Influence of Warm Vertical Compaction Technique on Physical Properties of Root Canal Sealers

Wei Qu, DDS, Wei Bai, MD,† Yu-Hong Liang, DDS, PhD,*‡ and Xue-Jun Gao, DDS, PhD**

Abstract

Introduction: The aim of this study was to evaluate the influence of warm vertical compaction on the physical properties of root canal sealers. **Methods:** The physical properties of 4 sealers (zinc oxide –eugenol [ZOE], AH Plus [Dentsply International, York, PA], RoekoSeal [Roeko/Coltene/Whaledent, Langenau, Germany], and iRoot SP [Innovative Bioceramix, Vancouver, Canada]) were tested. The setting time and flow of these sealers were measured at standard and high temperatures using ISO 6876 (2012) specifications. The percentage of voids in each sealer after complete setting at 37°C and 140°C was analyzed under a stereoscopic microscope. **Results:** The setting time of ZOE sealer increased significantly from 144.0 ± 4.1 minutes to 274.2 ± 7.4 minutes when the temperature increased from 37°C to 140°C, whereas there was a significant reduction in the other 3 sealers. At 37°C, the setting time of AH Plus, iRoot SP, and RoekoSeal was 543.8 ± 16.4, 245.8 ± 15.9, and 49.3 ± 1.5 minutes, and at 140°C the setting time decreased significantly to 12.9 ± 0.7, 14.2 ± 0.6, and 2.7 ± 0.4 minutes ($P < .05$). The flow of AH Plus increased when the temperature changed from 25°C to 140°C ($P < .05$), whereas the flow reduced for RoekoSeal and iRoot SP (for RoekoSeal from 24.8 ± 0.9 to 12.4 ± 1.3 mm and for iRoot SP from 22.9 ± 0.9 to 13.3 ± 1.5 mm) ($P < .05$). However, the flow of ZOE sealer was unaffected by the high temperature. ZOE sealer and iRoot SP exhibited a reduction of porosity at a high temperature ($P < .05$). **Conclusions:** Warm vertical compaction influenced some properties (the setting time, flow, and porosity) of 4 sealers. A significant reduction of setting time and flow was found in RoekoSeal and iRoot SP sealers at a high temperature. *(J Endod 2016;42:1829–1833)*

Key Words

Physical properties, root canal sealers, warm vertical compaction

Significance

We aimed to identify the influence of warm vertical compaction on the physical properties of root canal sealers in order to choose proper sealers in the warm vertical compaction technique.

It is well-known that the vertical compaction technique with warm gutta-percha produces consistently dense, dimensionally stable, 3-dimensional root canal fillings and has been developed to fill canal irregularities more effectively than is possible with cold gutta-percha (1). Although the warm filling technique improves the compaction of gutta-percha into root canals, it is still necessary to use a sealer because any small voids between the gutta-percha and canal wall irregularities or canal fins have to be filled. It has been reported that warm gutta-percha root fillings without sealer leak more than those with sealer (2).

In the warm compaction technique, most thermoplasticized systems are operated at 200°C, and safety considerations dictate a heating duration of no more than 4 seconds (3). A number of studies have investigated the actual temperatures of pluggers in thermoplasticized systems and found that they are at 50°C–126°C, which is much lower than that set on the LCD display (4–6). According to the findings of our previous study, the actual temperatures of continuous-wave pluggers are below the set temperature of 200°C, varying from 112°C–199°C (median = 140°C) (7).

In recent years, studies of the effects of temperature on obturation materials during warm vertical compaction have shown that the techniques of gutta-percha placement involving heating in the root canal cause reversible physical changes in the gutta-percha without any apparent change in its chemical composition (8). However, several studies have shown that heat does affect the physical properties and chemical composition of root canal sealers (6, 9–11).

With the new root canal filling materials and the popularity of warm vertical compaction in practice, the effects of heat produced in this technique on these materials need further investigation. As well as zinc oxide–eugenol (ZOE) sealers, resin-based root canal sealers such as AH Plus (Dentsply International, York, PA) and RoekoSeal (Roeko/Coltene/Whaledent, Langenau, Germany) have been used worldwide in root canal obturation. Recently, a bioceramic tricalcium silicate–based sealer called iRoot SP (Innovative Bioceramix, Vancouver, Canada) has been introduced to the clinic. It has attracted increasing attention because of its advantages of biocompatibility and suitable physicochemical properties (12, 13). These sealers have been

From the *Department of Cariology and Endodontology and †Dental Material Laboratory, Peking University School and Hospital of Stomatology, Beijing, China; and ‡Dental Clinic, Peking University International Hospital, Beijing, China

Address requests for reprints to Dr Yu-Hong Liang, Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology, Beijing 10081, China. E-mail address: leungyuhong@sina.com

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reported to show adequate properties under standard test conditions (13–15), but their performance in warm vertical compaction is still unknown. With so many choices of sealers, it is important to identify those that are most suitable for warm gutta-percha condensation. Therefore, the aim of this study was to measure the physical changes of different root canal sealers in the warm vertical compaction technique.

Materials and Methods

Four kinds of root canal sealers were tested: ZOE sealers, AH Plus, RoekoSeal, and iRoot SP. The material composition and manufacturers' information are listed in Table 1.

The ZOE sealer (powder/liquid ratio = 1.25 g:1g), AH Plus, RoekoSeal, and iRoot SP sealers were mixed according to the manufacturers' instructions.

Setting Time

The setting time test was performed following ISO 6876 (2012) specifications (16). The AH Plus and RoekoSeal sealers do not need moisture for setting, and they were mixed and inserted into stainless steel ring molds with an internal diameter of 10 mm and a height of 2 mm. The ZOE and iRoot SP sealers need moisture for setting, so they were dispensed in gypsum molds incorporating a cavity with a diameter of 10 mm and a height of 1 mm. Ten samples of each sealer were prepared. Half of the samples were transferred to an incubator (Shanghai Yiheng Technology Co, Ltd, Shanghai, China) with 95% relative humidity and a temperature of 37°C. The other half were placed in an electric heating oven (Tianjin Zhonghuan Co, Ltd, Tianjin, China) at 140°C. The setting time was determined using an indentation technique with a Gilmore-type metric indenter consisting of a weighted needle 2.0 $\pm$ 0.1 mm in diameter with a total mass of 100.0 $\pm$ 0.5 g, as suggested in ISO 6876 (2012) (16). The sealers were considered to have set when the needle was lowered gently onto the material surface at an interval of 1 minute and did not leave a visible indentation.

Flow

After mixing, 0.05 mL sealer was dispensed onto a glass plate measuring 40 mm $\times$ 45 mm and 5-mm thick. At 180 $\pm$ 5 seconds after the commencement of mixing, a second glass plate weighing 20 g was placed centrally on top of the sealer followed by a weight with a mass of 100 g. This assembly was left at 25°C or 140°C for 10 minutes from the start of mixing; after this, the maximum and minimum diameters of the compressed disc of sealer were measured using a micrometer. The mean was calculated if the diameters agreed to within 1 mm. If not, the test was repeated.

Porosity

Cylindrical polytetrafluoroethylene molds with an internal diameter of 2 mm and a height of 10 mm were filled with AH Plus or RoekoSeal sealer, and gypsum molds of the same size were filled with ZOE or iRoot SP sealer. Twenty samples of each sealer were made, 10 of which were stored at 37°C, and the other 10 were stored at 140°C in 95% humidity for 48 hours to ensure complete setting. Then, they were transversely sectioned (Leica Sp1600 0321; Leica, Wetzlar, Germany) at 3, 5, and 7 mm from the bottom of the mold. The porosity of sealers was analyzed under a stereoscopic microscope (Image Measure, CF-2000C; Shanghai Changfang Optical Instrument Co, Ltd, Shanghai, China) at 30$\times$ magnification. The slides were scanned as bitmap images. The area of the molds (A_M) and the area of the voids (A_V) were recorded using ImageJ 1.28 software (National Institutes of Health, Bethesda, MD), and the percentage of the area of voids (void% = 100 $\times$ A_V/A_M) was calculated. The image analysis was performed blindly by 2 investigators.

Statistical Analysis

Data were evaluated using SPSS version 20.0 (SPSS Inc, Chicago, IL) and Excel 2013 (Microsoft Corp, Redmond, WA). The setting time and flow results were evaluated using the Kolmogorov-Smirnov test to show the distribution of the data within groups. Means and standard deviations were calculated for each group. The data were subjected to analysis of variance and Tukey post hoc tests for multiple comparisons. Because the results of void% did not satisfy the normality assumption, the nonparametric Mann-Whitney test was used to compare the differences in 2 circumstances. The level of significance was set to 0.05.

Results

Setting Time

The mean and standard deviation of setting times at 37°C and 140°C are presented in Table 2. Considerable differences were found among the sealers at different temperatures ($P < .05$).

At 37°C, RoekoSeal had the shortest setting time, whereas AH Plus had the longest. At 140°C, the setting time of RoekoSeal was still the shortest, but that of ZOE was the longest.

There was a significant difference for each sealer between 37°C and 140°C. For ZOE, the setting time lengthened from 144.0 $\pm$ 4.1 minutes to 274.2 $\pm$ 7.4 minutes when the temperature increased from 37°C to 140°C ($P < .05$), whereas for AH Plus, iRoot SP, and RoekoSeal, the setting times reduced ($P < .05$).

Flow

The flow test results are shown in Table 2. At 25°C, RoekoSeal had the greatest flow ($P < .05$), but there was no difference among the other

TABLE 1. The Composition and Manufacturers' Information of the Materials Used in the Present Study

Root canal sealers	Composition	Manufacturer
ZOE	ZnO, Eugenol	Sinopharm Chemical Reagent Co, Ltd Shanghai, China
AH Plus	Epoxy resins, zirconium oxide, calcium tungstate, silicone oil, silica, iron oxide pigments, amines	Dentsply International York, PA
Roeko Seal	Polymethylsiloxane, silicone oil, paraffin-base oil, hexachloroplatinic acid, zirconium dioxide	Roeko/Coltene/Whaledent Langenau, Germany
iRoot SP	Zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler and thickening agents	Innovative Bioceramix Vancouver, Canada

ZOE, zinc oxide–eugenol.

TABLE 2. Setting Time (min) and Flow (mm) of 4 Root Canal Sealers at Different Temperatures

Root canal sealers	Setting time (min)		Flow (mm)	
	37°C	140°C	25°C	140°C
ZOE	144.0 ± 4.1	274.2 ± 7.4*	23.0 ± 1.1	23.7 ± 0.4
AH plus	542.8 ± 16.4	12.9 ± 0.7*	22.1 ± 0.4	25.6 ± 0.7*
RoekoSeal	49.3 ± 1.5	2.7 ± 0.4*	24.8 ± 0.9	12.4 ± 1.3*
iRoot SP	245.8 ± 15.9	14.2 ± 0.6*	22.9 ± 0.9	13.3 ± 1.5*

ZOE, zinc oxide–eugenol.

*Statistically significant differences between standard and high temperatures ($P < .05$).

sealers. At 140°C, the highest flow was recorded for AH Plus and the lowest for RoekoSeal ($P < .05$).

In the flow test, AH Plus showed an increase from 22.1 ± 0.4 mm to 25.6 ± 0.7 mm when the temperature was increased from 25°C to 140°C ($P < .05$), but RoekoSeal and iRoot SP showed a reduction (from 24.8 ± 0.9 mm to 12.4 ± 1.3 mm for RoekoSeal and from 22.9 ± 0.9 mm to 13.3 ± 1.5 mm for iRoot SP, $P < .05$). However, the flow of ZOE was unaffected by the high temperature.

Porosity

A significant reduction of porosity in the ZOE sealer group and the iRoot SP group was detected at high temperatures ($P < .05$) (Table 3). Stereoscopic micrographs of transverse sections of the sealers are shown in Figure 1.

Discussion

In our previous study, the actual temperature of different pluggers in 3 kinds of warm vertical compaction devices that were used popularly in practice (BeeFill 2in1 [VDW GmbH, Munich, Germany], SuperEndo Alpha II [B&L Biotech, Gyeonggi-do, South Korea], Elements [SybronEndo, Redmond, WA]) was measured (7). When thermoplasticized systems operated at 200°C, the actual median temperature of pluggers was 140°C (112°C∼199°C). Therefore, in the present study, a temperature of 140°C was set to evaluate the effect of a high temperature on sealers when warm vertical compaction was applied. In other similar studies, physical changes of sealers when heat was applied were observed. According to the actual temperature of System B pluggers (Analytic Technology, Redmond, WA), 100°C was used as the experiment condition in some studies (5, 10). In Beltes et al's study, a temperature of 80°C, which was based on the intracanal temperature induced during the application of warm condensation, was also used to observe the effect of heat application on the adhesion of epoxy resin sealer (11).

The setting time is dependent on the constituent components, their particle size, the ambient temperature, and the relative humidity (15, 17, 18). Clinical convenience demands that it must be long enough to allow the placement and adaptation of root filling if necessary (19). In the present study, when the temperature was increased from 37°C to 140°C, the setting time of ZOE was significantly lengthened from 144.0 minutes (2.4 hours) to 274.2 minutes (4.6 hours), which may have little influence on obturation. Conversely, a significant reduction of setting time occurred in the other sealers. When AH Plus was heated, the setting time was reduced, as previously reported (6, 10). It was suggested that this reduction was because of the loss of amine groups, which could accelerate the reaction (10). The reduction in the setting time of RoekoSeal (2.7 minutes at 140°C) would not allow enough operating time for practitioners. The setting time for iRoot SP declined to 14.2 minutes at 140°C. It is assumed that heat may accelerate the hydration and hydroxyapatite formation reactions of iRoot SP. To our knowledge, this is the first study on the effect of heat on the setting time of iRoot SP sealer.

Along with setting time, the flow of sealers at different temperatures was also evaluated. According to ISO6876 (16), in this test, “each disc shall have a diameter of no less than 17 mm.” In this flow test, whether at 25°C or 140°C, AH Plus and ZOE had flows >17 mm, but the flow was reduced in RoekoSeal and iRoot SP when the temperature increased from 25°C to 140°C ($P < .05$), and at 140°C the flow was <17 mm. An appropriate flow within the working time is important for any endodontic sealer to reach and seal the apical foramen and irregularities in the lateral dentinal wall (14). The ability of the sealer to flow is an important feature (20, 21) that depends on particle size, rate of shear, temperature, time, the internal diameter of the canals, and the rate of insertion (17). This reduction may be associated with a change in the setting reaction. A similar change was reported in the study by Camilleri (10), and a reduction of flow from 15 mm to 6 mm in another tricalcium silicate–based sealer introduced by Septodont (Saint Maur-des-Fossés, France) was reported.

In the process of obturation, setting time and flow are characteristic properties in the root canal filling process, and porosity is an indicator reflecting the seal of root canal obturation (5). Because water is needed during the setting process of ZOE and iRoot SP, gypsum molds were used in the tests of porosity. Bubbles in sealers are usually produced during the mixing and placement processes. It was more accurate to evaluate the porosity of sealers by calculating the percentage of voids in sealers than by morphologic observation. Viapiana et al (5) concluded that the reduction of porosity may improve the seal of root canal fillings.

In total, when heat was applied, the ZOE sealer group exhibited a lengthened setting time, increased flow, and decreased porosity. A possible reason was the decrease of the chelating reaction rate in the process of sealer setting. For AH Plus and RoekoSeal sealers, the reduction of setting time at a high temperature is very likely because of the catalyzing effect of heat on the polymerization reaction of these sealers. In Viapiana et al's study (6), the degradation of amine components in AH Plus was observed when it set at a high temperature, which may be responsible for the changes of setting time and flow, but the mechanism of these changes needs further investigation to provide more evidence. The setting of iRoot SP includes a hydration reaction of dicalcium silicate and tricalcium silicate and a hydroxyapatite formation reaction. The application of heat may accelerate the reaction rate; in this study, as the temperature increased, the sealer exhibited a reduction in setting time and flow.

TABLE 3. The Porosity (Void%) of 4 Root Canal Sealers in Different Temperatures

	ZOE		AH plus		RoekoSeal		iRoot SP	
	37°C	140°C	37°C	140°C	37°C	140°C	37°C	140°C
50th percentile	0.00	0.00	0.00	0.00	0.54	0.50	0.35	0.12
Interquartile	0.15	0.00	0.00	0.00	1.25	1.08	0.44	0.39
Range	2.60	1.35	2.97	1.61	4.32	4.53	1.20	0.94

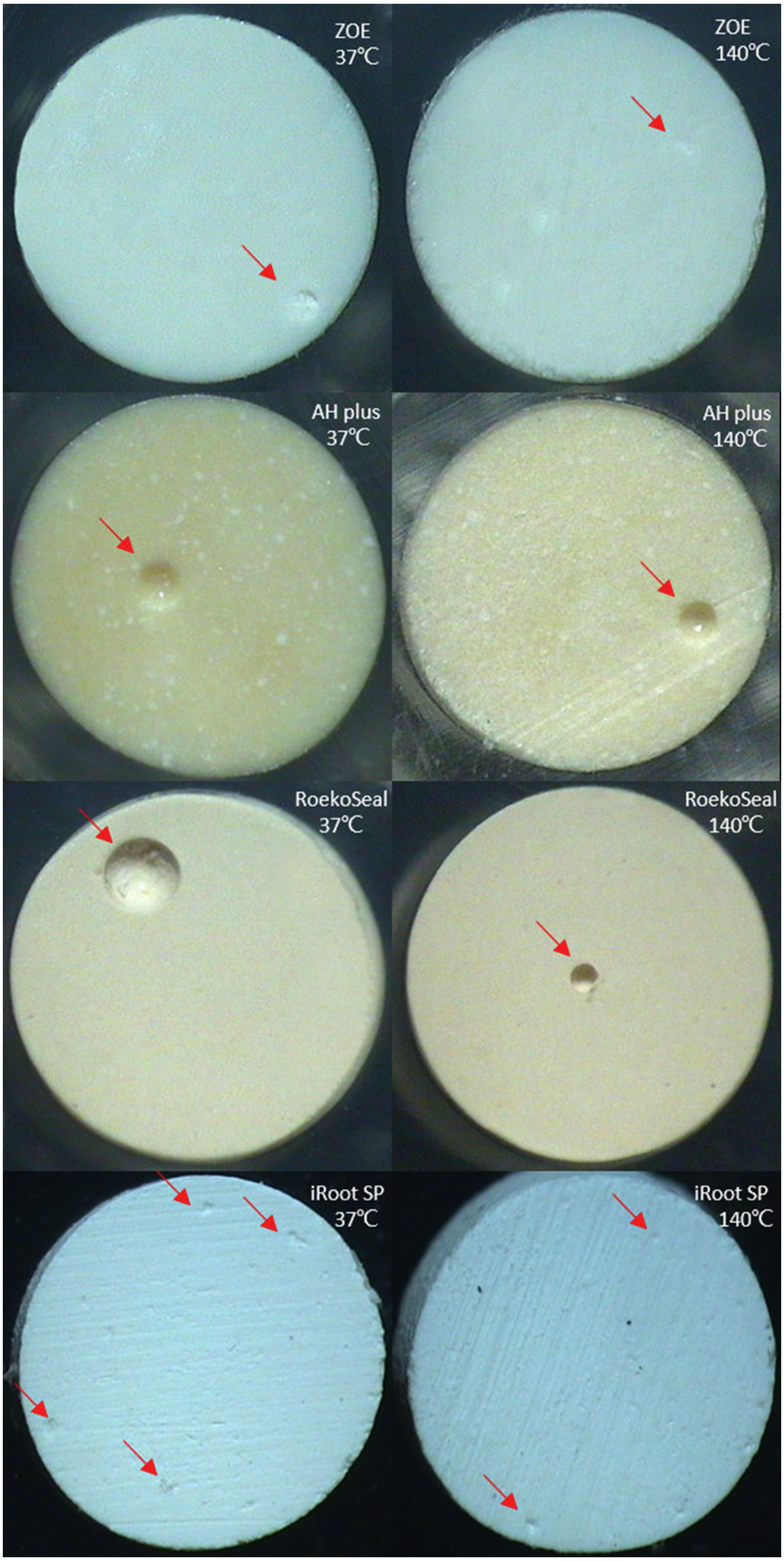

Figure 1. Light micrographs of transverse sections of molds filled with test sealers set in different temperatures at 30× magnification; voids are indicated by the *red arrows*.

Within the limitations of the current study, ZOE-based sealer and the resin-based sealer AH Plus showed acceptable changes in physical properties (setting time and flow) at a high temperature. However, significant reductions in the setting time and flow in the bioceramic tricalcium silicate–based sealer iRoot SP and the silicate-based sealer RoekoSeal were found, which could negatively affect the performance of clinical practice and quality of obturation in the warm vertical compaction technique.

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The authors deny any conflicts of interest related to this study.

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