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Leakage along warm gutta-percha fillings in the apical canals of curved roots

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Abstract – The aim of this study was to investigate the leakage along the apical portion of warm gutta-percha obturated curved canals. Human mandibular premolars with single, curved (21°–40°) canals were prepared using the Lightspeed technique. Two groups of prepared canals, matched according to curvature and prevalence of apical transportation, were obturated by two techniques. Coronal gutta-percha was removed immediately after root obturation was completed to simulate the procedure for post space preparation. Leakage along the apical 3 mm of root filling was measured with a fluid transport device. Vertical condensation of warm gutta-percha and Pulp Canal Sealer provided less leakage than Thermafil plastic obturators and AH26 sealer (P=0.002).

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Heat-softened gutta-percha has been found to adapt to the canal wall and occupy most of the canal space (1). Maximizing its volume in the root canal space facilitates formation of a very thin layer of the dimensionally less stable sealer. This possibly reduces leakage along root fillings (2).

Various warm gutta-percha techniques have been developed. Vertical condensation of warm gutta-percha, suggested by Schilder in 1967 (3), has been found to seal root canals tightly (4, 5). Johnson (6) in 1978 introduced the technique for placing thermoplasticized gutta-percha with a single penetration of a file. The Thermafil technique was developed from this idea and became a clinical alternative to other techniques. Leakage along Thermafil root fillings has been compared with leakage from root fillings applied by other techniques and the conclusions seem contradictory (7–13).

It may be more complicated to seal a curved root canal tightly than a straight canal (14). The seal provided by a full-length root canal filling can be compromised by removal of the coronal part of root filling during a post space preparation (15, 16). Little information is available about leakage along the apical portion of warm gutta-percha obturated curved canals.

In this study, curved canals were prepared by Lightspeed and obturated by the vertical condensation or Thermafil technique. Leakage along the apical root fillings was measured using a fluid transport device.

Material and methods

In total, 46 fully developed human mandibular premolars with a single, curved canal were used. The teeth had been stored in 10% formalin. The curvatures measured by Schneider's method (17), were 21°–40°.

Instrumentation

All the root canals were prepared with Lightspeed instruments according to the manufacturer's instructions. Before instrumentation, full working length was established by deducting 1 mm from the actual canal length, which had been determined by inserting a size 15 file into the canal until the tip of the file was just visible at the apical foramen. The nickel-titanium instruments were used in a handpiece (W&H, Bürmoos, Austria) powered by an electric motor (TCM 3000, NOUVAG, Goldach, Switzerland) at a constant speed of 1500 rpm. When a size 15 K-file fitted loosely in the canal at working length, the canal was

then successively enlarged to fit an ISO size 50 Lightspeed instrument. Each instrument was replaced by a new one after the preparation of 20 canals (18). A step-back flaring at 1-mm increments to size 80 was then performed, size 52.5 and 55 to a depth of 1 mm shorter than the working length, followed by 57.5 and 60 to 2 mm, 65 and 70 to 3 mm, and 80 to 4 mm shorter than the working length. The coronal portion of each root canal was enlarged using Gates-Glidden drills, ISO size 90 to a depth of 5 mm short of the working length, followed by 110 to 7 mm, 130 to 9 mm, and 150 to 11 mm short of the working length.

Each canal was irrigated with 2 mL of a freshly prepared 2% solution of sodium hypochlorite by using a syringe and a 27-gauge needle between each three instruments as recommended by the manufacturer. After completion of the preparation, the patency of each canal was confirmed by inserting a size 20 file through the apical foramen and the canals were finally irrigated with 10 mL 2% NaOCl.

During canal preparation three Lightspeed instruments fractured in three root canals. No action was taken to remove the broken instruments and these three teeth were excluded from the study. The remaining 43 teeth with curved root canals were divided into two groups, matched according to curvature and the prevalence of apical transportation.

Determination of the apical transportation (AT) index

The AT index was measured using a double-exposure radiographic technique as described by Wu et al. (14). Briefly, two projections were taken from each tooth, the first, before apical enlargement, with a size 15 pathfinding file inserted to the apical foramen and the second after apical enlargement with a size 50 instrument inserted to the full working length. Each double-exposed X-ray film with a superimposed Fixott grid showing 1-mm squares was used to determine the amount of AT, expressed as the AT index (in millimeters).

The radiographs were magnified 10 times by using a slide projector, which was adjusted until 1 mm of the Fixott grid showed an image of 1 cm on the projection screen. As shown in Fig. 1, line a was drawn over the long axis of the apical 2–3 mm straight segment of the small file, and line b over the long axis of the apical 2–3 mm straight segment of the large instrument. The distances from a to the inner surface of the root, at a point 1 mm short of the apical end of the small size file, and from b to the inner root surface, at the apical end of the large size instrument, i.e. distances A and B, were measured. The AT index (mm)=distance B − distance A (Fig. 1). Because the difference in diameters between the two instruments at the working length is 0.35 mm, the small instrument projection could be completely covered by the large instrument image when B–A ≤0.175 mm. Therefore, an AT was defined only when distance B–distance A >0.2 mm.

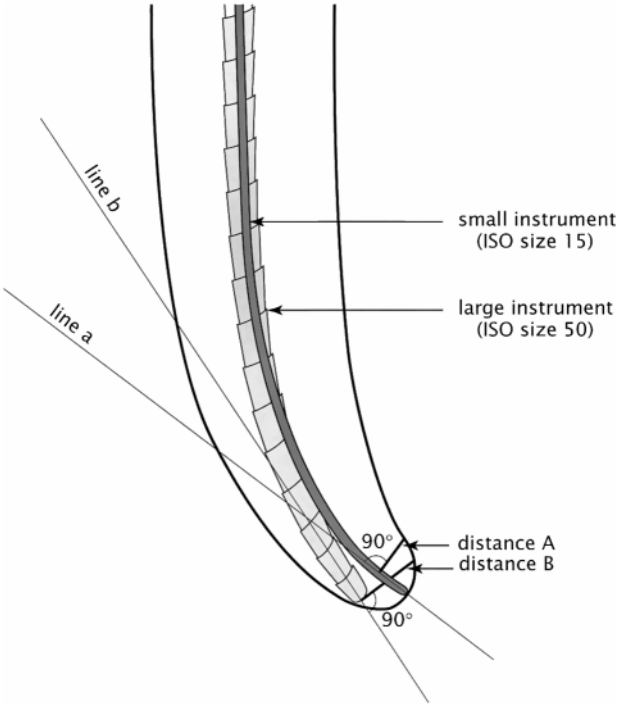

Fig. 1. Apical transportation (AT) index=distance B−distance A. See text for detailed explanation.

Obturation and leakage test

After the final irrigation, the canals were dried with paper points and obturated with gutta-percha cones and a sealer. In group 1 (22 teeth) the vertical condensation technique was used and in group 2 (21 teeth) the Thermafil technique.

According to the recommendation of Ruddle (19), Pulp Canal Sealer (Kerr, Romulus, MI, USA) was used for the vertical condensation technique. The tip of a medium size nonstandardized gutta-percha cone was trimmed back until there was a tug-back feeling when the cone reached the level of 0.5 mm short of the full working length. After the sealer was introduced into the root canal, the trimmed gutta-percha cone, lightly coated with the sealer, was placed into the canal to 0.5 mm short of the full working length. Approximately at the level of the cementum-enamel junction the gutta-percha was seared off with the tip of an activated heat carrier (Touch 'n Heat, Model no. 5004, Analytic Technology, Redmont, WA, USA). After the heat carrier had been deactivated, the cooling instrument was removed from the canal, bringing out a bit of gutta-percha. Vertical force was then applied with a size 11 plugger (1.1 mm diameter, Maillefer, Ballaigues, Switzerland) to compact the gutta-

percha in the coronal portion of the canal. The same procedure was then repeated twice but to different depths, first to a level of 3–4 mm deeper than the cementum-enamel junction and vertically condensing the gutta-percha in the middle portion of the canal using a size 7 plugger (0.7 mm diameter, Maillefer), and second to the level of 4 mm short of the full working length and vertically condensing the gutta-percha in the apical portion of the canal using a size 5 plugger (0.5 mm diameter, Maillefer). In order to have root fillings similar to those after application of the Thermafil obturators, the rest of the canal space was back-filled by injecting warm gutta-percha using the Hygenic Ultrafil system (Hygenic, Akron, OH, USA), each time injecting a 4–5 mm segment and condensing the gutta-percha with a prefit plugger.

With the Thermafil technique, a size 50 Thermafil obturator with plastic carrier (Maillefer) was placed in the slot groove of the Thermaprep heating oven for 7 to 8 min as recommended by the manufacturer. After AH26 silver-free root canal sealer (DeTrey Dentsply, Konstanz, Germany) was introduced into the root canal, the thermoplasticized Thermafil obturator was firmly placed into the canal to the full working length.

The coronal part of the root filling was removed immediately after completion of the root filling to simulate the procedure for post space preparation. This was done by using an ISO size 90 Gates-Glidden drill (Maillefer) for teeth obturated by the vertical condensation technique; or a size 50 Prepi bur (Maillefer) for teeth obturated by Thermafil obturators. The gutta-percha, plasticized by the heat produced by the Gates-Glidden drill or Prepi bur, was condensed in the apical portion of root canal with a plugger (0.5 mm diameter, Maillefer), leaving the apical 3 mm of root filling.

During root canal obturation, root fractures occurred in one tooth in the vertical condensation group. This tooth was not included in the leakage test. As shown in Table 1, 21 teeth obturated by vertical condensation and 21 teeth obturated by Thermafil were finally subjected to the leakage test.

After the root canal obturated teeth had been stored in 100% humidity and at 37° for 48 h, the outer surface of each root was modified using a stone bur in a low-speed handpiece. The aim was to develop a smooth, cylindrical surface that provided a good fit to the plastic tube of the fluid transport device (Fig. 2). The tooth crown was removed from each tooth using an Isomet 11–1180 low-speed saw (Buehler, Evanston, IL, USA). Each root was mounted in the fluid transport device (Fig. 2) described previously by Wu et al. (20). Leakage along the apical 3 mm of the root filling was measured under a head space pressure of 30 kPa (0.3 atm) during a 24-h period. Fluid transport was recorded by displacement of the air bubble in a glass capillary tube. The results were expressed in microliters/day.

Table 1. The two groups subjected to leakage testing

Obturation technique	*N*	Curvature degree (mean)	Number of teeth with apical transportation (AT index in mm)
Vertical condensation	21	21–40 (29)	4 (0.25,0.3,0.4,0.5)
Thermafil	21	21–37 (28)	4 (0.25,0.3,0.35,0.4)

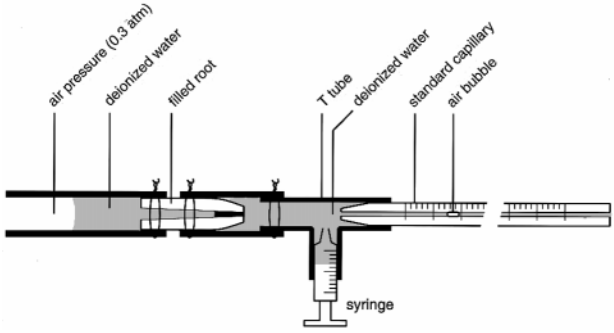

Fig. 2. Fluid transport device for leakage determination.

To exclude the presence of dentin cracks, the apical portion of all the leaking roots was cross-sectioned using a low-speed saw (Sägemikrotom 1600, Leitz, Germany). The cross-sections were observed under a stereomicroscope (Wild, Heerbrugg, Switzerland) at a magnification ×25.

Positive and negative controls, five teeth each, were used for this study. In the positive controls, canals were obturated with laterally condensed gutta-percha without sealer and no condensation was performed in the apical root canal after removal of gutta-percha with the Gates-Glidden drill. In the negative controls, canals were obturated with laterally condensed gutta-percha and AH26 sealer. Condensation was performed in the apical root canal after removal of gutta-percha using the Gates-Glidden drill, and two layers of nail varnish were applied to completely cover the surface of the roots before leakage testing.

Data of leakage measurements were statistically analyzed using a Mann-Whitney U-test.

Results

Apical transportation did occur in nine (21%) of the 43 curved root canals. One of them, which had an AT index of 0.3 mm, was excluded from the leakage test because of a root crack during canal obturation by vertical condensation. The other eight roots with apically transported canals were equally distributed over the two groups and underwent the leakage test (Table 1).

Table 2. Leakage (μL/day) along apical warm gutta-percha root fillings in curved root canals

Obturation technique	Number of root fillings			
	L=0	0<L≤20	L>20	Total
Vertical condensation	21	0	0	21
Thermafil	13	6	2	21

No fluid transport was recorded for the five negative controls whereas gross leakage (L >20 μL/day) was recorded for all five positive controls. The other leakage results are shown in Table 2. Leakage was found in eight canals when the canal was obturated using the Thermafil technique whereas no leakage was seen after using the vertical condensation technique (P=0.002).

Only one of the eight leaking roots obturated using the Thermafil technique showed canal transportation; the other seven did not. None of the cross-sections showed a dentin crack. Cross-sections of some Thermafil obturated roots showed that the plastic cone was not centred nor completely encased in gutta-percha.

Discussion

Eighteen Lightspeed prepared curved (21°–39°) canals, containing four canals with AT (AT index 0.25–0.5 mm), were obturated with laterally condensed gutta-percha cones and AH26 sealer in a previous study (14). No filling in the apical canals showed any leakage in a fluid transport device during the 24-h measurement. Under exactly the same experimental conditions in this study, the seal provided by the apical portion of the root filling was found to be just as effective when the canals were obturated by vertically condensed warm gutta-percha. In the present study the post space preparation was performed immediately after root canal obturation. In two previous studies using the same leakage model (15, 16) more leakage was detected along laterally condensed gutta-percha after delayed post space preparation, suggesting that a delayed preparation may disturb the seal, probably because of fractures occurring in the set sealer cement.

An effort was made to select the two obturation technique groups used in teeth with similar canal curvature and amount of AT (Table 1) to facilitate comparison of the seal provided by the different techniques. Leakage along Thermafil root fillings is not only caused by the presence of AT since seven of the eight leaking root fillings by Thermafil had no AT. In some cases the plastic carrier was not completely encased in gutta-percha, which is in agreement with Juhlin et al. (12) who found that the metal carrier of the Thermafil obturator is seldom completely encased in gutta-percha in curved canals. This may negatively influence the seal. On the other hand, in Thermafil plastic obturator filled canals, coronal root filling was removed using a Prepi bur. During this procedure the plastic that had melted onto the bur might have caused the bur to turn eccentrically, leading to excessive vibration, which, in turn, could have disturbed the seal (13).

Pulp Canal Sealer was used for the vertical condensation group as recommended by Ruddle (19). AH26 sealer was used for the Thermafil group because in a leakage study of Dalat & Spångberg (11) Thermafil and AH26 sealer showed the best seal, better than the lateral and vertical condensation groups. AH26 sealer was used for the lateral condensation group in a study of Wu et al. using the same fluid transport model (14), and no filling showed any leakage. However, we cannot exclude the possibility that the difference in sealers used in this study was also responsible for the difference in leakage.

The results of this study agreed with those of a dye leakage study by Ravanshad & Torabinejad (21) where the apical root fillings obturated by Thermafil leaked more than those obturated by lateral or vertical condensation after post space preparation. In many studies, however, dye penetration was measured along the full length of root fillings, and in some cases dye was found to penetrate to a similar depth when the root canals were obturated by Thermafil or by lateral condensation (10). A long filling contains many cul-de-sac type voids in which dye penetration might have been greatly hindered by entrapped air (22, 23). However, when the coronal root filling is removed, leaving a short apical root filling, many cul-de-sacs could have been opened to form open-ended gaps in which dye could penetrate by capillary action, and the penetration would be less hindered by entrapped air. This is perhaps why root fillings with Thermafil showed more dye leakage than lateral condensation after, rather than before, post space preparation (21).

Under the *in vitro* experimental conditions of this study, vertically condensed warm gutta-percha provided an excellent seal in the apical part of 21^0-40^0 curved root canals that had been instrumented using the Lightspeed technique. Obturation with Thermafil plastic obturators and AH26 sealer produced more leakage than vertical condensation and Pulp Canal Sealer under the same conditions.

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