Physical Properties of 5 Root Canal Sealers

Hui-min Zhou, PhD,*† Ya Shen, DDS, PbD,† Wei Zeng, PbD,† Li Li, PbD,* Yu-feng Zeng, PbD,*† and Markus Haapasalo, DDS, PbD†

Abstract

Introduction: The aim of this study was to evaluate the pH change, viscosity and other physical properties of 2 novel root canal sealers (MTA Fillapex and Endosequence BC) in comparison with 2 epoxy resin-based sealers (AH Plus and ThermaSeal), a silicone-based sealer (Gutta-Flow), and a zinc oxide-eugenol–based sealer (Pulp Canal Sealer). Methods: ISO 6876/2001 specifications were followed. The pH change of freshly mixed and set sealers was evaluated during periods of 1 day and 5 weeks, respectively. The viscosity was investigated at different injection rates (72, 10, and 5 mm/min) at room temperature by using a syringe-based system that was based on the Instron 3360 series universal testing system. Results: The flow, dimensional change, solubility, and film thickness of all the tested sealers were in agreement with ISO 6876/2001 recommendations. The MTA Fillapex sealer exhibited a higher flow than the Endosequence BC sealer (P < .05). The MTA Fillapex and Endosequence BC sealers showed the highest film thicknesses among the tested samples. The MTA Fillapex BC sealer exhibited the highest value of solubility, which was in accordance with 3% mass fraction recommended by the ISO 6876/2001, and showed an acceptable dimensional change. The MTA Fillapex and Endosequence BC sealers presented an alkaline pH at all times. The pH of fresh samples of the AH Plus and ThermaSeal sealers was alkaline at first but decreased significantly after 24 hours. The viscosity of the tested sealers increased with the decreased injection rates. Conclusions: The tested sealers were pseudoplastic according to their viscosities as determined in this study. The MTA Fillapex and Endosequence BC sealers each possessed comparable flow and dimensional stability but higher film thickness and solubility than the other sealers tested. (J Endod 2013;39:1281–1286)

Key Words
Flow, pH change, physical properties, root canal cements, tricalcium silicate sealer, viscosity

Endodontic sealers are used in the obturation of root canal systems to achieve a fluid-tight or hermetic seal throughout the canal including the apical foramen and canal irregularities and minor discrepancies between the dentinal wall of the root canal and the core filling material (1). Therefore, sealers help prevent leakage, reduce the possibility of residual bacteria from the canal to invade the periapical tissues, and resolve the periapical lesion (1, 2). According to Grossman (3), an ideal root canal sealer should provide the following: an excellent seal when set, dimensional stability, a slow setting time to ensure sufficient working time, insolubility to tissue fluids, adequate adhesion with root canal walls, and biocompatibility. Nowadays, various kinds of endodontic sealers are available, including sealers based on glass ionomer, zinc oxide–eugenol, resin, calcium hydroxide, silicone, and bioceramic-based root canal sealers. In particular, bioceramic-based materials that usually contain calcium silicate and/or calcium phosphate have attracted considerable attention because of their physical and biological properties such as their alkaline pH, chemical stability within the biological environment, and lack of shrinkage. They are also nontoxic and biocompatible (4–6). It has been reported that a premixed bioceramic endodontic sealer Endosequence BC Sealer (Brasseler USA, Savannah, GA) (4) and an experimental mineral trioxide aggregate (MTA)-based root canal sealer (MTA created in the Discipline of Endodontics, Araraquara Dental School, UNESP, University of Estadual Paulista, São Paulo, Brazil) (7) showed favorable physicochemical properties for root canal sealer.

Recently, another novel endodontic sealer (MTA Fillapex; Angelus Soluções Odontológicas, Londrina, PR, Brazil) was launched to the market, which is mainly composed of MTA, salicylate resin, natural resin, bismuth, and nanoparticulated silica according to the manufacturer’s instructions. However, little information is available for the physicochemical properties of MTA Fillapex.

The properties of root canal sealers have an impact on the quality of the final root filling (8–11). The handling properties of root canal sealers and their clinical behavior may be evaluated by conducting laboratory tests on their physical properties (11–14). The physical properties of various kinds of endodontic sealers according to these standards have been extensively studied, including the working time, setting time, flow, film thickness, solubility, dimensional change, and radiopacity (1, 4, 15–17). The flow of endodontic sealers may determine how effectively they obturate the accessory canals and voids between the master and accessory cones. Whereas adequate flow ability allows for the filling of irregularities, high flow may result in apical extrusion, leading to injury of the periapical tissues because of the cytotoxicity of the sealers (18). Thus, the flow characteristics of endodontic sealers have attracted attention recently. Several methods
have been proposed to evaluate the flow of endodontic sealers (15, 19, 20). However, limited data are available about the viscosity of endodontic sealers, which is an important parameter to determine their flow characteristics. In addition, the pH change of sealers may play a role in healing, because pH is associated with antimicrobial effects and deposition of mineralized tissue (21–24).

It has been found that an alkaline pH of root canal sealers could neutralize the lactic acid from osteoclasts and prevent dissolution of mineralized components of teeth; therefore, root canal sealers, especially bioceramic-based sealers, can contribute to hard tissue formation by activating alkaline phosphatase (25).

Therefore, the present study aimed to evaluate the physicochemical properties of 2 novel sealers and compare them with 4 traditional endodontic sealers. In particular, the pH change of freshly mixed and set sealers during a period of time and the viscosity of the sealers at different injection rates were investigated.

Materials and Methods

Two novel root canal sealers, EndoSequence BC (batch #210048P; Brasseler USA, Savannah, GA) and MTA Fillapex (batch #L19134; Angelus Soluc¸ SP; Brasseler USA, Savannah, GA) and MTA Fillapex (batch #11000800294; Dentsply Tulsa Dental, Tulsa, OK), a silicone-based sealer, GuttaFlow 2 (batch #6107673; Coltene/Whaledent GmbH+Co KG, Langenau, Germany), and a zinc oxide-eugenol–based sealer, Pulp Canal Sealer EWT (PCS) (batch #9-1309; Kerr Corporation, Romulus, MI), were used as the experimental materials. The physical specifications (12). All sealers were mixed and manipulated in accordance with the manufacturers’ instructions, except for the BC sealer, which is designed to set in a moist environment. In the present study, the following method was carried out to accelerate the setting of the BC sealer in the sample preparation of dimensional change and solubility tests. Two pieces of wet cloth were placed between the mold and the glass plates, and the glass plates were fixed by a clamp. The whole assembly was then put in a zip-lock bag containing enough water, which was stored in a 37°C water bath for 24 hours. Then the clamp was removed, and the assembly was kept in water for another 48 hours.

Flow and Viscosity

The flow of the sealers was tested according to ISO 6876/2001 (12); a volume of 0.05 ± 0.005 mL mixed sealer was placed on the center of a glass plate (40 × 40 × 5 mm³) using a graduated disposable 3-mL syringe. Three minutes later, a second glass plate weighing 20 g and a 100-g weight were placed centrally on top of the sealer. After 10 minutes from the start of mixing, the load was removed, and the minimum and maximum diameters of the sample disks were measured by a digital caliper (Gole-Parmer Canada Inc, Montreal, Canada) with a resolution of 0.01 mm. If the disks were not uniformly circular (the maximum and minimum diameters were not within 1 mm), the test was repeated. Five tests were taken for each sealer, and the mean, expressed in millimeters, was considered to be the flow of the material.

The viscosity of the endodontic sealers was assessed by using a syringe-based viscometer based on an Instron 3360 Series universal testing machine (26). A syringe with a diameter of 2.4 mm and a BD PrecisionGlide needle (BD Regular Bevel Needles 20G 1; Becton Dickinson & Co, Franklin Lakes, NJ) were used to construct the capillary rheometer. The viscosity was calculated by using a modified Hagen–Poiseuille equation as shown in equation (1).

$$\eta = \frac{(1 - \kappa)(F - F_r)r^4t}{8R^2LV}$$

where \(\eta\) is the viscosity after calibration, \(\kappa\) is the constant calculated by the errors of standard samples, \(F_r\) is the resistance of the plunger, \(F\) is the injection force, \(r\) is the radius of the capillary tube and equals to 0.32 mm for BD needle, \(R\) is the radius of the syringe and equals to 2.4 mm, \(L\) is the length of capillary tube and equals to 29 mm for BD needle, \(V\) is the volume extruded, and \(t\) is the extrusion time. The syringe-based viscometer was calibrated by 2 Brookfield standard viscosity fluids of 5.0 Pa s and 12.68 Pa s, from which the constant \(\kappa\) is calculated. The tests were performed at room temperature (23°C ± 2°C), and various cross-head speeds (72 mm/min, 10 mm/min, and 5 mm/min) were used. The tests were repeated 5 times for each sealer.

Film Thickness

The film thickness was determined as the difference in thickness between two 5-mm-thick glass plates with a size of 200 ± 25 mm² with and without the sealer interposed by a micrometer caliper (IP65, 293–340; Mitutoyo Corporation, Kanagawa, Japan) to an accuracy of 1 μm according to the method described in ISO 6876/2001 (12). The mixed sealers were placed between the glass plates. After 180 ± 5 seconds from the start of mixing, a load of 150 N was applied vertically on top of the glass plate, ensuring that the material filled the entire area between the top and bottom glass plates. After 10 minutes from the start of mixing, the thickness of the combined glass plates and sealer was measured by using a micrometer caliper. Three measurements were done for each sealer.

Working Time

The working time was measured from the start of mixing, during which time it is possible to manipulate the root canal sealer without causing any adverse effect on its properties. A volume of 0.05 ± 0.005 mL mixed sealer was placed on the center of a glass plate (40 × 40 × 5 mm³) by using a graduated disposable 3-mL syringe. Three minutes later, a second glass plate (20 g) and a 100-g weight were placed centrally on top of the sealer. After 10 minutes from the start of mixing, the minimum and maximum diameters of the sample disks were measured. The test was repeated with newly mixed material at increasing intervals of time after the start of mixing until the diameter had decreased by 10% of the value determined in the flow test. Three measurements were made for each sealer.

Setting Time

For MTA Fillapex, AH Plus, ThermaSeal, GuttaFlow 2, and PCS, stainless steel ring molds with an inner diameter of 10 mm and a height of 2 mm were used. The molds were placed on the glass plate, and then the materials were mixed and packed into them. The whole assembly was then transferred to an incubator (37°C, > 95% relative humidity). For BC sealer that requires moisture for setting, the plaster of Paris molds containing a cavity of 10-mm diameter and 1-mm height were used (12). The molds were first stored at 37°C in a water bath for 24 hours, and then the BC sealer was filled into the cavity. Then the whole assembly was stored in the water bath at 37°C.

To determine the setting time, a Gilmore needle with a weight of 100 g and an active tip of 2.0-mm diameter was used. The needle was lowered vertically onto the horizontal surface of the sealer, and the setting time was identified as the point when the indenter needle
failed to make an indentation. The materials were tested every 10 minutes or every hour, depending on the setting time stated by the manufacturers. The needle tip was cleaned before each test. The time from the start of mixing until the sealer was set was taken as the setting time. Three measurements were made for each sealer.

**Solubility**

The solubility of the sealers was tested as a percentage of the mass of specimen material removed from the distilled water compared with the original mass of the specimens. Six 1.5-mm-thick stainless steel rings with an inner diameter of 20 mm were used for each sealer. The rings were filled with the sealers and supported by a glass plate covered with a cellophane sheet, and the filled mold was placed in an incubator (37°C, >95% relative humidity) for a period of time 50% longer than the setting time. For fresh samples, the same volume as the set samples was averaged.

**Dimensional Change**

Cylindrical specimens were made in split molds with a diameter of 6 mm and a height of 12 mm to determine the dimensional change in water during a period of 30 days. The molds were slightly overfilled with mixed sealer and backed by a thin polyethylene plastic sheet and a glass plate on each side. The mold and plates were held firmly together with a clamp. After 5 minutes from the beginning of the mixing, the mold with the clamp was transferred to an incubator (37°C, >95% relative humidity), and kept in the incubator for at least 3 times the measured setting time. As for the Endosequence BC sealer, the accelerated setting method mentioned above was used. The sealers were removed from the mold and weighed 3 times each with an accuracy of 0.0001 g (Mettler AE 260 DeltaRange analytical balance; Mettler-Toledo International Inc, Columbus, OH). Two samples were put in a Petri dish, which was weighed before use and which contained 50 mL distilled water. After 24 hours in the incubator (37°C, >95% relative humidity), the samples were rinsed with 2–3 mL distilled water, and the washings were allowed to drain back into the Petri dish. The samples were then discarded, and the Petri dishes were dried in an oven at 110°C, cooled in the desiccator to room temperature, and reweighed. The amount of sealer removed from each specimen was calculated as the difference between the initial mass and the final mass of the Petri dish.

**pH Change**

The sealer samples mixed immediately after manipulation were denoted as fresh samples, and the samples mixed and stored in the incubator (37°C, >95% relative humidity) for 3 times the measured setting times were denoted as set samples. Five samples were prepared for each condition. Rubber molds were used to shape the set samples into disks 5 mm in diameter and 1 mm in thickness. Each set sample was put in a polyethylene tube containing 50 mL distilled water and kept in an incubator (37°C, >95% relative humidity) for 30 days. The samples were then removed from the distilled water, blotted dry with tissue paper, and measured again for length. The results from the 5 samples were averaged.

**Statistical Analysis**

The one-way analysis of variance test was used to analyze the physical property results and pH values by using SPSS software 10.0 (SPSS Inc, Chicago, IL). The significance level adopted was P < .05.

**Results**

The physical properties of the sealers are summarized in Table 1. According to the flow test, all the tested sealers demonstrated a flow greater than 20 mm, which is in agreement with the ISO 6876/2001 recommendations. The MTA Fillapex sealer had a higher flow than the Endosequence BC sealer (P < .05). The GuttaFlow sealer presented a flow significantly lower than the others. There was no significant difference in flow between the AH Plus and ThermaSeal sealers (P > .05). The flow values in increasing order were GuttaFlow < AH Plus < ThermanSeal < PCS = BC sealer < MTA Fillapex.

The PCS sealer had the lowest film thickness, and the 2 novel root canal sealers (Endosequence BC and MTA Fillapex) had the highest film thickness among the tested samples. The ranking order of the film thickness of the 5 sealers was PCS < GuttaFlow < AH Plus < ThermanSeal < BC sealer < MTA Fillapex.

The working time and setting time of the tested sealers were in agreement with the values stated by the manufacturers, with the exception of the setting time of the PCS, which in the present study was found to be much longer than the value given in the instructions (26 versus <2 hours). The working time values in increasing order were GuttaFlow < MTA Fillapex < AH Plus < ThermanSeal < PCS = BC sealer.

All tested materials showed solubilities within the limit allowed in the ISO 6876/2001 recommendations (3% mass fraction). The Endosequence BC sealer exhibited the highest value of solubility (2.9% ± 0.5%) among the tested materials, followed by MTA Fillapex. The solubility values in increasing order were ThermanSeal < GuttaFlow < AH Plus < PCS = MTA Fillapex < BC sealer.

MTA Fillapex, AH Plus, and PCS sealers exhibited shrinkage after being immersed in water for 30 days, whereas a slight expansion was measured with the Endosequence BC sealer, ThermanSeal, and GuttaFlow sealers. The dimensional change of all the tested sealers was in agreement with ISO 6876/2001 specifications, which recommends that dimensional change should not exceed 1.0% shrinkage or 0.1% expansion.

Fresh samples of MTA Fillapex, Endosequence BC, AH Plus, and ThermanSeal sealers produced an alkaline pH (Fig. 1A), whereas only the MTA Fillapex and Endosequence BC sealers had an alkaline pH also after setting (Fig. 1B). The pH of the fresh samples of AH Plus and ThermanSeal sealers decreased significantly from alkaline to neutral at 24 hours. The Endosequence BC sealer presented the highest pH in all experimental times.

The viscosity of the tested sealers increased with the decreased injection velocity (Fig. 2D). The PCS sealer presented the highest viscosity under all of the testing conditions, followed by the Endosequence BC sealer, whereas the ThermanSeal sealer had the lowest viscosity.

**Discussion**

With novel endodontic sealers being successively developed and commercialized by manufacturers, it has become important for the
clinician to understand the physicochemical properties of endodontic sealers. The properties of endodontic sealers, which are mainly determined by the type and proportions of the main components, can enable them to function adequately under clinical conditions. Laboratory studies on the physicochemical properties could contribute to a better understanding of the clinical behavior and handling performance of endodontic sealers. Recently, new endodontic materials have been developed that are based on the physicochemical properties of bio-ceramic cements in an attempt to develop a biocompatible sealer with ideal physical, chemical, mechanical, and biological properties (7, 27, 28).

MTA Fillapex is one of these recently developed endodontic sealers (29–31). According to the manufacturer’s information, MTA Fillapex is composed of salicylate resin, resin diluent, natural resin, bismuth oxide as a radiopaqueing agent, silica nanoparticles, MTA, and pigments. However, the details about the composition of the natural resin, pigments, and diluents are unknown. It is therefore necessary to investigate the physicochemical properties of the new endodontic sealers with the combination of the resins and other constituents. Few reports are available about the physicochemical properties and the clinical potential of MTA Fillapex (29–31). Therefore, the main purpose of this study was to assess the physicochemical properties of MTA Fillapex as well as a novel bioceramic-based sealer Endosequence BC and compare these with other, established sealers such as AH Plus, ThermaSeal, PCS, and GuttaFlow.

According to the physical properties of the 2 novel root canal sealers, MTA Fillapex had a higher flow and film thickness but a shorter working time, setting time, and solubility than the Endosequence BC sealer. On the other hand, both sealers produced an alkaline pH when immersed in distilled water, which may contribute to their osteogenic potential, biocompatibility, and antibacterial ability. In the present study, the MTA Fillapex sealer showed a lower pH value than the Endosequence BC sealer for both fresh samples and set samples, which is probably due to the shorter setting time and lower solubility of MTA Fillapex sealer. The differences between Endosequence BC sealer and MTA Fillapex probably reflect the fact that the former is a pure bioceramic sealer, whereas the latter is a combined bioceramic–resin–based sealer.

An acceptable flow within the working time is important for any endodontic sealer to reach and seal the apical foramen and lateral dentinal wall irregularities. The composition, particle size, shear rate, temperature, and time from mixing are the main factors related to the flow characteristics of sealers. The ISO and American Dental Association (ADA) specifications do not require a measurement of viscosity of endodontic sealers; they use the diameter of a film of sealer between 2 glass plates to evaluate the flow, which is related to viscosity but easier to measure. Viscosity is a quantitative parameter for the evaluation of rheological properties of endodontic sealers and may help to achieve an ideal flow pattern (19). Several studies have made an effort to examine the rheological properties of endodontic sealers by using a capillary rheometer (19) or extrusion through a bore (15). However, to some extent, they are still indirect methods related to the viscosity measurements and do not provide the viscosity of sealers. The present study used a flow model in fine capillary tubes to simulate flow in root canals and calculated the viscosity of the selected commercially available endodontic sealers by using a modified Hagen–Poiseuille equation. According to the results on viscosity in the present study, the tested endodontic sealers are pseudoplastic, so that their viscosity is reduced and flow is increased when the shear rate increases during compaction.

### Table 1. Physical Properties of the Sealers (mean ± standard deviation)

<table>
<thead>
<tr>
<th></th>
<th>BC sealer</th>
<th>MTA Fillapex</th>
<th>AH Plus</th>
<th>ThermaSeal</th>
<th>PCS</th>
<th>GuttaFlow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (mm)</td>
<td>23.1 ± 0.69</td>
<td>24.9 ± 0.54</td>
<td>21.2 ± 0.27</td>
<td>21.3 ± 0.47</td>
<td>23.1 ± 1.21</td>
<td>20.5 ± 0.32</td>
</tr>
<tr>
<td>Film thickness (µm)</td>
<td>22 ± 4.58</td>
<td>23.92 ± 7.05</td>
<td>204 ± 0.40</td>
<td>300 ± 4.00</td>
<td>453 ± 31</td>
<td>15 ± 5</td>
</tr>
<tr>
<td>Working time (min)</td>
<td>&gt;1440</td>
<td>45 ± 15</td>
<td>11.5 ± 1.5</td>
<td>23.0 ± 1.5</td>
<td>26.3 ± 2.5</td>
<td>0.7 ± 0.1</td>
</tr>
<tr>
<td>Setting time (h)</td>
<td>2.7 ± 0.3</td>
<td>2.5 ± 0.3</td>
<td>0.06 ± 0.04</td>
<td>0.0015 ± 0.07</td>
<td>0.07 ± 0.03</td>
<td>0.02 ± 0.001</td>
</tr>
<tr>
<td>Solubility* (%)</td>
<td>2.9 ± 0.5</td>
<td>1.10 ± 0.15</td>
<td>-0.034 ± 0.01</td>
<td>0.04 ± 0.02</td>
<td>-0.86 ± 0.03</td>
<td>0.037 ± 0.02</td>
</tr>
<tr>
<td>Dimensional change%</td>
<td>0.087 ± 0.04</td>
<td>-0.67 ± 0.01</td>
<td>-0.034 ± 0.01</td>
<td>0.04 ± 0.02</td>
<td>-0.86 ± 0.03</td>
<td>0.037 ± 0.02</td>
</tr>
</tbody>
</table>

*Solubility = (removed mass of sample)/(original mass of sample) × 100.

†Dimensional change: minus means shrinkage.
Pseudoplastic materials, particularly if they have low initial viscosities, will benefit from rapid placement and display a more rapid flow. On the other hand, an excessive flow rate increases the probability of extrusion into periodontal tissues. Sealer extrusion could injure the periapical tissues because of the cytotoxicity and low biocompatibility of several sealers, mainly at the initial stage of setting. In this aspect, the sealer with good biocompatibility may be more favorable.

The physical tests performed in this study were chosen to characterize the physical and handling properties of the commercial sealers and were carried out by using methods based on ISO 6876/2001. Another frequently used standard for the evaluation of the physical properties of root canal sealers is the ADA no. 57 specification. The main difference between these 2 standards is the amount of sealer used to assess the flow and working time (0.5±0.05 mL is required for ADA no. 57 and 0.05±0.005 mL for ISO 6876/2001). The evaluated physical properties such as flow, dimensional change, solubility, and film thickness comply with the requirements of ISO 6876/2001 specification for all tested sealers. The setting time of the AH Plus and PCS sealers was longer than the values given by the manufacturers. The setting time of AH Plus in the present study was similar to one investigated in a previous study (18) and longer than in other studies (32, 33). The setting time of PCS was probably influenced by the humidity condition. In addition, it is worth noting that the EndoSequence BC sealer is a material that needs moisture during the setting process. Therefore, a plaster of Paris mold was used and stored at 37°C and >95% relative humidity for 24 hours before use. The height of the cavity used for determining the setting time of EndoSequence BC sealer (height = 1 mm) was also different from other materials that do not require moisture for setting (height = 2 mm) according to ISO 6876/2001. The setting time of EndoSequence BC sealer determined by using this method in the present study was shorter than that in a previous study (5) because of the different testing methods.

In the present in vitro study, GuttaFlow showed the lowest flow among the tested sealers. However, according to the manufacturer, GuttaFlow has excellent flow properties because its viscosity diminishes under shear stress (thixotropy) (34). The material is believed to flow into the lateral canals and completely fill the space between the root canal and the master cone (35). Thixotropic materials have a higher viscosity when moved at a slow speed and a lower viscosity when moved at a higher speed. In the present study, the testing method of flow according to the ISO 6876/2001 specification could not reflect the relationship between the viscosity and shear speed; thus a slow loading rate to test flow was used. Although both thixotropic and pseudoplastic properties describe a fluid with decreasing viscosity, thixotropic materials exhibit this change as a result of time (under constant shear), whereas pseudoplastic materials exhibit this change as a result of increasing the rate of shear stress. Although the viscosity at different injection rates revealed that GuttaFlow was a pseudoplastic material, it is not a dynamic test able to reveal the relationship between shear rates and viscosity, so it also failed to reveal the thixotropic characteristic of the GuttaFlow.

In the present study, we proposed a new method to accelerate the setting process of the EndoSequence BC sealer. Because the inorganic and radiopacifier components of the sealer are premixed with water-free liquid-thickening carriers, water is required for the sealer to reach its final set (5). In addition, although the solubility of the EndoSequence BC sealer was in agreement with ISO 6876/2001 specifications, it was the highest among the tested materials and close to the maximum permitted limit for solubility. This may be attributed to the intrinsic properties of the materials used in the EndoSequence BC sealer, which is a calcium phosphate silicate–based sealer. It has been reported that the EndoSequence BC sealer was designed to set only when exposed to an environment such as dentinal tubules, which contain approximately 20 wt% water (36). However, it is important to notice that the total dimensional change of the EndoSequence BC sealer was small, in fact a slight expansion was measured, and it complied with ISO 6876/2001 specification. The results show that the solubility of the EndoSequence BC sealer has no impact on
the dimensional stability and indicates that it does not impair the sealing ability of the sealer.

**Conclusions**

In this study, the tested endodontic sealers are pseudoplastic as determined by their viscosity. All sealers met the requirements for flow, film thickness, solubility, and dimensional change. The new endodontic sealers, MTA Fillapex and Endosequence BC, each possessed comparable flow and dimensional stability but higher film thickness and solubility than AH Plus, ThermaSeal, PCS, and GuttaFlow.

**Acknowledgments**

The authors thank Brasseler USA and Angelus Soluções Odontológicas for donating the materials used in this study.

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

**References**