A Comparison of Thermal Properties Between Gutta-Percha and a Synthetic Polymer Based Root Canal Filling Material (Resilon)

Marcus R. Miner, DDS, David W. Berzins, PhD,* and James K. Bahcall, DMD, MS**

Abstract

A new polymer-based obturating material, Resilon, has been developed but there have been no studies identifying its thermal properties. The purpose of this study was to compare the melting point, specific heat, enthalpy change with melting and heat transfer between gutta-percha (GP) and Resilon (R). The first three tests were determined using a differential scanning calorimeter and the heat transfer test was determined using a split-tooth model. Results show no significant difference (*t* test, $p > 0.05$) between gutta-percha and Resilon for the melting point temperature (GP: 60.01°C; R: 60.57°C). There was a significant difference (*t* test, $p < 0.05$) in specific heat capacity (GP: 0.94 J/g °C, R: 1.15 J/g °C) and endothermic enthalpy change (GP: 10.88 J/g, R: 25.20 J/g) between the two materials. The heat transfer test showed a significant difference (Mann-Whitney, $p < 0.05$) in temperature increase between gutta-percha and Resilon within 3 mm of the heat source. *(J Endod 2006;32:683–686)*

Key Words

enthalpy change, gutta-percha, heat transfer, melting point, Resilon, specific heat, thermal properties

Obturation of the root canal system is an integral component in promoting periapical healing and preventing disease progression. The root canal filling material accomplishes this by reducing microleakage and entombing any inflammatory irritants. The effectiveness of a material to adequately seal the root canal space is established by its physical properties and handling characteristics. Gutta-percha has been the preferred root canal filling material because it possesses many favorable properties, which include biological compatibility, dimensional stability, pliability, easy placement and removal, and radiopacity.

Studies have shown that gutta-percha can be adapted to the root canal wall by various filling techniques (1, 2). Despite close proximity, it has been shown that gutta-percha does not have a complete dentinal seal (3). Potential unfilled spaces may allow coronal microleakage and infection of the root canal system, which may contribute to treatment failures (4, 5). To address this problem, advancements in polymer technology have lead to the development of resin-based obturating materials. A new polymer obturating material, Resilon (R), has been shown to reduce microleakage by more effectively sealing the root canal system (6). In addition to the aforementioned properties of gutta-percha, Resilon has been shown to increase the resistance to fracture of endodontically treated teeth (7) and have reduced periapical inflammation after microbial inoculation (8). Although displaying desirable characteristics, few studies have evaluated the physical properties of Resilon.

Schilder stated that a key factor in successful root canal treatment is to seal the canal space with a three-dimensional obturation (9). Studies have shown that gutta-percha has favorable thermal properties, enabling it to conform to the complexities of the root canal system (10, 11). This material can be softened by heat application without changing the chemical composition of the material (12). Thermoplastic compaction of gutta-percha is an obturating technique that has been advocated because it seals the root canal system and reduces microbial leakage (13, 14). Where there have been studies addressing the thermal properties of gutta-percha, there have been no studies evaluating the thermal properties of Resilon (15, 16). The purpose of this study was to compare the melting point, enthalpy change with melting, specific heat capacity and heat transfer between gutta-percha and Resilon.

Materials and Methods

Melting Point and Enthalpy Change

The differential scanning calorimeter (DSC) is a tool for measuring the melting points of certain thermoplastic polymers and other solids. Samples of gutta-percha (Dentsply Tulsa Dental, Tulsa, OK) and Resilon (Resilon Research, LLC, Madison, CT) were weighed (AG 245, Mettler Toledo, Inc., Columbus, OH) and heated, using a DSC (DSC822e, Mettler-Toledo, Inc.), from 0 to 200°C at a rate of 10°C/min ($n = 3$ for each material). On the recordings, the phase transition was identified and the melting point was determined. The endothermic peak areas yielded the enthalpy associated with the melting phase transition. Enthalpy change is the amount of heat released or absorbed when a reaction takes place. Data was analyzed using a *t* test ($p < 0.05$).

Specific Heat Capacity

Specific heat capacity is the heat that must be added to raise the temperature of 1 g of material by 1°C. Using a DSC, the specific heat for gutta-percha and Resilon ($n =$

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*From the Department of Endodontics, Marquette University, School of Dentistry, Milwaukee, Wisconsin.

Address requests for reprint to Dr. Marcus R. Miner, Department of Endodontics, Marquette University, School of Dentistry, 1801 West Wisconsin Avenue, Room 245, Milwaukee, WI 53233. E-mail address: marcus.miner@marquette.edu.

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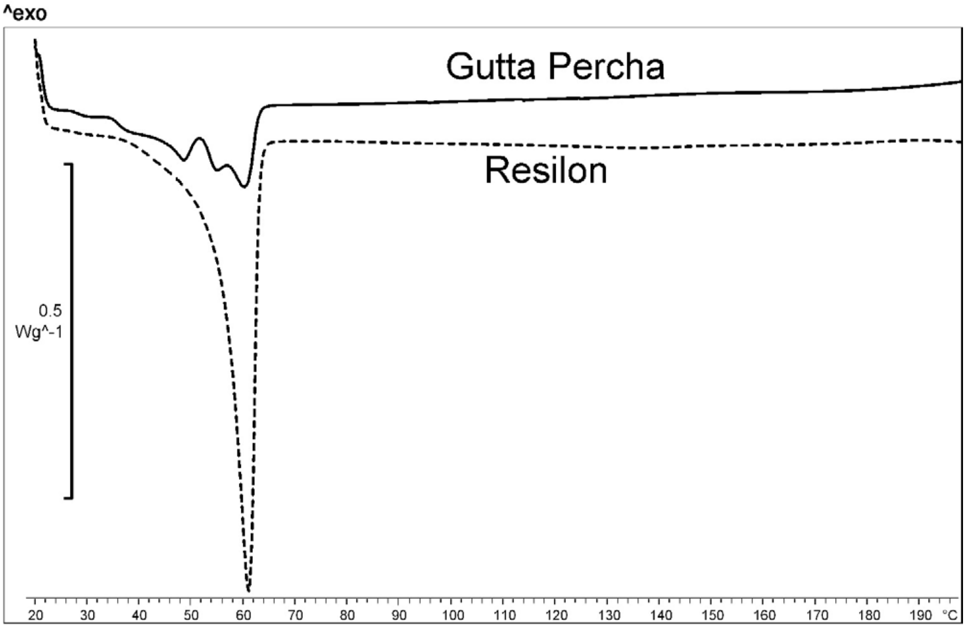


Figure 1. Melting point and enthalpy change for gutta-percha and Resilon.

4/materials) was determined over the temperature range 0 to 200°C. The t test was used for statistical analysis ($p < 0.05$).

Heat Transfer

A split-tooth model, as described by Weller (17), was used to determine heat transfer within each material. A human maxillary canine was mounted in a block of acrylic and sectioned longitudinally. The two halves of the tooth could be repositioned in the same orientation to perform numerous tests.

The tooth was accessed and working length was established 1 mm short of the anatomical foramen. The tooth was instrumented to 40/0.06 with Profile rotary files (Dentsply Tulsa Dental, Tulsa, OK). Eight channels were drilled from the exterior surface of the acrylic to the canal space of the tooth. The channels were made at 1-mm increments from the apex.

A 40/0.06 gutta-percha or Resilon master cone was placed to working length. Endodontic sealer was not used during the experiment. Eight Type-K thermocouples (Omega Engineering, Inc., Stamford, CT) contacted the cone through the channels. The thermocouples were connected to a computerized data acquisition system (iNet Series, Omega Engineering, Inc.) to record the temperature at each channel every 0.5 s. A System B unit and medium-sized plugger (Analytic Technology, Orange, CA) were used to heat the cone. The temperature for gutta-percha was set at 200°C (GP-200) and Resilon at 150°C (R-150). Resilon was also tested at 200°C (R-200) to allow a direct comparison with gutta-percha. Before recording, the System B unit was calibrated to ensure exact temperature output.

The plugger was activated and placed 1 mm short of the first thermocouple. The heat was deactivated and apical pressure was maintained for 10 s. Temperature changes were continually measured for 3 min ($n = 6$ for each material). Statistical analysis was performed using the Kruskal-Wallis test followed by the Mann-Whitney test for multiple comparisons ($p < 0.05$).

Results

Melting Point and Enthalpy Change

There was no significant difference (t test, $p < 0.05$) between gutta-percha and Resilon for the melting point temperature (GP: 60.01 ± 0.35°C; R: 60.57 ± 0.43°C, Fig. 1). There was a significant difference (t test, $p < 0.05$) in the enthalpy change between gutta-percha and Resilon. The endothermic change was 10.88 ± 0.60 J/g and 25.20 ± 0.68 J/g for gutta-percha and Resilon, respectively.

Specific Heat Capacity

The specific heat values were determined over the temperature range of 0 to 200°C (Fig. 2). Disregarding specific heat values during first order transitions, such as melting where values may be infinitely large, the mean specific heat values of gutta-percha (0.94 ± 0.09 J/g°C) and Resilon (1.15 ± 0.12 J/g°C) were significantly different (t test, $p < 0.05$).

Heat Transfer

Qualitatively, gutta-percha and Resilon displayed similar temperature change patterns with the application of heat. There was an initial spike in temperature close to the heat source, with minimal increases further from the heat. As time elapsed there was a gradual decline in the temperature change which stabilized at the end of the test period (Fig. 3).

There were significant differences (Mann-Whitney, $p < 0.05$) in maximum temperature changes between gutta-percha and Resilon within 3 mm of the heat source. The mean temperature increase 1 mm from the heat source was 4.46°C for GP-200, 2.54°C for R-200 and 2.42°C for R-150 (Fig. 3). No significant differences (Mann-Whitney, $p > 0.05$) were found in temperature changes 4 mm and further from the heat source. The temperature increase 4-mm away was 1.01°C for GP-200, 0.96°C for R-200, and 0.79°C for R-150.

Discussion

The results of the melting point determination for gutta-percha are consistent with other studies (16). The material tested is β gutta-percha because of the typical endothermic peaks. A third isolated peak was found and can be attributed to various additives (15). The means for the three peaks of this gutta-percha sample were 48.58, 54.97, and 60.01°C.

Distinct from the thermal behavior of gutta-percha, Resilon has a single, isolated peak at 60.57 ± 0.43°C. The melting temperature is

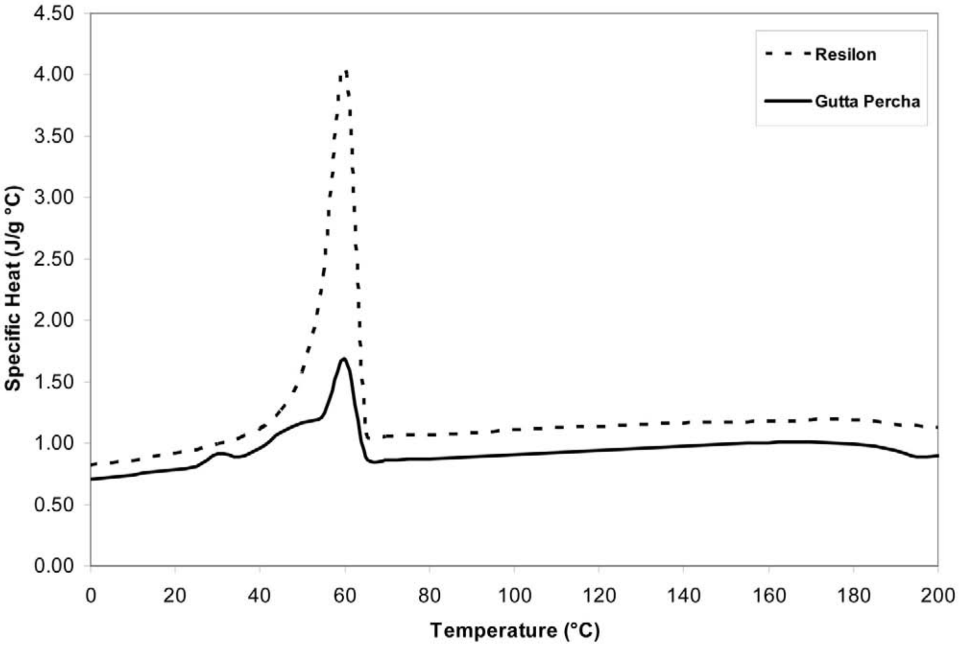
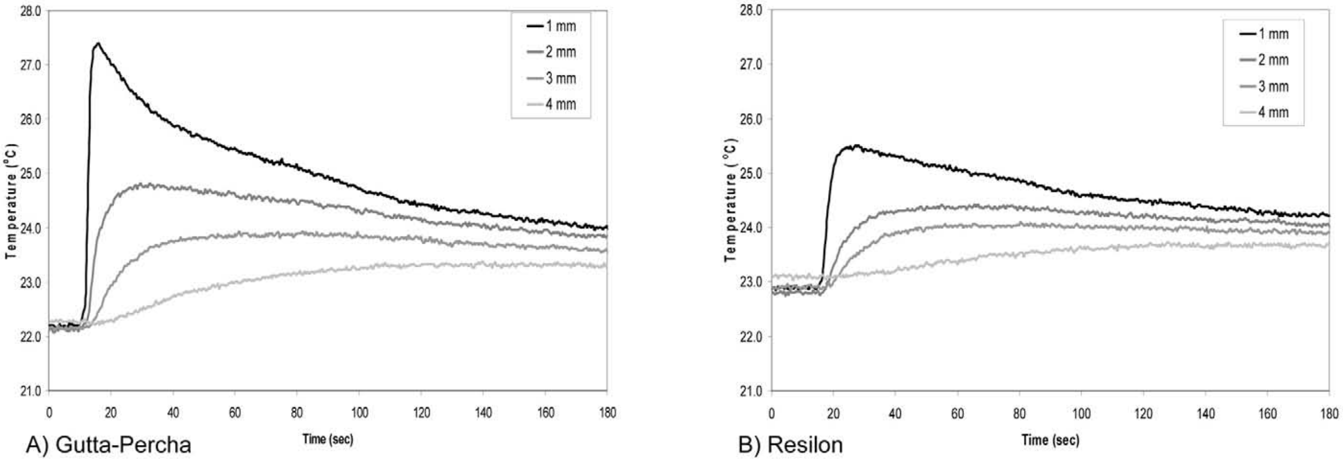
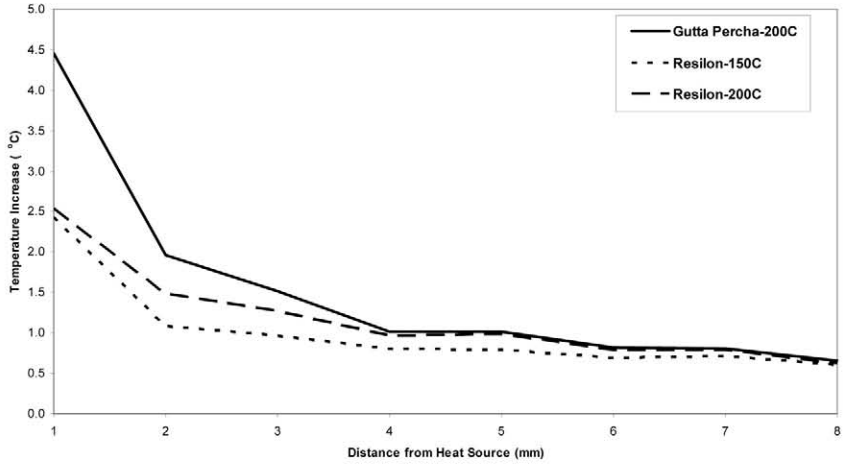


Figure 2. Specific heat capacity for gutta-percha and Resilon.



A) Gutta-Percha

B) Resilon



C) Temperature increase from heat source

Figure 3. (*A*) Heat transfer test for gutta-percha. (*B*) Heat transfer test for Resilon. (*C*) Temperature increase from heat source, gutta-percha, and Resilon.

slightly lower than that, 70 to 80°C, reported by the manufacturer (18). There was no significant difference (*t* test, $p > 0.05$) in the melting temperatures between gutta-percha and Resilon.

Enthalpy change quantifies the amount of heat released or absorbed during a reaction, such as the melting of a solid. The DSC is an instrument that can measure the enthalpic energy of these transformations. A comparison of the endothermic peak areas between the two materials shows a significantly (*t* test, $p < 0.05$) higher value for Resilon. These data suggests that more heat would be required to thermoplasticize Resilon compared to gutta-percha during warm vertical compaction because Resilon absorbs more heat during melting.

The specific heat of a material gives the amount of heat needed to change the temperature of a unit mass one degree and is known to vary with temperature. The 0 to 200°C temperature range was selected for its relevance to warm vertical compaction. Comparing the two materials, Resilon had a significantly higher (*t* test, $p < 0.05$) specific heat capacity than gutta-percha. This finding is consistent with the enthalpy results since Resilon requires more heat than gutta-percha to increase the material temperature.

The amount of heat transferred through a material is significant when considering thermoplastic obturation. Goodman found that an increase of 4°C in gutta-percha would produce softening for compaction (19). This study found that gutta-percha had a mean maximum temperature increase of 4.46°C 1 mm away from the heat source, which is similar to other studies (20).

Compared to gutta-percha, the temperature increase of Resilon was significantly less (Mann-Whitney, $p < 0.05$) 1 to 3 mm away from the heat source. Gutta-percha had approximately a 2°C greater temperature change 1 mm from the heat source compared to the Resilon groups. This finding is consistent with the differences in enthalpy change and specific heat between the two materials, showing that more heat is required to increase the temperature of Resilon compared to gutta-percha.

The System B was set at 150°C for Resilon, following manufacturer recommendations, and at 200°C for a direct comparison to gutta-percha. Interestingly, there was not a significant difference (Mann-Whitney, $p > 0.05$) between the 150 and 200°C settings for Resilon. It is possible that a higher heat source temperature may increase the Resilon temperature closer to gutta-percha; however, a significant increase may cause damage to the physical structure of Resilon or the periodontal ligament (21).

There was no significant difference (Mann-Whitney, $p < 0.05$) between gutta-percha and Resilon in temperature increase more than 4 mm from the heat source. Findings from the split-tooth model imply that clinically the two materials may have different heat transfer within 3 mm of the heat source, but not beyond. Given comparable melting temperatures but differences in its ability to transfer heat, Resilon may not perform similar to gutta-percha during thermoplastic obturation. Many studies have investigated the optimal depth of heat plugger penetration to plasticize the gutta-percha at the apex (22–24). Recent studies suggest placing the heat source within 3 to 4 mm of the working length to reliably soften gutta-percha. Data from this study indicates that Resilon may require more heat application to equally plasticize the material. However, as shown by increasing the temperature to 200°C, there is not an appreciable improvement in heat transfer.

This study intentionally omitted the use of a sealer to eliminate a possible variable since different sealers are used during obturation. The results may also vary if the heat transfer test was performed in a water bath at physiologic temperatures. As found in other studies, the System B unit needed to be calibrated since the digital reading was about 20 to 30°C higher than the actual output (25, 26).

Although the melting temperatures are similar, the results of this study suggest that Resilon may not thermoplasticize similar to gutta-percha because there is a higher specific heat, higher enthalpy change with melting and less heat transfer. It is not known at this time whether the lack of heat transfer within 3 mm from the heat source is clinically relevant. Further studies addressing the clinical success of the Resilon and the role of the sealer affecting the thermal properties are needed.

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