An In Vitro Model to Investigate Filling of Lateral Canals

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Abstract

Aims of this work were to examine lateral canals in extracted teeth, to propose a new technique to produce artificial lateral canals, and to compare two obturation techniques. Cleared roots were examined to record measure and shape of lateral canals. Artificial lateral canals were prepared on human demineralized teeth before final clearing. Specimens were divided in two groups: canals of group 1 were filled with Schilder's technique, canals of group 2 were filled with vertical compaction with apical backfilling. Stereomicroscopic analysis of lateral canal filling revealed lower filling rates in apical canals compared to coronal ones and higher filling rates with "vertical compaction with apical backfilling" compared to Schilder's group. The tested procedure appears to be a reliable technique to obtain standardized lateral canals and to compare filling procedures.

Key Words

Lateral canals, clearing, filling technique, endodontic treatment.

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Lateral canals (1) are difficult to instrument and to irrigate during the endodontic therapy and may allow bacterial growth (2–4). Although Barthel et al. showed no correlation between unfilled lateral canals and inflammation of the periodontal ligament (5), other studies demonstrated a their potential pathogenicity after healing of periradicular lesions in relation with full filling of lateral canals (6–8).

The capability of an endodontic filling technique to ensure obturation and sealing of thin and irregular ramifications is an important clinical parameter, and may represent a favorable aspect of the filling technique. Among different techniques proposed over the years, the Schilder's technique has been shown to effectively fill lateral canals (9). Brothman (10) demonstrated that vertical compaction of warm gutta-percha approximately doubled number of filled lateral canals if compared to gutta-percha lateral compaction. Recently, the capability of filling lateral canals of a new obturation technique (11, 12) has also been investigated.

Several in vitro models have been proposed to compare results of different filling techniques. For this purpose artificial lateral canals were created using various methods and resulting in different shape and size. Wong et al. (13) and Tagger and Gold (14) used a split and hinged hard metal model containing a main canal with extensions mimicking lateral canals, while other authors proposed resin blocks with a main curved canal with lateral ramifications (15–17). Tooth embedded in acrylic block was also proposed (18–21): the resin block containing the tooth was longitudinally sectioned and root canal irregularities were subsequently produced with a one-half round bur, before re-approximate and secure the two halves. Goldberg et al. (22) created simulated lateral ramifications with reverse taper in human teeth by using a #15 engine reamer to drill into the center of the canal. Similarly Dulac et al. (16) used a #20 K file to fabricate lateral canals in epoxy resin blocks in which simulated root curved canals had been previously mechanically prepared. All these models of lateral canals have diameters greater than natural ones. In fact previous studies showed that 61.3% lateral branches in mandibular incisors and 70.1% in maxillary central incisors had thickness less than #10 reamer (23, 24).

Considering the high number of in vitro techniques proposed over the years a standardized model with a main and various lateral canals, furnishing homogeneity of the specimens, would be an important tool to investigate and compare filling techniques.

Aims of this study were: (a) to analyze morphology, shape, taper and diameter of lateral canals of cleared natural teeth; (b) to standardize a novel procedure to prepare lateral canals (with diameters of 60 μm) during the clearing procedure on extracted human teeth; (c) to investigate the quality of the filling in these artificial accessory canals obtained in vitro by comparing two warm gutta-percha techniques, the Schilder's technique (Schilder) and the "vertical compaction with apical backfilling" (12).

Materials and Methods

Teeth Preparation for Natural Lateral Canals Analysis

There were 102 maxillary (21 central incisors, 20 lateral incisors, 22 canines, nine first premolars, eight second premolars, eight first molars, seven second molars, seven third molars) and 120 mandibular human extracted teeth (21 central incisors, 24 lateral incisors, 19 canines, 16 first premolars, 17 second premolars, nine first molars, seven second molars, seven third molars) selected and provided 330 canals. The root canals had apical orifice diameters from 0.20 to 0.35 mm measured under steromicroscope (Zeiss Stemi 2000-C, Carl Zeiss Jena GmbH).

TABLE 1. Morphological analysis of natural lateral canals after endodontic treatment following the Schilder's technique

Inner Ø (μm)	Coronal third			Middle third			Apical third		
	Internal Taper	Cilindric canals	External Taper	Internal Taper	Cilindric canals	External Taper	Internal Taper	Cilindric canals	External Taper
<50 μm	—	13	2	4	8	6	10	61	24
50–100 μm	2	11	6	17	4	8	45	59	28
105–150 μm	5	6	—	8	—	4	13	14	—
155–300 μm	9	8	—	11	—	2	18	6	4
>300 μm	2	—	2	2	—	—	—	—	—
TOTAL and %	18 27.3%	38 57.6%	10 15.1%	42 56.8%	12 16.2%	20 27.0%	86 30.5%	140 49.7%	56 19.8%

Number of lateral canals.

Canals were counted in relation to their location within the root (apical, middle and coronal third). Internal diameter was measured in proximity to the endodontic space; outer diameter was measured in proximity to the external surface of the root. Canals were grouped depending to the inner diameter. Internal taper shape was defined if inner diameter > outer diameter, external taper shape was defined if inner diameter < outer diameter.

Canals were instrumented by one operator under X3.5 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 (12). Irrigation was performed with RC-Prep (Hawe Neos Dental, Bioggio, Switzerland) and 5% NaOCl to remove the smear layer (25). The root canals were rinsed, dried and a cotton pellet was fixed on the external surface to cover the apical foramina and simulate the clinical apical patency conditions (12). Specimens were then immersed in a base of impression material (Express Putty, 3M/ESPE, St. Paul, MN), connected to a grid, and immersed in a thermostatic bath of water at 37°C, so that the access of every pulp chamber was above the water surface (26).

Canals were filled with warm vertical condensation technique (9) using gutta-percha cones (Mynol, Block Drug Corporation, Jersey City, NJ), cut 1 mm short to the apex, and Pulp Canal Sealer cement (Kerr Co., Romulus, MI) (Dentsply DeTrey GmbH), Touch'N Heat (model 5004; Analytic Technology, Redmond, WA), and endodontic pluggers (Hu-Friedy Manufacturing Co. Chicago, IL), and back-filled by compacting heated gutta-percha fragments. Filled specimens were demineralized, cleared (11), and examined by a stereomicroscope (Zeiss Stemi 2000-C, Carl Zeiss Jena GmbH, Zeiss Group, Jena, Germany) with magnifications from 5× to 40× by two independent observers who counted the number of visible lateral canals and measured diameter in proximity to the endodontic main canal (inner diameter) and on the external root surface (outer diameter) by means of a micrometer. Lateral canals were grouped considering location (coronal, middle, and apical third) and inner and outer diameter, thus discriminating the shape as cylindrical or conical with external (i.e., inner greater than outer diameter) or internal taper (i.e., inner smaller than outer diameter).

Preparation of Artificial Lateral Canals

There were 30 teeth (10 maxillary molars, three canals each; 10 maxillary premolars, two canals each; 6 maxillary incisors, one canal each; four mandibular premolars; one canal each) for a total of 60 canals, selected, prepared, instrumented, and demineralized as previously described (11) until reaching a rubber-like consistency. The 5 to 8 mm apical part of the shaft of #06 K-Files was cut and carefully inserted into the softened root perpendicular to the surface of the demineralized specimens to reach the endodontic lumen, following apical coronal lines to create standardized artificial lateral canals at 1, 2, 3, 4.5, and 6 mm from the apex. A portion of 2 to 4 mm was left out as to be further easily removed. One to three lines of perforations were created depending on the root thickness. A total of 600 lateral canals on 120 lines were prepared. The clearing procedure was then completed (11) by immersion in methyl-salicylate to harden the specimens and restore their initial consistency. Each specimen was removed by methyl-salicylate, handled with ethanol wet gauze and K-File fragments were removed. Patency of lateral canals was tested with a #06 K File.

Filling Techniques

Specimens were randomly divided in two groups (A and B) of thirty roots, treated as previously described, and subsequently connected to a grid and immersed in a thermostatic bath of water at 37°C (26).

Canals of group A (control group) were filled with Schilder's technique (9), modified by using AH-Plus cement (Dentsply DeTrey GmbH) as endodontic cement and the Obtura II (Obtura Corp., Fenton, MO) to complete back-filling. Canals of the group B (test group) were filled using the same gutta-percha cones and AH-Plus cement with the vertical compaction with apical backfilling (12).

Specimens were then removed from the silicone base, re-dehydrated in 95% ethanol, immersed in methyl-salicylate to re-achieve optimal transparency and then analyzed by a stereomicroscope (Zeiss Stemi 2000-C) with magnifications from 5× to 40× by two independent observers who counted the number of visible lateral canals discriminating the quality of filling with five different scores (from 0 to 4) related to the presence of endodontic cement and/or gutta-percha in accordance with Venturi et al. (11). Discordant data were submitted to a third examiners to score the filling of accessory canals (Table 1). Grade 0 and 1 were considered as not acceptable, grade 2, 3, and 4 were considered as acceptable (11). Data were statistically analyzed with Kruskaal-Wallis and Mann-Whitney tests.

Results

Analysis of Natural Lateral Canals

Table 1 summarizes the details of the morphological analysis of natural lateral canals.

Analysis of Artificial Lateral Canals

Scores of artificial lateral canals at different distances from apex are reported in Table 2. No filling (grade 0) was particularly evident in lateral canals close to the apex, at 1 mm (68.3% in group A and 53.3% in group B) and at 2 mm (56.7% in group A and 41.6% in group B), while partial filling with cement (grade 1) was found scattered in the two groups between 8.3% and 45.0%. Complete filling with cement (grade 2) was frequently found at 4.5 mm from the apex (23.3% in

TABLE 2. Number of specimens showing acceptable (filling rate 2, 3, 4) of artificial lateral canals in relation to the filling procedure (Group A = Schilder's technique; Group B = Vertical compaction with apical back-filling) and to distance from the apex

Distance from apex	Acceptable		Mean of filling grades ± SD		Significance
	Group A	Group B	Group A	Group B	A vs B
1 mm	5/60 (8.3%)	14/60 (23.3%)	0.45 ± 0.81	0.90 ± 1.23	$P < 0.05$
2 mm	8/60 (13.3%)	1/60 (18.3%)	0.68 ± 1.02	0.95 ± 1.14	NS
3 mm	29/60 (48.3%)	34/60 (56.7%)	1.85 ± 1.23	2.15 ± 1.32	NS
4.5 mm	27/60 (45.0%)	40/60 (66.7%)	1.63 ± 1.07	2.06 ± 1.18	$P < 0.05$
6 mm	24/60 (40.0%)	39/60 (65.0%)	1.67 ± 1.30	2.32 ± 1.36	$P < 0.01$
Total	93/300 (31.0%)	138/300 (46.0%)	1.26 ± 1.23	1.68 ± 1.39	$P < 0.001$

The statistical analysis revealed that distance from the apex influenced the mean of filling grades of articial lateral canals (i.e. $1 = 2 < 3 = 4.5 = 6$ mm) for both groups A and B, confirming the difficulty to achieve filling of the apical delta. The comparison between the two filling technique revealed that the vertical compaction with apical back-filling (Group B) has higher filling grades compared to the Schilder's technique (Group A) at distances of 1, 4.5 and 6 mm. Similarly statistical differences were observed considering the total of the observations on artificial lateral canals regardless to the distance from the apex.

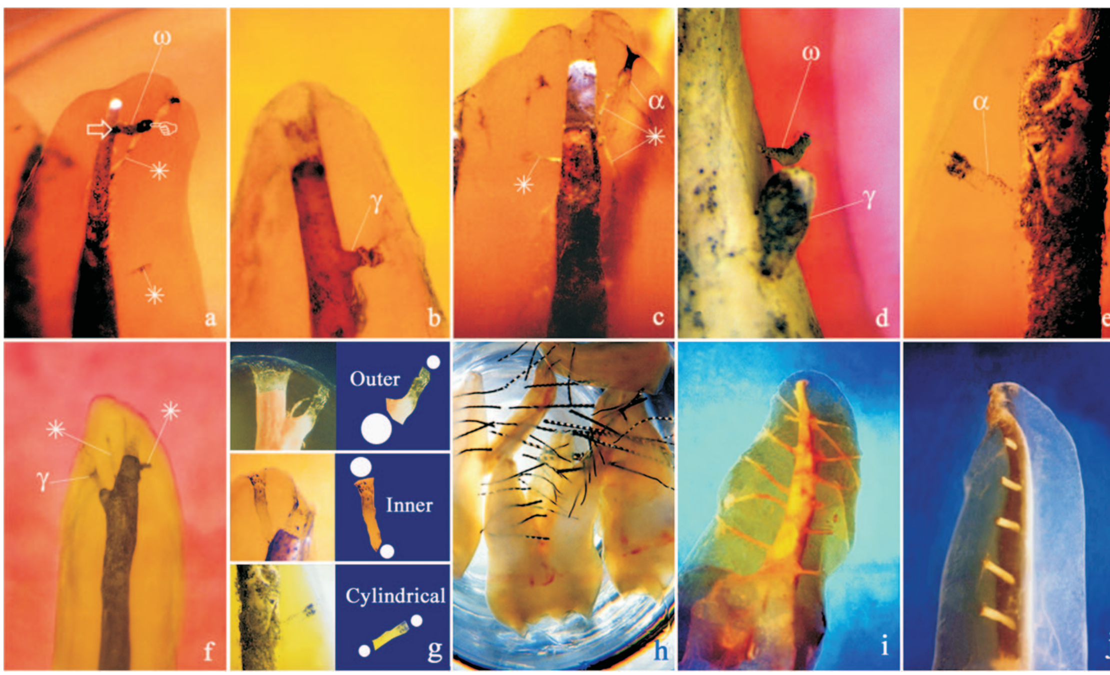

Figure 1. (a–f) Stereomicroscopic images of human cleared roots. Inner diameter of the ramifications was measured in proximity to the endodontic main canal (a, arrow), outer diameter was measured in proximity to the external surface of the root (a, pointing hand). (a, c, f) Asterisks: lateral canals in the apical third with inner diameter smaller than 50 μm. (b, d, f) γ: lateral canals showing inner diameter greater than outer diameter. (a, d) ω: lateral canals showing inner diameter smaller than outer diameter. (c, e) α: lateral canals showing cylindrical shape. (g) Diagram of each type of lateral canals described in the study. (h-j) Stereomicroscopic images of artificial lateral canals. (h) Specimens with the instruments inserted immersed in methyl-salicylate for hardening. (I) Specimen after final clearing showing the filling of the artificial lateral canals obtained at different distances from the apex (1, 2, 3, 4.5, and 6 mm). (j) Specimen showing a regular line of lateral canal.

group A and 38.3% in group B) and at 6 mm (but only in group B, 35.0%), while full filling with cement and partial filling with gutta-percha (grade 3) was mostly found at 3 mm (31.7% in group A and 26.7% in group B) and at 6 mm from the apex (20.0% in group A and 35.0% in group B). Full filling with cement and gutta-percha was more frequently revealed in group B at 3 (20.0%), 4.5 (18.3%), and 6 mm from the apex (21.7%).

Acceptable filling rate (i.e., groups 2, 3, and 4) was 8.3% in group A and 23.3% in group B at 1 mm; at 2 mm 13.3% in group A and 18.3% in group B. At 3 mm from the apex the acceptable filling rate was 48.3% in group A and 56.7% in group B, at 4.5 mm from the apex the acceptable filling rate was at 45% in group A and 66.7% in group B, while at 6 mm from the apex the acceptable filling rate was 40% in group A and 65.0% in group B (Table 2).

No statistical difference was found in group A or B between acceptable rates at 1 mm (mean score values: Group A 0.45 ± 0.81; group B 0.90 ± 1.23) and 2 mm (mean score values: Group A 0.68 ± 1.02; group B 0.95 ± 1.14) from the apex, similarly no difference was found at 3 mm (mean score values: Group A 1.85 ± 1.23; group B 2.15 ± 1.32), 4.5 (mean score values: Group A 1.63 ± 1.07; group B 2.06 ± 1.18), and 6 mm (mean score values: Group A 1.67 ± 1.30; group B 2.32 ± 1.36) from the apex (Table 2). Statistical difference was evident between acceptable filling rates obtained close to the apex (1 or 2 mm) and at more than 3 mm (3 or 4.5 or 6 mm) from the apex ($p < 0.05$). Group B revealed higher acceptable filling rate in lateral canals located at 1, 4.5, and 6 mm from the apex ($p < 0.05$), while at 2 and 3 mm from the apex no statistical difference was found between the groups (Table 2).

Discussion

The root canal system has a complex anatomy (29) with fins and lateral canals that may contain bacteria and necrotic tissue debris that are difficult to reach by instruments and irrigants. Few studies were performed to investigate presence, dimension, shape, and localization of lateral canals. Villegas et al. (27) found that 99% of the accessory canals were located within the apical 3 mm, often related to complex anatomy with multiple ramifications and curves less than 0.1 mm in diameter. Rubach and Mitchell (2) detected lateral canals in 45% of the teeth while Venturi et al. (11) found 308 lateral canals in 30 roots, most of them located in the apical third of the roots. De Deus (1) observed lateral canals in 27.4% of teeth, located in the apical (17%), middle (8.8%), and coronal (1.6%) thirds. In the present study 222 human cleared teeth were examined after obturation with the Schilder's technique and lateral canals were found in 65.5% of the specimens, most of them localized in the apical third (66.8%).

Shape and Diameter of Lateral Canals May Also Influence Cleaning and Obturating Effectiveness

Diameters of lateral canals less than 0.15 mm (150 μ) were reported in the furcal area (30, 31). On mandibular incisors it has been observed that 30.7% lateral branches had thickness less than #10 reamer, 29.6% similar to #10 reamer, 22.7% similar to #15 reamer, and very few were larger than a #20 reamer (23). Similarly on maxillary incisors it has been reported that 56.4% lateral branches had thickness less than #10 reamer, 24.7% approximately equal to #10 reamer, 9.7% approximately equal to #15 reamer, and very few were larger than a #20 reamer (24). In this study most of the apical lateral canals revealed diameters smaller than 50 μ m, and some between 50 and 100 μ m. Similar diameters were also reported in middle and coronal third even if major sizes were sometimes found.

Up to our knowledge this is the first attempt to investigate shape and taper of lateral canal analyzing inner and outer diameter. The three different shapes such as conical with internal (34.6%) or external (20.4%) taper and cylindrical (45.0%) were all represented (Table 1).

These preliminary observations on natural lateral canals were used to justify size and morphology of the artificial lateral canals that were prepared from the outside of the root using a stainless steel # 06 K file with a very small 0.2 external taper, almost undetectable if compared to the cylindrical shape most frequently observed in natural teeth. Various models with artificially created lateral canals have been utilized to evaluate filling produced by different techniques. Most of the previously proposed artificial models are time consuming and produce final dimensions of lateral canals greater than 100 μm thus major than in vivo (23, 24). Moreover being all different on from each other (1, 2, 23, 24, 27) they do not allow comparison between the studies.

The standardized and "easy-to-produce" model proposed in the present study allowed to create up to 15 ramifications on the same rubber-like root after a slow and mild demineralization which respects tooth integrity (11). The insertion of very thin instruments in the roots allowed to obtain lateral canals of 60 μm in diameter, thus comparable with the majority of them in natural teeth (23, 24, 30, 31). After the creation of the artificial lateral canals, the further immersion in methylsalicylate allowed to harden the specimens and to obturate the canals such as in not-demineralized roots, and subsequently allowed a direct three-dimensional observation of the transparent specimens with a stereomicroscope.

This model allowed to obtain standardized specimens in which comparison between different filling techniques may be properly performed because of the homogenous distribution of the lateral canals within the specimens. Thus the efficacy to of two filling technique were investigated: the Schilder's technique and the vertical compaction with apical backfilling (12). This technique is a modified gutta-percha warm vertical compaction up to 3 mm from the apex, followed by a thermomechanical compaction of the gutta-percha at a distance of 5 mm to the apex (12). The two techniques were compared in the present study in relation to their ability to fill the artificial lateral canals that were created on human teeth in accordance with the model previously described. AH-Plus was utilized with both techniques as better sealing performances than non resin-based sealers were reported (11).

The results revealed that the vertical compaction with apical backfilling has higher acceptable filling rate (filling rate 2, 3, or 4; $p < 0.05$) compared to the Schilder technique, while no differences were found at 2 and 3 mm from the apex. Both techniques demonstrated significantly lower probability to achieve full filling in the ramifications located at 1 and 2 mm to the apex than in the ones located at 3, 4.5, and 6 mm ($p < 0.05$). The vertical compaction with apical backfilling revealed the higher values for filling score 4 at 3, 4.5, and 6 mm from the apex confirming findings previously reported on the excellent capability of this technique to flow gutta-percha into wide accessory canals, usually located in coronal areas, rather than in smaller apical ones (11).

Three major reasons may be involved in determining these results: the viscosity of the gutta-percha that allows to better fill large spaces compared to tight ones; the small temperature increases that can be obtained in the apical gutta-percha also using electric heat-carriers (9, 26) and finally the thermo-mechanical compaction of the gutta-percha that could be more effective in the middle and coronal thirds (11, 12). In fact the "vertical compaction with apical backfilling" involves the placement of a condensed filling plug at apical level to allow a protracted and effective compaction without risk of apical extrusion (12) up to 5 mm from the apex. This results in a better three-dimensional filling of those endodontic ramifications that are located at a distance of more than 3 mm to the apex.

In conclusion the present study showed presence of lateral canals in a large number of natural teeth, most of them located in the apical third of the root, with prevalent cylindrical shape and diameter less than 100 μm. Using a standard model to produce artificial lateral canals on demineralized teeth the use of vertical compaction with apical back filling produced an excellent three dimensional filling, particularly in lateral canals located at more than 3 mm from the apex.

Acknowledgments

The authors wish to thank Aurelio Valmori for the extensive photographic work. This investigation was supported by PRIN and ex-60% grants of MIUR, Italy.

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