicates that the use of both an immediate bulk technique and a slow paint-on brush technique with a large volume of acrylic resin without spray coolant will generate cervical heating capable of tissue damage.

Clinically, the amount of autopolymerizing acrylic used in impression abutment connection, soldering index connection, and lining of provisional restorations can be larger than the contents of the medium-sized copper bands used in this study. Thus, the expected temperature change could be higher. Spray cooling has been shown to reduce intrapulpal heat generation during the fabrication of

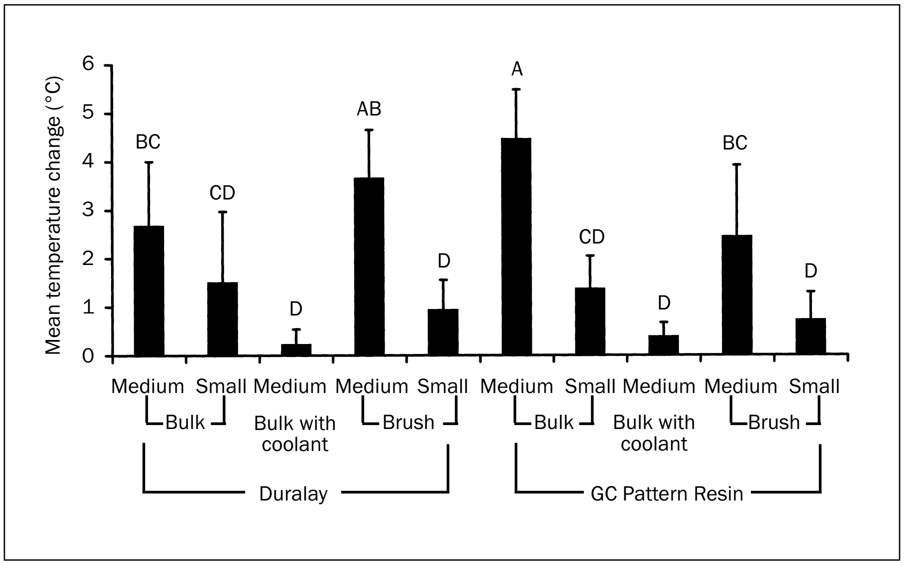

Fig 3 Mean cervical temperature changes between beginning and end of polymerization for Duralay and GC Pattern Resin, applied to small- and medium-sized copper bands on implant abutment, using bulk and brush-on techniques, with or without spray coolant (n = 10 for each group). A, B, C, D = treatments with the same letter are not significantly different ($P > .05$). Vertical bars represent standard error of the mean.

Table 1 Results of Student *t* Test (*P* Values) at Implant Cervical Level for All Treatment Groups

	GC Pattern Resin				Duralay			
	Brush		Bulk		Brush		Bulk	
	Small	Medium	Small	Medium	Small	Medium	Small	Medium
Duralay								
Bulk, medium	.05	.05	.5	.05	.05	.5	.5	—
Bulk, small	.5	.5	.5	.005	.5	.05	—	.5
Brush, medium	.005	.5	.005	.5	.005	—	.05	.5
Brush, small	.5	.05	.05	.0005	—	.005	.5	.05
GC Pattern Resin								
Bulk, medium	.0005	.05	.0005	—	.0005	.5	.005	.05
Bulk, small	.5	.5	—	.0005	.05	.005	.5	.5
Brush, medium	.05	—	.5	.05	.05	.5	.5	.05
Brush, small	—	.05	.5	.0005	.5	.005	.5	.05

provisional restorations.[13] Temperature increases were reduced from 7.1 to 2.4°C by spray cooling. In the present study, spray coolant reduced the temperature increase at the implant cervical during polymerization to less than 0.5°C for both Duralay and GC Pattern Resin. Thus, the use of spray coolants in these techniques allows the use of larger quantities of acrylic resin without damage to cervical bone at the bone-implant interface.

The present study showed a temperature increase of up to 6°C at the implant cervical. According to Eriksson and associates,[9–11] hyperemia and increased capillary filtration can occur at 41 to 43°C. After 2 weeks at 47°C, vascular stasis and some bone tissue damage has been reported.[10] Controlled bulk application and cooling as used in this study will avoid excessive heat generation and potential tissue damage.[8,10]

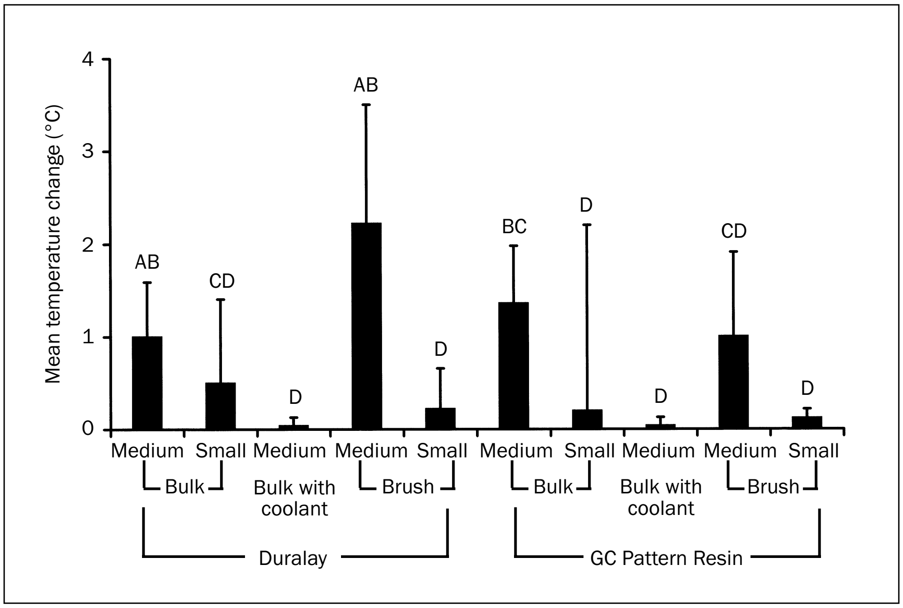

Fig 4 Mean apical temperature changes between beginning and end of polymerization for Duralay and GC Pattern Resin, applied to small- and medium-sized copper bands on implant abutment using bulk and brush-on techniques, with or without spray coolant (n = 10 for each group). A, B, C, D = treatments with the same letter are not significantly different ($P > .05$). Vertical bars represent standard error of the mean.

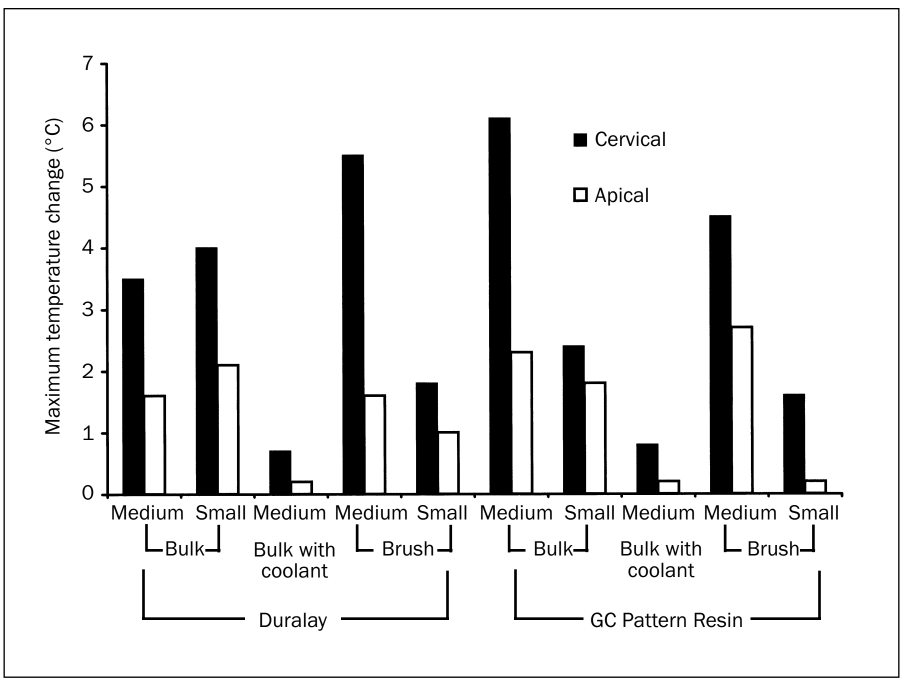

Fig 5 Maximum cervical and apical temperature increases caused by polymerization of Duralay and GC Pattern Resin, applied in small- and medium-sized copper bands on implant abutment using bulk and brush-on techniques, with or without spray coolant.

CONCLUSIONS

Direct application of autopolymerizing resin to titanium alloy abutments caused the following changes in the implant body surface temperature:

1. A mean maximum increase in temperature of 4 to 5°C was seen at the implant cervical for both materials in medium-sized copper bands, with a maximum temperature increase of 6°C.
2. Similar temperature changes were seen in Duralay and GC Pattern Resin.
3. Similar temperature changes were seen for both bulk application and the brush-on technique.
4. The use of spray coolant reduced the temperature increase to less than 1.5°C.

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