COMPARISON OF HEAT TRANSFER CHARACTERISTICS OF TEMPORARILY AND PERMANENTLY CEMENTED CROWNS

Nesrin Anıl, DDS, PhD
Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey

Canan Hekimoğlu, DDS, PhD
Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey

Umut Çakan, DDS, PhD
Prosthodontist, Private practice, Istanbul, Turkey

ABSTRACT

Background and Aim: Crown material and cement type may have influence on heat transfer to dental tissues. The aim of this study was to compare the temperature changes in pulp chamber and root surface after application of heat to different crown types cemented either with permanent or temporary cements.

Materials and Methods: Thirty six freshly extracted mandibular second premolars were embedded in acrylic resin blocks and channels to pulp at cementoenamel junction, midpoint and apex of the root were prepared. Test samples were randomly divided into three groups. All metal, metal ceramic, and all ceramic crowns were fabricated. Cementation was made with eugenol-free temporary and glass ionomer cements. Samples were placed in a 37±1 °C water bath and temperature was kept constant during the experiment. 5±1 °C and 60±1 °C water was applied to the crowns and instant temperature change in the pulp chamber within first second was measured with thermoelement. Temperature changes at pulp chamber, midpoint and apex of the root were also consequetively measured one minute after the application of water.

Results: Difference between the temperature changes measured in pulp and at two measurement points determined on root was statistically significant (p=0.01) for crowns cemented temporarily and permanently. Permanently cemented metal ceramic and all ceramic crowns demonstrated similar heat transfer characteristics. All metal crowns were found significantly more conductive (p=0.001).

Conclusion: Crown material and cement type affect the temperature changes. All metal crowns cemented permanently were found more conductive than others.

Key words: All Ceramic, All Metal, Metal Ceramic Crown, Temporary and Permanent Cement, Thermal Conductivity
INTRODUCTION

The esthetic and functional restoration of severely mutilated tooth either with metal-ceramic, all ceramic or all metal crowns is a common procedure in dental routine. Restorative procedures are often injurious to dental tissues. Protection of vital dental tissues especially pulp is essential during and after extensive restorative procedures. According to Goodis et al., pulp is considered as a low compliance system since it is encased in hard dentinal walls consisting large amount of connective tissue with a small blood supply and it has no possibility of developing collateral circulation. Pulpal injuries may occur due to chemical, mechanical or thermal factors and effects of different harmful procedures are cumulative. Heat application to pulp and periodontium may cause reversible or irreversible necrotic and histopathologic changes such as burn reactions at the periphery of the pulp including formation of “blisters”, ectopic odontoblasts and their destruction, protoplasm coagulation, expansion of liquid in dentinal tubules and pulp with increased outward flow from tubules. This process can affect pulpal vessels and lead to vascular injuries with tissue necrosis. Temperature rise in the pulp chamber greater than 5.6 °C is considered unacceptable because of a potential for loss of pulpal vitality. Teeth are subjected to temperature variations of up to 60 °C during consumption of hot or cold food or beverages, and breathing cold air. So far the effect of the thermal conductivity of different restorative materials and procedures on the pulp has been mostly investigated. It is also necessary to investigate the heat conduction characteristics of different crown materials and cements in order to determine to what extent hot and cold beverages and food affect temperature changes in pulp chamber and periodontium.

The aim of this study was to compare the temperature changes in pulp chamber and root surface after application of heat to different restorations cemented either with permanent or temporary cements.

MATERIALS AND METHODS

Thirty six freshly extracted caries-free human mandibular second premolars were used in the study. Teeth with approximately equal mesiodistal, buccolingual widths, cervico occlusal lengths and root dimensions were selected and stored in 0.9% saline solution. Soft tissue remains and calculus were removed and teeth were brushed with pumice. Pulp chamber, the midpoint of the mesial root surface and root apex were marked as the points of temperature measurement. Pulp chamber of each tooth was perforated perpendicular to the long axis with a 1 mm diameter diamond bur through its midpoint of cementoenamel junction on the mesial surface. Sprue wax (Sprue wax, Bego, Germany) with 5 mm length and 2 mm diameter was perpendicularly attached to the previously marked points. Teeth were embedded in autopolymerizing acrylic resin (Palavit, Heraus Kulzer, Germany) blocks (3 cm length, 3 cm width, 3 cm height). After sprue wax elimination, three channels were obtained for the evaluation of temperature changes in the pulp chamber and at the root surface.

Test samples were randomly selected and divided into 3 groups of 12 each. Fabrication of all metal, metal-ceramic and all ceramic crowns was planned. Silicone putty indexes of the teeth were made using polyvinyl siloxane impression material (Putty Speedex, Coltene Whaledent, Switzerland) prior to preparation. Silicone indexes were sectioned longitudinally and each half was used for crown preparation. For standardization of occlusal preparation depth, orientation grooves were prepared with 1.5 mm wide diamond bur. Orientation grooves were put together in the next step. Axial taper was prepared parallel to the long axis of the tooth. 1.5 mm wide chamfer finish line was prepared for all metal crowns and metal-ceramic crowns, shoulder finish line was prepared for all ceramic crowns. Preparation was made with a high speed hand piece under water coolant. Occlusal reduction was 1.5 mm for each sample. Three layers of interspace varnish, (approx. 45 µm), (Interspace varnish, Vita, Germany) was applied on the prepared teeth by the same dental technician.

Wax patterns of the all metal and metal-ceramic crowns were directly fabricated on the prepared teeth. Longitudinally sectioned silicone indexes were also used for crown waxing. By this method twenty four full waxed crowns were fabricated. Cervical part outline of the twelve of the waxed crowns was used as a guide for a cylindrical modelation. Flat occlusal surfaces were performed at the cusp levels.

All-wax technique was used for forming metal copings. Orientation grooves were carved in the other twelve full waxed crowns using discoid carver for standardization of coping thickness. Then the remaining wax was removed with a sharp knife to the desired thickness.
Casts were made with Ni-Cr alloy (Ceraplus S, President, Germany). Castings were adjusted using conventional procedures and thicknesses were controlled with a thickness gauge.

Porcelain (Ceramco II, Dentsply Ceramco, N.York, PA) was applied on the metal copings using silicon indexes and conventional methods. All crowns were fabricated in cylindrical form by the same method as described above.

For fabrication of all ceramic crowns (In-Ceram Alumina, Vita, Germany), with slip technique, impression of each prepared tooth was taken with a polyvinyl siloxane impression material (Speedex, Coltene Whaledent, Switzerland) and poured with a dimensionally stable plaster (CAM Base, Dentona, Germany). Three layers of interspace varnish (Interspace varnish, Vita, Germany) was applied onto the die. The working die was duplicated using polyvinyl siloxane impression material (Speedex, Coltene Whaledent, Switzerland) in a ratio of 1:1 using the dual impression technique. After deflasking the finished impressions, plaster of the system (In Ceram Special Plaster, Vita, Germany) was poured. Slip was mixed and applied according to the manufacturer’s recommendations with occlusal 0.7 mm and circumferential 0.5 mm wall thickness. After first sintering, fit of coping was checked on the working die. Second sintering and glass infiltration of the adjusted copings were performed according to the directions of the In-Ceram system. Crown copings were veneered with porcelain (VITA VM 7, Vita, Germany) using sectioned silicone indexes and conventional methods.

All fabricated crowns were cemented with eugenol free temporary cement (Cavex temporary cement, Cavex, Holland) according to the manufacturer’s recommendations and stored in water for 24 hours before testing (Figure 1).

A water storage unit with equal volume was fabricated over acrylic resin blocks in order to simulate the fluid intake during diet (Figure 2).

In order to simulate in vivo conditions, the samples were preheated in a 37±1 °C water bath. The bath temperature was kept constant with a heater controlled by digital thermostat during the experiment. 5±1 °C cold water was applied over the cemented crowns and instant temperature change in the pulp chamber within first second was measured with probe of a NiCr-Ni thermocouple (Elimko-4000, Elimko, Turkey) connected to an electronic digital thermometer. Second measurement was made 1 minute later in the pulp chamber and measurements were followed at the root surface and the apex of the root consecutively. The same procedure was repeated on the cemented crowns with 60±1 °C water. Digital thermometer was calibrated to 0 °C after each measuring sequence. After testing procedure, all crowns were decemented and cleaned in an ultrasound cleaning device. Crowns were cemented with glass ionomer cement (Ionobond, Voco, Germany) according to the manufacturer’s recommendations and stored in water for 24 hours before testing. The same testing procedures were repeated for permanently cemented crowns.

**Statistical Analysis**

Means and standard deviations determined for crown types are shown in Tables 1, 2 and 3.

Repeated Measures ANOVA was used to evaluate the differences among measuring points according to crown type, heat application and cement type. Since, interaction terms was found significant in Repeated Measures ANOVA, subgroup analysis were performed. Adjusted Bonferroni method was used for multiple comparisons.

One way analysis of variance (ANOVA) was applied to determine statistically significant differences among crown types in each simian type and heat application. The significance level was established at a p value <0.05. Differences between significant groups were identified with Duncan multiple comparison test.

Independent Samples t-test was used to examine the statistically significant difference between cement type in each crown type and heat application.
Table 1. Means and standard deviations determined for all metal crowns.

<table>
<thead>
<tr>
<th></th>
<th>5 °C-temporary</th>
<th>60 °C-temporary</th>
<th>5 °C-permanent</th>
<th>60 °C-permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 s-P</td>
<td>34.75±1.60</td>
<td>39.50±2.02</td>
<td>37.00±0.00</td>
<td>40.00±1.53</td>
</tr>
<tr>
<td>1 min-P</td>
<td>17.08±2.10</td>
<td>52.33±1.92</td>
<td>28.83±2.16</td>
<td>57.75±1.76</td>
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<tr>
<td>Root-M</td>
<td>33.33±2.22</td>
<td>39.83±1.40</td>
<td>34.00±2.48</td>
<td>45.00±2.59</td>
</tr>
<tr>
<td>Root-A</td>
<td>36.50±1.44</td>
<td>37.92±0.44</td>
<td>34.25±4.71</td>
<td>40.00±2.29</td>
</tr>
<tr>
<td>Final-P</td>
<td>17.50±2.27</td>
<td>51.00±2.29</td>
<td>19.67±1.61</td>
<td>57.08±1.92</td>
</tr>
</tbody>
</table>

s: second; min: minute; M: mesial; A: apex; P: pulp

Table 2. Means and standard deviations determined for all ceramic crowns.

<table>
<thead>
<tr>
<th></th>
<th>5 °C-temporary</th>
<th>60 °C-temporary</th>
<th>5 °C-permanent</th>
<th>60 °C-permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 s-P</td>
<td>35.08±0.79</td>
<td>38.67±0.77</td>
<td>36.92±0.51</td>
<td>38.08±0.66</td>
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<tr>
<td>1 min-P</td>
<td>16.92±1.56</td>
<td>51.92±1.16</td>
<td>31.08±2.67</td>
<td>55.42±0.90</td>
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<tr>
<td>Root-M</td>
<td>31.92±2.77</td>
<td>40.92±2.02</td>
<td>34.75±1.48</td>
<td>44.00±1.59</td>
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<tr>
<td>Root-A</td>
<td>36.25±1.47</td>
<td>38.08±0.99</td>
<td>36.42±0.99</td>
<td>38.25±0.75</td>
</tr>
<tr>
<td>Final-P</td>
<td>17.17±1.99</td>
<td>50.83±1.33</td>
<td>20.58±3.34</td>
<td>54.75±1.05</td>
</tr>
</tbody>
</table>

s: second; min: minute; M: mesial; A: apex; P: pulp

Table 3. Means and standard deviations determined for metal ceramic crowns.

<table>
<thead>
<tr>
<th></th>
<th>5 °C-temporary</th>
<th>60 °C-temporary</th>
<th>5 °C-permanent</th>
<th>60 °C-permanent</th>
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</thead>
<tbody>
<tr>
<td>1 s-P</td>
<td>35.42±0.90</td>
<td>39.00±0.60</td>
<td>37.00±0.00</td>
<td>38.00±0.00</td>
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<tr>
<td>1 min-P</td>
<td>17.92±2.10</td>
<td>52.67±2.01</td>
<td>31.50±2.71</td>
<td>54.83±2.36</td>
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<tr>
<td>Root-M</td>
<td>33.58±1.62</td>
<td>40.75±1.48</td>
<td>34.83±1.99</td>
<td>43.92±2.50</td>
</tr>
<tr>
<td>Root-A</td>
<td>36.58±0.90</td>
<td>38.50±1.08</td>
<td>35.75±2.26</td>
<td>39.17±1.88</td>
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<tr>
<td>Final-P</td>
<td>18.50±1.78</td>
<td>51.42±2.02</td>
<td>22.83±3.09</td>
<td>54.25±2.56</td>
</tr>
</tbody>
</table>

s: second; min: minute; M: mesial; A: apex; P: pulp
RESULTS

Comparison of Crown Types

Permanent cementation, 5 °C ± 1 heat application - within first second:
Temperature change in the pulp chamber was found insignificant (p=0.732) for all crown types cemented with glass ionomer cement (Figure 3).

Permanent cementation, 5 °C ± 1 heat application - after one minute:
Temperature changes in pulp chambers of all metal crowns were significantly higher than all ceramic and metal ceramic crowns (p=0.031). The difference between all ceramic and metal-ceramic crowns was found statistically insignificant (p=0.689), (Figure 4).

Permanent cementation, 60 °C ± 1 heat application - within first second:
Temperature changes in pulp chambers of all metal crowns were significantly higher than all ceramic and metal ceramic crowns. (p=0.001). The difference between all ceramic and metal-ceramic crowns in the pulp chamber was found statistically insignificant (p=0.834), (Figure 5).

Permanent cementation, 60 °C±1 heat application - after one minute:
Temperature change in pulp chamber of all metal crowns was found significantly higher than the others. (p=0.001). The difference between all ceramic and metal ceramic crowns was found statistically insignificant (p=0.428) (Figure 6).

Permanent cementation, root measurements:
After application of cold and hot water, temperature changes in the mesial surfaces of the root, showed no significant differences for all crown types (p=0.547; p=0.440) (Figure 7). After application of cold and hot water, temperature changes in apex of the root, showed insignificant differences for all crown types (p=0.224; p=0.068) (Figure 8).

Temporary cementation, 5 °C ± 1 - 60 °C ± 1 heat application:
Temperature changes determined in all measurement points were statistically insignificant (p values varied between 0.166 and 0.782).

Comparison of Temporary and Permanent Cements

Application of 5±1 °C heat:
After application cold water temperature changes measured in the pulp of all metal crown cemented permanently were
HeAT TransFer ThrougH crowNS

found significantly higher than the measured in pulp of crown cemented temporarily (p=0.001).

When mesial surfaces compared, for all metal and metal ceramic crowns, differences between permanent cement and temporary cement were found statistically insignificant (p=0.496; p=0.106).

All ceramic crowns cemented permanently showed significantly higher temperature changes at the mesial surface (p=0.005).

For all metal, metal ceramic and all ceramic crown types cemented with either cements, the differences between temperatures measured at the apex were found statistically insignificant (p=0.128; p =0.248; p=0.717).

Application of 60±1°C heat:

For permanently and temporarily cemented all metal and all ceramic crowns, within first second in the pulp the difference between temperatures was statistically insignificant (p=0.503; p=0.062). For metal ceramic crowns within first second, temporary cement was found significantly more conductive when compared to permanent cement (p=0.001).

For all ceramic and metal ceramic crowns, temperatures measured at the root apex, the difference between cements was found statistically insignificant (p=0.649; p=0.307). For all metal crowns permanently cemented, temperature measured at the root apex was significantly higher when compared to temporarily cemented crowns (p=0.010).

Comparison of the Temperatures Measured at Different Points

For all crowns cemented temporarily and permanently, one minute after cold water application, the temperatures measured in the pulp were found significantly lower than measured at mesial root surface and apex (p=0.001). For all crowns cemented temporarily and permanently, the temperatures measured in the pulp one minute after hot water application were found significantly higher than measured at mesial root surface and apex (p=0.001). The differences between mesial and the root apex were also significant (p=0.001).

For all crowns cemented temporarily the differences between temperatures measured in the pulp after one minute and final pulp measurement with cold water application were found insignificant (p=0.100). For metal ceramic, all metal and all ceramic crowns cemented permanently, the differences between temperatures measured in the pulp after one minute and final pulp measurement with cold water application were found insignificant (p=1.000).
water application were found significant (p=0.001). For all metal crowns cemented temporarily and permanently, the differences between temperatures measured in the pulp after one minute and final pulp measurement with hot water application were found statistically significant (p=0.001).

**DISCUSSION**

The thermal behaviour of restored and unrestored teeth has been the subject of dental studies for many years. They were mainly focused on pulpal reactions and/or thermal properties of biological and restorative materials. Reports in the literature substantiate the deleterious pulpal response to heat.15-17 According to Zach and Cohen7, for 50% of the cases, after 10 °F (5.5 °C) temperature increase in the pulp, tissue can not regain its initial state while, the temperature increase is more than 20 °F, for 60% of the cases, irreversible pulp response was observed. Necrotic reaction takes place when the temperature increase reaches 30°F. On the other hand, experimentally alveolodental ankylosis has resulted after replantation of teeth, root canal treatment, high crown placement and thermal injury in the periodontium. 1,3,18-22 Atrizadech et al.3 have established that heat application has a role of co-factor to trauma in the genesis of destructive periodontal disease. It has been extensively reported that heat produced during dental procedures causes pulpal damage and the studies concerned with the influence of heat on the pulp predominate.23-25 Agreemently heat conduction by restorative materials will affect primarily the pulp and it is a well known fact that pulpal health is directly related to tooth vitality. From our point of view, heat conduction problem should not be restricted only with its effect on the pulp, the tooth should be investigated as a whole system and periodontium should also be included.

Heat conduction properties of different crown types and cements was investigated to predict the pulpal and periodontal response to heat and heat transfer capacity of used materials. In present study, temperature differences measured in pulp were stable and higher than the values obtained in other measuring points.

Hypersensitivity to cold stimuli within 24 hours after dental treatment has been reported to be experienced by 50% of patients whereas discomfort resulting from hot stimuli has been reported by 19% of patients.26 Temporary post operative hypersensitivity to thermal stimuli is not only the result of operative procedures but may also be experienced due to the thermal diffusivity of restorative materials. Gluskin et al.4 supposed that dentinal walls exposed during tooth preparation are considered excellent nonconductors because thicker residual dentin has a greater insulating effect necessary to protect pulpal tissues from thermal injuries. It is often met with post operative hypersensitivity and generally this hypersensitivity is depended on heat transmission through the restorations. The use of a cement base has to be recommended in order to limit thermal trauma and to promote the production of reparative dentin.

For vital teeth in situ, the subgingival part of the root is insulated by the enviromental tissues. The temperature at the subgingival cervical outer surface is assumed to be stable.27 According to Boehm28, the ambient temperature, humidity and dryness of the oral cavity affect the temperature of the cavity when the mouth is opened. In our experimental setup, in order to simulate oral conditions, the roots were immersed continuously in 37 °C water bath during measurement procedures and only crowns were subjected to different thermal environment. Spierings et al.27 analysed the temperature distribution in human teeth restored with an occlusal amalgam and various cement bases. The maximum interface temperature within the tooth model restored with amalgam was only 38.4 °C. The presence of a 0.5 mm thick cement base of calcium hydroxide Ca(OH)₂ below this amalgam restoration was found to reduce the maximum temperature to 0.4 °C at the restoration-dentin interface.27 In our study, applied layer of interspace varnish for cement film thickness is lower than 0.5 mm so its effect on reducing the maximum temperature can be considered lower.

Spierings et al.27,29 concluded that not only the temperature increase but also the rate in temperature rise could be an important factor in the reaction mechanism of the pulp to thermal stimuli. Spierings et al.22 performed a study on an unrestored tooth model and maximum temperature of 37 °C reached at the PDJ in 18.5 seconds. Trowbridge et al.30 also related both temperature increase and rate in temperature rise to the dentinal fluid velocity and the sensory response. In this study immediate temperature rise in pulp within first second and after one minute was measured. For all specimens, the pulp reached maximum temperature in one
minute. The measurements on the root were performed at the end of this period. Temperature ranges for testing have often been selected arbitrarily. Typical temperature ranges in current literature are: 5 °C to 60 °C, 10 °C to 50 °C, 4 °C to 58 °C, 5 °C to 55 °C, 4 °C to 60 °C, 2 °C to 50 °C and 7 °C to 50 °C. In this study temperature range was selected as 5 °C to 60 °C.

The results of this study showed that crown material, cement type and applied heat affected the temperature change. Among all crowns cemented with noneugenol temporary cement, there were insignificant differences measured at the different points and under two different temperature conditions. The temperatures measured in the pulp by applying of 5±1 °C varied between 16.92 °C and 17.92 °C. The temperatures measured in the pulp by applying of 60±1 °C varied between 51.92 °C and 52.67 °C. Permanent cementation showed different behaviour according to the applied temperature and to the crown material. The highest heat transmission was determined by the permanently cemented all metal crowns in application of 60±1 °C heat. Maximum increase in the pulp determined by the all metal crowns was 57.75 °C. By applying of 5±1 °C heat, maximum decrease in the pulp determined also by the all metal crowns was 28.83 °C. The greatest increase determined in this study was about 20 °C, the greatest decrease was about 10 °C. Temperature changes in our study is less than the values which Zach ve Cohen considered unacceptable because of potential for loss of pulpal vitality. For the temperatures measured at the mesial surface of the root and at the apex, insignificant differences were found between cements and crowns. The greatest temperature determined at the mesial surface by the full metal crowns cemented permanently was 45 °C for application of 60±1 °C. The temperatures measured at the mesial surface of the roots of all crown types cemented permanently, varies between 43.9 °C and 45 °C for 60±1 °C application.

One minute after heat application, temperature changes occurred in pulp chambers of all metal crowns were significantly higher than all ceramic and metal ceramic crowns. This may be related with higher heat transfer coefficient of metals. Differences in thermal conductivity of studied crown materials may have been compensated by temporary cement. Thermal effects on periodontium can be considered secondary.

Keeping extreme cold or hot food in oral cavity for one minute may be unrealistic when in vivo conditions considered. This duration of time was preferred in order to analyze the heat transfer characteristics of different cement and crown materials appropriately. Standardization of material thickness, simulation of oral conditions and precise measurement of thermal changes are the limitations of in vitro thermal studies. Because of the differences in dimension of pulp chambers, it is difficult to standardize dentin thickness when human teeth are used. Therefore, teeth without abrasion and malformation were included in present study. Thus dentin is a good insulator, minimal deviations of thickness was assumed ineffective. For permanent cementation of all ceramic, metal-ceramic and all metal crowns, glass ionomer cement was preferred in present study. Glass ionomer cement may be a viable alternative for most of the clinicians because of its reasonable price when compared to resin cement. Further clinical thermal studies are needed in order to validate the results of in vitro studies.

**CONCLUSIONS**

Within the limitations of this study, following conclusions were withdrawn:

1. Crown material and cement type affect the temperature changes.
2. All metal crowns have higher heat transfer capacity when compared with all ceramic and metal ceramic crowns for permanent cementation.
3. Temporary cement may compensate thermal conductivity of different crown materials.
4. Temperature changes in pulp are higher than temperature changes at the root surface and apex. Apex is the least affected point under different thermal conditions.
5. Temperature changes in pulp are stable for a long time of period.

**REFERENCES**


