JOURNAL OF ENDODONTICS
Copyright © 2004 by The American Association of Endodontists

Printed in U.S.A.
VOL. 30, NO. 6, JUNE 2004

Evaluation of Apical Filling After Warm Vertical Gutta-Percha Compaction Using Different Procedures

Mauro Venturi, MD, DDS, and Lorenzo Breschi, DDS, PhD

The aim of the present study was to evaluate the quality of endodontic sealing in the apical 4 mm of narrow and curved canals using different filling techniques. Human teeth were selected and assigned to four different techniques: group A, Schilder's warm vertical condensation; group B, Schilder's technique modified by using an electric heater; group C, Schilder's technique modified by compaction of the apical tract at body temperature; and group D, a modified vertical compaction with apical back-filling. A dye penetration test was performed, and specimens of group D showed increased apical sealing and reduced extension of voids. The use of the vertical compaction with apical back-filling technique allowed the creation of an effective apical plug and an excellent adaptation of back-filling to apical gutta-percha and to root canal walls.

Gutta-percha and endodontic sealer are currently the materials of choice to obturate root canals (1, 2). However, inadequate sealing may contribute to failure of the endodontic treatment (3, 4). Among different obturation techniques, warm vertical compaction has been demonstrated to produce an optimal three-dimensional filling (5). It has been declared that ideal adaptation of the gutta-percha is obtained after softening at 2 to 4°C higher than body temperature (6) and compacting at a minimum distance of 7 mm to the apex (7). However, previous studies demonstrated that almost no temperature rise occurs in the apical gutta-percha using flame-heated thermal carriers (7) and electric heat carriers (8). These data suggest that frequently, especially in small canals, apical gutta-percha is compacted at body temperature. Allison et al. (9) reported that to achieve excellent filling, gutta-percha compaction should performed as close as possible to the apex. However, this procedure could produce voids within the apical gutta-percha.

The aim of this study was to compare the quality of the apical seal obtained with four filling techniques and to evaluate the effectiveness of four back-filling techniques in producing the final complete three-dimensional obturation of the root canal.

MATERIALS AND METHODS

Eighty-four noncarious human extracted teeth with apical orifices of 0.20 to 0.35 mm were randomly and equally divided into four groups with 30 canals each. Each group contained one maxillary first molar with four canals, one maxillary second molar with three canals, four maxillary premolars with two canals, four maxillary premolars with one canal, and 11 mandibular incisors with one canal. All selected roots revealed thin canals and no sharp curves. None of the teeth exhibited resorption, fractures, or open apices on visual inspection.

Canals were instrumented by one operator under ×3.5 magnification (Designs for Vision, Ronkonkoma, NY) with the crown-down followed by the step-back technique to obtain .05 tapered canals. Stainless-steel K files (F.K.G. Dentaire, La Chaux-de-Fonds, Switzerland) and #1-2 Gates-Glidden burs (Dentsply-Maillefer, Ballaigues, Switzerland) were used under irrigation with RC-Prep (Hawe Neos Dental, Bioggio, Switzerland) and 5% NaOCl. A cotton pellet was fixed with dental wax on the foramina, and specimens were fixed to a metallic grid. To simulate in vivo conditions, the filling techniques were performed after roots were immersed in thermostated water at 37°C (8).

The canals were dried with paper points and filled with gutta-percha cones (Kerr Co., Romulus, MI) and Pulp Canal Sealer (Kerr Co.) using the following techniques:

- Group A: Schilder's technique was followed using heat carriers heated on flame (Hu-Friedy Manufacturing Co., Chicago, IL) and endodontic pluggers (Hu-Friedy Manufacturing Co.) to the maximum depth allowed by canal curvatures and dimensions; canals were then back-filled by compacting heated gutta-percha fragments.
- Group B: specimens were filled as group A, but using Touch'N Heat (model 5004; Analytic Technology, Redmond, WA) at a power setting of 7 as heating device. Because of the higher instrument flexibility, gutta-percha heating was performed deeper than in group 1, and precurved finger pluggers #30 (Kerr Co.) were used to reach at least 2 mm to the apex. Canals were back-filled with compacting gutta-percha fragments heated with Touch'N Heat.
- Group C: coronal and middle thirds were prepared as in group 1, but the apical tract was compacted to 1 to 2 mm to the apex with precurved finger pluggers #30 at body temperature. Back-filling

TABLE 1. Number (and percentages) of specimens related to the number of lateral canals found under stereomicroscope analysis in the four views*

No. lateral canals		0	1	2	3	4	5	9	Total
		N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Apical lateral canals	Group A	23 (76.7)	5 (16.7)		1 (3.3)				29 (24.4)
	Group B	19 (63.3)	3 (10.0)	5 (16.7)	1 (3.3)		1 (3.3)	1 (3.3)	30 (25.2)
	Group C	19 (63.3)	6 (20.0)	2 (6.7)	2 (6.7)		1 (3.3)		30 (25.2)
	Group D	23 (76.7)	3 (10.0)	1 (3.3)	2 (6.7)	1 (3.3)			30 (25.2)
Middle lateral canals	Group A	23 (76.7)	4 (13.3)	1 (3.3)	1 (3.3)				29 (24.4)
	Group B	26 (86.7)	3 (10.0)	1 (3.3)					30 (25.2)
	Group C	26 (86.7)	3 (10.0)	1 (3.3)					30 (25.2)
	Group D	29 (96.7)	1 (3.3)						30 (25.2)
Coronal lateral canals	Group A	29 (96.7)							29 (24.4)
	Group B	27 (90)	3 (10.0)						30 (25.2)
	Group C	29 (96.7)		1 (3.3)					30 (25.2)
	Group D	29 (96.7)	1 (3.3)						30 (25.2)

* No statistical differences were found among the four tested groups; thus, groups were considered homogenous.

TABLE 2. Mean and SDs (in mm) of the dye penetration, voids extension, and maximum width*

		Mesial	Buccal	Distal	Lingual
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Dye penetration	Group A	$3.07^{a} \pm 1.20$	$2.70^{a} \pm 1.05$	$3.08^{a} \pm 1.02$	$2.77^{a} \pm 1.14$
	Group B	$2.77^{a} \pm 1.17$	$2.19^{a} \pm 1.15$	$2.98^{a} \pm 1.04$	$2.34^{a} \pm 1.23$
	Group C	$2.28^{a} \pm 1.44$	$2.35^{a} \pm 1.33$	$2.80^{a} \pm 1.29$	$2.44^{a} \pm 1.38$
	Group D	$0.77^{b} \pm 1.08$	$0.27^{b} \pm 0.66$	$0.83^{b} \pm 1.20$	$0.30^{b} \pm 0.74$
Voids extension	Group A	$2.88^{a} \pm 1.37$	$0.88^{a} \pm 1.32$	$2.90^{a} \pm 1.49$	$0.84^{ab} \pm 1.40$
	Group B	$2.76^{a} \pm 1.22$	$0.62^{a} \pm 1.21$	$2.88^{a} \pm 1.24$	$0.67^{ab} \pm 1.22$
	Group C	$2.16^{a} \pm 1.57$	$0.88^{a} \pm 1.42$	$2.11^{ab} \pm 1.55$	$0.90^{a} \pm 1.40$
	Group D	$1.05^{b} \pm 1.19$	$0.14^{a} \pm 0.34$	$1.20^{b} \pm 1.33$	$0.12^{b} \pm 0.40$
Voids maximum width	Group A	$0.10^{a} \pm 0.07$	$0.04^{a} \pm 0.06$	$0.16^{a} \pm 0.22$	$0.03^{a} \pm 0.08$
	Group B	$0.18^{a} \pm 0.35$	$0.02^{a} \pm 0.07$	$0.17^{a} \pm 0.22$	$0.07^{a} \pm 0.20$
	Group C	$0.11^{a} \pm 0.10$	$0.05^{a} \pm 0.10$	$0.12^{a} \pm 0.10$	$0.07^{a} \pm 0.11$
	Group D	$0.11^{a} \pm 0.14$	$0.03^{a} \pm 0.07$	$0.12^{a} \pm 0.21$	$0.01^{a} \pm 0.04$

* The reported lacunae length value corresponded to the sum of tracts with absence of filling adaptation to the canal walls within the apical 4 mm. The reported width values corresponded to maximum width of the lacunae. Width and length values were calculated on buccal, lingual, mesial, and distal views. Means with the same superscript letter are not statistically different at $p \leq 0.05$.

was performed with the Obtura II (Obtura Corp., Fenton, MO) following the manufacturer's instructions.

- Group D: vertical compaction with apical back-filling was performed. After insertion of a gutta-percha cone cut 1 mm short to the apex, small amounts (1–2 mm) of heated gutta-percha were progressively removed using Touch'N Heat, and gutta-percha was adapted with standard pluggers, applying delicate pressure, to reach a distance of 2.5 to 4 mm to the apex.

A single compaction movement was realized at body temperature, pushing a finger plugger #30 for 1 mm to apically shift the gutta-percha and to adapt it to the canal walls.

Thermomechanical compaction at 8000 to 10000 rpm for at least 5 s (10) against the apical gutta-percha plug was performed using Gutta-Condensors #25 (Dentsply-Maillefer) to 5 mm to the apex to soften gutta-percha to 3 mm apically to their tip. Back-filling was achieved by thermomechanical and manual compaction until canal full filling was reached.

Cavity access was sealed with Ketac Silver (3M ESPE Dental Products, St. Paul, MN). Each specimen was radiographed in mesiodistal and buccolingual projection and immersed in vials containing saline solution for 24 h. Roots were cut from the crowns, cleaned by wax and cotton pellet, dried on absorbent paper, covered with nail varnish to 4 mm from the apex, and immersed in 2% methylene blue for 48 h (11). Nail varnish was then removed using acetone, and specimens were rinsed under tap water, cleared (12), and stored in methylsalicylate. A stereomicroscope (Zeiss Stemi 2000-C; Carl Zeiss Jena GmbH, Germany) equipped with a calibrated grid was used to evaluate each specimen, recording the following:

(a) Distance between apex and apical limit of the filling in buccal vision
(b) Presence of apical hourglass shape
(c) Number of lateral canals in the coronal, middle, and apical thirds
(d) Dye penetration into apical tract (apical 4 mm) under buccal, lingual, mesial, and distal views; dye penetration was referred to the end of the filling if shorter than the root canal
(e) Voids in the apical tract. The reported voids length value corresponded to the sum of tracts with absence of filling adaptation to the canal walls within the apical 4 mm. The reported width values corresponded to maximum width of the voids. Width and length values were calculated on buccal, lingual, mesial, and distal views

Working length and apical diameter after instrumentation were also recorded. Compaction deepness is reported as residual apical gutta-percha compacted.

Statistical analysis was performed using Snedecor ANOVA and Scheffe post hoc tests to analyze all possible comparisons for canal length, apex diameter, distance between apex and apical limit of the filling, dye penetration and voids, and Kruskal-Wallis and Mann-Whitney tests to evaluate number of lateral canals and presence of apical hourglass shape. Before ANOVA testing, homoscedasticity of the data was tested with Levene test.

RESULTS

Analysis of the data revealed no statistical difference between the groups for canal length, apex diameter, distance between apex and apical limit of the filling in buccal vision (group A, 0.42 $\pm$ 0.76; group B, 0.20 $\pm$ 0.81; group C, 0.40 $\pm$ 0.57; group D, 0.46 $\pm$ 0.49), position of filling apical limit (mean values, 0.2–0.5 mm greater than working length), presence of apical hourglass shape (group A, 9; group B, 6; group C, 10; group D, 4), and number of lateral canals (Table 1).

Compaction deepness was calculated by analyzing mean values of compacted apical gutta-percha: group A, 3.61 $\pm$ 1.06 mm; group B, 1.15 $\pm$ 1.06 mm; group C, 1.12 $\pm$ 0.66 mm; and group D, 1.90 $\pm$ 0.98 mm. The Scheffe test revealed that group A $>$ group D $>$ group B and C ($p < 0.01$).

Dye penetration, voids extension, and maximum width are reported in Table 2. The Scheffe test revealed a significantly lower dye infiltration in all views and lower voids extension in mesial views for group D compared with all other groups. Similarly, group D revealed less mean extension of voids on the distal view compared with groups A and B ($p < 0.01$), whereas on the lingual view, group C had the greatest mean extension of voids ($p < 0.05$).

Voids width revealed no statistical differences among the groups.

Stereomicroscope images obtained after tooth clearing (Figs. 1 and 2) reveal the different morphological features representative for each group of specimens.

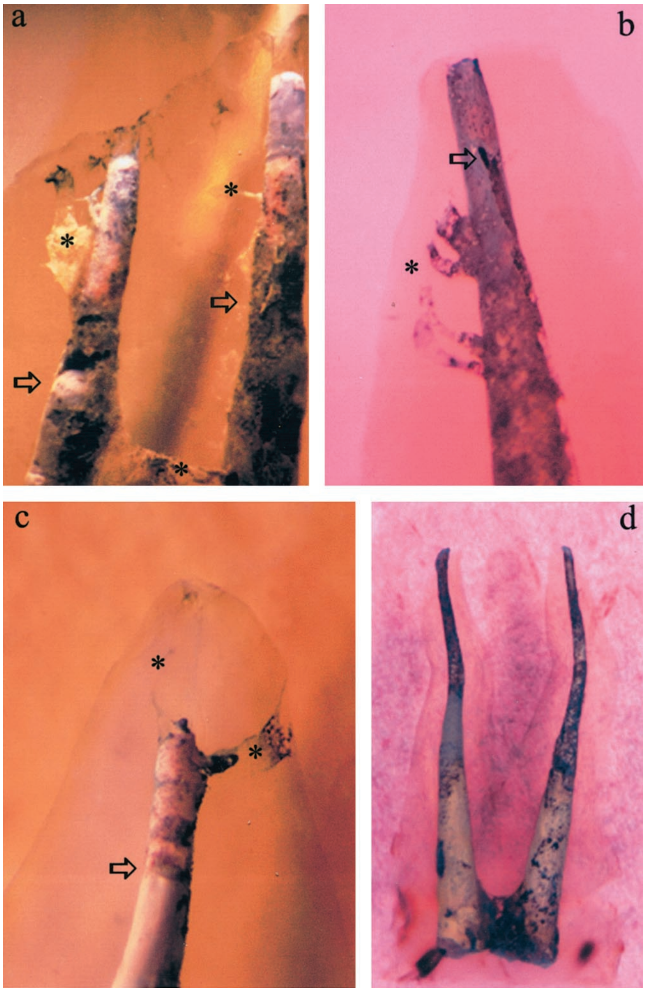

FIG 1. Stereomicroscope images of cleared teeth after filling with different techniques. (a) Specimen of group A obtained after obturation with Schilder's technique. Few lateral canals appear unfilled (*), revealing only minor presence of endodontic cement. Poor integration between the apical gutta-percha and the back-filling can be observed (arrows), and several voids and porosities are frequently observable within the back-filled mass of gutta-percha. (b) Specimen of group B obtained after obturation with a modified Schilder's technique using an electric heat carrier. The insertion of the carrier into the apical tract reveals an empty tract (arrow). Lateral canals of the apical tract appear to be partially filled by gutta-percha and cement (*). (c,d) Specimen of group C obtained after filling with gutta-percha modified Schilder's technique (as per group B) and back-filling with the Obtura system. The apical tract reveals lateral canals partially filled with gutta-percha and cement. The integration between the apical compacted gutta-percha and the back-filling is clearly observable (arrow), and minor pores and voids can be found within the back-filling (d)

DISCUSSION

This study evaluated the quality of endodontic filling in the apical 4 mm of small canals by measuring voids extension, voids maximum width, and dye penetration. Filling of the apical 4 mm was obtained by a combination of compaction close to the apex and back-filling. Statistical analysis revealed that canal length, apex dimension, presence of apical hourglass shape, and number of lateral canals did not influence the results. The filling technique used for specimens of group D revealed significantly less voids extension in most of the views compared with the other groups, and less dye penetration in all views. Because of their small molecular size (13), dye penetration has been used as a dependent measure of sealing ability; however, whether dyes mimic penetration of microorganisms or antigens is still not known (11). In fact, entrapped air in the canal filling may falsify dye penetration depth (14, 15), suggesting the application of vacuum techniques or centrifugation (16, 17), even if previous studies (18, 19) showed that dye penetration did not differ whether centrifugation was applied or not.

Warm condensation techniques can be differently applied depending on preparation parameters such as dimensions, taper, shape and curvature of root canals, and patency and diameter of the foramen. Previous studies stated that optimal apical sealing occurs by heating and compacting gutta-percha at 5 to 7 mm to the apex (7) at a temperature of 40 to 42°C (6). Other thermoplasticized obturation techniques (e.g. Thermafill) have also been demonstrated to flow into lateral spaces and to replicate the root surface, but produced greater extrusion out of the apical foramen compared with a lateral condensation technique (20). Recently, Deitch et al. (21) obtained a significant improvement of gutta-percha density using a two-phase ultrasonic condensation after a lateral compaction, thus confirming the importance of an effective back-filling phase.

Allison et al. (9). reported that compaction should reach 1 to 2 mm to the apex to produce apical seal, and a 3 to 5°C apical

FIG 2. Stereomicroscope and radiographic images of the same tooth after filling with the vertical compaction with apical back-filling—that is, specimen of group D. (a) After clearing, a homogenous gutta-percha filling is clearly detectable within the endodontic space. The apical tract reveals no empty spaces or gutta-percha porosities, and the back-filling obtained after thermomechanical compaction reveals an excellent adaptation to the whole endodontic space, indistinguishable from the apical plug. Several lateral canals appear to be fully filled by gutta-percha. Only small empty spaces are visible in the apical tract. (b) Radiographic image revealing the excellent gutta-percha integration within the endodontic space.

increase from body temperature is impossible to control under clinical conditions. Bowman and Baumgartner (22) recently found significantly better gutta-percha flow into apical lateral grooves and dentin depressions by using System B Fine heat pluggers at 3 mm from working length than at 4 and 5 mm from working length.

In the present study, Schilder's technique was applied in group A and produced greater apical dye penetration and voids extension, although compaction was performed until 3.6 mm (mean) to the apex and back-filling by compacting small, heated gutta-percha fragments (Fig. 1*A*). In group B, heating was taken closer to the apex by using an electric device and its flexible inserts, but after back-filling compaction of small, heated gutta-percha fragments, many apical voids were still observable (Fig. 1*B*). Previous in vitro reports recorded different gutta-percha temperatures during warm vertical compaction (23–25) as a result of variables such as material mass and dentin thickness (26–28). Also, the kind of heat carrier, its power, insert dimensions, and flexibility are important. Periradicular blood circulation is effective in thermodispersion in vivo (29), and its simulation is important in in vitro tests. A recent study (8) on the System-B Heat Source revealed that insertion depths of distances 2.86 to 3.26 mm from the apex produced temperature increases ranging from 0.5 to 0.9°C if root canals were immersed in bath at 37°C. This finding has led to the proposal that the final condensation of apical gutta-percha is obtained at body temperature.

In group C (Figs. 1*C*, *D*), the use of finger pluggers close to the apex at body temperature and the back-filling obtained with the Obtura system revealed similar effects of group B, confirming that empty spaces within the material in the apical tract (30) are difficult to refill.

In group D, canals were filled using a thermomechanical compaction against an apical stop produced by forcing gutta-percha at body temperature with a single 1 mm compaction movement toward the apex (vertical compaction with apical back-filling). Group D (Figs. 2*A*, *B*) had the best results in terms of gutta-percha filling. The apical plug created a stop to avoid risk of extrusion (31) during thermomechanical compaction that could be performed long enough to soften the back-filled gutta-percha and the coronal part of the apical gutta-percha, melting them together. The manual compaction with finger pluggers to 5 mm from the apex allowed the integration of the back-filled gutta-percha with the apical plug, thus reducing the possibility of creating voids within the mass.

In conclusion, the present study revealed that in narrow canals, a better quality of apical filling (evaluated by reduced dye penetration and less extension of apical voids) can be obtained using vertical compaction with apical back-filling.

Supported by ex-40% and ex-60% grants of MIUR, Italy.

The authors thank Mr. Aurelio Valmori for extensive photographic work, Mr. Massimo Gamberini for laboratory technical support, and Dr. Giulia Habib for statistical analysis.

Dr. Venturi is in private practice, Bologna, Italy; and Dr. Breschi is Associate Professor, Department of Surgical Sciences, University of Trieste, Trieste, Italy.

Address requests for reprints to Prof. Lorenzo Breschi, Department of Surgical Sciences, University of Trieste, Via Stuparich, 1, 34129 Trieste—Italy. E-mail: lbreschi@units.it

References

1. Canalda-Sahli C, Brau-Aguade E, Sentis-Vilalta J, Aguade-Bruix S. The apical seal of root canal sealing cements using a radionucleide detection technique. Int Endod J 1992;25:250–6.
2. Nguyen TN. Obturation of the root canal system. In: Pathways of the pulp. 6th ed. Cohen S, Burns RC, eds. St. Louis: Mosby, 1994:219–71.
3. Ingle JI, Bakland LK. Endodontics. 4th ed. Baltimore: William & Wilkins, 1994:1–46.
4. Nguyen NT. Obturation of the root canal system. In: Pathways of the pulp. 4th ed. Cohen S, Burns RC, eds. St. Louis: Mosby, 1987:183–94.
5. Schilder H. Filling root canals in three dimensions. Dent Clin North Am 1967;11:723–44.
6. Goodman A, Schilder H, Aldrich W. The thermomechanical properties of gutta-percha, part IV: a thermal profile of the warm gutta-percha packing procedure. Oral Surg Oral Pathol Oral Med 1981;51:544–51.
7. Marlin J, Schilder H. Physical properties of gutta-percha when subjected to heat and vertical condensation. Oral Surg Oral Pathol Oral Med 1973;36:872–9.
8. Venturi M, Pasquantonio G, Falconi M, Breschi L. Temperature modification of the gutta-percha induced by System-B Heat Source. Int Endod J 2002;35:740–6.
9. Allison DA, Michelich RJ, Walton RE. The influence of the master cone adaptation on the quality of the apical seal. J Endodon 1981;7:61–5.
10. McSpadden J. Self study course for the thermatic condensation of gutta-percha. Toledo: Ransom and Randolph, 1980.
11. Barthel CR, Moshonov J, Shuping G, Òrstavik D. Bacterial leakage versus dye leakage in obturated root canals. Int Endod J 1999;32:370–5.
12. Venturi M, Prati C, Capelli G, Falconi M, Breschi L. A preliminary analysis of the morphology of lateral canals after root canal filling using a tooth-clearing technique. Int Endod J 2003;36:54–63.

13. Kersten HW, Moorer WR. Particles and molecules in endodontic leakage. Int Endod J 1989;22:118–24.

14. Spångberg LSW, Acierno TG, Cha BY. Influence of entrapped air on the accuracy of leakage studies using dye penetration methods. J Endodon 1989;15:548–51.

15. Goldman M, Simmonds S, Rush R. The usefulness of dye-penetration studies reexamined. Oral Surg Oral Med Oral Pathol 1989;67:327–32.

16. Oliver CM, Abbott PV. Entrapped air and its effects on dye penetration of voids. Endod Dent Traumatol 1991;7:135–8.

17. Boussetta F, Bal S, Romeas A, Boivin G, Magloire H, Farge P. In vitro evaluation of apical microleakage following canal filling with a coated carrier system compared with lateral and thermomechanical gutta-percha condensation techniques. Int Endod J 2003;36:367–71.

18. Dickson SS, Peters DD. Leakage evaluation with and without vacuum of two gutta-percha filling techniques. J Endodon 1993;19:398–403.

19. Karagöz-Küçükay I, Küçükay S, Bayirli G. Factors affecting apical leakage assessment. J Endodon 1993;19:362–5.

20. Clinton K, Van Himel T. Comparison of a warm gutta-percha obturation technique and lateral condensation. J Endodon 2001;27:692–5.

21. Deitch AK, Liewehr FR, West LA, Patton WR. A comparison of fill density obtained by supplementing cold lateral condensation with ultrasonic condensation. J Endodon 2002;28:665–7.

22. Bowman CJ, Baumgartner JC. Gutta-percha obturation of lateral grooves and depressions. J Endodon 2002;28:220–3.

23. Blum JY, Parahy E, Machtou P. Warm vertical compaction sequences in relation to gutta-percha temperature. J Endodon 1997;23:307–11.

24. Silver GK, Love RM, Purton DG. Comparison of two vertical condensation obturation techniques: Touch'n Heat modified and System-B. Int Endod J 1999;32:287–95.

25. DuLac KA, Nielsen CJ, Tomazic TJ, Ferrillo PJ, Hatton JF. Comparison of the obturation of lateral canals by six techniques. J Endodon 1999;25:376–80.

26. Craig RG, Peyton FA. Thermal conductivity of teeth structures, dentin cements, and amalgam. J Dent Res 1961;40:411–8.

27. Figdor D, Beech DR, Waterson JG. Heat generation in the McSpadden compaction technique [abstract]. J Dent Res 1983;62:405.

28. Fors U, Jonasson E, Bergquist A, Berg JO. Measurements of the root surface temperature during thermo-mechanical root canal filling in vitro. Int Endod J 1985;18:199–202.

29. Hardie EM. Heat transmission to the outer surface of the tooth during the thermo-mechanical compaction technique of root canal obturation. Int Endod J 1986;19:73–7.

30. Jurcak JJ, Weller RN, Kulild JC, Donley DL. In vitro intracanal temperatures produced during warm lateral condensation of gutta-percha. J Endodon 1992;18:1–3.

31. Lugassy AA, Yee F. Root canal obturation with gutta-percha: a scanning electron microscope comparison of vertical compaction and automated thermatic condensation. J Endodon 1982;8:120–5.