JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 26, NO. 8, AUGUST 2000

SCIENTIFIC ARTICLES

The Effect of Immediate Vs. Delayed Post Space Preparation on the Apical Seal of a Root Canal Filling: A Study in an Increased-Sensitivity Pressure-Driven System

Itzhak Abramovitz, DMD, Michael Tagger, DMD, MS, Aviad Tamse, DMD, and Zvi Metzger, DMD

A 5 mm remaining length of root canal filling, after post space preparation, is commonly assumed to maintain sealing ability similar to that of the intact filling. Post spaces were prepared either immediately using hot pluggers, or later, using drills. The sealing ability of the fillings, 5 mm remaining length, were compared with each other and with an intact root canal filling control, using radioactive tracer in a pressure-driven system. When no pressure was applied, no differences could be detected between either of the groups and the control. When a pressure of 120 mm Hg was applied to the same teeth, the control group clearly maintained a better seal than each of the experimental groups, which did not significantly differ from each other. These results suggest that (a) the pressure-driven system was more sensitive than the passive leakage assay that failed to detect differences even at 14 days; (b) a remaining root canal filling of 5 mm was inferior to the intact root canal filling; and (c) the immediate post space preparation with hot pluggers did not differ from a delayed preparation with drills.

Endodontically treated teeth are commonly restored by a post and core followed by a crown. The required post space may be prepared either immediately after the completion of the endodontic procedure using hot pluggers (1) or alternatively at a later stage after a full setting of the sealer using rotatory instruments (2, 3).

Immediate removal of the coronal part of a root canal filling by hot pluggers often requires a modification of the canal preparation to allow the insertion of the desired plugger to the predetermined length. When this procedure is performed by the same operator who has just finished obturating the canal, it can be done under rubber dam, using the same aseptic conditions (1). An additional advantage of this protocol is that the condensation of the remaining gutta-percha filling can be assessed and improved if necessary. Finally the familiarity of the operator with the root canal system minimizes the risk of perforation or stripping.

Yet the common procedure is late removal of the coronal part of the root canal filling performed at a subsequent visit and frequently by a different operator—a restorative dentist rather than an endodontist (2, 3). The procedure is usually done using rotatory instruments such as Gates Glidden drills, with or without a gutta-percha solvent. It is rather uncommon to perform this procedure using a rubber dam, and it is usually performed in conditions similar to those used in general restorative dentistry.

The length of the post preparation is dictated by the mechanical retention requirements on one hand and by the need to leave sufficient length of the root canal filling to maintain its seal on the other. It is commonly believed that the remaining part of the root canal filling provides an adequate seal. Furthermore it is assumed that the seal provided by that minimal remaining root canal filling of 5 mm does not differ from that of the intact root canal filling (4). Most studies upon which this concept was based were semiquantitative (linear), short-term, apical percolation studies that were conducted under passive conditions, with no pressure applied. This methodology has been widely criticized (5–8). In some of these studies no difference could be demonstrated between the leakage of an intact root canal filling and that of a remaining filling of 4 to 5 mm (9, 10); in others no such comparison is reported (11, 12). The alleged similar leakage of both lengths may be true; however it may also indicate that the sensitivity of the leakage assays used was not sufficient to enable one to detect the difference.

In the present study the seal maintained by a remaining root canal filling of 5 mm, after immediate preparation was compared with that following delayed preparation and both were compared with that of an intact filling.

MATERIALS AND METHODS

Teeth

Fifty-three 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 microscopically (×40) for absence of cracks. Soft debris was removed with hand curettes. Crowns were removed at the cementoenamel junction and the roots 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. Gates Glidden drills were used to prepare the root canal to a length 5.0 mm short of the working length, and the remaining apical 5.0 mm of the canal was prepared to size 35 that was carried through the apical foramen to reduce the influence of anatomical apical variations on the results. Sodium hypochlorite solution (2.5%) was used as a working solution, followed by a saline rinse. This canal preparation was used to facilitate the removal of the root canal filling by a hot plugger to a defined length as detailed herein. The plugger to be used for this procedure was tested at this stage for light engagement of the canal walls when inserted to the working length minus 5.0 mm. Root canal obturation was done using the lateral condensation method with AH26 sealer.

Post Space Preparation

Partial removal of the root canal filling was done either immediately after the obturation or 7 days later, after the setting of the sealer.

GROUP A: IMMEDIATE REMOVAL

Post space preparation was done immediately after the obturation, using a hot plugger of a predetermined size. The root canal filling removal was carried to the working length minus 5 mm. The quality of the remaining filling was checked by a finger spreader and 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 to confirm that the procedure resulted in a 5 mm root canal filling in the apical part of the canal.

GROUP B: LATE REMOVAL

The sealer was allowed to fully set for 7 days at 37°C, at 100% humidity, followed by root canal filling removal to the same length as in group A using #3 and #4 Gates Glidden drills.

GROUP C: INTACT ROOT CANAL FILLING

The sealer was allowed to fully set as in group B, but the root canal filling remained intact and served as a negative control.

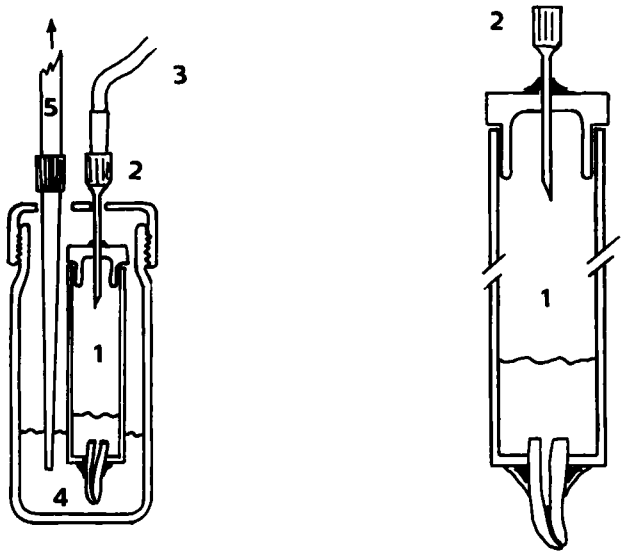

FIG 1. The pressure cell. The root was inserted through the bottom of a polyethylene scintillation vial (*1*) and secured with epoxy resin. An 18G needle (*2*) is inserted into the stopper and sealed. The needle was used as a connector to the manifold (*3*) (Fig. 2), as well as to stabilize the pressure cell in a slot in the cap of a larger glass scintillation vial containing the outer buffer (*4*) that was sampled periodically using a micropipette tip (*5*).

GROUP D: NO ROOT CANAL FILLING

Roots were endodontically treated as in the other groups but no obturation done. This group served as a total positive control, representing the maximal leakage possible in the system as a reference.

GROUP E: INTACT TEETH

Intact teeth were used as a control for the quality of seal of the experimental setup itself: cementation of the teeth and connectors, as detailed herein.

The Pressure Cell

Individual pressure cells were constructed, using polyethylene scintillation vials (commonly used for radioactive tracer studies). The root tip was inserted through an opening prepared in the bottom of the vial and secured, coronal part inside the vial, using epoxy cements (Fig. 1). A first layer of liquid epoxy cement (Duro, Loctite Corp., Cleveland, OH) was applied at the interface of the protruding root and the bottom of the vial, followed by a putty type of epoxy (Poxilina, Akapol, Argentina) and a second coating of the fluid epoxy cement (Fig. 1). A final double coat of nail polish was then applied to the epoxy cement and the bottom of the vial. This resulted in a structure that was both rigid and properly sealed to withstand the pressure in the system. The coronal part of the root was inside the vial, whereas the apical 1.0 mm of the root tip remained free of epoxy and nail polish.

The pressure cell was then completed by insertion of the vial's stopper, using a fluid epoxy cement and a layer of nail polish to seal it. To prevent development of unwanted pressure in the vial at this stage, the escape of excess air was allowed through a 27G

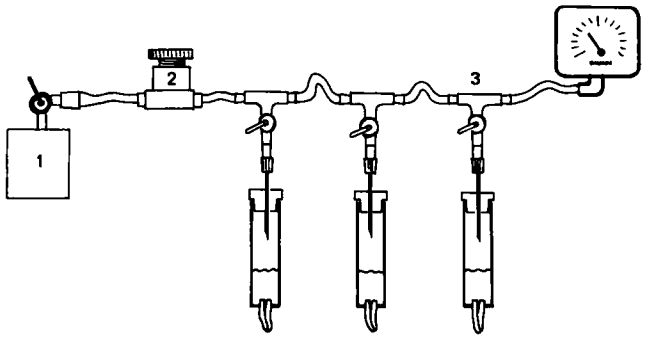

FIG 2. The pressure manifold. The pressure manifold was constructed from intravenous infusion tubing and connectors. A compressed air source (*1*) was connected through a fine pressure regulator (*2*) to a manifold (*3*) and to a manometer. A pressure of 300 mm Hg was used to test the system for an air tight seal, under water, before use. In the second part of the study a constant pressure of 120 mm Hg was applied for 7 days.

hypodermic needle that was inserted through the stopper. Each vial was then tested in a water bath under an air pressure of 300 mm Hg to confirm its seal.

Pressure System

Intravenous infusion tubes, connectors, and valves (Biometrix, Jerusalem, Israel) were used to construct the pressure system manifold (Fig. 2). Compressed air was used to generate a constant pressure of 120 mm Hg. A compressed air source of 2.0 Atm was connected through a fine pressure regulator (ERI200, S.M.C., Osaka, Japan) to a manifold built from infusion tubes, connectors, and valves. A manometer with a range of up to 360 mm Hg was also attached to this system. It allowed an accurate regulation and monitoring of a constant pressure of 120 mm Hg in the system's manifold. Each individual pressure cell was connected to this manifold through a valve that allowed activation of the pressure in the cell or its disconnection from the system if required. The manifold was tested in a water bath for airtight fitting.

Radioactive Tracer Assay

The 27G needle was removed from the stopper and 1.0 ml of a radioactive tracer solution (^{3}H-thymidine, 10 μCi/ml) was injected through the hole into each chamber using a 31G needle. The thinner needle allowed escape of air through the larger opening, thus avoiding undesired pressure. A thicker, 18G, needle was then inserted into the opening and secured to the stopper by epoxy that both stabilized the needle and provided an airtight seal (Fig. 1).

Each pressure chamber was inserted into a glass vial (a larger glass scintillation vial) containing 5.0 ml of saline with 0.05% sodium azid to prevent microbial growth. The vial's screw cap was used to close it and the needle secured by epoxy to the narrow part of a keyhole opening prepared in the cap (Fig. 1). The wider part of the hole was designed to allow the insertion of a pipette tip to sample the saline. Each chamber was connected to the manifold by the hub of the needle.

For the first 14 days no pressure was applied in the system. On day 14 a constant pressure of 120 mm Hg was applied simultaneously to all vials and was maintained with careful monitoring through day 22.

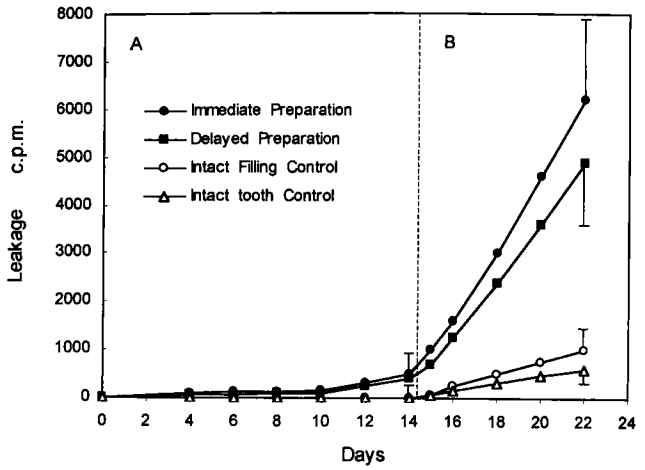

FIG 3. Leakage through root canal fillings. Radioactive tracer leakage through root canal fillings, expressed as the amount of tracer in cpm, accumulating in the outer buffer surrounding the root apex. (*A*) No pressure applied. (*B*) A pressure of 120 mm Hg applied to the radioactive tracer solution in the pressure cells.

Samples consisting of 50 μl of the saline were collected at the indicated intervals, using a Gilson pipette with disposable tips. The opening in the cap was sealed with a removable adhesive tape throughout the experiment to prevent evaporation of the saline. Each sample was immediately diluted in 3.5 ml scintillation fluid (Scintillate 299, Packard, IL) and the amount of radioactive tracer in it measured using a scintillation counter (Tri-Carb 4530, Packard) and expressed in counts per minute (cpm).

Statistical Analysis

The results were analyzed by ANOVA for repeated measures after logarithmic transformation.

RESULTS

Leakage of the radioactive tracer solution through the root canal from coronal to apical end of the root canal filling was monitored by sampling the tracer in the saline surrounding the apex.

Leakage without Pressure

In group D, which consisted of an empty canal, an immediate total leakage occurred and reached 64,000 cpm. In none of the other groups could significant amounts of tracer be detected through day 8. By day 9 initial signs of leakage appeared in the outer solution in groups A, B, and C. The leakage gradually increased in the following 5 days and reached up to 500 cpm (Fig. 3). By day 14 no significant difference was found between groups A and B and between each of them and control group C.

Leakage under Pressure

Through the last 8 days, under a constant pressure of 120 mm Hg, the leakage gradually increased in all experimental and control groups (Fig. 3). The leakage after immediate partial removal of root canal filling (group A) did not statistically differ from that in

root canal fillings partially removed with rotary instruments after full setting of the sealer (group B). The leakage in each of these two groups significantly differed from that of the intact root canal filling control (group C) ($p < 0.0001$). There was no difference between the last group and the negative control of intact teeth (group E). In each of the groups tested there was a significant difference between their time-dependent leakage before and after the pressure application ($p < 0.001$).

DISCUSSION

It is commonly recommended that post space preparation should allow a remaining root canal filling of 5 mm to avoid compromising the apical seal (13). This concept has been based on the results of a selective number of apical leakage dye penetration studies, all of which were performed in passive (no pressure) systems. These studies were usually of a short duration (14, 15).

Air pressure-driven systems have been suggested to overcome the problem of entrapped air (7). However our results suggest that the pressure may provide yet another major benefit: increased sensitivity of the assay. A passive system might not be sensitive enough to detect differences between the leakage of an intact root canal filling and that of a remaining root canal filling of 5 mm. Thus through the first stage of the present study, with no pressure applied, no difference could be found between the intact fillings and those of 5 mm for as long as 14 days. Only in the second part, when sensitivity was enhanced by the pressure, could these differences be detected and demonstrated. Therefore if our study was limited to 3 to 4 days without any pressure, it may have led to erroneous results. This should raise the question of whether previous studies that addressed the same issue and led to a "no difference" conclusion were sensitive enough to detect these differences.

The application of pressure largely enhanced the sensitivity of the assay and within a relatively short period of observation differences between the groups could clearly be demonstrated. 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 does not necessarily mimic an in vivo condition.

A "no difference" result between two experimental groups in a leakage study should be considered valid *only* if the system used was sensitive enough to pick up such differences. This should be demonstrated in such an assay by *proper* control groups that differ from the experimental groups only in the investigated parameter. Failure to include such positive controls in many of the published leakage studies (11, 12, 16, 17) might make it necessary to view their "no difference" results with caution. It clearly seems that passive assays of short duration are apt to miss differences and therefore may have to be considered as an inadequate way to conduct such a comparative study.

Pressure-driven systems have recently been used also by Wu et al. (18), who used a modification of the "fluid transport model." This system required a relatively high pressure (1.2 Atm = 912 mm Hg) to allow detectable amounts of fluid to pass through the system and be expressed in μl/min. The use of a radioactive tracer in combination with a scintillation liquid in our system greatly enhances the sensitivity of the system and would have allowed the detection of even 1 μl (which was read in this system as ~100 cpm), thus permitting the use of a much lower pressure of 120 mm Hg (13% of that used in the previous model).

The results of the present study indicate that an intact root canal filling provided a proper seal that did not differ from that of an intact tooth control. The leakage observed in both groups was low and most probably represented the background leakage in the system rather than a true leakage through the root canal. On the other hand, a root canal filling of 5 mm had a seal that was clearly inferior to that of the intact filling. Nevertheless, when root canal fillings of a remaining length of 5 mm were compared, no significant difference was found between those remaining after immediate removal with a hot plugger and those in which late removal was done with rotatory instruments. This result is in agreement with Madison and Zakariasen (4); however no other studies examined these parameters.

Having a similar quality of seal, the hot plugger method has additional benefits in terms of efficiency and safety. Preparing the post space by this method takes less time and is performed at the same session as the root canal filling. Being performed without rotatory instruments it also reduces the risk of perforations and strip perforations by an operator who is unfamiliar with this particular root canal (1). The extreme depth to which it was performed in the present study was chosen to represent the shortest, minimal remaining filling commonly recommended in the endodontic literature (4). Nevertheless, this method may be applied to a shorter depth, providing a proper plugger may be preadapted to the desired length. Because it is done by the same operator it is best to check this adaptation before obturation, thus saving time and effort. The commonly used "crown down" methods are easily combined with such a removal method because they follow a similar concept of widening the coronal part first.

Keeping in mind the reduced sealing ability of 5 mm root canal fillings, one should consider performing both the preparation of the post space and even the cementation of a post, under conditions similar to those required during an endodontic procedure: using rubber dam isolation and an aseptic operating field. If post space and the post itself are prepared in the same session as the root canal filling these aseptic conditions may easily be followed with no additional effort or attention.

Our results raise an obvious issue: if a residual root canal filling of 5 mm is inferior to an intact filling, how would one explain the proven clinical success of such short fillings in teeth restored by post and cores with or without a covering crown? One should clearly not argue with success! Nevertheless the reasons leading to such a success might be other than those commonly accepted.

Ray and Trope (19) have demonstrated the critical role that the restoration plays in determination of endodontic success or failure. In an extensive clinical survey they found that the success rate is greater when an adequate coronal restoration is placed in the tooth, even if its root canal filling is not perfect, compared with good root canal fillings with a faulty coronal restoration.

Wu et al. (20) have also demonstrated that even though a residual root canal filling of 4 mm is inferior to the intact one, once a post and core are constructed, no difference existed between the two groups.

This may explain the perpetuation of the clinical concept that a minimal remaining filling of 4 to 5 mm should be adequate. Nevertheless no long-term controlled clinical study is currently available to establish a recommended, ideal remaining root canal filling length, whereas retrospective data are also not conclusive.

Keeping all of the above in mind one should not consider a remaining root canal filling of 5 mm *alone* as an adequate barrier.

The burden of maintaining proper seal should rather be shared also by the post, core, and crown constructed for this tooth.

Our results do not attempt to change a successful clinical concept but rather draw attention to some of its aspects that might be overlooked. Because the remaining filling is inferior to an intact one, caution should be practiced in two clinical aspects. (a) Partial removal of a root canal filling should be followed by either immediate construction of post and core, or if that is not possible, preventing contamination of the post space should be practiced as if it were a root canal system undergoing root canal therapy: proper isolation during procedures and durable coronal seal with $Ca(OH)_2$ dressing between visits. (b) Because long-term success may greatly depend on the quality of the seal provided by the post and core, materials and methods used for their construction should be evaluated for their *sealing ability* and not only for their other mechanical properties.

The excellent technical assistance of Mrs. Miri Dotan is gratefully acknowledged.

This study is part of the requirements for DMD degree of Itzhak Abramovitch and was conducted at The Alpha Omega Research Laboratories.

Dr. Abramovitz is a graduate student, Department of Endodontology; Dr. Tagger is associate professor and head of the Department of Endodontology; Dr. Tamse is associate professor and coordinator of the Department of Endodontology; and Dr. Metzger is associate professor in the Departments of Restorative Dentistry and Oral Biology and is director of Research Laboratories, The Goldschleger School of Dental Medicine at Tel Aviv University, Tel Aviv, Israel. Address requests for reprints to Dr. Zvi Metzger, Goldschleger School of Dental Medicine, Tel Aviv University, Ramat Aviv, Tel Aviv 96978, Israel.

References

1. Galen WW, Mueller KI. Restoration of the endodontically treated tooth. In: Cohen S, Burns RS, eds. Pathways of the pulp. 7th ed. St. Louis: Mosby, 1998:691–717.

2. Hussely DL, Killough SA. A survey of general dental practitioners' approach to the restoration of root filled teeth. Int Endod J 1995;28:91–4.

3. Morgano SM, Hashem AF, Fotoohi K, Rose L. A nationwide survey of contemporary philosophies and techniques of restoring endodontically treated teeth. J Prosth Dent 1994;72:259–67.

4. Madison S, Zakariasen KL. Linear and volumetric analysis of apical leakage in teeth prepared for posts. J Endodon 1984;10:422–7.

5. Matloff A, Lipton S, Goldman M. The reliability of dye studies to determine leakage. J Dent Res 1982;61:344.

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

7. Spangberg 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.

8. Wu M-K, Wesselink PR. Endodontic leakage studies reconsidered. Part 1. Methodology, application and relevance. Int Endod J 1993;26:37–43.

9. De Nys M, Martens L, De Coster W, Thys M. Evaluation of dowel space preparation on the apical seal using image processing system. Int Endod J 1989;22:240–7.

10. Saunders EM, Saunders WP, Rashid MYA. The effect of post space preparation on the apical seal of root canal fillings using chemically adhesive material. Int Endod J 1991;24:51–7.

11. Haddix JE, Mattison GD, Shulman CA, Pink FE. Post preparation techniques and their effect on the apical seal. J Prosth Dent 1990;64:515–9.

12. Camp LR, Todd MJ. The effect of dowel preparation on the apical seal of three common obturation techniques. J Prosth Dent 1983;50:664–6.

13. Weine FS, Potashnick SR, Strauss S. Restoration of endodontically treated teeth. In: Weine FS, ed. Endodontic therapy. 5th ed. St. Louis: Mosby, 1996:764.

14. Kwan EH, Harrington GW. The effect of immediate post preparation on apical seal. J Endodon 1981;7:325–9.

15. Portell FR, Bernier WE, Lorton L, Peters D. The effect of immediate versus delayed dowel space preparation on the integrity of the apical seal. J Endodon 1982;8:154–60.

16. Mattison GD, Delivanis PD, Thacker RW, Hassel KJ. Effect of post preparation on the apical seal. J Prosth Dent 1984;51:785–9.

17. Hiltner RS, Kulild JC, Weller RN. Effect of mechanical versus thermal removal of gutta-percha on the quality of the apical seal following post space preparation. J Endodon 1992;18:451–5.

18. Wu M-K, De Gee AJ, Wesselink PR, Moorer WR. Fluid transport and bacterial penetration along root canal fillings. Int Endod J 1993;26:203–8.

19. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to technical quality of the root canal filling and the coronal restoration. Int Endod J 1995;28:12–8.

20. Wu M-K, Pehlivan Y, Kontakiotis EG, Wesselink PR. Microleakage along apical root fillings and cemented posts. J Prosth Dent 1994;79:264–9.