Aust Endod J 2007; 33: 18–22

ORIGINAL RESEARCH

Leakage evaluation of three different root canal obturation techniques using electrochemical evaluation and dye penetration evaluation methods

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Keywords:
apical leakage, dye penetration, electrochemical evaluation, root canal obturation.

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doi: 10.1111/j.1747-4477.2007.00050.x

Abstract

The aim of this study was to compare the apical sealing ability of three different obturation techniques using an electrochemical evaluation and evaluating dye penetration. One hundred and thirty-two maxillary anterior teeth were randomly divided into six groups. There were 20 teeth in each group. The teeth were obturated as follows: Groups 1 and 4 with Thermafil, Groups 2 and 5 with System B, and Groups 3 and 6 with cold lateral condensation (CLC). The apical leakage in these groups was evaluated using an electrochemical method for Groups 1, 2, 3 and a dye penetration method for Groups 4, 5 and 6. In both methods, the lowest mean leakage values were observed for Thermafil and the highest were observed for the CLC groups. The difference between Thermafil and CLC was statistically significant ($P < 0.05$). In both groups, System B fillings showed moderate leakage and the difference was not significant with Thermafil and CLC groups.

Introduction

The goals of non-surgical root canal treatment are to clean the root canal thoroughly, to remove bacteria and debris, to shape the canal and fill this space completely. Obturation after cleaning and shaping provides a seal that prevents reinfection of the canal and subsequent leakage into the periradicular tissues (1). Ingle and Bakland suggested that the most common cause of endodontic failures (60%) was incomplete obturation of the root canal (2). Attempts were made to develop filling materials and techniques to increase the quality of the canal seal.

Although numerous materials have been used for obturation, the most commonly used material is still gutta-percha (3). Several techniques using gutta-percha have been used in an attempt to achieve a homogenous well-sealing filling. The cold lateral condensation (CLC) method is still one of the most frequently used techniques (4–6). In recent years, a number of plasticised gutta-percha techniques have been introduced that have purported to seal the root canal better (5). Obturation systems have been developed using heat-softened gutta-percha delivered via injection or with a carrier which delivers heat to cold gutta-percha cones cemented in the canal (7).

Numerous studies have evaluated the apical sealing ability of root canal fillings using methods such as dye leakage (8), electrochemical techniques (9,10), bacterial penetration measurement (11), radioisotope techniques (12) and fluid filtration (13) techniques.

Although there are many studies of the apical sealing abilities of different root obturation techniques, studies that compare leakage evaluation methods are less common and their results conflict with each other.

The aims of this study were to compare the apical sealing ability of Thermafil, System B and CLC of gutta-percha using electrochemical and dye penetration methods and to evaluate whether there was a correlation between the two test methods.

Materials and methods

One hundred and thirty-two maxillary anterior teeth that were extracted for periodontal and prosthetic reasons were collected for this study. All preparation and obturation procedures were carried out by one operator. The crowns were removed at the cemento-enamel junction with a diamond disc under water coolant. Following pulp extirpation, a size 15 K-file (Dentsply, Maillefer, Ballaigues) was inserted into the canal until it was seen at the apical foramen. The working length was determined to be 1 mm short of that position. The root canals were instrumented using step-back technique to ISO size 40 master apical file within 1 mm of the apex. Two millilitres of 5.25% NaOCl solution was used for irrigation between each file size.

After the completion of the preparation procedure, the teeth were randomly divided into six groups consisting of 20 samples in each group. The remaining 12 teeth were used for negative and positive control groups. The canals were dried using paper points (Meta, Meta Dental Co., Seoul, South Korea). Diaket (ESPE, Seefeld, Germany) was used as the sealer cement and the root canals were obturated as follows:

Groups 1 and 4: CLC using gutta-percha (Diadent ML. 029, Korea)

Groups 2 and 5: continuous wave of condensation technique (System B Heat Source, Analytic Technology, Redmond, WA, USA)

Groups 3 and 6: Thermafil (Dentsply, Maillefer, USA)

After the obturation procedures were completed, all roots were stored at 100% humidity for 24 h in order to allow complete setting of the sealer cement. The apical sealing ability of the obturated canals was then assessed using electrochemical and linear dye penetration methods.

Electrochemical method

The apical leakage of 60 teeth in Groups 1, 2 and 3 was evaluated using an electrochemical method. The method used for the electrochemical leakage test was based on the method described by Jacobson and von Fraunhofer (9). Approximately two-thirds of the gutta-percha was removed from each tooth root. Copper wires were used as anodes and inserted into each root canal until they contacted the gutta-percha. The contact of the wires to the gutta-percha was confirmed by radiographs. The teeth were attached to the copper electrode by using sticky wax. Then, all root surfaces, except the apical 2 mm, were covered with two coats of nail varnish. Six teeth were biomechanically prepared and not obturated. The root surfaces of three teeth were entirely covered with two coats of nail varnish and served as negative controls. The other three teeth were covered with two coats of nail varnish except the apical 2 mm and served as positive controls.

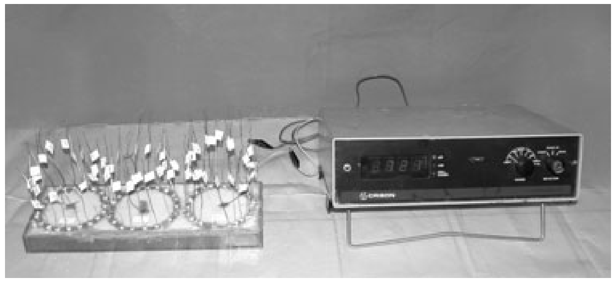

Figure 1 Apical leakage test system for the electrochemical method.

The coronal part of each tooth was passed through a hole in a plastic plate. The apical part of the root protruding from the plate was calibrated to a 10 mm length. Each tooth was fixed in place using sticky wax. Platinum wires were used as cathodes and passed through the plate and fixed in place using sticky wax.

A glass container ($10 \times 30 \times 2$ cm) was used to hold the electrolyte solution of 0.01 mol/L NaCl. The plastic plate was placed on the glass container so that the last 5 mm of each root was plunged into the solution.

The system was connected to a conductivity meter (CDM 750 WPA, Cambridge, UK) and the measurements were taken at baseline, 1 day, 1 week, 2 weeks, 3 weeks and 4 weeks (Fig. 1). The conductivity was recorded in microsiemens (μs) (Conductivity (Siemens) = 1/Resistance(Ohm)).

Linear dye penetration method

The apical sealing ability of Groups 4, 5 and 6 was evaluated using a linear dye penetration method. All root surfaces except the apical 2 mm were covered with two coats of nail varnish. Positive and negative control groups were arranged the same as in the electrochemical method. The teeth were then immersed in India ink (Pelikan, Hannover, Germany) for 7 days. After removal from the dye, the teeth were washed under running tap water and stored in acetone for 2 h to clean off the excess dye.

A demineralisation and clearing process was completed as described by Robertson *et al.* (14). The teeth were demineralised in 5 % nitric acid solution and dehydrated in 80%, 90% and absolute alcohol. The clearing process was completed by immersing the teeth in methyl salicylate solution.

The extent of dye penetration was measured by two observers using a stereomicroscope (Leica MZ6, Germany) in millimetres. The measurements were made from the most apical extent of gutta-percha to the most coronal extent of dye penetration. The data were analysed statistically using ANOVA and Bonferroni tests.

Table 1 Mean leakage values for the electrochemical method (µs) ([Xmacr] ± SD)

	Root canal obturation technique			Control groups	
Time period	Thermafil	System B	CLC	Control (–)	Control (+)
Beginning	1.64 ± 0.60	2.41 ± 1.21	3.10 ± 2.48	0.29 ± 0.15	21.92 ± 1.60
1 day	1.77 ± 0.84	3.05 ± 1.62	5.07 ± 5.43	0.34 ± 0.12	29.43 ± 11.03
1 week	2.23 ± 1.23	4.34 ± 3.15	7.76 ± 8.92	0.40 ± 0.12	35.87 ± 10.23
2 weeks	2.84 ± 1.75	4.69 ± 3.33	9.58 ± 10.56	0.43 ± 0.11	38.12 ± 9.45
3 weeks	3.03 ± 2.04	4.87 ± 3.39	10.26 ± 11.34	0.44 ± 0.10	39.67 ± 10.10
4 weeks	3.25 ± 2.47	5.18 ± 3.68	11.22 ± 12.87	0.50 ± 0.11	41.64 ± 10.12

CLC, cold lateral condensation; SD, standard deviation.

Results

Electrochemical method

The data were processed using logarithms because it did not show normal distribution and ANOVA and Bonferroni tests were used.

The mean electrochemical leakage values in all time periods are shown in Table 1. While the lowest leakage values at all time periods were observed in the Thermafil group, the highest values were observed in the CLC group. The difference between these two groups was statistically significant ($P < 0.05$). The System B group showed moderate leakage values and the difference was not significant compared with either the Thermafil or the CLC group. For all groups, apical leakage values increased over time (Fig. 2).

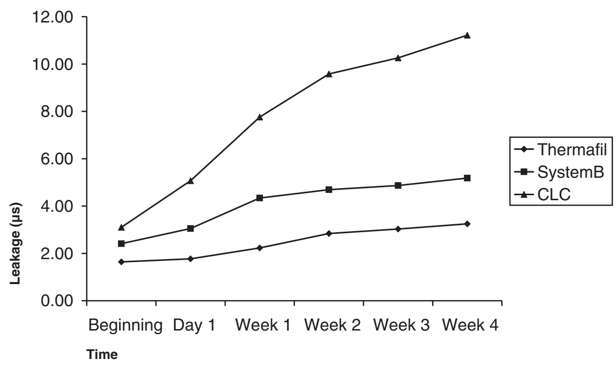

Figure 2 Mean leakage values over the 30-day time period for the electrochemical method. CLC, cold lateral condensation.

Linear dye penetration method

The mean dye penetration values for Thermafil, System B and CLC groups were 1.45 ± 0.94 mm, 1.86 ± 0.87 mm and 2.38 ± 0.72 mm, respectively. The difference between Thermafil and CLC groups was statistically significant ($P < 0.05$). The System B group showed moderate leakage and the difference from both the Thermafil and CLC groups was not significant.

Discussion

In the present study, the apical sealing abilities of Thermafil, System B and CLC techniques were compared using electrochemical and linear dye penetration methods. The lowest mean leakage values were observed for Thermafil and the highest mean leakage values were observed for CLC groups in both methods.

Consistent with our results, Beatty *et al.* (15), Dummer *et al.* (16) and Gencoglu *et al.* (17) all reported that Thermafil resulted in less leakage than did the CLC technique. Kytridou *et al.* compared the leakage of Thermafil and System B and found no significant difference between the two techniques at 24 h and 10 days, but reported that the leakage of the Thermafil group was significantly higher at 67 days (18). However, the authors stated that the samples of the 67-day group were kept in Hank's Balanced Salt Solution and this could be the reason for the increased leakage. More recently, Boussetta *et al.* evaluated the apical microleakage following canal fillings with a coat carrier system (Herofill Soft-Core System) and found that the coat carrier system created a better apical seal than lateral condensation (19).

Dye penetration is commonly used to evaluate leakage because it is simple and cheap (20). However, this method has been criticised for providing semi-quantitative results and yielding a high level of variation (21). It has also been suggested that the method should employ a vacuum. The electrochemical method provides quantitative results and measurements that can be made at different time periods (20).

Delivanis and Chapman compared electrochemical, dye penetration and radioisotope methods and found a correlation at the two ends of the electric score ranges (22). Martell and Chandler compared three root-end restorative materials using electrochemical and dye penetration methods and found a correlation between these two methods (23). However, Matloff *et al.* reported no correlation between a dye penetration and a radioisotope method (12). Similarly, a study by Barthell *et al.* showed no correlation between dye penetration and bacterial leakage test methods (24). Moreover, Pommel *et al.* found no correlation between dye penetration, electrochemical and fluid filtration methods (25). According to Camps and Pashley, the reason of this lack of correlation is related to the physical mechanisms involved in these methods (26).

Pommel *et al.* stated that the lack of correlation among the leakage evaluation methods is related to the difference in criteria (25). The dye penetration method is a passive method depending on capillary fluid movement. The electrochemical method is based on the diffusion of ions and depends on electrical laws. However, some studies that compare the apical sealing ability of root canal obturation techniques employing different test methods use the same samples for each of the tests. It may be inappropriate to use the same samples for different test methods in sequence. Amditis *et al.* evaluated apical leakage with an electrochemical and a dye penetration method (27). They reported that the conditions of the electrochemical experiment could cause dissolution of some of the sealer and subsequent linear dye penetration occurred along the spaces created by the lost sealer. They proposed that electrochemical leakage testing should not precede the dye penetration test. Pathomvanich and Edmunds compared four different leakage evaluation techniques performing each technique on different specimens and reported that there was no significant difference between the four microleakage techniques (28). Therefore, different test groups were used for each of the leakage test methods in this study.

In our study, Diaket was used as root canal sealer because of its low solubility. Schafer and Zandbiglari compared the solubility of root canal sealers in water and artificial saliva and reported that Diaket showed less than 3% of weight loss (29). However, the material has a short setting time (6 min) and this could be considered as a disadvantage that may have had an effect on results in the CLC group.

Under the conditions of this study, the thermoplastic gutta-percha techniques (Thermafil and System B) created a better apical seal than CLC. The dye penetration and electrochemical techniques ranked the three obturation techniques in the same order and gave similar results.

Acknowledgement

This study was supported by Ondokuz Mayis University Committee of Research Projects (DHF-028).

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