PHYSICAL PROPERTIES OF GUTTA-PERCHA WHEN SUBJECTED TO HEAT AND VERTICAL CONDENSATION

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Physical properties of gutta-percha when subjected to heat and vertical condensation

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Vertical condensation of warm gutta-percha is a relatively new technique in the endodontic therapeutic regimen. The physical properties of gutta-percha when used in this manner have been evaluated. Part I is concerned with the determination of the distance to which the mass of gutta-percha will conduct heat ahead of heat application and vertical condensation. Part II deals with the evaluation of volume stability of gutta-percha when used in a repeated sequence of heating and vertically condensing the material. Results showed that the temperatures recorded vary from a 12.5° C. increase in the gutta-percha in the body of the preparation to a 4.0° C. increase at the apex at the time condensation is completed. The volume of gutta-percha recovered from the preparations was significantly greater than the volume of the preparations.

In order to obtain a three-dimensional obturation of root canal systems, various techniques have been devised, employing the solvents chloroform, eucalyptol, and chloroform-rosin in combination. All of these have been clinically successful. However, they have certain shortcomings, as demonstrated by Price.[1] For example, a creamy mix of chloropercha has a volume three times greater than the original material. If a canal is filled with this mixture alone, it would be two-thirds empty after evaporation of the chloroform. Even when solid gutta-percha displaces 90 per cent of the chloropercha, the canal eventually will be minus 6.6 per cent of its filling. Similar considerations probably apply to eucapercha and chloroform-rosin combinations.

The lateral condensation technique takes advantage of the dimensional

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stability of gutta-percha when used without a solvent. There are certain disadvantages in this approach also. Lateral canals can be obturated only with the cementing medium, if at all. Owing to the fact that the filling is composed of a number of gutta-percha cones pressed together, the mass is held together only by friction and the cementing substance. Homogeneity occurs only at the point where the coronal excess is removed with a hot instrument. The technique also provides the most dense filling in the middle and coronal thirds of the canal, with little improvement of the apical seal as additional cones are added.[2, 3]

The technique which best fulfills the requirements of a root canal filling is the vertical condensation of warm gutta-percha. Using gutta-percha in a plastic state without solvent provides a homogenous, dimensionally stable filling which is lacking in other techniques. Also, greater density is obtained in the apical portion of the canal, and accessory canals and the foramina are filled with a greater frequency than in any other technique.[3] However, because of the relative newness of this method of therapy, no studies have been made of the physical properties of gutta-percha when subjected to vertical condensation and heat. It is the objective of this study to provide data on heat transport (Part I) and volume (Part II) of gutta-percha introduced into a confined space by means of vertical condensation.

MATERIALS AND METHODS

Part I. Heat studies

Cavities were prepared in Teflon rods 23.5 mm. long with an outer diameter of 12.5 mm. This material was chosen because of its poor thermal conducting properties, and the large diameter was selected to minimize deformation under pressure.[4]

The preparation was started by machining a "root canal" with a $\frac{1}{32}$ inch drill bit to within 3 mm. of the apical end. The preparation of the root canal was then carried out to provide a continuously tapering funnel with its widest opening at the orifice and its narrowest opening at the apex. To form the "apex," the Teflon was perforated from the bottom of the drilled hole to the external surface of the sample. A No. 6 file (Kerr) was carried to the apex to produce an apical opening of 0.5 mm. The preparation of the body of the canal was completed with a No. 11 reamer (Kerr) until the orifice was 2.5 mm. wide.

This provided the approximate internal dimensions of a maxillary central incisor,[5, 6] as prepared for vertical condensation of warm gutta-percha[3] (Fig. 1).

Thermistors (Fenwal Electronics Uni-curve thermistors UUA33J1) were chosen for heat determination because of their size and accuracy.[7, 8]

A gutta-percha core (Mynol) was fitted and trimmed, so that it was binding 1 to 2 mm. short of the apical end of the preparation. Five holes were then drilled along the length of each Teflon rod, so that they were equidistant from each other, starting 1 mm. from the coronal opening and ending 1 mm. short of the foramen (Fig. 1).

The thermistors were placed into the five holes, so that they were in contact with the gutta-percha. Epoxy bonding material (Tra-Bond #BB-2151, Tra-Con, Inc.) was used to cement the thermistors in their correct positions.

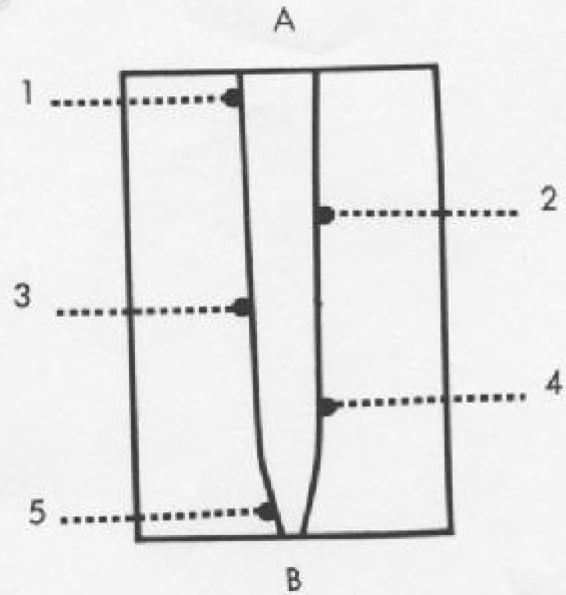

Fig. 1. Diagram showing 23.5 mm. long Teflon rod with root canal preparation. The "orifice" (*A*) is 2.5 mm. wide and the "apex" (*B*), 0.5 mm. The placement of the thermistors 1 to 5 in relation to the preparation is also shown.

The thermistors were then connected to a power supply (1.3 volt mercury cell) with 500 ohm wire. Two two-channel recorders (Hewlett Packard) were attached to the second, third, fourth, and fifth thermistors. The first thermistor was used as a check on the recording system.

The gutta-percha cones were then condensed into the Teflon rods, using the vertical condensation of warm gutta-percha technique, except that the cementing medium was omitted.[3] Simultaneous recordings were made of the temperature changes along the length of the preparation. The readings were correlated with the depth of penetration of the heat carrier and plugger until the apex was sealed.

Part II. Volume studies

To conduct volume studies on condensed warm gutta-percha, twenty glass cylinders were used to simulate the root canal preparations. This material was chosen because of its dimensional stability under pressure, thermal conductivity in the range of that of tooth structure,[9-11] and ease of visualization of dye penetration.

Glass cylinders were obtained by fracturing a 23.5 mm. long tip off Kimax pipets (1/10 ml. in 1/100 ml. graduations). Prior to fracturing, the tip was rotated in a Bunsen burner until its opening was 0.5 mm. in diameter. The resulting glass specimens had the same dimensions as the Teflon rods prepared for Part I, that is, those of a maxillary central incisor.

All cylinders were identified by placing grooves with a diamond stone on the external surface. They were then carefully grooved with a diamond wheel on two sides from coronal to apical end in order to facilitate the final breakage of the glass and recovery of gutta-percha.

The glass cylinders were covered at both ends with paraffin film (Parafilm "M," American Can Co.) and weighed under water (23° C.) to 0.1 mg., using a Mettler Gram-O-Matic balance. The film was then removed from the ends and added to the exterior of the cylinder. Cylinders were reweighed under water (23° C.). The difference in the two weights represented the weight of water displaced by the internal volume of the cylinder, and this volume could then be correctly calculated.

A cone of Mynol gutta-percha was fitted in each of twenty glass cylinders, so that the cones were binding in the preparation 1 to 2 mm. from the apical end. These were condensed to the apex, using the same technique as previously described.

The remaining portion of the cylinder was filled flush with the coronal opening, using one of the following techniques repeatedly:

1. Warming a small segment of gutta-percha and condensing it to the previously condensed filling.
2. Reheating the coronal 1 to 2 mm. of the filling with the heat carrier and condensing a room-temperature segment of gutta-percha into it.
3. Reheating the coronal 1 to 2 mm. of the filling and condensing a warm segment of gutta-percha into it. (This was done in only one sample because of difficulty in manipulation.)

Ten cylinders were stored in aqueous dye (naphthol blueblack) solution at 37° C. for one week, and the other ten for one month. The use of the dye permitted assessment of leakage.

The cylinders were then fractured by placing them between paper towels and tapping with a mallet. All glass was removed, and the gutta-percha filling was carefully checked under a magnifying glass to ensure complete removal of any adherent glass particles.

The gutta-percha was weighed in air and water to 0.1 mg. The difference in weight represented the weight of water displaced, and volumes were determined accordingly.

Comparisons were then made between the initial internal volume of the glass cylinders and the final recovered volume of the gutta-percha filling.[12]

Results: Heat studies

Temperature changes during vertical condensation of one sample as observed with the thermistors (2 to 5) are shown in Fig. 2. Apical seal was complete in 8 minutes. It may be seen that the highest temperature initially was recorded from the most coronal thermistor (No. 2). After 5 to 6 minutes of manipulation, the same temperature was recorded also from thermistor 3. The most apical thermistors (4 and 5) showed less temperature change; even here, however, there was a measurable temperature increase after 4 minutes (from 22.5° C. to 24.0° C.). Maximal temperature (26.5° C.) in the apical segment was reached after 11 minutes.

Similar data were recorded in Fig. 3 for another specimen. In this instance,

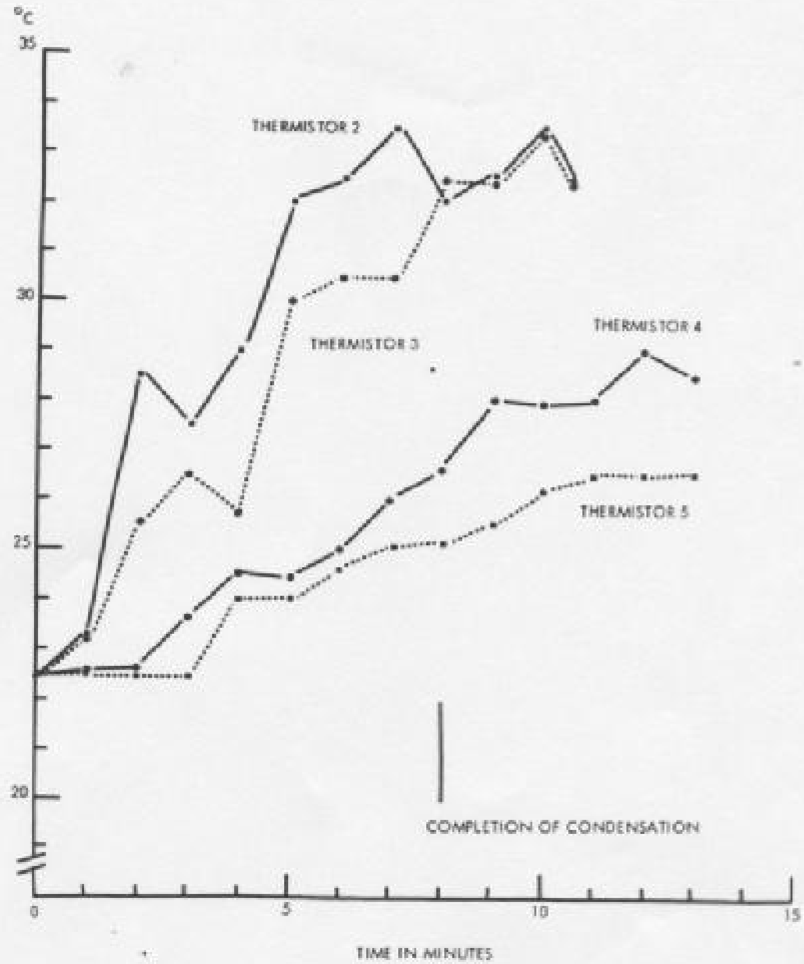

Fig. 2. Temperature recordings from thermistors 2 to 5 during condensation of gutta-percha. The condensation was complete after 8 minutes.

the apex was sealed after 5½ minutes. Again, maximal apical temperatures were reached after 11 minutes. Monitoring for an additional 15 minutes after apical sealing did not show any temperature decrease in the apical segment.

Volume studies

Mean findings on cavity and gutta-percha filling volumes are listed in Table I. The data in line 1 refer to fillings recovered 1 week after insertion. The mean volume of the cavities was 0.08376 c.c. The mean volume of the recovered gutta-percha was 0.08952 c.c. On an individual basis, the volume of the gutta-percha was greater than the volume of the preparation in every case. The per cent volume difference (6.8 per cent) is statistically significant at the 99 per cent level ($t = 3.57$).[13, 14] Data on glass models incubated for 1 month are also listed in the table (line 2). The findings show this group of cavities to be similar to

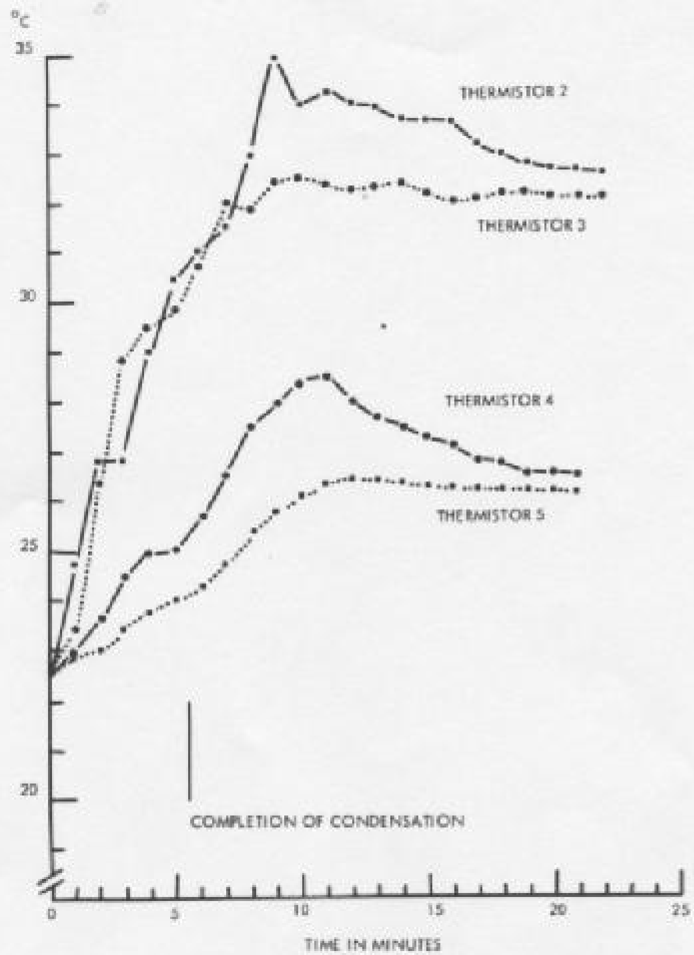

Fig. 3. Temperature recordings from thermistors 2 to 5 during condensation of gutta-percha. The condensation was complete after 5½ minutes.

the 1-week specimens with a mean volume of 0.08013 c.c. Again, the mean volume of the gutta-percha fillings (0.08266 c.c.) is greater than the mean volume of the preparations. On an individual basis, the volume of the gutta-percha was less than the volume of the preparation in two instances. The per cent difference (3.1 per cent) is statistically significant at the 95 per cent level ($t = 2.33$).

Visual inspection of the glass models after 1 week and 1 month of incubation showed no visible extrusion of gutta-percha. Dye penetration was about equal, whether "backfilling" was done by (1) adding heated gutta-percha segments to the previously condensed material or (2) adding room-temperature segments to the previously condensed but reheated most coronal material. The latter technique, however, tended to give fillings that were recovered in one piece (eleven out of twelve cases, compared to four out of seven). From the stand-

Table I. Mean volume of gutta-percha fillings recovered 1 week and 1 month after obturation

Recovered after	*Number of samples*	*Mean volume of sample (c.c.)*	*Mean volume gutta-percha (c.c.)*	*Gutta-percha volume as per cent of starting volume (per cent)*
1 week	10	0.08376	0.08952	106.8
1 month	10	0.08013	0.08266	103.1

point of the investigator, it was far more convenient to add room-temperature segments to previously heated material in the root canal.

DISCUSSION

One finding in the present study is that temperature increases at the apex of root canal preparations are only about 4° C. at the time of completion of condensation with the warm gutta-percha technique. In view of the highly insulating properties of the Teflon material used, it is believed that temperature loss is not responsible for the limited increase observed. Nor does it seem attributable to the displacement of the thermistors, since they remained in contact with the filling material. Rather, it is a reflection of the low thermal conductivity of the gutta-percha. The degree temperature increase is probably so small that it is clinically insignificant, since gutta-percha remains solid even at temperatures 10° C. higher than body temperature.

The observation that the temperature decrease is minute even 15 minutes after completion of the condensation is in accord with the findings of Price.[1] From a clinical point of view, it may well be that gutta-percha condensation is completed much before the gutta-percha reaches body temperature in apical sections of the root canal.

The volumetric studies show that it is possible to "overfill" a root canal preparation when heat and vertical condensation are applied, because the volume of the gutta-percha filling is greater than the space the filling occupies. In other words, the filling material is compressed. The finding of two specimens in which the gutta-percha volume was less than the cavities is believed to be associated with air entrapment during the vertical condensation, since entrapped air was frequently heard to escape during the condensation process.

The clinical significance of the compressibility of the gutta-percha filling is that it provides an obturating material which closely adapts to the cavity walls and maintains the adaptation because of the internal pressure in the material when introduced into the root canal space by the warm gutta-percha technique.

Dye penetration was only moderate in the absence of a sealer, but the data suggest that a sealer is necessary to obliterate completely the space between the filling and the walls of the preparation.

In the present study, two techniques were used for filling the body of the canal, once the apical segment was sealed. Both techniques yielded results which were comparable with respect to dye penetration and comparison of the filling.

Consequently, convenience becomes a deciding factor, and we recommend the approach in which room-temperature segments of gutta-percha are added to previously condensed but reheated material in the root canal space.

SUMMARY

Root canal preparations were made in Teflon rods and gutta-percha was packed into the preparations by the warm gutta-percha technique. Temperature changes were monitored by means of thermistors placed at intervals along the length of the preparations. The results indicated that only a 4° C. increase in temperature occurred in the apical segment, while in the more coronal portions temperature increases of up to 12.5° C. occurred.

Glass cylinders with dimensions similar to those of the Teflon preparations were packed with gutta-percha by the warm gutta-percha technique. Weight analysis of the gutta-percha fillings and the filled and unfilled glass cylinders indicated that the fillings were significantly greater in volume than the volume of the preparations.

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