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Heat conductive properties of set root canal sealers

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Abstract

Objective. The aim of this study was to examine the thermal conductivity of five different root canal sealers *in vitro*. ***Materials and methods.*** Sealapex, AH Plus, AH 26, Endomethasone and RoekoSeal root canal sealers were examined. These materials were prepared in accordance with the manufacturer's instructions and applied to standard molds. Three samples of each material were prepared. The samples were kept for 5 days under 37°C conditions. Measurements were taken using a heat conduction unit (P.A. Hilton Ltd. Stockbridge, Hants, UK). The thermal conductivity coefficient was calculated for each sample using the Fourier equation. Coefficients were analyzed statistically by the Kruskal–Wallis test. ***Results.*** Significant differences were found for thermal conductivity between some materials ($p < 0.05$). The conductivity coefficient of AH Plus was found to be higher than those of the other materials ($p < 0.05$). No statistically significant differences were found between AH 26 and RoekoSeal ($p > 0.05$) and the conductivity coefficients of these sealers were found to be lower than those of the other materials ($p < 0.05$). No statistically significant differences were found between Sealapex and Endomethasone ($p > 0.05$) and the conductivity coefficients of these sealers were found to be lower than that of AH Plus but higher than those of RoekoSeal and AH26 ($p < 0.05$). ***Conclusions.*** The results showed that root canal sealers functioned as thermal insulators and had different heat-conductive properties that depended on their composition.

Key Words: *heat conduction, heat insulation, root canal sealer*

Introduction

Heat is used during endodontic treatment when inserting root canal fillings [1–4] or during re-treatments [5–8]. The heat produced in the root is passed through the root dentine to the periodontal membrane and the cement [9]. It is believed that, if a high amount of heat is transferred to these tissues, it can cause damage to these tissues and the alveolar bone [10]. Generally, it has been accepted that, when there is a heat increase of 10°C above the normal body temperature, this will cause damage to the tissues surrounding the teeth [11–13]. Many researchers have examined the increase of heat that occurs at the outer surface of the root, the use of heat during re-treatment and the use of the heated gutta-percha technique. Some studies have reported that, during obturation techniques with the heated gutta-percha, the heat increase that occurs on the root's outer surface is between 3–9.6°C [2,13–15]. Other researchers have shown that the heat increase on the root's outer surface ranges from 12.3–35°C [4,11,16,17]. In a study of the heat increase at the root's outer surface during re-treatment using a System B heat source, Lipski and Wozniak [7] demonstrated that the heat increase produced was higher than the values of critical degrees, ranging from 26.7–46.0°C. Based on these studies, during endodontic procedures, the heat increase that occurs at the root's outer surface can rise well above the critical heat temperature of 10°C.

If a temperature difference arises inside a solid material, heat is transferred from areas of higher temperature to those of lower temperature by the process of heat conduction. Heat conduction can be explained by Fourier's law of heat conduction: $Q = -kA\Delta T/`\Delta x$ [18]. This equation is used, in particular, to estimate the thermal conductivity coefficient of solids and fluids [19–21]. The units of heat that are transferred in time (Q) are directly

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Table I. Sealer included in this study.

Type of sealer (chemical group)	Sealer	Manufacturer
Epoxy resins	AH 26	Dentsply, DeTrey GmbH, Konstanz, Germany
	AH Plus	Dentsply, DeTrey GmbH, Konstanz, Germany
Silicone	RoekoSeal	Roeko, Langenau, Germany
Calcium hydroxide	Sealapex	Kerr,Salerno, Italia
Zinc oxide-eugenol	Endométhasone	Septodont, Paris, France

proportional to the cross-section of the material used in the experiment (A) and the heat difference between the two points (ΔT), but indirectly proportional to the thickness of the material in which the direction of the heat produced is transferred (Δx). k is the thermal conductivity coefficient, which is one of the most important properties of the material.

Sealers play a heat-insulating role in the canal and they can help the dentine to prevent heat conduction to the outer surface of the root [9]. Root canal sealers contain different chemical structures and components, which results in them exhibiting different insulating behaviors. They can provide various degrees of heat insulation. The aim of the research reported herein was to examine the heat conduction properties of sealers of different compositions.

Material and methods

The sealers used in this research are listed in Table I. Polyurethane, an insulating material, was used to prepare molds with diameters of 25 mm and thicknesses of 1.5 mm. Root canal sealers were prepared according to the manufacturer's instructions and then placed into these molds. During the preparation of Sealapex, the spatula was dampened using tap water, as previously advised [22]. Three samples were prepared for each material. These samples were kept at 37°C for 5 days. First, with the help of grainy sandpaper, both sides of the sample were polished to remove excess sealers until a smooth polished surface was obtained (Figure 1). After this procedure was completed, with the help of an electronic compass, the sample's thickness was measured again to verify that it was 1.5 mm.

Heat conduction experiment

The linear heat conduction module of a heat conduction unit (P.A. Hilton Ltd. Stockbridge, Hants, UK) was used to determine the heat conductivity of the sample (Figure 2). To enable higher surface contact between the sample and the part of the apparatus, both sides of the sample were coated with a

Figure 1. A prepared test specimen.

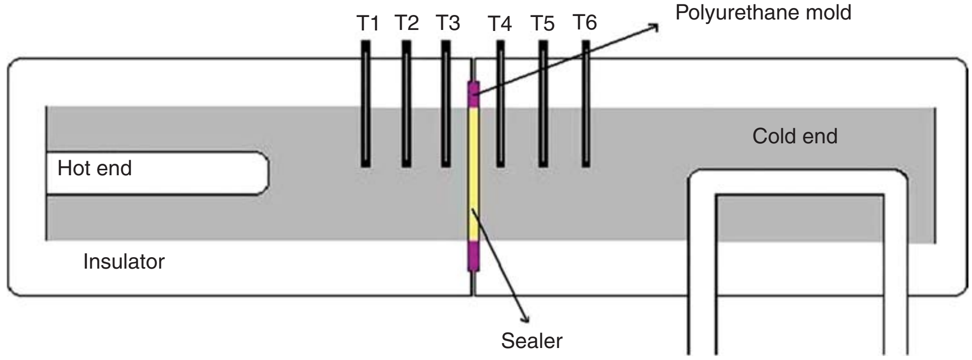

Figure 2. Diagrammatic representation of the heat conduction test apparatus used to measure heat conduction.

Table II. The values of the test sample's heated surface (*T*a) and its cooled surface (*T*b).

Sealer	*T*a, Mean ± SD	*T*b, Mean ± SD
AH Plus	51.76 ± 1.16	19.21 ± 0.35
Endomethasone	57.36 ± 0.97	18.44 ± 0.09
Sealapex	58.83 ± 1.35	18.50 ± 0.13
RoekoSeal	62.75 ± 1.01	18.42 ± 0.17
AH 26	65.64 ± 1.65	17.99 ± 0.2

Table III. Heat conduction coefficients of the sealers.

Sealer	Mean values ± SD
AH Plus	0.940 667^{a} ± 0.0428
Endomethasone	0.786 067^{b} ± 0.0205
Sealapex	0.758 433^{b} ± 0.0225
RoekoSeal	0.690 100^{c} ± 0.0183
AH 26	0.642 233^{c} ± 0.0254

Different superscript letters between samples represent statistically significant differences ($p < 0.05$).

heat-conducting paste. The test sample was placed in the sample slot of the linear module of the conduction apparatus, between the heating and the cooling compartments. The pieces of the apparatus were then locked in a suitable form. For every sample that was tested, the heat entrance point of the module was heated with 10 W energy and the heat pit section was cooled with water. Thus, the apparatus was heated on one side of the test sample and cooled on the other side until the desired stability was reached. The time required for the system to attain stability varied among the samples; however, the average time needed was 40–60 min. When the experimental system reached stability, the heat values were recorded from the thermostat temperature sensors that were situated on both sides of the test sample using a digital heat reader.

Three temperature sensors were placed in both the heated and the cooled sections; the sensors closest to the sample were at a distance of 5 mm from the sample and there was a distance of 10 mm between each sensor. The recorded temperature values were subjected to regression curve analysis and the heat of the heated surface (*T*a) and the cooled surface (*T*b) of the test samples were determined using Microsoft Excel 2007 (Table II). In this way, the temperature at eight points was recorded for every sample. Then, using the Fourier equation, the value of k was calculated for each sample, as W/mK, with Excel. Coefficients were compared by performing the Kruskal–Wallis test (SPSS 10.0; SPSS, Chicago, IL) and differences were considered to be statistically significant at $p < 0.05$.

Results

Significant differences with respect to thermal conductivity were found between some materials ($p < 0.05$) (Table III). The thermal conductivity coefficient of AH Plus was found to be higher than those of the other materials ($p < 0.05$). No significant differences were found between AH 26 and RoekoSeal ($p > 0.05$) and the thermal conductivity coefficients of these sealers were found to be lower than those of the other materials ($p < 0.05$). No significant differences were found between Sealapex and Endomethasone ($p > 0.05$) and the thermal conductivity coefficients of these sealers were found to be lower than that of AH Plus but higher than those of RoekoSeal and AH 26 ($p < 0.05$). The average temperature values and heat conduction graphics for each measuring point for all the materials are shown in Figure 3.

Discussion

When a temperature difference occurs inside a solid material, heat is transferred from regions of higher temperature to those of lower temperature by conduction [18]. The various methods to measure

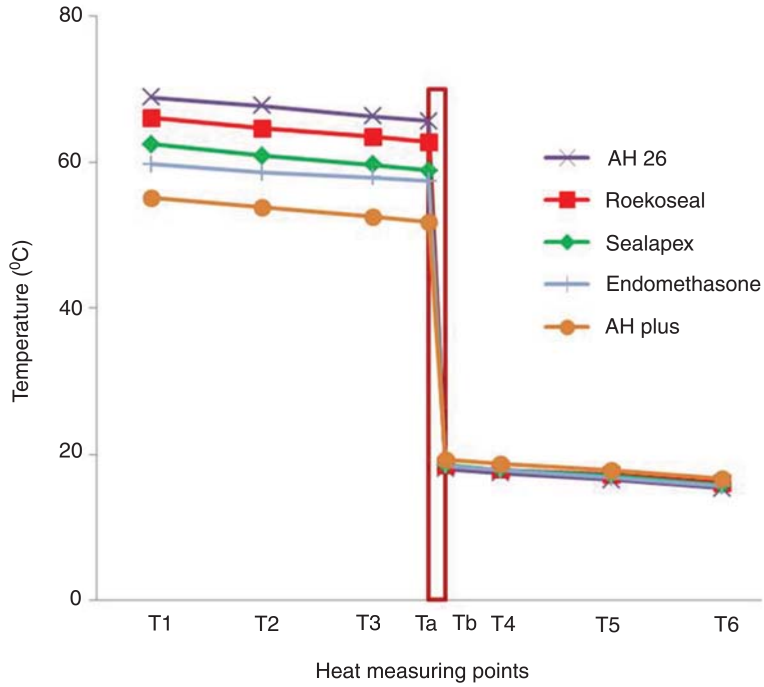

Figure 3. The average heat values and heat conduction schema from each heat measuring point of all the sealers.

thermal conductivity fall into two categories: steady state and non-steady state. In steady-state methods, the specimen is subjected to a temperature profile that does not vary over time; after equilibrium has been reached, thermal conductivity is determined directly by measuring both the rate of heat flow per unit area and the temperature gradient [23]. The thermal conductivity of dental tissues and materials has been examined by many researchers using different methods [10,24–26].

In the present study, Fourier's law of heat conduction was applied. The heat conduction properties of the test samples were examined by placing the samples in a test apparatus between heated and cooled sections, which were equipped with temperature sensors. In this system, heat is transferred from the heated to the cooled end by means of conduction through the test material. If the tested material has high thermal conductivity, the heat produced in the heated section can be transferred easily to the cold end. Thus, the system can reach a steady state without having more increase of heat in the heated section. If the thermal conductivity of the tested material is poor, less heat is transferred to the cold end and the temperature at the hot end increases. Once the rate at which heat is generated is equal to the rate at which it is removed, steady state conditions exist, temperatures will become fairly constant and readings can be taken.

In the test procedure used, a heat-conducting paste is applied to both surfaces of the test samples. The function of this paste is to convey the heat efficiently from the heated section to the test sample. The paste does not affect the thermal conductivity of the test material. When heat-conducting paste is not used, there might not be full contact between the heated section and the test samples. Hence, the heat produced cannot be transferred fully to the samples.

Dentin is a poor thermal conductor [2,26] and a small difference in dentin thickness may have a large effect on the conduction of heat [27]. The thickness of dentin appears different in various areas of the root. In addition, endodontic procedures result in a decrease in the thickness of the root dentin [28] and the remaining dentin layer may inadequate to provide effective heat insulation. Barkhordar et al. [9] reported that using sealer reduces the conduction of heat to the root surface by ~ 1–2°C and that the presence of sealer acts like an insulator along the dentin wall. The thickness of the test samples analyzed in the present study differed from that used clinically. Although the difference in the thickness of the material altered the amount of heat conducted, it did not change the thermal conductivity coefficient of the material.

This study has shown that root canal sealers are poor thermal conductors, while also demonstrating that the thermal conductivity coefficients of the tested sealers have statistical differences ($p < 0.05$). These differences may be the result of variations in the sealers' structure and composition.

Although the results of this study are significant, additional research is needed to evaluate the heat conductivity of different sealers during re-treatment with heat, presence of dentine and gutta percha. Moreover, the state of a material in a solid and a liquid phase may affect heat conduction properties.

These properties should be assessed in freshly prepared sealers in warm gutta percha obturation techniques.

Conclusion

Root canal sealers functioned as thermal insulators and had different heat conductive properties that depended on their structure and composition.

***Declaration of Interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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