Intracanal temperature rise evaluation during the usage of the System B: replication of intracanal anatomy

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Abstract

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Aim To evaluate and determine intracanal temperature rises at 2 and 4 mm from the working length (WL) necessary to obtain proper replication of intracanal anatomy with gutta-percha (GP) using the System B heat source during vertical condensation.

Methodology A split-tooth model was prepared and artificial shallow depressions were cut in the buccal canal wall 2 and 4 mm from the WL. At the same level on the palatal wall holes were drilled to adapt two thermocouples. The canal was filled using GP in a vertical condensation technique by placing the System B plugger at 2 and 4 mm from the WL in groups A and B, respectively. Two control groups in which no GP was used were carried out placing the plugger 2 and 4 mm from the WL (groups A.c and B.c, respectively) and activating the heat source. Recording of temperature rise was carried out during the filling procedure for groups A and B and during activation for control groups A.c and B.c; the highest temperatures were recorded. After each filling was completed, 3 min were allowed for the GP to cool and the model divided to reveal the filling. Images of the GP were taken with a CCD camera to evaluate the presence of replication of artificial round depressions. In control groups, the temperature was recorded for 20 s after a 3 s activation of the heat source. The rise in temperature was compared between the groups individually at each level (2 or 4 mm) and statistically analysed using one-way ANOVA and Fisher PLSD tests at 5% of significance level ($P < 0.05$).

Results Mean temperature rises of 14 ± 3 and 12 ± 2 °C at 2 and 4 mm from the WL, respectively, were observed in group A fillings, and 4 ± 1 and 6 ± 1 °C at 2 and 4 mm, respectively, in group B fillings. Recordings at 2 mm showed significantly ($P < 0.05$) higher temperature rises with group A.c when compared with groups B and B.c. Replication of intracanal anatomy with GP was always found in group A fillings at both levels but only 4 mm from the WL in group B fillings.

Conclusions Positioning the plugger close to WL and a temperature rise of 6 °C were necessary to obtain replication of intracanal anatomy. A mean temperature rise of 4 °C at 2 mm from WL (group B) resulted in no replication of intracanal anatomy. Further studies simulating clinical conditions are necessary.

Keywords: canal fillings, gutta-percha, replication, temperature, thermoplasticized.

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Introduction

One goal of root canal treatment is to fill and seal the root canal system after thorough cleaning and shaping (Schilder 1967). Inadequate sealing of the apex and incomplete filling of the canal system has been found to be associated with post-treatment disease (Petersson

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et al. 1986, Hoen & Pink 2002). Gutta-percha (GP) is the most common obturation material used and several techniques including vertical condensation have been proposed to achieve complete filling of the canal system (Schilder 1967). Various GP heating systems have been developed in an attempt to ensure appropriate adaptation of GP to the canal wall. The System B heat source (Analytic Technology, Redmond, WA, USA) was developed for use with a modified vertical condensation technique called the 'continuous wave of condensation' (Buchanan 1998), which was designed to simplify the vertical condensation technique. It is claimed by the manufacturer that the System B heat source allows sufficient heat for the apical GP to be softened and adapted to the irregularities of the intracanal anatomy. However, previous studies have found poor adaptation of GP to the canal wall in the important apical part of the canal (Villegas *et al.*, in press) and negligible increase in temperature of the GP at the apical end of the canal (Goodman *et al.* 1981, Weller & Koch 1995, Blum *et al.* 1997, 2001, Sweatman *et al.* 2001) when System B was used following the manufacturer's instructions.

The aim of this study was to determine intracanal temperature rises 2 and 4 mm from the working length (WL) necessary to obtain good replication of intracanal anatomy when the System B heat source was used to fill a split-tooth model.

Materials and methods

A maxillary central incisor was prepared for the split-tooth model as follows.

The crown was removed and the WL set at 15 mm. The root canal was instrumented in a crown-down sequence using Gates-Glidden burs for the coronal third, followed by GT rotary instruments (Dentsply Tulsa Dental, Tulsa, OK, USA) driven by a Tri-auto ZX motor at 300 rpm (Morita Co., Kyoto, Japan) and hand-held K-files (Zipperer, Munich, Germany). The master apical file was size 55 and the last rotary instrument used was a size 30, .10 taper GT rotary instrument. Grooves were made along the mesial and distal external surfaces of the root using a diamond disc. The buccal surface of the root was carefully attached to a mould ($15 \times 35 \times 6$ mm) made of self-curing resin (Ostron II; GC Dental Products, Tokyo, Japan). The palatal half of the root was attached in the same manner to another mould, and the moulds were fixed to each other with nuts and bolts. When the acrylic resin had completely set, the nuts and bolts were removed and the root was split using a chisel and a hammer.

Artificial shallow round depressions (0.5 mm in depth and 0.5 mm in diameter) were cut intracanally into the labial canal wall with a number 1/2 round bur 2 and 4 mm from the WL. At the same level of the palatal wall, 0.4 mm diameter holes were created using a number 1/4 round bur at low speed and finished using a size 40 K-file (Zipperer) to allow the placement of two Chromel-Alumel K-type thermocouples (Wintex, Tokyo, Japan) (Fig. 1).

The thermocouples were placed in the holes so they would make direct contact with GP and were connected to a digital thermometer NR-1000 (range: −200–1300 °C, estimated error: 0.05%; Keyence, Osaka, Japan). The digital thermometer was connected to a computer and set to record the temperature at 0.5 s intervals using Wave Thermo 1000 software (Keyence).

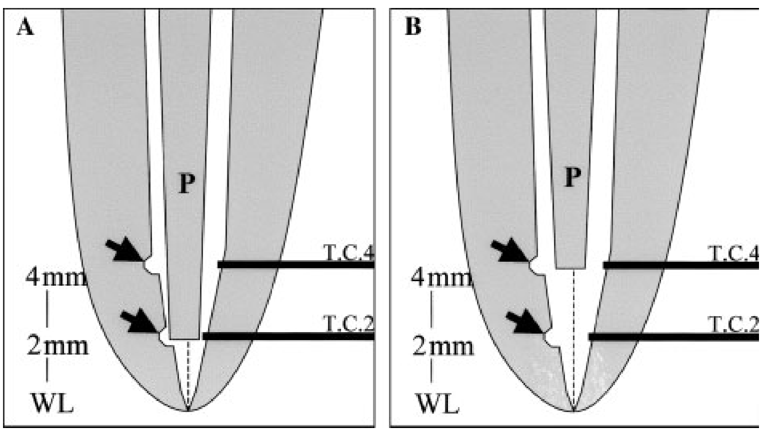

Figure 1 Illustration of the split-tooth model with the plugger in place in groups A and B. TC thermocouples; P, plugger. Arrows indicate artificial round depressions. Observe the deeper location of the plugger in group A, at 2 mm from the WL.

Before the fillings were placed, the thermocouples were placed in direct contact with the plugger at different levels to evaluate the real temperature produced when the System-B was set at 200 °C. Similar results to those reported by Venturi *et al.* (2002) were found, the highest temperature (135 °C) was recorded 1 mm from the tip and 120 and 110 °C were found at 2 and 3 mm, respectively.

The fillings were carried out following the manufacturer's instructions as follows.

In group A, no sealer was used and a 0.10-tapered GP cone (Autofit; Analytic Endodontics, CA, USA) was trimmed and fitted to obtain tug-back. The System B with a Buchanan FM plugger (Analytic Endodontics) was set at 200 °C in 'touch mode' and a full power setting of 10. The coronal end of the cone was removed by activating the heat source and applying the plugger at the orifice with lateral movements. The power was activated again and the plugger was introduced to a distance 2 mm short of the WL (no more than 3 s were allowed during this activation time), constant pressure was kept for 10 s with the power off and then a 2 s separation burst of heat was carried out. The tip of an Obtura II (Obtura Corporation, Fenton, MO, USA) device was immediately placed 4 mm from the WL and the canal was filled with GP. Constant pressure was then maintained on the GP for 30 s using Hand pluggers (Hu-Friedy, Chicago, IL, USA).

In group B, the same procedure with the same settings used in group A was carried out except that the Buchanan FM plugger was inserted to a distance 4 mm short of WL.

The same operator filled the canal 10 times for each group and the temperature measurement started 5 s before the filling and continued at 0.5 s intervals for 55 s. The highest temperatures were recorded. The baseline room temperature was 26 °C during all procedures. After each filling, GP was allowed to cool for 3 min, the holding nuts and bolts were removed, and the model was split open. Images of the GP were taken with a CCD camera (VH-8000; Keyence, Osaka, Japan) to evaluate the replication of the artificial round depressions made previously.

Twenty control temperature measurements, 10 for each control group in which no GP was used were carried out placing the plugger at 2 mm (group A.c) and 4 mm (group B.c) from the WL. The power was activated for 3 s and the temperature measurement was carried out starting 5 s before the activation and continued in 0.5 s intervals for a total of 20 s.

The temperature rises were compared between the groups at each level and statistically analysed using one-way ANOVA and Fisher PLSD tests at 5% of significance level ($P < 0.05$).

Results

The present study showed mean temperature rises of 14 ± 3 and 12 ± 2 °C at 2 and 4 mm from the WL, respectively, in group A fillings, and 4 ± 1 and 6 ± 1 °C at 2 and 4 mm, respectively, from the WL in group B fillings (Table 1).

The temperature rises recorded at 2 and 4 mm in group A were statistically significantly higher ($P < 0.05$) when compared with groups B, A.c and B.c. Recordings at 2 mm showed statistically higher ($P < 0.05$) temperature rises of group A.c when compared with groups B and B.c.

Adaptation (presence of replication of artificial round depressions) of GP to the canal walls was always found in group A fillings at both levels (Fig. 2a) and at 4 mm from the WL in group B fillings. The depression located at 2 mm from the WL was never replicated in group B fillings (Fig. 2b).

Discussion

The split-tooth model has been used previously to measure both intracanal and root surface temperature changes during thermoplasticized GP filling techniques (Weller & Koch 1995, Sweatman *et al.* 2001). Concerns about damage to the supporting tissues prompted researchers to evaluate the root surface temperature changes. It is generally accepted that a 10 °C rise in temperature on the root surface is considered damaging to the supporting tissues (Eriksson & Albrektsson 1982, Hardie 1986, Weller & Koch 1995) and several studies have investigated this matter (Goodman *et al.* 1981, Barkhordar *et al.* 1990, Weller & Koch 1995). However, none of these studies correlated the tem-

Table 1 Means of highest temperature (°C) rise recordings of the thermocouple (TC) placed at 2 and 4 mm from the WL, TC2 and TC4, respectively

Group	TC2	TC4
A	14 ± 3	12 ± 2
B	4 ± 1	6 ± 1
A.c	7 ± 1	8 ± 1
B.c	4 ± 1	6 ± 2

Statistically significant difference ($P < 0.05$) was present between the experimental groups at each level of measurement.

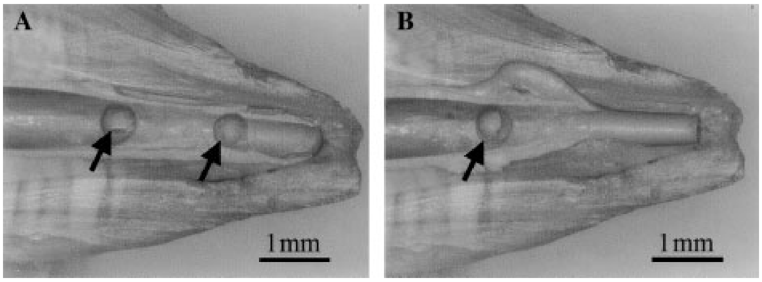

Figure 2 Representative pictures of group A and B fillings. Arrows show artificial round depressions replication. Observe the absence of replication of the round depression located at 2 mm from WL in the group B filling.

perature rises recorded with the adaptation of GP to the canal walls. Smith *et al.* (2000) evaluated the effect of varying the depth of heat application on the adaptability of GP, and found better results when the heat application was closer to the WL during warm vertical compaction of GP. Goodman *et al.* (1981) concluded that the thermal effect rarely penetrated into the GP more than 4–6 mm and generally no more than 2–3 mm beyond the deepest penetration of the heat carrier. Venturi *et al.* (2002) reported similar results when investigating the temperature change within GP induced by the System B heat source. In this study, thermocouples were placed in the cervical and apical thirds of the canal and warm vertical compaction was then carried. The results showed a mean value of 4 °C increase in the cervical portion and negligible temperature rises within the GP in the apical third.

These results can be explained by the closer position of the plugger to the thermocouples when it was placed 2 mm from the WL. Due to the taper of the root canal, the tip of the plugger would be closer to the thermocouples when placed at 2 mm from the WL than at 4 mm from the WL. In addition, in group B the tip of the plugger was closer to the thermocouple placed 4 mm from the WL (Fig. 1a,b). This explains the higher temperature rise at this point compared with 2 mm from the WL. However, the results showed that a plugger in this position and a 6 °C rise in temperature were enough to produce good adaptation of GP to the canal walls at 4 mm from the WL.

When the plugger was inserted 4 mm from the WL there was no replication of the artificial round depressions located 2 mm from the WL. At this point the mean temperature rise was 4 °C and the mean temperature rise at 4 mm from the WL was 6 °C (Table 1, Fig. 2). Furthermore, a study in which Young's modulus of warmed GP was evaluated, it was concluded that it was necessary for the plugger to be introduced apically to obtain permanent deformation. The high percentage of deformation and the low yield strength of GP mean that it is easily compacted but the plugger must be introduced apically as the permanent deformation is undergone only after 50% reduction in volume is enhanced (Camps *et al.* 1996). A previous laboratory study was carried out to evaluate the quality and adaptation of GP to the canal walls when System B was used in a single and a three-step manner to fill three split-tooth models with different canal morphology (Villegas *et al.* 2004). This study concluded that better adaptation of GP to the canal walls in the apical third was obtained when the System B's plugger was used in three steps, placing the heating source 1 mm short of the WL and repeating the procedure two more times, decreasing the inserting length 1 mm in each attempt regardless of the canal morphology (Villegas *et al.* 2004). It is well documented that in small canals, apical GP is generally compacted at body temperature when a thermoplasticized GP filling technique is used, sometimes resulting in a poor quality filling (Jung *et al.* 2003, Venturi & Breschi 2004).

The results obtained in the present study might have differed if the experimental design had included a simulation of the clinical situation in which the radicular supporting tissues play an important role in dissipating heat. However, difficulties in designing such a model and the absence of observable differences regarding the replication of intracanal anatomy observed in previous studies (Villegas *et al.* 2004, in press), led us to adopt the design described above. In this study, peak temperature rises were obtained when the System B was used, therefore it seems reasonable to conclude that the backfilling procedure with the Obtura II did not affect the results.

Conclusion

A better understanding of the currently used endodontic heating systems should be adopted by clinicians to ensure good quality fillings without harming the periodontal tissues.

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