Thermal Conductivity of Different Temporary Crown Materials

Geçici Kron Materyallerinin İsisal İletkenliği

**OBJECTIVE:** The purpose of this study was to evaluate and compare the thermal conductivity of commonly used different provisional crown materials. **Material and Methods:** A total of 70 specimens were prepared from provisional crown materials (Revotek, Luxatemp, Systemp, Access Crown, Cooltemp, Tempofit N) with a dimension of 12 mm diameter x 2 mm thickness and stored in water at 37°C for 3 days. Specimen’s surfaces were ground smooth on either side using a polishing disc with water coolant and for standardization all specimen’s thickness were measured and controlled. All specimens were divided into 7 groups, each containing 10 specimens. A cylindrical steam chamber that had at one end and, circular brass disc approximately 20 mm in diameter and 3 mm thick. A second disc (made from copper) of similar size was fabricated. Between these two discs, the test specimens were placed. Small holes were drilled into the sides of the brass and copper discs and the K-type thermocouples were placed into the holes to record the temperatures. Thermal conductivity of specimens was obtained from the formula: \( kA(Q_2-Q_1)/x= mca/b \). Data were statistically analyzed by 1-way ANOVA with Tukey HSD tests (\( \alpha= .05 \)). **Results:** The highest mean thermal conductivity “k” values were obtained with Luxatemp group (4.3 x 10\(^{-3}\) ± 5.4 x 10\(^{-4}\)) and there were no significant difference observed between Revotek, Luxatemp, Access crown, Cooltemp (\( p> 0.05 \)), the lowest values were obtained in the Protemp 4 group (2.6 x 10\(^{-3}\) ± 2.7 x 10\(^{-4}\)) and significant difference were observed between other groups except Tempofit N (\( p< 0.05 \)). **Conclusion:** Thermal characteristics and conductivity were affected by the chemical composition of the test materials and test values approximate the value for tooth structures’ thermal conductivity.

**Key Words:** Thermal conductivity; dental restoration, temporary

**ÖZET** Bu çalışmanın amacı, rutin olarak kullanılan değişik geçici kron materyallerinin ısıl iletenlik katısalarının karşılaştırılması olarak incelenmesidir. **Gereç ve Yöntemler:** Disk şeklinde toplam 70 adet, 12 mm çapında, 2 mm kalınlığında test örnekleri, geçici kron materyallerinden (Revotek, Luxatemp, Systemp, Access Crown, Cooltemp, Tempofit N) hazırlanı ve 37°Cdeki suda 3 gün bekletildi. Test örneklerinin her iki yüzeyi su soğutması altında parlatma diskleri ile parlatıldı ve kalınlıkları standardizasyonun sağlanmasını amaçla ölçüldü ve kontrol edildi. Örnekle her iki 10’ar örnek içeren 7 grup ayırdı. Bir ucu 20 mm çapında 3 mm kalınlığında pirinç bir disk ile kapalı olan bir buhar silindiri hazırlanı. Ayrıca ölçülede ikinci bir bakır disk hazırlanı ve test örnekleri iletenlik ölçümları için bu iki diskin arasına yerleştirildi. İsil ölçümleri sonradan kıymetlendirilmiş amaç ile disklere küçük delikler açıldı, k tıpi isı kaydediciler bu deliklere yerleştirildi ve veri kıymetlendicisi bağlandı. Isısil iletenlik değerleri kA(Q₂-Q₁)/x= mca/b formülü ile hesaplandı. Elde edilen değerler istatistiksel olarak tek yönlü ANOVA, Post-Hoc Tukey testi ile değerlendirildi (\( \alpha= .05 \)). **Bulgular:** En yüksek ortalaması isısil iletenlik “k” değerleri Luxatemp grubunda (4.3 x 10\(^{-3}\) ± 5.4 x 10\(^{-4}\)) elde edildi ve Revotek, Accesscrown, Cooltempp grupları ile aralarında anlamli fark gözlenmezken (\( p> 0.05 \)), en düşük değerlerin elde edildiği Protemp 4 grubunda (2.6 x 10\(^{-3}\) ± 2.7 x 10\(^{-4}\)) Tempofit N hariç diğer gruplar ile anlamli farklı gözlemdı (\( p< 0.05 \)). **Sonuç:** Isil isısil iletenlik değerleri test materyallerinin kimsasal özelliklerinden etkilendi ve doğal dış dokusunun isısil iletenlik değerlerine yakın değerler gösterdi.

**Anahtar Kelimeler:** Sıcaklık iletenliği; dış onarımı, geçici

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Thermal conductivity, “k”, of a substance is the quantity of heat in calories, or joules, per second passing thorough a body 1 cm thick with a cross section of 1 cm² when the temperature difference is 1°C. The units are cal/sec/cm²/(°C/cm).¹ Thermal properties of tooth structure and dental restorative materials have been investigated by several authors.²⁻⁶ Most of the studies involve direct thermal conductivity measurements.⁷ Common experience indicates that metals are better heat conductors than non-metals. Several important applications of thermal conductivity exist in dental materials. For example, a large gold or amalgam filling or crown in proximity to the pulp may cause the patient considerable discomfort when hot or cold foods produce temperature changes; this effect is mitigated when adequate tooth tissue remains or nonmetallic substances are placed between the tooth and filling or insulation.¹

Temporary crowns are fabricated to protect prepared teeth and gingiva until permanent crowns are placed. They are essential components of fixed prosthodontic treatment.⁸⁻¹² These restorations allow the clinician and patient a chance to determine the appropriate esthetic, phonetic, and functional occlusal features for each individual situation as well as reduce teeth mobility, protect the pulp, and maintain the positions of the prepared teeth. In the waiting period of permanent tooth fabrication, abutment tooth must be protected from thermal shocks by the temporary crowns.⁹⁻¹⁶ Therefore, temporary crown materials must have enough thermal conductivity for protecting the abutment from physiological thermal shocks. Recent years many temporary crown materials have been introduced and a wider range of temporary crown materials is now available.¹³ The preparation of temporary crowns using different fabrication methods with autopolymerizing and heat-polymerized PMMA resins and bis-acryl composite resins has been described by various researchers.⁹⁻¹⁷⁻¹⁸

One of the desirable properties of restorative materials is the ability to prevent extremes of temperature reaching the dental pulp and causing it injury. The thermal conductivity of human enamel and dentin have been reported by Braden² to be 2.2 and 1.5 x 10⁻³ cal/sec/cm²/(°C/cm). Thermal properties of dental and restorative materials are very important for pulpal health and also success of restorations.⁷ The purpose of this study is to determine the thermal conductivity of different commonly used different provisional crown materials. Research hypothesis in this study is thermal conductivity value (k) would not be affected by the chemical composition of the provisional crown material.

## MATERIAL AND METHODS

Seven temporary crown materials (Protemp 4, Access crown, Tempofit, Systemp, Revotek, Cooltemp, Luxatem) were used in this study. The materials used and their chemical compositions are listed in Table 1. Ten disc specimens were prepared from each provisional crown material according to each manufacturer’s instructions. A plastic transparent mold with a hole in the center (12 mm diameter and 2 mm thickness) was used to fabricate the specimens. The provisional crown material was placed into the mold, and clamped between two glass plates. The glass plates were pressed until getting a tight contact with the plastic mold and waited for the polymerization to be completed. In Revotek group temporary crown material was light polymerized for 20 seconds with a polymerization unit. (Astralis 3, Ivoclar Vivadent, Schaan, Liechtenstein). All specimens were stored in distilled water at 37 °C for 3 days. Specimen’s surfaces were smoothened on either side using a polishing disc (Sof-Lex, 3M Espe, St. Paul, MN, USA) under water cooling. For standardization all specimens’ thicknesses were controlled with a micrometer (Absolute Digimatic, Mitutoyo Corp., Japan) after polishing.

The measurement of thermal gradients and conductivity involved the construction of a Lee’s Disc.⁶ A cylindrical steam chamber had at one and, circular brass disc approximately 20 mm in diameter and 3 mm thick. A second disc (made from copper) of similar size was fabricated. Between these two discs, the sample materials were placed. Both the brass and the steam chest and free copper disc were highly polished (Figure 1).
Small holes were drilled into the sides of the brass and copper discs and the K-type thermocouples were placed into the holes to record the temperatures which were capable of measuring from -50 to 200 (±3) °C. Brass disc was fixed on top of the steam chamber and its surface was brushed with a thin layer of petrolatum jelly. Before the measurements, sample discs’ surfaces were also brushed to ensure a good contact for heat transfer. The samples were placed on the top of the steam chamber and then the copper disc (with thermocouple) was inserted. The thermocouples were connected with Digitron Datalogger (Version 1.14, Digitron Instrumentation Ltd, Hertford, UK) to a Psion Organizer II, Model LZ64 (Kuma Computers Ltd, Berkshire, UK). The data were transferred to a computer using an analysis program (Digitron Instrumentation Ltd, Hertford, UK). All procedures were performed in a closed-room environment with temperature controlled at 21 ± 1°C.

When the steam chamber had reached its equilibrium, temperatures were started to be saved by the analysis program every 5 seconds, when the copper and brass disc were initially brought together, separated by the sample disc. The measurements were continued to be made until a steady state was reached. After that the disc was removed from the top of the copper disc and placed under the steam chamber for preserving its temperature. Copper and brass discs were placed together to allow a second steady state to be reached. Once it was reached, free copper disc was removed from the top of the steam chamber and placed on a non-conductor material with sample disc to allow for cooling. This was effectively held in mid-air by the thermocouple wires to ensure that no interference heat loss had occurred while the temperatures were still being recorded every 5 s. Once the free copper disc and sample disc temperature had fallen at least 15/20 °C below the original steady state data recording was stopped.

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Filler Content %wt</th>
<th>Main components of the monomer mixture</th>
</tr>
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<tbody>
<tr>
<td>Cool Temp Natural</td>
<td>Coltène/Whaledent, Altstätten, Switzerland</td>
<td>53</td>
<td>Bisphenol-A diethoxy methacrylate, aliphatic methacrylate</td>
</tr>
<tr>
<td>Systemp C&amp;B</td>
<td>Ivoclar Vivadent, Schaan, Liechtenstein</td>
<td>48</td>
<td>Bis-GMA, polyfunctional methacrylates(Polyurethane polymethacrylate, polyalkane methacrylate),</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bis-EMA(ethoxylated bisphenol A-dimethacrylate), barium glass filler</td>
</tr>
<tr>
<td>Tempostit N colors</td>
<td>DETAX GmbH &amp; Co. KG, Germany</td>
<td>55</td>
<td>Mixture of methacrylic resins and silane treated glass with auxiliary matters and pigments</td>
</tr>
<tr>
<td>Luxatemp AM Plus</td>
<td>DMG, Hamburg, Germany</td>
<td>44</td>
<td>Multifunctional metacrylate (urethane dimethacrylate, aromatic dimethacrylate, glycol methacrylate,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>glass powder and silica filler, Bisacrylate composite resins</td>
</tr>
<tr>
<td>Protemp 4 Garrant</td>
<td>3M ESPE, St. Paul, USA</td>
<td>10</td>
<td>Dimethacrylate, silane treated amorphous silica, polyurethane methacrylate, silane treated silica</td>
</tr>
<tr>
<td>Revotek LC</td>
<td>GC Corporation, Tokyo, Japan</td>
<td>15-20</td>
<td>Urethane, Silica powder, Camphorquinone</td>
</tr>
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</table>

**TABLE 1:** Chemical compositions of the materials used in this study.
Thermal conductivity of specimens was obtained from the formula:

$$kA(Q-Q)/x = mca/b$$

- m: mass of copper disc (in this case $12.61 \times 10^{-3}$ kg)
- c: the specific heat capacity of the copper disc, $(385 \text{ J/kg/°C})$
- a/b: it is the gradient of heat loss, obtained from the data.
- x: sample thickness
- A: Area of sample disc ($r^2$)
- Q-Q: the temperature of the steam chamber at steady state minus the temperature of the copper disc at steady state (°C) the steady state temperatures were calculated using an average of twenty corresponding values before the sample disc removed.

Using this equation an average value for “k” and its associated standard deviation were obtained for each group.

“k” values were statistically evaluated with Kolmogorov-Smirnov test and showed that the distributions “k” values were normal ($P > .05$). A homogeneity of variance test was performed with Levene’s test ($F: 1.297, P > 0.05$). Means and standard deviations of thermal conductivity values were calculated and mean values were compared by one-way analysis of variance (ANOVA) (SPSS 12.0; SPSS Inc., Chicago, Ill), followed by a multiple comparisons’ test performed with a Tamhane test ($\alpha = .01$).

### RESULTS

One-Way ANOVA test revealed that type of the provisional crown and bridge material used had a significant influence on the thermal conductivity ($p < 0.05$). One-way analysis of variance of the data is presented in Table 2. The highest thermal conductivity value was obtained from the Luxatemp group ($4.3 \times 10^{-3} \pm 5.4 \times 10^{-6}$) and lowest value was obtained from the Protemp 4 group ($2.6 \times 10^{-3} \pm 2.7 \times 10^{-4}$). The mean “k” values and standard deviations of the groups are listed in Table 3.

### DISCUSSION

Interim treatment promotes numerous adjunct benefits to definitive prosthodontic treatment. The materials and techniques used for these purposes must reflect these variable treatment demands and requirements. Consistent with nearly all areas of dental management where material science plays such a significant role, there is presently no ideal provisional material suitable for all clinical conditions, however, there are many materials that have been used successfully for this purpose. There are many requirements needed for provisional crown materials such as appropriate marginal adaptation, color stability, low thermal conductivity, non irritating reaction to the dental pulp. These requirements are affected from the chemical compositions of materials.

In this study 7 provisional crown materials were evaluated for thermal conductivity. According to research results, research hypothesis was rejected. Generally the chemical nature of the provisional crown material used in the present study had a significant influence on the thermal conductivity value.

The differences between the test groups can be related to filler proportion of the test materials. The lowest mean “k” values were obtained with Protemp 4, this provisional crown material include 10% filler proportion. And the highest values were obtained with Luxatemp which include 44% filler proportion. Although Tempofit and Cooltemp provisional crown materials have higher filler proportion ratios, these test materials showed lower mean

<table>
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<th>TABLE 2: Statistical differences between groups.</th>
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<tr>
<td>Sum of Squares</td>
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<td>----------------</td>
</tr>
<tr>
<td>Between Groups</td>
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<tr>
<td>Within Groups</td>
</tr>
<tr>
<td>Total</td>
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</table>
The thermal conductivity of provisional crown material. Although no data are available to compare the type of resin matrix or filler content of those bis-acryl materials, it is evident that the differences in thermal conductivity performance was material specific. The objective of this study was not finding the thermal conductivity values of different temporary crown materials. It rather, was to evaluate and compare the effect of chemical composition on the thermal conductivity of different temporary crown materials.

Results of the present study suggest that in routine clinical practice non-metallic restorative materials, can provide a similar degree of thermal conductivity to natural tooth structure.

**CONCLUSION**

The thermal conductivity of provisional crown materials was determined by using in improved steady-state procedure. Within the limitations of this study following results were drawn:
1. Thermal characteristics were affected by composition and chemical nature of provisional crown materials.

2. The average thermal conductivity of dimethacrylate based provisional crown material was significantly lower than other groups.

3. Test values that obtained in this study, are between $2.6 \times 10^{-3}$-$4.3 \times 10^{-3}$ cal/sec/cm²/°C/cm. Obtained thermal conductivity values were close to natural tooth, therefore in the range of good thermal insulators.

REFERENCES