Coronal leakage following three obturation techniques

S. D. Gilbert,[1] D. E. Witherspoon[1] & C. W. Berry[2]

[1]Department of Restorative Sciences, Graduate Endodontics, Baylor College of Dentistry, Dallas, Texas, USA; and [2]Office of Academic Services, Baylor College of Dentistry, Dallas, Texas, USA

Abstract

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Aim To compare coronal bacterial and India ink leakage in three different obturation techniques with the smear layer having been removed.

Methodology Seventy extracted single-rooted teeth were instrumented to an apical preparation size 7 Profile Series 29 (Tulsa Dental Products, Tulsa, OK, USA). The smear layer was removed and 20 teeth were randomly obturated with lateral compaction, 20 teeth with vertical compaction, and 20 teeth with Thermafil (Tulsa Dental Products, Tulsa OK, USA). Ten teeth were used for positive (five teeth) and negative (five teeth) controls. Teeth were stored for 90 days in 100% humidity, then subjected coronally to *Proteus vulgaris* for 21 days to assess bacterial leakage. Following bacterial challenge, India ink was placed coronally for a further 21 days, then scored according to depth of dye leakage.

Results Vertical compaction leaked significantly less than lateral compaction during bacterial challenge. However, when dye was used there were no significant differences.

Conclusions Bacterial leakage and dye leakage demonstrated considerable variability. The use of a dye following bacterial testing may highlight the failure of experimental devices and vertical root fractures, thus avoiding false positive results found with bacterial testing alone.

Keywords: bacteria, coronal leakage, dye, lateral compaction, smear layer, Thermafil, warm vertical compaction.

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Introduction

Currently the material of choice to obturate the prepared root canal space is gutta-percha. However, there is no single generally accepted method for the delivery of gutta-percha to the canal. For this purpose four basic techniques exist: (i) the cold compaction of gutta-percha; (ii) the compaction of gutta-percha that has been heat-softened in the canal and then cold compacted; (iii) the compaction of gutta-percha that has been thermoplasticized, injected into the system, and then cold compacted; and (iv) the compaction of gutta-percha that has been placed in the canal and softened through mechanical means (Gutmann & Witherspoon 1998). A multitude of variations on these four basic themes exists. Of these, cold compaction of gutta-percha or lateral compaction is the most widely taught method and the technique against which others are usually measured.

Prior to canal obturation, removal of the smear layer has been advocated. The smear layer is a combination of organic and inorganic debris that is present on the root canal walls following instrumentation that represents dentinal shavings, tissue debris, odontoblastic processes, and microbial elements (McComb & Smith 1975, Goldman *et al.* 1982, Mader *et al.* 1984). The presence of the smear layer has been postulated to be an avenue for leakage and source of substrate for bacterial growth and ingress (Goldman *et al.* 1982, Pashley 1984, Meryon & Brook 1990, Pitt Ford & Roberts 1990, Garberoglio & Becce 1994). The frequency of bacterial penetration in the presence of a smear layer, when canals were obturated with thermoplasticized gutta-percha and sealer has been shown to be significantly higher than when the smear layer was removed (Behrend *et al.*

Correspondence: Dr David E. Witherspoon, Department of Restorative Sciences, TAMUS – Baylor College of Dentistry, 3302 Gaston Ave., Dallas 75214, Texas, USA (fax: +214 828 8209; e-mail: dewspoon@tambcd.edu).

1996). Technically, the smear layer may interfere with the penetration of gutta-percha into the tubules and the adhesion and penetration of root canal sealers into the dentinal tubules (White *et al.* 1984, 1987, Gettlemen *et al.* 1991, Oksan *et al.* 1993). Significant tubular penetration of obturation material has been shown using thermoplasticized gutta-percha and smear layer removal (Gutmann 1993). Studies have also shown a decreased incidence of leakage with gutta-percha and sealer obturations when the smear layer was removed and the gutta-percha was softened prior to obturation. Thus, the retention or removal of the smear layer prior to obturation may influence the quality of obturation that has been evaluated historically by leakage studies.

Numerous studies have attempted to assess *in vitro* leakage (Wu & Wesselink 1993). The methods used include methylene blue (Ishley & ElDeeb 1983, Kennedy *et al.* 1986, Cergneux *et al.* 1987, Peters & Harrison 1992, Scott *et al.* 1992, Dummer *et al.* 1993), India ink (Gutmann 1993, Saunders & Saunders 1992, 1994a, Baumgardner *et al.* 1995, Lloyd *et al.* 1995), silver staining (Hovland & Dumsha 1985), radio-isotopes (Dow & Ingle 1955, Marshall & Massler 1961, Cook *et al.* 1976, Rhome *et al.* 1981), electrochemical circuits (Jacobson & Von Fraunhofer 1976), saliva (Magura *et al.* 1991, Wu *et al.* 1993, Khayat *et al.* 1993), and bacteria (Goldman *et al.* 1980, Kos *et al.* 1982, Williams & Goldman 1985, Torabinejad *et al.* 1990, Behrend *et al.* 1996). As pointed out by Wu & Wesselink (1993) there is a great deal of variability in the results and minimal consensus as to the most appropriate method to assess leakage.

Recently the significance of the integrity of the coronal seal has become more evident in the long-term success of root canal treatment (Trope *et al.* 1995). Some of the causes for a loss of the coronal seal after endodontic therapy are delay of placing a restoration, fracture of restoration, or postspace preparation when the remaining apical section of root filling is inadequate (Saunders & Saunders 1994b).

The purpose of this study was to compare coronal bacterial and India ink leakage following obturation with three different techniques and the smear layer having been removed.

Materials and methods

Seventy (70) extracted single-rooted teeth were selected, cleaned of extraneous tissue and calculus, then sterilized in 5.25% sodium hypochlorite (NaOCl) for 2 weeks (OSHA regulations). Subsequently, the teeth were decoronated at or below the cemento-enamel junction (CEJ) and stored in deionized water prior to instrumentation. The canal systems were instrumented using Profile rotary instruments (Tulsa Dental Products, Tulsa, OK, USA) following the manufacturer's instructions. Briefly, working lengths (WL) were established by placing a size 10 file to the apex, then subtracting 1 mm from this measurement. All canals were enlarged to the size 7 (brown) in the .04 series. Patency was maintained by placing a size 10 file through the apex. Canals were irrigated after each file with 1.0 mL of 5.25% NaOCl. Following instrumentation, the smear layer was removed with 3 mL of 17% EDTA for 30 s, followed by 5 mL 5.25% NaOCl (Yamada *et al.* 1983, Ciucchi *et al.* 1986, Baumgartner & Mader 1987, Gutmann 1993). The canal was then dried with sterile paper points.

Teeth were then randomly distributed into three groups of 20 teeth:

Group 1 was obturated using size 40 Thermafil gutta-percha carriers and Roth's 801 elite sealer (Roth Dental Company, Chicago, IL, USA). Following the manufacturer's instructions, a thin layer of sealer was placed at the coronal orifice; subsequently the thermoplastisized gutta-percha was delivered into the canal. After the gutta-percha cooled, the excess gutta-percha and handles were removed using a heated DG-7.

Group 2 was obturated using lateral compaction. The process included first checking the size 45 master cone fitted with tugback. Sealer (Roth's 801) was then introduced into the canal with a paper point. The master apical cone's tip was dipped in sealer, then seated apically. Two fine–fine accessory cones were placed, then using a spreader measured 1 mm short of WL the accessory cones and master cone were compacted. Accessory cones were then incrementally placed until a spreader was unable to penetrate into the middle one-third of the canal. Cones were seared off with a DG-7 and no vertical compaction was performed.

Group 3 was obturated using warm vertical compaction. Pluggers were fitted without binding to ensure that they could be introduced predictably at specific lengths. A nonstandard cone was fitted 0.5 mm short of the WL. Sealer (Roth's 801) was then placed in the canal with the master cone. A heat carrier instrument was introduced to plasticize the gutta-percha, which was then compacted with the prefitted pluggers. After packing gutta-percha to within 4–5 mm of the apex, gutta-percha was backpacked until it was at the coronal orifice of the canal.

Group 4 was made up of the control teeth. Positive controls consisted of five teeth with patent apices without a gutta-percha filling. Negative controls consisted of five

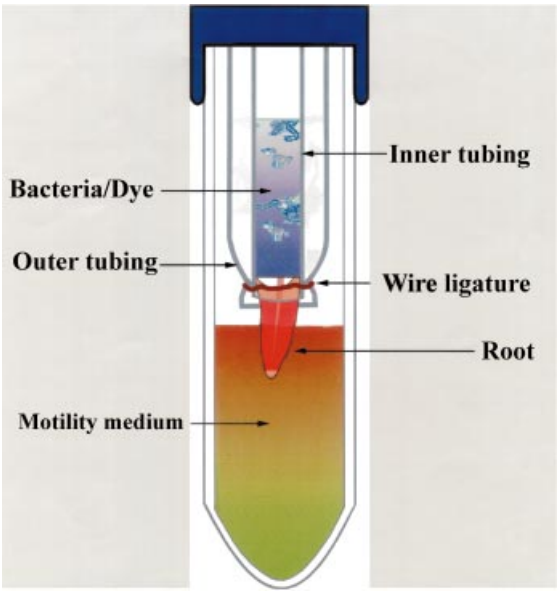

Figure 1 Leakage apparatus.

teeth with gutta-percha filling but with all orifices sealed with cyanoacrylate.

After obturation, the teeth were stored in 100% humidity for 30 days to ensure the sealer was set. Teeth were then assembled into the testing apparatus. The test apparatus consisted of two tube sizes. The larger diameter external tube was chosen to coincide with the circumference of the coronal portion of the test tooth. The external tube was affixed to the tooth with cyanoacrylate cement. The second tube, which fitted into the lumen of the first tube, was advanced to sit directly on the orifice of the canal. This second tube was used to deliver the bacteria/ink directly to the coronal canal orifice. After the construction of the delivery system, the remaining portion of the root was painted with two coats of nail varnish staying 1 mm short of the apex (Fig. 1).

After being assembled in the testing apparatus, teeth were stored at 100% humidity for an additional 90 days. At 88 days the teeth were sterilized with ethylene oxide gas (Khayat *et al.* 1993) and subsequently degassed prior to being placed in Motility Medium (MM). At the 90th day sterile test tubes were filled with 0.5 mL of MM media. After filling the test tubes with media the tooth/tube apparatus was filled with 0.25 mL of *Proteus vulgaris* in Trypticase Soy Broth (TSB). The tubes were agitated to ensure that the bacteria reached the orifice. The teeth were then placed into the media. The racks of teeth were oriented vertically, and placed into an incubator at 37 °C for 21 days. The reservoirs of MM in the test apparatus were inspected daily to check for turbidity as an indicator for the presence of bacterial leakage. The bacteria in the coronal reservoir were replenished every 6 days by aspirating and repipetting 0.25 mL of innoculum in TSB.

Following the bacterial challenge, the bacteria were removed from the internal tube by vacuum. The test apparatus were placed in new sterile tubes with fresh agar at the apex, thus retaining continuity between the bacterial group and India ink. India ink (0.25 mL) was placed in the coronal reservoir and shaken down to ensure dye reached the orifice of canals. The four groups were placed into an incubator. The teeth were evaluated daily to assess whether some teeth that had leaked previously had fractures or a poorly sealed testing device. India ink was in place for 21 days. After 21 days the testing apparatus was disassembled, nail varnish removed, and the teeth transferred to glass containers to be cleared. Clearing the teeth was achieved as follows: the teeth were placed in 70% nitric acid for 3 days, then dehydrated in sequential washes of 70, 80, 90, and 100% ethyl alcohol. After the final wash, the teeth were placed in methyl salicylate to clear.

After the teeth were cleared, each tooth was photographed with a stereomicroscope at 6× magnification. Photographs were examined by two independent examiners that were calibrated to the following scoring system:

1 = ink staining within the coronal one-third of the obturated canal space

2 = ink staining within the coronal and middle thirds of the obturated canal space

3 = ink staining within the coronal, middle and apical third of the obturated canal space.

Each examiner evaluated the teeth with a ruler (0.5 mm increments) and all scoring was done independently. Each scorer had no knowledge of leakage results from the bacterial leakage portion of the experiment.

The results from the bacterial leakage were analysed statistically using Cox's Proportional Hazards Regression Model ($P < 0.05$) for days to leakage as means of survival analysis. The results from the dye leakage were analysed statistically using Likelihood Ratio Chi^2 Test ($P < 0.05$).

Results

The leakage data are recorded in Tables 1–3 and Figs 2 and 3. Tables 1 and 2 and Fig. 2 record the leakage with bacteria. All teeth that leaked following exposure to the bacteria also leaked following challenge with India ink. All three groups had some teeth that leaked when exposed to bacteria. Table 3 and Fig. 3 record the data for India ink

Table 1 Incidence of bacterial leakage by filling technique

	No Leakage	Leakage
Vertical compaction	19	1
Lateral compaction	11	9
Thermafil	15	5

leakage. After completion of the India ink portion of the study, three teeth in the lateral compaction group were excluded due to vertical root fractures. Two more in the lateral compaction group were excluded due to leakage around the test apparatus. The India ink test also had teeth from each group that leaked beyond the coronal third. No teeth from any group in the India ink groupings had leakage into the apical one-third of the canal.

Comparing the bacterial leakage values, teeth obturated with lateral compaction and Thermafil were 11.56 and 5.39 times more likely to leak, respectively, than vertical compaction. Lateral compaction was 2.14 times more likely to leak than Thermafil. However, the only statistically significant value occurred when comparing vertical and lateral compaction ($P = 0.0204$). There was no statistically significant result between any of the obturating techniques when India ink was used to measure leakage.

The positive controls in the bacterial portion exhibited total microbial contamination. The positive controls in

Table 2 Day of bacterial leakage by filling technique

Day of leakage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Number of teeth with leakage																					
Vertical compaction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
Lateral compaction	0	0	0	0	6	7	7	7	7	7	7	7	8	8	8	8	9	9	9	9	9
Thermafil	0	0	0	0	0	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5

Table 3 Incidence of dye leakage by filling technique

	Coronal 1/3	Middle 1/3	Apical 1/3
Vertical compaction	17	3	0
Lateral compaction	10	5	0
Thermafil	17	3	0

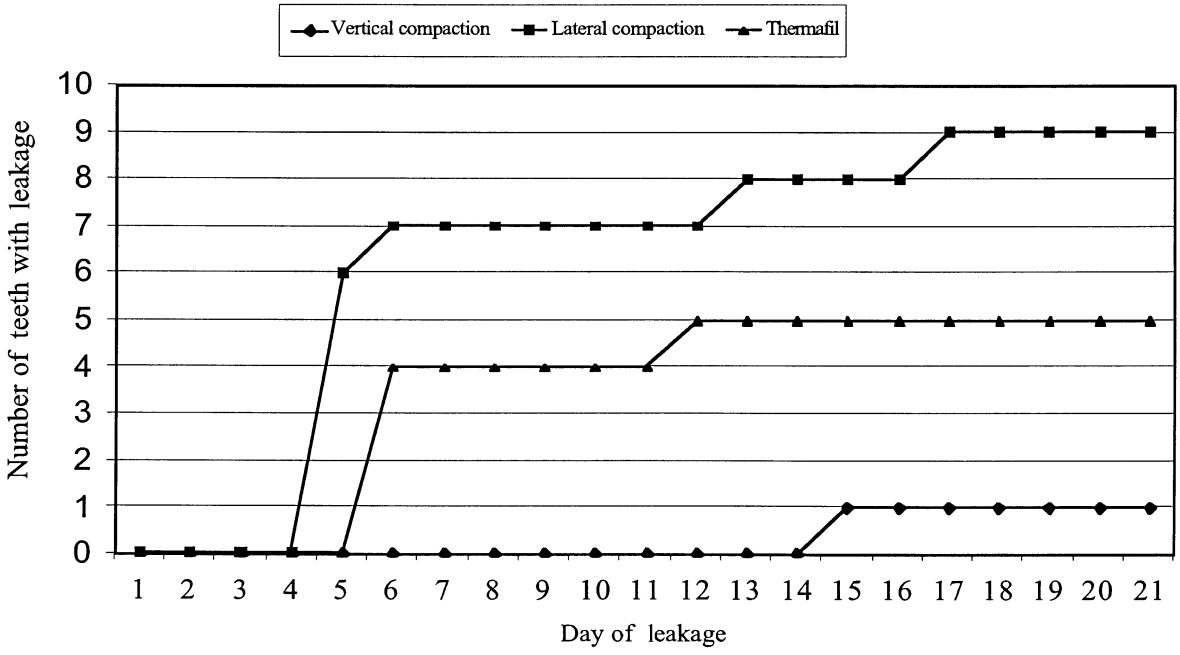

Figure 2 Bacterial leakage. The number of teeth with leakage and number of days to leak.

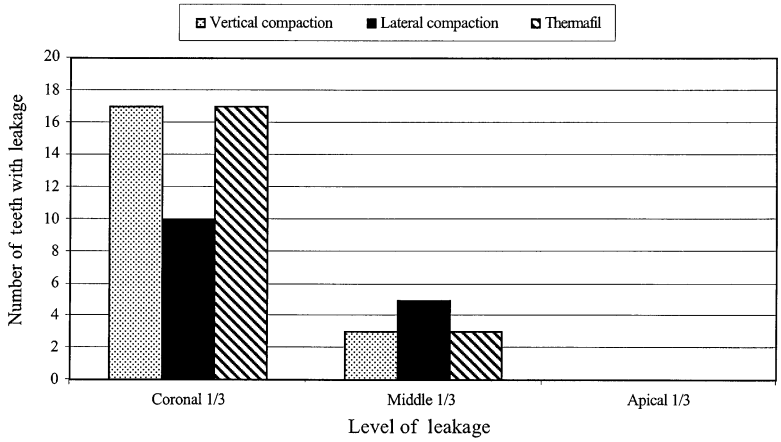

Figure 3 Dye leakage. The number of teeth with leakage and extent of leakage.

the dye portion exhibited total penetration of dye to the apex. The negative controls in the bacterial portion exhibited no microbial contamination. The controls in the dye portion exhibited no leakage into the canal space.

Discussion

One goal of this study was to attempt to correlate leakage data using both bacteria and India ink. No statistical correlation between the two methods was seen. However, an interesting observation was the fact that all teeth that exhibited bacterial leakage also leaked when challenged with India ink. Furthermore, the teeth that had bacterial leakage in the vertical compaction and Thermafil groups also displayed India ink leakage into the middle third. From this it would appear that if dye enters the middle third of the canal then there is a greater chance of leakage of bacteria.

The results showed that when challenged with bacteria the vertical compaction technique exhibited less leakage than lateral compaction. Although not statistically significant, Thermafil obturation had numerically less leakage than lateral compaction, but more than vertical. Furthermore, both vertical compaction and Thermafil obturation techniques had delayed bacterial leakage, although the clinical significance of this is unknown. In this study the laterally compacted gutta-percha cones were simply seared off with no vertical compaction. Vertical compaction of gutta-percha in the coronal third is commonly advocated when lateral compaction technique is used clinically; not doing this may lead to early bacterial leakage.

Proteus vulgaris was chosen for its comparable size to endodontic pathogens, ease of growth and viability, and it has been used effectively in previous studies (Goldman *et al.* 1980, Williams & Goldman 1985, Behrend *et al.* 1996). This organism's comparable size to pathogens provides a biologically relevant model. Additionally, the ease it affords in identifying contamination and species identification is useful in experimental management.

In both tests the teeth obturated using lateral compaction produced more leakage. This may have been due to any of a number of factors. Following compaction of the gutta-percha into the coronal one-third of the canal space it was seared off with a heated instrument without vertical compaction. Baumgardner *et al.* (1995) found that using lateral compaction followed by vertical forces decreased leakage with carbon dye. Simply searing off the ends leaves a nonhomogeneous grouping of accessory cones. This lack of solid core of material may have created a greater number of voids between cones in the canal. Another possible variable is that there may have been a greater amount of sealer used that may have contracted or washed out with the addition of the liquid media. Greene *et al.* (1990) compared obturation techniques and found that groups with the least leakage had very little sealer.

The teeth obturated using Thermafil had a greater tendency for material extrusion beyond the apex, similar to previous reports by Gutmann (1993) and Dummer *et al.* (1993). In some specimens the carrier did not stay centred and gutta-percha was stripped from the carrier in the apical portion of the canal. However, the cleared teeth also showed that the thermoplasticized gutta-percha had entered lateral canals. The teeth obturated using the vertical compaction technique exhibited a dense fill throughout the canal space. In this experiment, the results from the bacterial leakage gave evidence that under these circumstances vertical compaction was superior to lateral compaction.

In this study 16% of the specimens displayed bacterial leakage. Three previous studies had total bacterial

leakage of 7% (Wu *et al.* 1993), 50% (Behrend *et al.* 1996), and 85% (Torabinejad *et al.* 1990) of the specimens. This project closely resembled that of Behrend *et al.* (1996) except for the period of time from obturation to testing. Torabinejad *et al.* (1990) used a longer exposure period of 78 days, which could possibly account for the increased leakage that they observed. Wu *et al.* (1993) varied from this and other studies by using a horizontal test apparatus, which may cause a variation in results. A further reason for all these variations is the possible problem with aseptic technique or the species of bacteria used.

Although the results were not statistically significant, the vertical and Thermafil obturation techniques exhibited a tendency to leak less to dye than lateral compaction. This finding is in opposition to previous studies (Lares & ElDeeb 1990, Baumgardner *et al.* 1995) which found lateral compaction to leak less than Thermafil. However, it corroborates the findings that Thermafil exhibits less leakage (Gencoglu *et al.* 1993, Gutmann 1993). The lack of significant difference when comparing vertical compaction to Thermafil obturation agrees with a study by Bhambhani & Sprechman (1994).

The data comparing the ink scores and bacterial leakage results were not statistically significant. Therefore, in this experiment if dye penetrated into the middle third of the root canal system there was a greater probability of bacterial leakage. After reviewing several leakage studies and the data obtained in this study, all leakage studies must be viewed with suspicion. Even when investigators conduct their studies with the greatest of care, variability in results occurs. In assessing any leakage study it is difficult to compare the results with other studies, or to determine how the variables from each influence the results.

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