Temperature Rise under Normal and Caries-Affected Primary Tooth Dentin Disks during Polymerization of Adhesives and Resin-containing Dental Materials

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The purpose of this study was to compare the temperature rise under normal and caries-affected primary tooth dentin during photopolymerization of two adhesives and resin-containing restorative materials.

Caries-affected and normal dentin disks were prepared from extracted primary molars with only mesial or distal approximal caries (4 mm in diameter, 1 mm in height). Temperature rise during photopolymerization of adhesive materials was measured with a J-type thermocouple wire that was connected to a data logger. Data were analyzed with two-way ANOVA and independent samples t-test.

Temperature rise under caries-affected primary tooth dentin disks was higher than that of normal primary tooth dentin disks during polymerization of both adhesive systems and resin-containing dental materials (p<0.05). It was found that adhesive systems induced a higher temperature rise during polymerization as compared to the resin-containing restorative materials (p<0.05). In particular, temperature rise during polymerization of adhesive materials exceeded 5.5°C under caries-affected primary tooth dentin.

Key words: Temperature rise, Caries-affected primary tooth dentin, Photopolymerization

INTRODUCTION

It is commonly believed that temperature increases associated with certain dental procedures pose a serious threat to pulp vitality10. Thermal trauma may be induced by cavity preparation or by the exothermic polymerization reaction of restorative materials21. It has been suggested that visible light activation units may also contribute to temperature rise within the pulp chamber and which may harm the pulp22. The classic animal study by Zach and Cohen set forth a threshold temperature for irreversible pulpal damage when external heat was applied to a sound tooth: a 5.5°C intrapulpal temperature increase induced necrosis in 15% of the tested pulps9.

Many laboratory studies have been conducted on ground or non-curious dentin substrates to measure temperature rise during photopolymerization of resin-containing dental materials5-8. However, non-curious dentin is not the substrate most frequently encountered in clinical dentistry9. On the contrary, dentists are restoring teeth with carious dentin. Carious dentin is characteristically described as consisting of infected and affected layers. The affected layer is generally not removed during treatment10-12. Therefore, following caries removal and cavity preparation for an adhesive restoration, a large area of the cavity floor is composed of caries-affected dentin.13.

The physical and chemical characteristics of caries-affected dentin are very different from those of normal dentin. Caries-affected dentin is softer than normal dentin because it is partially demineralized11,14-16. Compared with normal dentin, crystals of intertubular caries-affected dentin are scattered and randomly distributed with larger apatite crystallites and wider inter-crystalline spaces17. Moreover, most tubules of caries-affected dentin are occluded with mineral deposits15,16. Electron probe microanalysis also showed that elemental contents are different between normal and caries-affected dentin surfaces18. With due consideration of these differences, they may have significant implications for temperature rise between normal and caries-affected dentin.

To date, few studies have been carried out to measure temperature rise during the photopolymerization of resin-containing dental materials under normal and abnormal dentin18. Fanibunda and De Sa18 found that carious dentin had a significantly higher thermal conductivity — that is, less thermal insulating properties — than normal dentin. As for the comparison of temperature rise between normal dentin and caries-affected primary tooth dentin, it has not been reported to the best of our knowledge.

The increasing demand for esthetic restorative treatment has totally transformed the landscape of...
pediatric dentistry practice\(^{(19)}\). Since the introduction of esthetic restorations to the market in 1993, the indication range of composites has been extended to both anterior and posterior restorations of primary teeth\(^{(20-22)}\). By virtue of their high esthetics, good physical and mechanical properties, composites can be accepted as an alternative to glass ionomer and hybrid composite restorative materials\(^{(23-25)}\). Recently, packable composite resins are also introduced for posterior restorations, and they may well gain a foothold in restorative dentistry for children\(^{(26)}\).

The purpose of this in vitro study was to compare the temperature rise under normal and caries-affected primary tooth dentin during photopolymerization of two adhesive systems and resin-containning restorative materials by a conventional light source. The hypothesis was that the temperature rise measured under normal dentin during photopolymerization of dental materials will be different from that of caries-affected primary tooth dentin.

**MATERIALS AND METHODS**

Table 1 shows the adhesive systems and restorative materials used in this study. Shade A3 of each material was used in this study. One light source (Hilux, Express Dental Products, Toronto, Canada; 450 mW/cm\(^2\), 40 seconds) was used to polymerize the light-curing resin materials. The light output of the polymerizing unit was checked before each testing procedure using a digital radiometer (Curing Radiometer, Demetron Inc., Danbury, CT, USA).

**Specimen preparation**

The research protocol used was approved by the Human Ethical Committee of the Faculty of Dentistry, University of Selcuk (2007 15/1). Twenty extracted human primary molars with only mesial or distal approximal caries were used in this study within one month of extraction.

Approximal surfaces with and without caries and parallel to the long axis of each tooth were prepared by using a low-speed diamond saw (Isomet, Buehler Ltd., Lake Bluff, IL, USA) under water cooling. The surfaces were wet-ground with 320-grit SiC paper under water cooling to create flat surfaces.

To obtain caries-affected dentin disks, grinding was performed based on the combined criteria of visual examination and staining with a Caries Detector dye (Kuraray Co. Ltd., Osaka, Japan) as previously described\(^{(11)}\). The surface was covered with the caries detector solution and then the latter rinsed off with water. Surrounding yellow and hard dentin was classified as sound dentin, while discolored and harder dentin that was stained pink was classified as caries-affected dentin\(^{(10)}\). A second cut was performed parallel to the first one, and dentin disks of 4 mm diameter and 1 mm height were thus obtained. One proximal surface of each tooth was used to obtain caries-affected dentin disk and the other proximal surface for normal dentin disk. The dentin disks were kept in water to avoid dehydration until testing.

**Temperature measurement**

To evaluate whether histochemical and/or structural variables of the dentin disk would affect temperature change, temperature rise in the dentin disk without any restoration and prior to photopolymerization was measured. The measured mean temperature rise

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Manufacturer</th>
<th>Mixing Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compoglass F</td>
<td>UDMA, TEGDMA, CDCMA, Ytterbium trifluoride,</td>
<td>Ivoclar Vivadent AG,</td>
<td>Apply resin material in 2 mm thickness, photoactivate 40 s</td>
</tr>
<tr>
<td></td>
<td>barium aluino fluorosilicate glass</td>
<td>Liechtenstein</td>
<td>with QTH</td>
</tr>
<tr>
<td>Aelite LS</td>
<td>UDMA, TCB resin,</td>
<td>Bisco, IL,USA</td>
<td>Apply resin material in 2 mm thickness, photoactivate 40 s</td>
</tr>
<tr>
<td></td>
<td>Strontium-Al-Na-Flupo-P-silicate glass, strontium fluoride</td>
<td></td>
<td>with QTH</td>
</tr>
<tr>
<td>AdheSE Bond</td>
<td>Primer: Dimethacrylate, phoshoric acid acrylate Bond: HEMA, silicon dioxide, water, stabilizers</td>
<td>Ivoclar Vivadent AG,</td>
<td>Apply primer, apply bond, gently air-thin, photoactivate 10 s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liechtenstein</td>
<td>with QTH</td>
</tr>
<tr>
<td>One Step Plus</td>
<td>HEMA, BPDM, BIS-GMA, acetone</td>
<td>Bisco, IL, USA</td>
<td>Apply primer, apply bond, gently air-thin, photoactivate 10 s</td>
</tr>
</tbody>
</table>

TEGDMA: triethyleneglycol dimethacrylate; HEMA: 2-hydroxyethyl methacrylate; Bis-GMA: bisphenyl-glycidylmethacrylate; TCB: tetracarboxylic acid hydroxyethyl methacrylate ester; BPDM: biphenyl dimethacrylate
during application of polymerizing unit was $8 \pm 1^\circ C$.

To measure temperature rise during photopolymerization of the visible light-cured adhesive resins (AdheSE Bond and One Step Plus), these materials were applied on the dentin disks and polymerized according to manufacturers’ instructions (Table 1). After polymerization of adhesive resin, the central cylinder aperture was filled with the resin material, namely a componer (Compoglass F) or composite (Aelite LS), and polymerized according to their manufacturers’ instructions (Table 1).

Temperature rise was measured under a dentin disk to simulate the temperature rise in the pulp. A silicone mold was prepared as a supporting structure to dentin and the resin materials (Fig. 1). Light tip of the curing unit was centered on the resins materials with no distance apart. A silicone heat transfer compound (ILC P/N 213414, Wakefield Engineering, MA, USA) was applied under the dentin disk. This compound facilitated the transfer of heat from the wall of the dentin disk to the thermocouple wire. A J-type thermocouple wire of 0.91 cm diameter (Omega Engineering Inc., Stamford, CT, USA) was connected to a data logger (XR440-M Pocket Logger, Pace Scientific, NC, USA) during the photopolymerization of the adhesives and resin-containing restorative materials (Fig. 1).

Sampling rate of the data logger was set to one sample every two seconds for a recording period which started with light curing for approximately 60–90 seconds until the temperature started to decrease. Collected data, which were available in both tabular and graphic forms, were monitored real-time and transferred to a computer.

Light output of the curing unit was measured before each testing procedure using a digital curing radiometer (Curing Radiometer, Demetron Inc., Danbury, CT, USA). Following light output measurement, the test was repeated 10 times with the curing unit. Difference between start and highest temperature reading was taken, and the 10 calculated temperature changes were averaged to determine the mean value in temperature rise.

Mean temperature values and standard deviations were calculated for each material with caries-affected and normal dentin. Number of specimens was 10 for each group. Statistical analysis was carried out on a personal computer using an appropriate software (SPSS/PC, Ver. 10.0, SPSS Inc., Chicago, IL, USA) for comparisons among groups at 0.05 level of significance. Obtained data were analyzed by two-way ANOVA (dentin type and dental material). Independent t-test was used to detect differences between groups defined by the specific interacting variables.

RESULTS

Table 2 shows the mean temperature rise values during the photopolymerization of adhesive systems and resin-containing restorative materials.

Two-way ANOVA revealed significant differences in mean temperature rise value between caries-affected and normal primary tooth dentin for the polymerization of both adhesive systems ($p=0.048$) and resin-containing restorative materials ($p=0.002$). Temperature rise values measured under caries-affected primary tooth dentin were higher than those of normal dentin during the photopolymerization of adhesive materials and resin-containing dental

<table>
<thead>
<tr>
<th></th>
<th>Caries-affected dentin disk (°C)</th>
<th>Normal dentin disk (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AdheSE Bond</td>
<td>$5.7 \pm 0.8^a$</td>
<td>$5.2 \pm 1.2^b$</td>
</tr>
<tr>
<td>One Step Plus</td>
<td>$6.1 \pm 0.7^a$</td>
<td>$5.5 \pm 0.9^b$</td>
</tr>
<tr>
<td>Compoglass F</td>
<td>$5.2 \pm 0.6^c$</td>
<td>$4.5 \pm 0.5^d$</td>
</tr>
<tr>
<td>Aelite LS</td>
<td>$5.4 \pm 1.09^c$</td>
<td>$4.6 \pm 0.5^d$</td>
</tr>
</tbody>
</table>

Groups with the same letters indicate no significant differences ($p>0.05$).
materials (p<0.05).

The adhesive systems induced a higher temperature rise during polymerization than the resin-containing restorative materials (p=0.01). The highest temperature rise observed was during the photopolymerization of One Step Plus (6.1±0.7°C) and AdheSE Bond (5.7±0.8°C) under caries-affected primary tooth dentin.

**DISCUSSION**

This *in vitro* study measured the temperature changes under caries-affected and normal primary tooth dentin disks during the photopolymerization of two adhesive systems and two resin-containing restorative materials by a conventional halogen light curing unit. The results obtained supported the hypothesis that the temperature rise measured under normal dentin during photopolymerization was significantly different from caries-affected primary tooth dentin.

In clinical practice, dentists frequently encounter caries-affected dentin after carious dentin removal. Principles of conservative dentistry advocate the removal of outer caries-affected dentin while conserving the remineralizable inner caries-affected dentin. Results of the current study showed that a higher temperature rise was induced during photopolymerization when using caries-affected dentin as a substrate, as compared to normal dentin. This result was in agreement with the findings of Fanibunda and De Sa who reported significantly higher temperature rise with abnormal dentin specimen.

To date, temperature rise when using composites was measured only in one study in published literature. Al-Qudah et al. suggested that the resin content of dental materials was one important factor that affected temperature rise. The higher the resin filler content of a dental material, the lower was the temperature rise, and therefore a lower proportion of resin available for polymerization. The filler is chemically inert and does not contribute to the heat of reaction. Nonetheless, its temperature is raised alongside that of matrix. Therefore, a considerable fraction of the energy which might otherwise raise the matrix temperature is absorbed by the filler. In this thermal context, the filler is an active phase playing a moderate role. In the present study, both the restorative materials used had a high filler content (77% by weight for Compoglass and 84% by weight for Aelite LS) and they induced a similar temperature rise (p>0.005). This result was in agreement with that of Al-Qudah et al., whereby it was reported that there were no significant differences between the compomer and packable composite.

In the present study, adhesive resins and resin-containing restorative materials showed different maximum temperature rise values which were statistically different (p<0.05). This difference could be related to their resin contents as mentioned above. Adhesive resins, which are unfilled materials, produced a higher temperature rise than resin-containing restorative materials. It is also noteworthy that adhesive resins absorb heat energy during photopolymerization, as they provide protective thermal insulation for the underlying dentin and pulpal tissue during polymerization of resin composites.

Although dentin has a relatively low thermal conductivity, the potential for pulpal damage is greater in deep cavities where the residual dentin thickness is small and the tubular surface area increases. Zach and Cohen used a Macaca Rhesus monkey model to conclude that a temperature rise of 5.5°C within the pulp chamber could lead to irreversible pulpal damage. Fifteen percent of the pulps of small teeth became necrotic following such a temperature rise. In this study, the maximum temperature rise was induced during photopolymerization of One Step Plus (6.1°C) and AdheSE Bond (5.7°C) under caries-affected dentin specimens. These values were higher than the temperature threshold for the pulp. However, in clinical conditions, temperature rises are mitigated and reduced by blood circulation in the pulp chamber and fluid motion in the dentinal tubules. In addition, the surrounding periodontal tissues can promote heat conduction *in vivo*, further limiting the intrapulpal temperature rise.

Nonetheless, pediatric dentists should be aware of the potential thermal hazard to the pulp, which might result from the photocuring of resin-containing restorative materials—especially when used on caries-affected primary tooth dentin. In such conditions, a simple yet highly effective way to protect the pulp is to apply a cement base or lining material. It has been reported that a 2-mm-thick insulation layer of glass ionomer could reduce the intrapulpal temperature increase during composite resin polymerization.

**CONCLUSIONS**

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1. The adhesive systems induced a higher temperature increase than the resin-containing restorative materials.
2. The structural differences between normal and caries-affected primary tooth dentin affected temperature rise during photopolymerization of resin materials.
REFERENCES


