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Correlation Between Remaining Length of Root Canal Fillings After Immediate Post Space Preparation and Coronal Leakage

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The seal provided by root canal fillings after post space preparation was studied using a pressure-driven radioactive tracer assay. The coronal part of root canal fillings was immediately removed, using a hot plugger, to a remaining length of either 3, 5, 7, or 9 mm. Intact root canal fillings of 14 mm served as control. Application of air pressure of 130 mm Hg to the tracer solution drove it through the fillings and into phosphate-buffered saline surrounding the apex. Leakage gradually increased for 28 days, and differences in the leakage through 3 to 9 mm fillings were demonstrated. In a passive system by which an additional group of teeth were tested none of these differences could be detected. It was concluded that: (a) root canal fillings of 3, 5, and 7 mm have an inferior seal, compared with that of an intact filling; (b) the sealing is proportional to the length of the remaining filling; and (c) a passive system is unable to detect these differences, even when conducted for as long as 28 days.

Endodontically treated teeth are commonly restored with a post and core over which a crown is constructed. This procedure calls for partial removal of the root canal filling to prepare a post space, the depth of which is dictated by biomechanical considerations. Post-space preparation is frequently done by a restorative dentist who may not follow, when doing this procedure, the strict aseptic conditions practiced in endodontics. The assumption is that, once the cement in the root canal filling is fully set, the apical part of the filling remaining after post-space preparation will provide a seal that is equivalent to that of the intact filling.

This concept, which is frequently expressed in textbooks, is based on a body of literature that has been recently challenged. Abramovitz et al. (1) have demonstrated that a remaining filling of 5 mm is clearly inferior to the intact filling, providing that the assay used is sensitive enough to pick up the difference. They have demonstrated that, in passive conditions, even 14 days of exposure to the marker were not sufficient to demonstrate differences in leakage that were clearly demonstrated in a pressure-driven system within few days.

Their results did not preclude the possibility that longer assays may finally demonstrate such differences even without pressure. Furthermore even if 5 mm is not the "magic length" that will provide a seal equivalent to that of the intact filling, a slightly longer remaining filling might after all do it. We therefore used the same pressure-driven radioactive tracer assay to study root canals, with remaining root canal fillings ranging from 3 to 9 mm to try to establish whether such a "magic length" existed. Furthermore we extended both the pressure-driven assay and its passive control to 28 days to establish whether a longer passive assay will be adequate to demonstrate the differences.

MATERIALS AND METHODS

Teeth

One hundred and five single-rooted extracted teeth were selected from a random collection stored in buffered 10% formalin solution, pH 7.0. Each was checked for absence of root caries and examined with a microscope (×40) for the absence of cracks. Soft debris were removed with hand curettes. Crowns were removed at the cementoenamel junction using a water spray-cooled high-speed diamond bur, and the roots were trimmed (coronally) to a uniform length of 14 mm and stored at 100% humidity throughout the experiment.

Endodontic Procedure

A size 10 file was inserted to the apical foramen, and the working length was defined as 0.5 mm shorter than this length. The canals were instrumented to the working length with K-files to size 40 using sodium hypochlorite solution (2.5%) as a working solution, followed by a saline rinse. The remaining apical 0.5 mm of the canal was prepared to size 30 that was carried through the apical foramen to ensure patency and to reduce the influence of anatomical apical variations on the results. Gates-Glidden drills (#4) were used to prepare the root canal to a length of either 3, 5, 7, or 9 mm short of the working length, following a crown-down preparation. This canal preparation was used to facilitate the removal of the root canal filling by a hot plugger to a predetermined length, as detailed herein.

The plugger (Luks) to be used for this procedure was tested at this stage for light engagement of the canal walls when inserted to the designed length. Root canal obturation was conducted using the lateral condensation method with AH26 sealer.

Post Space Preparation

Partial removal of the root canal filling was done immediately after the obturation, using a hot plugger, to the predetermined depth. The quality of the remaining filling was checked using a finger spreader; whenever required additional accessory cones were added and the excess removed again with the hot plugger. The remaining root canal filling was then vertically condensed using a cold plugger. The teeth were radiographed, buccolingually and mesiodistally, to confirm that the procedure resulted in an acceptable root canal filling of the predetermined length in the apical part of the canal. The sealer was allowed to fully set for 7 days at 37°C in 100% humidity.

Coronal Leakage Assay

Coronal leakage of the root canal fillings was studied using the pressure-driven radioactive tracer assay described by Abramovitz et al. (1). Briefly each root was attached to the bottom of a pressure-cell constructed from a scintillation vial, with the tooth's coronal part inside and its apical part protruding through the bottom. The root was secured to the vial using epoxy cement and the quality of the seal ensured using air pressure of 260 mm Hg under water (1). The pressure cell was then filled with 1.0 ml of radioactive tracer solution (^{3}H-thymidine, 10 μCi/ml) and the cell inserted into a larger glass vial containing phosphate-buffered saline with 0.05% sodium azide added to prevent the growth of microorganisms. The cells were then connected to a manifold constructed from intravenous infusion tubes, connectors, and valves that allowed application of a uniform and continuous air pressure of 130 mm Hg to the tracer solution in the pressure cells (1).

Leakage of the tracer solution, through the obturated root canals, was monitored daily by sampling the buffer solution in the outer container. Fifty-microliter samples were transferred into a scintillation vial, containing 3.5 ml of scintillation fluid (Scintillator 299, Packard, IL) and the amount of radioactivity in it measured using a scintillation counter (4530 Tri Carb, Packard) and expressed as counts per minute (cpm).

Experimental Design

The coronal leakage was studied for 28 days either under a pressure of 130 mm Hg or with no pressure applied (normal atmospheric pressure). Five groups of roots were studied under each pressure regime, each consisting of 10 roots with a remaining root canal fillings of either 3, 5, 7, or 9 mm and a control of an intact root canal filling of 14 mm. A positive control consisted of five roots in which no obturation was done.

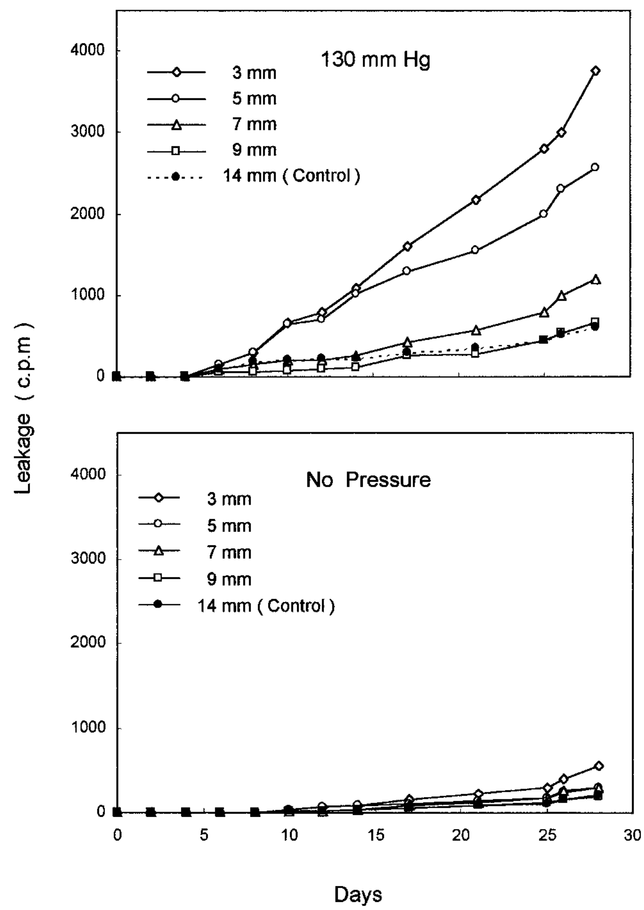

FIG 1. Kinetics of leakage through root canal fillings: passive vs. pressure-driven systems. Coronal leakage of radioactive tracer through root canal fillings expressed as the amount of tracer in cpm accumulating in the outer buffer surrounding the root apex. Each point represents the mean of 10 roots. Standard errors are detailed in the text.

Statistical Analysis

The kinetics of leakage over 28 days in each of the groups were compared with each of the other group length and to the teeth in which no pressure was applied, using analysis of variance and covariance with repeated measures. The amount of leakage as a function of the length of the remaining filling on days 7, 14, 21, and 28 with and without pressure were also compared with each other using analysis of variance and covariance with repeated measures.

RESULTS

In the nonobturated roots immediate total leakage occurred, expressing the maximal possible leakage in the system: 41,000 cpm.

Passive System

In the passive system practically no leakage was recorded for the first 9 days (Fig. 1). Initial leakage appeared on day 10 and by day 14 the average leakage was 95($\pm$63) cpm for the 3 mm fillings,

TABLE 1. Statistical analysis

	3 mm	5 mm	7 mm	9 mm	14 mm Control
3 mm	—	ND	$p < 0.04$	$p < 0.02$	$p < 0.01$
5 mm	ND	—	ND	$p < 0.04$	$p < 0.03$
7 mm	$p < 0.04$	ND	—	ND	ND
9 mm	$p < 0.02$	$p < 0.04$	ND	—	ND
14 mm Control	$p < 0.01$	$p < 0.03$	ND	ND	—

Comparison between the leakage through root canal fillings remaining after post space preparation. Day 28 in a pressure-driven system. ND, no significant difference.

85(±63) cpm for the 5 mm fillings, and 39(±14) and 28(±11) cpm for the 7 and 9 mm fillings, respectively. The average leakage for the intact, 14 mm, root canal fillings was 37(±14) cpm.

The leakage gradually increased and by day 28 the average leakage was 552(±495) cpm for the 3 mm fillings, 302(±187) cpm for the 5 mm fillings, and 303(±263) and 188(±151) cpm for the 7 and 9 mm fillings, respectively. The average leakage for the intact, 14 mm, root canal fillings was 206(±166) cpm.

In the first 14 days no significant difference was found between any of the groups and between them and the control (an intact root canal filling). The differences between the average leakage of the groups that were recorded on days 21 and 28 were also not significant.

Pressure-Driven System

During the first 4 days practically no leakage was recorded in any of the groups (Fig. 1). By day 14 the average leakage was 1,082(±1,343) cpm for the 3 mm fillings, 1,016(±1,051) cpm for the 5 mm fillings and 249(±224) and 117(±91) cpm for the 7 and 9 mm fillings, respectively. The leakage for the intact, 14 mm, root canal fillings was 227(±415) cpm.

The leakage gradually increased and by day 28 the average leakage was 3,766(±3,259) cpm for the 3 mm fillings, 2,571(±2,125) cpm for the 5 mm fillings, and 1,190(±797) and 669(±602) cpm for the 7 and 9 mm fillings, respectively. The average leakage for the intact, 14 mm, root canal fillings was 602(±575) cpm.

The kinetics of leakage were significantly different between the passive system and the pressure-driven one ($p < 0.05$). The difference between root canal fillings of 3 and 5 mm was not significant, but both groups were significantly different from those of 7 and 9 mm ($p < 0.04$ and $p < 0.02$, respectively) and from intact root canal fillings ($p < 0.01$; Table 1).

Correlation Between Filling Length and Leakage

The average leakage was plotted against the length of the remaining root canal filling (Fig. 2). When no pressure was applied no difference could be noted between the different groups. Initial shift in these results could only be seen on day 28 (Fig. 2*B*). On the other hand, in the pressure-driven system, it was clear that the shorter the remaining root canal filling, the greater was the leakage (Fig. 2*A*). This was true for the 3, 7, and 9 mm root canal fillings. No difference could be demonstrated between the 9 mm fillings and the intact, 14 mm, root canal fillings. This correlation was best demonstrated in a prolonged pressure-driven assay (28 days in Fig. 2*A*).

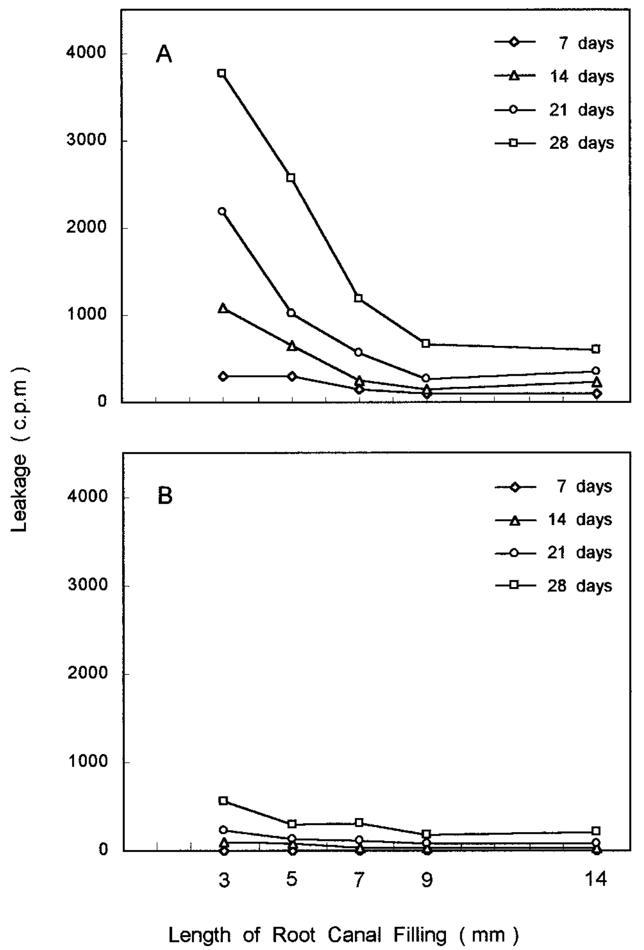

FIG 2. Leakage of root canal fillings as function of their length: passive vs. pressure-driven systems. Radioactive tracer leakage through remaining root canal fillings of increasing lengths expressed as the amount of tracer in cpm accumulating in the outer buffer surrounding the root apex. *(A)* A pressure of 130 mm Hg applied to the tracer solution. *(B)* No pressure applied. Each point represents the mean of 10 roots. Standard errors are detailed in the text.

DISCUSSION

The widely accepted notion that, a remaining root canal filling of 5 mm maintains a seal similar to that of an intact root canal filling, is supported by a series of studies (2–5). Most of these used the apical passive percolation model, in which the roots are immersed in a liquid containing a marker. The latter, usually a dye or radioactive tracer, is expected to penetrate through the apical foramen into voids within or around the root canal filling. Neagly (2) found no difference in leakage between residual fillings of 4 mm and intact fillings, following a 2-day assay. Similar results were reported by Madison and Zakariasen (3), in a 14-day assay, as well as by Bourgeois and Lemon (4), who studied the leakage for 2 h. They also found no difference in such comparisons. Dickey et al. (5), who extended these observations to remaining root canal fillings of 3 mm, also stated that these short fillings were not different from the intact ones (a 2-h assay).

In contrast to these reports, Wu et al. (6) and Abramovitz et al. (1) have recently demonstrated that this is not essentially true. When a pressure-driven system is used, 4 or 5 mm long remaining root canal fillings were clearly inferior in their ability to prevent leakage, compared with the intact fillings. However comparison to a passive, no pressure control, used by Abramovitz et al., demonstrated that passive systems might not be sensitive enough to pick up the differences and may lead to erroneous conclusions (1).

In the present study we extended their findings and demonstrated that even if it is extended to 28 days, a passive penetration study was not adequate to demonstrate differences clearly detected in a pressure-driven system. The passive control in the last study was of 14 days, whereas in most previous studies the observation period was much shorter and ranged from a few hours to a few days. It is apparent that, unless a proper *positive control* is included in such a study, that will verify that the study is *adequately sensitive* to detect the type of differences looked for, a "no-difference" result cannot be trusted. It is possible that such differences did exist but could not be detected in the study conditions. Positive pressure and sufficient time might have revealed it.

This may even be taken to an extreme by stating that the results of studies with an experiment design of a passive assay of short duration of 3 to 5 days should be considered with caution. Such studies are most likely to provide a "no-difference" result, regardless of the true condition. More sensitive assays, such as the pressure-driven system used herein, may better serve as the proper tool for such studies.

It may be argued that pressures of the kind applied herein do not exist in the clinical environment; however the pressure-driven system was used to enhance the sensitivity of the assay in the *relatively short duration* of an in vitro leakage study that in any case does not necessarily mimic the in vivo condition.

The increased sensitivity of the assay, which allowed the demonstration of the differences between fillings of various lengths, picked up also the high variability among the biological samples used. It is apparent that, even with meticulous control of the root canal filling quality, a great variability exists in the microanatomy of the root canal in natural teeth, especially in the apical area. The high variability, expressed as high standard errors in many of the groups, made it impossible to demonstrate statistical differences (Table 1) between some of the groups.

Overcoming this problem may require much larger groups or an alternative study design. A gradual removal of the root canal filling, with repeated leakage measurements after each step, using the same tooth as its own control, may overcome this problem. A study of such design is currently in progress in our laboratory. The option of avoiding the pressure altogether, to artificially reduce this natural variability, should be dismissed, as it will also reduce the assay's ability to pick up the differences in sealing ability.

Our finding, that a correlation exists between the length of a remaining root canal filling and the efficacy of its seal, is in agreement with those of Mattison et al. (7) who have found that the shorter the remaining filling, the higher was the leakage measured. Portell et al. (8) and Nixon et al. (9) have also reported a similar correlation between remaining length and seal; however none of these studies presented an intact, full-length root canal filling as a control. Our results, together with the last mentioned studies, indicate that the "magic length" of 5 mm that allegedly maintains a seal similar to that of an intact root canal filling does not exist. Leaving only a 5 mm residual root canal filling substantially diminishes the quality of the seal.

Nevertheless it is a common clinical observation that in teeth restored with a post, core, and a crown endodontic success was maintained, providing that a 5 mm root canal filling was left when preparing the post space. Based upon this observation and the findings of the experimental studies that a 5 mm long filling is not sufficient, one may conclude that the seal provided by the post, core, and crown complements that of the remaining root canal filling and significantly contribute to the clinical long-term success.

Support for this concept can be found in a recent study by Ray and Trope (10) who established in a clinical survey that the quality of the coronal seal provided by the restoration may be as important as the seal of the root canal filling.

Even intact root canal fillings were reported to leak when exposed for long periods to either bacteria or lipopolysaccharide (11, 12), and they should never be left exposed to the oral environment. This should be particularly important in the case of a shorter root canal filling, such as that remaining after post space preparation.

Failing to adequately prevent bacterial contamination of the post space may lead to an endodontic failure. Preventive measures should be considered at three levels: (a) during the process of post space preparation; (b) between visits, if the post is not completed immediately; and (c) for the extended duration of the functional life of the restored tooth.

The first calls for maintaining aseptic conditions throughout the process of post space preparation. The second calls for the use of strong temporary restorations or fillings that will withstand occlusal loads; even these should be used for as limited periods as possible. The third calls for evaluation of post and core construction methods not only for their mechanical quality, but also for their *sealing* properties. The first and second objectives could be best served if the same operator builds a permanent post and core immediately after completing the root canal filling. The third aspect, on the other hand, will require additional studies that will challenge this important aspect of the restoration of endodontically treated teeth.

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The Way It Was

Recent outcroppings of sinophilia lead to renewed interest in Confucian sayings as guides for modern living. Here are two:

> "When the ruler himself does what is right, he will have influence over the people without giving commands, and when the ruler himself does not do what is right, all his commands will be of no avail."

And another:

> Tsekung asked Confucius, "What would you say if all the people of a village liked a person?" Confucius said, "That is not enough. It is better when the good people of the village like him and the bad people of the village dislike him."

Hmmmm? Now, what was it again that it takes a village to do?

Zachariah Yeomans