In Vitro Leakage Associated with Three Root-filling Techniques in Large and Extremely Large Root Canals

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Abstract

This study assessed the apical leakage of ultrasonically condensed root fillings in extremely large canals, compared to cold lateral condensation and thermoplastic compaction. Ninety single-rooted teeth were used. In 45 teeth canals were enlarged to size 70 (large). The remaining 45 canals were enlarged to size 140 (extremely large). Each set of teeth was subdivided into three root-filling groups ($n = 15$): (1) cold lateral condensation (LC); (2) thermoplastic compaction (TC); and (3) ultrasonic lateral condensation (UC). Teeth in all six subgroups were subjected to drawing ink penetration, cleared, and evaluated for linear apical dye leakage. Significantly deeper dye penetration ($p < 0.04$, Wilcoxon rank-sum test) was observed for LC than for UC. TC did not differ significantly from LC and UC. Dye penetration was significantly deeper ($p < 0.0001$) in canals enlarged to size 140 than to size 70, independent of root-filling method. Apical leakage associated with ultrasonically condensed root fillings was less than that with cold lateral condensation. It was consistently greater in extremely large canals than that in large ones. *(J Endod 2007;33:306–309)*

Key Words

Apical leakage, dye penetration, partially developed permanent teeth, quality of filling

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Cold lateral condensation of gutta-percha is a widely accepted method for root canal filling (1), followed by thermoplastic compaction techniques. Although both root-filling methods have been used routinely with satisfactory clinical results (2), there are specific concerns regarding both, particularly in teeth with extremely large canals. In teeth with partially developed roots, cold lateral condensation may induce root dentine cracks as a result of the condensation load, imparted by the pressure of the spreader against the canal wall (3–6). Thermoplastic compaction techniques may overheat the periodontium when the remaining dentine is thin (7–9). In these conditions, a temperature increase $\geq$10°C can damage the periodontal ligament (10). An additional risk associated with thermoplastic compaction techniques is extrusion of filling materials into the periapical tissues (11–13).

The above concerns may be alleviated by use of ultrasonically activated spreaders in lateral condensation. The ultrasonic vibration plasticizes the gutta-percha, allowing reduction of the condensation load and the practitioner's hand strain (14). Ultrasonic lateral condensation is relatively new. Root fillings performed using ultrasonic lateral condensation in small- and medium-sized canals in vitro were denser and afforded less apical dye leakage than fillings done with cold lateral condensation (15, 16). To the best of the authors' knowledge, leakage of root fillings performed with ultrasonic lateral condensation has not been assessed in large canals.

The aim of this study was to assess the leakage of ultrasonically condensed root fillings in large (apical size 70) and extremely large (apical size 140) canals, in comparison with cold laterally condensed and thermoplastic root fillings performed with the continuous wave of condensation technique.

Materials and Methods

Tooth Specimens

Preparation of all specimens was performed by one operator. Ninety single-rooted maxillary incisors and canines were inspected to exclude the presence of cracks, fissures, and previous root fillings. They were cleaned with a scalpel to remove residual periodontal tissue and calculus from the root surface and stored until used in 0.5% thymol solution. The canals were accessed and the working length was established by inserting a size 10 K-type file (VDW, Munich, Germany) until it emerged at the apical foramen and then subtracting 1 mm. Passing the instrument through the foramen also established apical patency. Canals were then enlarged with reamers and Hedstroem files (VDW), while being intermittently irrigated with 2.5% sodium hypochlorite (NaOCl) and finally flushed with 20 mL of 17% ethylenediaminetetraacetic acid (EDTA).

Canals of 45 teeth were enlarged apically to size 70, 1 mm from the anatomic apex. The middle and coronal thirds of the canals were shaped in step-back manner with files sizes 80 to 100. Canals of the remaining 45 teeth were shaped similarly, then apically enlarged with consecutive files to size 140 to simulate the canal shape of incompletely developed roots. A gutta-percha master cone (VDW) was fitted into each canal and adjusted to working length with a tugback. AH Plus (Dentsply, Konstanz, Germany) root canal sealer was mixed according to the manufacturer's instructions. The master cone was coated with sealer and inserted into the canal to the working length using a pumping motion. The two sets of teeth were each divided into three groups and root-filled using one of the following techniques:

1. *Cold lateral condensation*: A nickel–titanium finger spreader size 25 (VDW) was inserted 1 mm short of the working length and the space filled with a corresponding gutta-percha cone coated with sealer. Condensation continued until the canal was filled. Excess gutta-percha was seared off with a heated instrument (PLG 2T 71, Hu-Friedy, Chicago, IL, USA) at the canal orifice and the heated gutta-percha condensed vertically with a Machtou plugger (Dentsply Maillefer, Baillagues, Switzerland). The access was sealed with zinc-phosphate cement (Harvard, Richter & Hoffmann, Berlin, Germany).
2. *Ultrasonic lateral condensation*: An ultrasonic spreader (F 88 009–S04, Satelec by Acteon Group, Mérignac Cedex, France) was inserted alongside the master cone and activated with an ultrasonic unit (P-MAX, Satelec) for 3 seconds, pushed apically, and activated again for 3 seconds. This sequence was repeated until the spreader reached 3 mm short of the working length. The spreader was then briefly activated and removed and a size 35 standardized gutta-percha cone (VDW), coated with sealer, was inserted into the space. Condensation was continued until the canal was filled. Excess gutta-percha was seared off and the heated gutta-percha vertically condensed with an ultrasonic plugger (F 00 250-5, Satelec). The access was sealed as in the cold lateral condensation group.
3. *Thermoplastic compaction technique* (continuous wave of condensation): A System-B plugger (SybronEndo, Orange, CA, USA) was fitted within 3 mm of the working length (17) and marked with a rubber stopper 3 mm shorter than the binding point. The System-B unit (SybronEndo) was set to a temperature of 200°C. The plugger was activated and inserted into the canal to the level of the stopper, the power switched off, and the plugger pushed apically to the binding point, and kept there for 10 seconds to offset shrinkage of the gutta-percha. It was removed after an additional 1-second "separation burst" of heat (200°C). The warm gutta-percha mass was then condensed further with a Machtou plugger (Dentsply Maillefer) to 3 mm of the working length. Canals were backfilled with injectable gutta-percha at 185°C (Obtura II, Obtura Spartan, Fenton, MO, USA), the injected gutta-percha mass condensed with Machtou pluggers at the orifice level, and the access sealed as in the other two groups. Root-filled specimens were stored for 1 week in a humidor (Memmert, Schwabach, Germany) at 100% humidity and 37°C, to allow setting of the sealer.

Dye Penetration

Drawing ink (Pelikan, Hannover, Germany) was applied through a silicone tube affixed over the apical third of the teeth with nail varnish. Specimens were positioned vertically (18) in a vacuum device (Heraeus, Hanau, Germany), and vacuum of 620 mmHg (19) applied for 5 minutes. Passive dye penetration followed at 37°C, 100% humidity for 7 days, silicone tubes were disconnected, and specimens washed under running water for 1 minute. Varnish and external dye on the apical third of the teeth were scraped off with a scalpel.

Specimens were cleared by demineralization, dehydration, and subsequent immersion in methyl salicylate (20), until rendered transparent (Fig. 1). Linear dye penetration into the canals was determined using a stereo-microscope (Carl Zeiss, Oberkochen, Germany) at 20× magnification. Apical leakage was measured as the distance from the apical terminus of the root filling to the deepest extent of dye penetration in a coronal direction. Measurements were performed twice each by two independent examiners and repeated jointly only if disagreement occurred in reaching consensus.

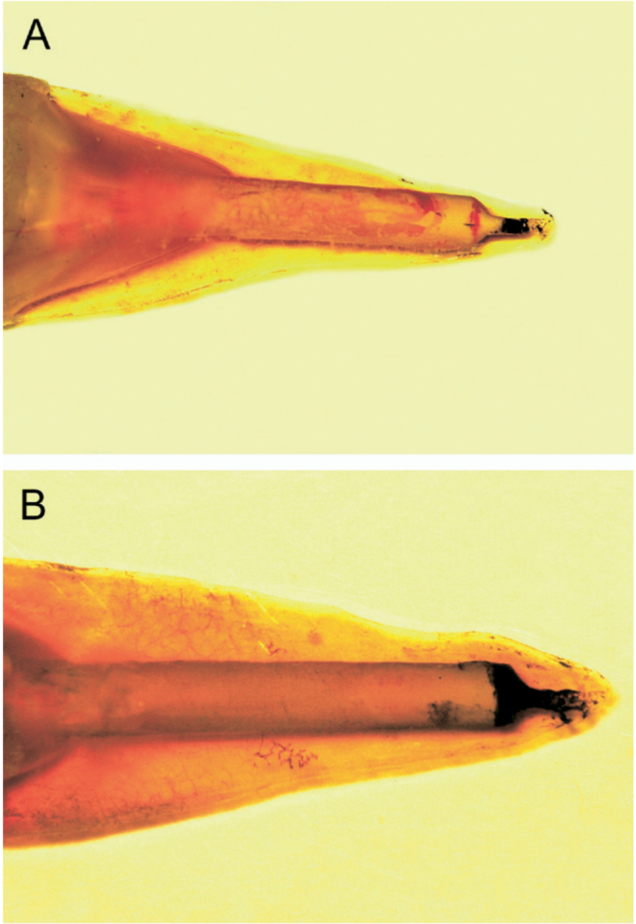

Figure 1. (*A*) Cleared tooth with canal enlarged apically to size 140 and filled by ultrasonic lateral condensation, subjected to dye penetration for 7 days. The depth of dye penetration was 0 mm. (*B*) Cleared tooth with canal enlarged apically to size 140 and filled by cold lateral condensation, subjected to dye penetration for 7 days. The depth of dye penetration was 2.2 mm.

Analysis

Results were analyzed with software from SAS (SAS Institute, Cary, NC, USA) and SPSS (SPSS, Chicago, IL, USA). The mean, median, standard deviation, and quartile values of dye penetration depth were calculated. The three root-filling groups were compared in canals enlarged to sizes 70 and 140, using two-tailed two-way ANOVA with SAS Procedure-Mixed by ranking. Intergroup differences were determined using Wilcoxon rank-sum test. Significance level was $p < 0.05$.

Results

Dye penetration depth values are summarized in Fig. 2. No significant interaction was detected ($p = 0.4818$) between root-filling technique and size of apical enlargement, suggesting that both variables were independent of each other. ANOVA revealed significant differences ($p < 0.05$) among the three groups. Dye penetration was significantly deeper ($p < 0.04$) for cold lateral condensation than for ultrasonic lateral condensation, whereas other intergroup differences were not significant (Table 1).

Dye penetration was significantly deeper ($p < 0.0001$) in canals enlarged to size 140 than to size 70 (Fig. 2). This difference was consistent in all three root-filling groups.

Discussion

All root canal preparations and fillings were standardized and performed by one operator, to minimize procedural errors. The operator was intensively trained during a pilot project, particularly in the relatively new ultrasonic lateral condensation technique. In addition, as an added safeguard, only noncurved single-rooted maxillary incisors and canines were included.

The clinical relevance of dye penetration studies has been questioned (21–24), in light of poor correlation between dye and bacterial penetration (22, 23) and clinical performance of root-filling materials (24). Nevertheless, in vitro assessment of leakage is a preliminary step in investigation of root-filling techniques before these are applied clinically. In this study, dye penetration was used to assess the relatively new ultrasonic lateral condensation technique, in comparison with the conventional techniques of cold lateral condensation and thermoplastic compaction. The assessment was performed in canals prepared to large and extremely large dimensions, to assess possible advantages of either technique in such canals.

Although it is recommended to remove entrapped air from root-filled teeth by vacuum before dye penetration testing (18, 25, 26), this procedure was not performed in the studies that showed no correlation with bacterial penetration (22, 23). In the present study, vacuum was applied for the first 5 minutes of exposure to dye, to avoid potential interference with dye penetration by entrapped air.

Kersten and Moorer (27) proposed that the size of dye particles used should preferably match the size of bacteria commonly found in the root canal flora of infected teeth, whereas Tamse et al. (19) observed different penetration behaviors with pigments of different particle size and molecular weight. Therefore, drawing ink was used as the tracer in the present study. Drawing ink—a dispersion of soot particles and shellac—has a particle size between 0.1 and 2 μm, which is comparable to that of many bacteria (28–30). In contrast, methylene-blue dye, with particles 10^3 times smaller than bacteria, was used to compare in vitro leakage and clinical performance (24).

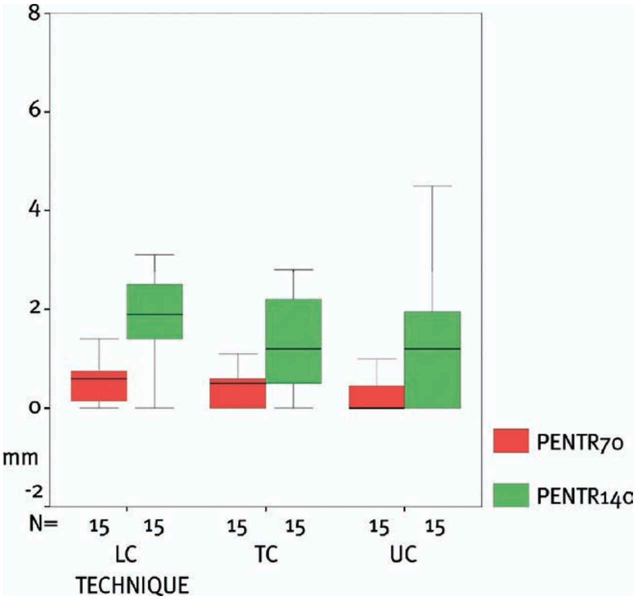

Figure 2. Graphic representation of dye penetration depth (mm) in large (size 70, PENTR70) and extremely large (size 140, PENTR140) root canals filled with either cold lateral condensation (LC), thermoplastic compaction (TC), or ultrasonic lateral condensation (UC). *N* identifies the number of specimens in each group. Outliers and far outliers not depicted.

TABLE 1. Statistical analysis (Wilcoxon rank-sum test) of apical dye penetration depth in the three root-filling techniques tested

Comparison of techniques	p-value
Ultrasonic lateral condensation vs. cold lateral condensation	0.0365
Ultrasonic condensation vs. thermoplastic compaction	0.3469
Thermoplastic compaction vs. cold lateral condensation	0.1458

Dye penetration in canals filled with ultrasonic lateral condensation was less than that in canals filled with cold lateral condensation and comparable to that in canals filled with thermoplastic compaction. Indeed, earlier in vitro studies (15, 16, 31) reported that ultrasonic lateral condensation results in denser root fillings than cold lateral condensation. Electron-microscopic examination showed more homogeneous fillings in the former than in the latter (15). In an in vivo radiographic study (14) root fillings performed by ultrasonic lateral condensation appeared adequately condensed along the entire working length. Zmener and Banegas (14) also reported less hand fatigue with ultrasonic lateral condensation than with cold lateral condensation technique, a finding corroborated by the impression of the operator in the present study. No difference in dye penetration was observed between cold lateral condensation and thermoplastic compaction. In contrast, previous studies (11, 12, 32) consistently showed better apical seal for thermoplastic compaction techniques.

Dye penetration was greater in the extremely large canals, such as occur in partially developed roots after trauma. Teeth subjected to trauma, which appear to be relatively frequent (33, 34), are difficult to fill using conventional techniques because the wide-open apex allows extrusion of root-filling materials and the thin root walls may crack under normal condensation loads. Cold lateral condensation is associated with less material extrusion than thermoplastic compaction (11–13), and thus it may be suitable for teeth with wide canals, although the condensation load may be excessive. The results of this study suggested that ultrasonic lateral condensation might be a valuable root-filling technique in such teeth, in that it appears to afford better apical seal than can be achieved using the cold lateral condensation technique. In addition, injury to periradicular tissues caused by ultrasonically generated heat can be avoided if activation time does not exceed 15 seconds (35).

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