Thermal Conductivity of Different Temporary Crown Materials

Geçici Kron Materyallerinin Isısal İletkenliği

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ABSTRACT 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, Protemp 4, 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 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 ($4.3 \times 10^{-3} \pm 5.4 \times 10^{-4}$) 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 ($2.6 \times 10^{-3} \pm 2.7 \times 10^{-4}$) 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 Amaç: Bu çalışmanın amacı, rutin olarak kullanılan değişik geçici kuron materyallerinin ısısal iletkenlik katsayılarının karşılaştırmalı olarak incelenmesidir. **Gereç ve Yöntemler:** Disk şeklinde toplam 70 adet, 12 mm çapında, 2 mm kalınlığında test örneği, geçici kuron materyallerinden (Revotek, Luxatemp, Systemp, Access Crown, Cooltemp, Protemp 4, Tempofit N) hazırlandı ve 37 °C'deki suda 3 gün bekletildi. Test örneklerinin her iki yüzeyi su soğutması altında parlatma diskleri ile parlatıldı ve kalınlıkları standardizasyonun sağlanması amacı ile ölçüldü ve kontrol edildi. Örnekler her biri 10'ar örnek içeren 7 gruba ayrıldı. Bir ucu 20 mm çapında 3 mm kalınlığında pirinç bir disk ile kapalı olan bir buhar silindiri hazırlandı. Aynı ölçülerde ikinci bir bakır disk hazırlandı ve test örnekleri iletkenlik ölçümü için bu iki diskin arasına yerleştirildi. Isı ölçümlerinin kaydedilmesi amacı ile disklere küçük delikler açıldı, k tipi ısı kaydediciler bu deliklere yerleştirildi ve veri kaydediciye bağlandı. Isısal iletkenlik değerleri $kA(Q_2-Q_1)/x= mca/b$ formülü ile hesaplandı. Elde edilen değerler istatistiksel olarak tek yönlü ANOVA, Post-Hoc Tukey testi ile değerlendirildi ($\alpha= .05$). **Bulgular:** En yüksek ortalama ısı iletkenlik "k" değerleri Luxatemp grubunda ($4.3 \times 10^{-3} \pm 5.4 \times 10^{-4}$) elde edildi ve Revotek, Accesscrown, Cooltemp grupları ile aralarında anlamlı fark gözlenmezken ($p> 0.05$), en düşük değerlerin elde edildiği Protemp 4 grubunda ($2.6 \times 10^{-3} \pm 2.7 \times 10^{-4}$) Tempofit N hariç diğer gruplar ile anlamlı fark gözlendi ($p< 0.05$). **Sonuç:** Isısal iletkenlik değerleri test materyallerinin kimyasal özelliklerinden etkilendi ve doğal diş dokusunun ısısal iletkenlik değerlerine yakın değerler gösterdi.

Anahtar Kelimeler: Sıcaklık iletkenliği; diş 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 cm^2 when the temperature difference is 1°C. The units are cal/sec/cm^2/(°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 Braden[2] to be 2.2 and 1.5 x 10^{-3} cal/sec/cm^2/°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, Luxatemp) 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).

TABLE 1: Chemical compositions of the materials used in this study.

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

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.

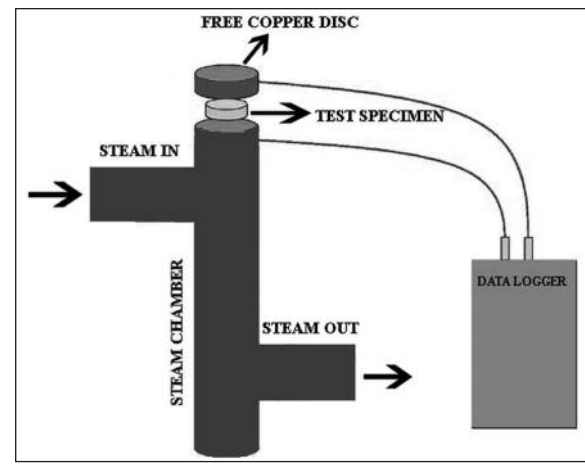

FIGURE 1: Schematic view of the steam chamber.

Thermal conductivity of specimens was obtained from the formula ;

$kA(Q-Q)/x = mca/b$ [6]

m: mass of copper disc (in this case 12.61×10^{-3} kg)

c: the specific heat capacity of the copper disc, (385 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-Qthe temperature of the steam chamber at steady state minus the temperature of the copper disc at steady state (6) 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-Simirnov 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 ($4.3 \times 10^{-3} \pm 5.4 \times 10^{-4}$) 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.[19] 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.[13,20,21] 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 2: Statistical differences between groups.

	Sum of Squares	Difference	Mean Square	F	Significance
Between Groups	0.000	7	0.000	14.527	0.000
Within Groups	0.000	72	0.000		
Total	0.000	79			

TABLE 3: Means and standard deviations of "k" values of the test groups.

Material	Mean ± SD
Revotek	0.0038 ± 0.00047^{bcd}
Luxatemp	0.0043 ± 0.00054^{d}
Systemp	0.0033 ± 0.00034^{bc}
Access crown	0.0038 ± 0.00067^{cd}
Cool Temp	0.0041 ± 0.00037^{d}
Protemp 4	0.0026 ± 0.00027^{a}
Tempofit N	0.0031 ± 0.00030^{ab}

Values having same letters were not significantly different (p> 0.05)

"k" values than Luxatemp. Discrepancies can be attributed to the variations in chemical compositions and specimen homogeneity.[7] The effect of additives on thermal properties of resin materials was previously demonstrated.[7] Whereas the unfilled resin was the least conductive, the filled resin had the highest diffusity and conductivity.[7] The increased values were attributed to the higher degree of conductivity of the filler.[22] In contrast, Watts et al. reported that the highly filled posterior composites with 70% inorganic filler had acceptably low magnitudes of thermal diffusity.[22]

Watts et al. stated that the lack of significant difference between the dry and wet stored specimens was consistent with the generally low water absorption properties of dental composite materials.[22] In this research test specimens were stored in water for 3 days so thermal characteristics may also be affected by water absorption properties of test materials. It was reported that typically the equilibrium of water absorption in composites is less than 3% by weight, and this tends to decrease with increasing filler fraction.[22] By contrast, significant differences are apparent in thermal diffusity between dry and wet stored dental cements attributable to their greater water absorption.

Another season of the differences in "k" values can be partly attributed to differences in monomer chain types. Traditional methyl methacrylate type resins are monofunctional. They are low-molecular weight, linear molecules that exhibit decreased strength and rigidity. Bis-acryl composite materials are difunctional and capable of cross linking with another monomer chain. This crosslinkage imparts physical properties of the 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 difference in physical properties was material-specific.[8] So thermal properties of test materials may be effected this difference. 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 difference in thermal conductivity performance was materials specific. Direct comparison of the results of the present study with other studies is not possible due to differences in materials, methodology, and specimen configuration. However, a review of the limited research on filling materials or cavity liners thermal conductivity also showed this property to be material specific.[1,3,23] The objective of this study was not finding the thermal conductivity values of the 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.

One of the limitation of this in vitro study is that only temporary crown materials were evaluated for thermal conductivity. Different results might have been obtained with temporary crowns and cements together. It should be emphasized that the numerical thermal conductivity values are independent of sample thickness, but the effectiveness of a cement base as an insulating medium is directly proportional to the thickness. This fact should be considered in the placement of a cement base. Therefore, further in vivo investigations are needed.

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 2.6×10^{-3}-4.3×10^{-3} cal/sec/cm^2/°C/cm. Obtained thermal conductivity values were close to natural tooth, therefore in the range of good thermal insulators.

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