An *in vitro* study of apical and coronal microleakage of laterally condensed gutta percha with Ketac-Endo and AH-26

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Abstract

The purpose of this *in vitro* study was to compare both apical and coronal dye penetration when Ketac-Endo and AH-26 sealers were used with laterally condensed gutta percha. Crowns were removed from 28 teeth and the root canals were biomechanically prepared. The teeth were divided into two groups of 12 teeth each and a control group of 4 teeth. Root canals in the two experimental groups were filled with laterally condensed gutta percha and either Ketac-Endo or AH-26 sealer. The Ketac-Endo group had the coronal 3 mm of gutta percha and sealer removed and the resultant cavity was filled with Ketac-Endo alone. After the sealers had set, the root surfaces were coated with nail varnish except at the apex and at the coronal end. Positive controls had no root fillings and were coated with nail varnish in the same manner while the negative controls were sealed apically and coronally with Cavit prior to sealing the entire external root surface with nail varnish. Specimens were placed in 2% methylene blue dye in a vacuum of 660 mm of mercury for five minutes and then left immersed for a further two days. The roots were vertically sectioned to determine the following mean levels of dye penetration: Ketac-Endo, 1.08 mm apically and 6.29 mm coronally; AH-26, 0.75 mm apically and 6.67 mm coronally. Positive controls had total leakage and negative controls had no leakage. This study demonstrated that the apical and coronal seals obtained with Ketac-Endo and AH-26 were not significantly different although the apical seal obtained with each material was significantly better than the corresponding coronal seal.

Key words: AH-26, apical leakage, coronal leakage, Ketac-Endo.

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Introduction

One of the main aims of endodontic treatment is to fill the prepared root canal space as well as any lateral canals, fins and cul-de-sacs that are present with a biocompatible filling material in order to obtain a seal as close as possible to the cemento-dentinal junction. Work reported by Dow and Ingle[1] and Ingle *et al.*,[2] the latter in the so-called 'Washington study', suggested that apical percolation of periapical exudate into an incompletely filled root canal accounted for approximately 60 per cent of endodontic failures. As a result of these findings, many changes in the techniques of biomechanical preparation and root canal obturation have been made on the basis of apical leakage studies.[3] However, despite these changes, it appears that current materials and techniques still fail to predictably provide a complete seal of the root canal system.

A recent study[4] comparing apical leakage in extracted human teeth that had been obturated by orthograde root canal fillings reported that *in vitro* linear and volumetric measurements of apical dye leakage are poor indicators of the success or failure of clinical endodontic treatment. However, despite this poor correlation, *in vitro* studies of apical microleakage can still be useful. The results of these tests should be regarded as showing a theoretical maximum amount of leakage which may or may not occur *in vivo*[5] and, as such, they are probably good indicators of the future potential for failure. Theoretically these tests could also provide a basis for comparison of sealers and techniques[6] but, unfortunately, there has been no standardization of testing methods and most studies have had inadequate controls to test the experimental design.[4,7-9]

The results of Oliver's study[4] and other recent work[5,10-12] suggest that apical leakage may not be the most important factor leading to the failure of endodontic treatment. Several other studies have used *in vitro* bacterial and dye leakage tests to investigate the concept of coronal microleakage of bacteria into obturated root canals and it is now widely accepted by endodontists that coronal leakage is far more likely to be the major determinant of clinical success or failure.[10-12] Therefore, it now appears that tests concerning the sealing ability of root canal sealers and techniques should be designed to test both the apical and the coronal seals.

Glass polyalkenoate (glass ionomer) cements were first developed in the late 1960s and further developments have resulted in considerable improvements in their properties and handling characteristics. These improvements have led to more widespread acceptance and use by the dental profession. Glass polyalkenoate cements are often used in dentistry because of their long term adhesion to the hydroxyapatite structure of enamel and dentine. It is this property that has prompted the development and introduction of a root canal sealer based on glass polyalkenoate cement, which is marketed as Ketac-Endo.‡ The manufacturer of this material claims the following favourable properties:

(a) long term biocompatibility

(b) durable reinforcement for endodontically treated, fracture prone teeth

(c) adhesion to dentine, thus preventing bacteria penetrating the sealer/dentine junction

(d) improved radiopacity, working and setting times compared with other glass polyalkenoate cements

(e) optimum flow characteristics; and

(f) it does not shrink in the moist medium of the root canal.

However, few of these claims have been substantiated by independent research and reports in the literature.

Ray and Seltzer[13] reported that the physical properties and ease of manipulation of various experimental samples of glass ionomer root canal sealers were equal, or superior, to those of a zinc oxide-eugenol based sealer made according to Grossman's formulation. Eight different formulations of potential glass ionomer cements were tested in this study but the manufacturer has not advised which one of these samples, if any, was finally adopted as Ketac-Endo. Trope and Ray[14] reported that the obturation of canals in conjunction with Ketac-Endo sealer significantly 'strengthened the roots' when compared with roots instrumented but not obturated and when compared with roots obturated with gutta percha and Roth's 801 Sealer§ (a zinc oxide-eugenol based sealer). This *in vitro* study appeared to have been performed on dry tooth roots which may have affected the bond between Ketac-Endo and the root dentine so it is impossible to relate these findings to normal clinical situations.

The antibacterial action of Ketac-Endo has been reported to be less than that of Roth's 801 Sealer over a 48 hour period in one study[15] and another study[16] showed no antibacterial action after 24 hours although there was some inhibition of bacterial growth after 7 days. Overall, in this latter study, Ketac-Endo was significantly less effective than Sealapex‖ (a calcium hydroxide based sealer), Pulp Canal Sealer EWT‖ (zinc oxide-eugenol base) and AH-26¶ (resin based). AH-26 had the best antibacterial action of these sealers.[16]

The biocompatibility of Ketac-Endo has been compared with that of Tubliseal‖ (a zinc oxide-eugenol base) in an implantation study in rats.[17] The Ketac-Endo caused a mild inflammatory response after five days and this gradually subsided over the 120 days of the study. However, the Tubliseal caused a severe inflammatory reaction which was sustained throughout the entire 120 days examined, presumably due to the constant realease of eugenol from this type of material.[18]

Apical leakage testing has been carried out by several groups using different methodologies which makes any comparison of their results difficult. In one passive dye penetration study,[19] Ketac-Endo leaked significantly more than Roth's 801 Sealer and AH-26 when used with gutta percha and the lateral condensation technique. A further interesting finding of this study is that 28 of the 30 Ketac-Endo specimens had dye penetration throughout the entire canal system even though a vacuum testing method was not used to remove entrapped air, as advocated by several authors.[7-9] Another passive dye penetration study[6] reported that Ketac-Endo leaked significantly more than Roth's 801 Sealer and Tubliseal. However, this study had inadequate positive control specimens that could not demonstrate total dye penetration of voids since their canals were filled with gutta percha (but no sealer) – a true positive control should have an empty canal and should show dye penetration throughout the entire length of the canal. In addition, a vacuum technique was not used to eliminate the effects of any entrapped air within the specimens.

One study[20] which did use a vacuum method to test apical leakage showed no significant difference between Ketac-Endo and Roth's Sealer, although

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§Roth Drug Co., Chicago, Il, USA.
‖Kerr/Sybron, Romulus, MI, USA.
¶DeTrey Fréres, Zurich, Switzerland.

there was less leakage with Roth's Sealer. Another study,[21] which used a fluid filtration method to remove entrapped air from the experimental system, demonstrated that Ketac-Endo leaked significantly more than AH-26. In the latter study,[21] the shear bond strengths were also tested and Ketac-Endo had adhesive failure in 85 per cent of specimens compared with 15 per cent of the AH-26 teeth. There was also a significant difference between the mean adhesive strength of 0.4±0.3 MPa for Ketac-Endo and 1.6±1.0 MPa for AH-26.

The aim of this study was to compare the apical and coronal seal obtained with laterally condensed gutta percha root canal fillings when used with Ketac-Endo and AH-26 utilizing methylene blue dye and a vacuum technique.

Materials and methods

Twenty-eight single-rooted human maxillary central and lateral incisor teeth with a single root canal were selected for use in this study. Each specimen was examined with a stereomicroscope (x12 magnification) and rejected from the study if there were any previously undetected root fractures or evidence of previous apical surgery. Pre-operative radiographs were taken from both the mesiodistal and faciolingual directions and any teeth with previous root canal fillings, open apices, bifurcating or ribbon-shaped canals or root curvatures greater than five degrees were also excluded from the study. The selected teeth were stored in a 1% sodium hypochlorite (NaOCl) solution for two days to remove any organic debris and thereafter they were stored in normal saline solution.

The crowns were removed from the teeth with a low speed diamond disc at the cemento-enamel junction and any residual pulp tissue was removed from the root canals with a barbed broach. Each canal was negotiated with a size 15 Hedström file until the tip of the file was seen at the apical foramen and each canal's working length was calculated to be 0.5 mm less than the length obtained with this initial file. Hedström files were then used sequentially to clean and shape each canal until a size 45 file had reached the working length. The canal was continuously flared during the entire canal preparation process in order to produce a tapered canal form.

The canals were irrigated copiously with a 15% solution of EDTAC (EDTA with cetrimide) prior to filing and in between each file size from size 15 to 35. A 1% solution of NaOCl was used after file sizes 35 and 40. Then the EDTAC solution was re-introduced into the canal for the final file (size 45) and it was also used as a final flush (according to Abbott *et al.*[22]). After the instrumentation had been completed, a size 10 file was passed one millimetre through the

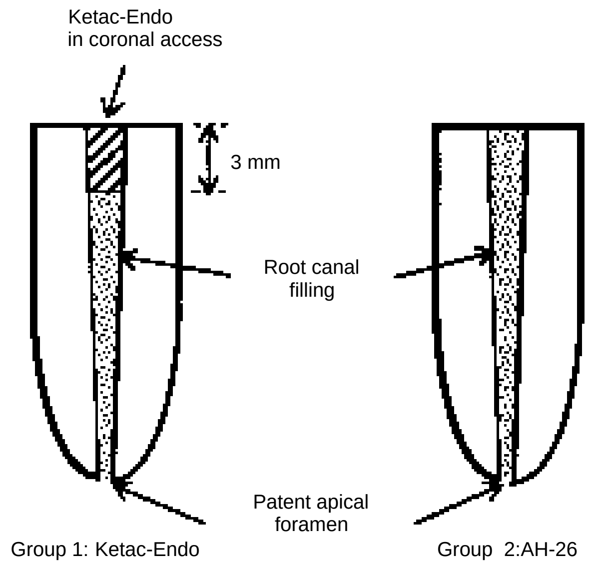

Fig. 1.–Diagrammatic representation of prepared teeth in Groups 1 and 2.

apical foramen to ensure that it was patent to allow dye penetration.

On completion of the canal preparation, the teeth were randomly divided into two experimental groups of 12 teeth each and a control group of four teeth. The root canals of the control teeth were left empty and the experimental teeth had the root canals filled with a sealer and gutta percha points using the lateral condensation technique (as outlined below) while the specimens were held in saline-moistened gauze. The sealers used were: Group 1, Ketac-Endo; and Group 2, AH-26.

The root canals of the teeth in Groups 1 and 2 were dried with paper points and standardized size 45 gutta percha points were selected as master points. Each point was tested visually and radiographically in the root canal to ensure placement to the full working length. The sealers were mixed according to the manufacturers' directions and were introduced into the canals using a spiral root filler which was kept 2 mm short of the working length. This process was repeated until sealer was observed to be flush with the sectioned coronal surface of the root. The master gutta percha point was then coated with sealer and inserted into the canal to the full working length. A D11T spreader was introduced into the canal to within 1 mm of the working length and lateral condensation utilizing non-standardized fine-fine gutta percha accessory points was performed until the entire canal was filled. Excess gutta percha was removed with a heated instrument and the coronal one-third of the root filling was condensed further in a vertical direction. Specimens in Group 1 then had the coronal 3 mm of gutta percha removed with heated pluggers and the resultant coronal cavity was sealed with the remaining mixture

Table 1. Mean linear dye penetration (values expressed as millimetres)

Group	Sealer	No of teeth	Apical dye penetration Mean±SD	Apical dye penetration Range	Coronal dye penetration Mean±SD	Coronal dye penetration Range
1	Ketac-Endo	12	1.08±0.85	0-3.0	6.29±1.85	3.5-9.0
2	AH-26	12	0.75±1.16	0-3.5	6.67±3.01	2.0-11.0
3	Controls:					
	– Positive	2	Total		Total	
	– Negative	2	None		None	

[Values connected by vertical lines were not significantly different (p>0.05, Student's *t* test).
|—| Values connected by horizontal lines were significantly different (p<0.05, Student's *t* test).

of Ketac-Endo sealer (Fig. 1). The teeth from Groups 1 and 2 were then kept in 100 per cent humidity for 72 hours to allow complete setting of the sealers.

The tooth roots were then coated with two layers of coloured nail varnish except for the sectioned surface of the coronal root face and the apical 2 mm of the root. The nail varnish was allowed to dry thoroughly before applying the second coat. At this stage the control group was sub-divided into two groups – the positive and negative control groups. The two positive control specimens were coated with nail varnish externally in the same manner as the experimental tooth roots to demonstrate that the method of leakage testing would completely disclose the prepared, but empty, root canal with the disclosing dye. The two negative control specimens were placed in a vacuum flask containing distilled water and a partial vacuun of 660 mm of mercury was applied for 5 minutes. The specimens were then retrieved, dried externally and the coronal and apical ends were sealed with Cavit‡ prior to two coats of nail varnish being applied to the entire external surface of the roots. The negative control teeth were used to demonstrate the ability of the nail varnish to seal the external lateral root surfaces against dye penetration.

The experimental and control tooth roots were each placed in numbered containers which were filled to identical levels with 2% methylene blue dye and then placed in a vacuum flask. A vacuum of 660 mm of mercury was applied and maintained for 5 minutes. The containers were then removed from the vacuum flask and the tooth roots were left immersed in the dye for a further two days. Each tooth root was then removed from its container, washed under running tap water for one minute and dried overnight in an incubator at 36°C.

The tooth roots were grooved bucally and lingually with a diamond disc, ensuring that the root canal filling was not penetrated, and then they were split into halves by levering with a plaster knife. The linear extent of dye penetration from the apical and coronal root ends was measured using a stereo-microscope (x12 magnification) and a metric rule with 0.5 mm gradations.

The results were analysed statistically using the Student's *t* test to determine whether there were any statistically significant differences between and amongst the experimental groups at the 5 per cent level of significance (p<0.05).

Results

The two positive control specimens demonstrated total dye penetration of the root canal systems whilst the two negative control specimens showed no dye penetration into the roots.

Measurements of the maximum apical and coronal linear dye penetration for each of the experimental groups are summarized in Table 1. All of the experimental groups demonstrated coronal leakage but there was no apical leakage in three of the Ketac-Endo specimens and in six of the AH-26 specimens. There were no specimens that had complete dye penetration between the coronal and apical ends of the canal.

The Student's *t* test was used to determine whether there were significant differences in apical and coronal leakage values between Ketac-Endo and AH-26, and between apical and coronal leakage within each experimental group at the 5 per cent level of significance (p<0.05). Although the AH-26 group showed less apical leakage than the Ketac-Endo group, and the Ketac-Endo group showed less coronal leakage than the AH-26 group, neither of these differences were statistically significant (p=0.43 and p=0.72, respectively). However, there was a highly significant statistical difference between apical and coronal leakage for both the Ketac-Endo group (p<0.0001) and the AH-26 group (p<0.0001).

Discussion

Many previous dye penetration studies have not had adequate positive and negative controls to test the experimental system being used which has led to the reporting of results that cannot be relied upon for accuracy or clinical relevance.[4] As a result, these studies cannot be used for comparisons with other studies and any clinical recommendations based on such results must be viewed with caution.[16-18] In this study, the experimental system was tested by using both positive and negative control specimens in a

Fig. 2.–Routes of dye penetration in a sectioned specimen from Group 1 (Ketac-Endo). Dye penetration can be seen along the gutta percha:Ketac-Endo interface in the mid-root portion of the root canal (larger arrow) and at the dentine:Ketac-Endo interface in the coronal 3 mm portion (smaller arrow).

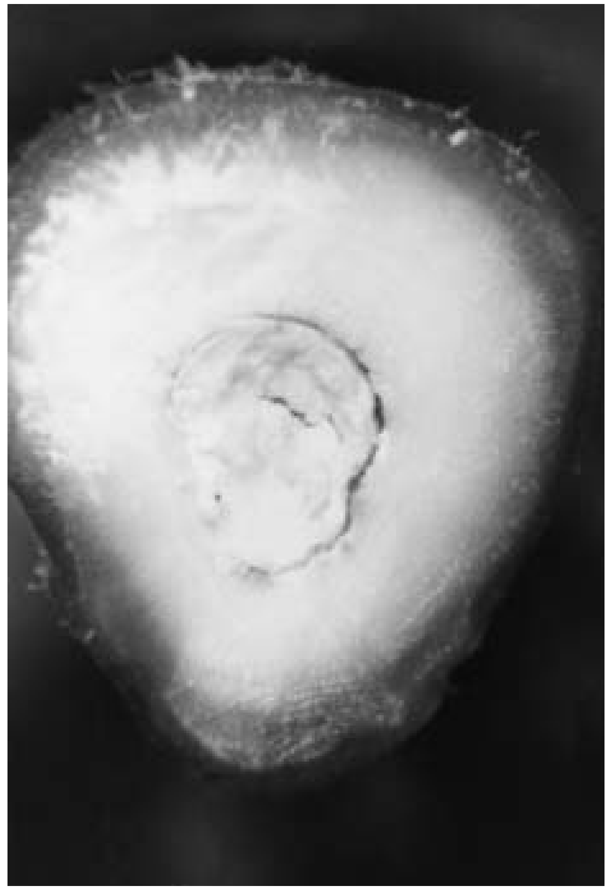

Fig. 3.–A typical specimen from Group 1 (Ketac-Endo) showing shrinkage of the Ketac-Endo material in the coronal 3 mm of the canal.

similar manner to the experimental groups. The two positive control specimens demonstrated total dye penetration of the root canal which indicated that the vacuum method of leakage testing was a suitable and reliable method for disclosing all of the unfilled voids within the root canal system. The two negative control specimens showed no dye penetration at all which indicated that using two layers of nail varnish was an effective means of preventing dye penetration. This is important as it demonstrated that any dye noted within the root canal of the experimental teeth must have penetrated through the uncovered apical and/or coronal end and it could not have entered via lateral canals or other openings on the surface of the tooth roots as these were sealed with the nail varnish.

The results of this dye penetration study showed that Ketac-Endo sealed the root canals as well as AH-26 at both the coronal and apical ends under the experimental conditions used. However, neither sealer used in conjunction with laterally condensed gutta percha provided a statistically better coronal seal compared with the seal obtained at the apical foramen. This suggests that even with vertical condensation of the coronal gutta percha, the apical foramen of a root canal can be sealed more effectively than the coronal orifice. A possible explanation of this phenomenon may be that sealer is continually being removed each time the spreader is withdrawn from the canal which results in less sealer being left at the gutta percha:dentine interface in the coronal portion of the canal. Another explanation may be that the tapered shape of the canal provides a more effective matrix in the apical portion against which the gutta percha and sealer can be condensed.

Ketac-Endo has been reported to bond chemically to dentine.[13] Therefore, it was surprising to find that when the coronal 3 mm of gutta percha was removed from the Group 1 specimens which were subsequently filled with Ketac-Endo, the material failed to prevent microleakage. In fact, the quality of its seal was no different from that achieved with the more conventional vertical condensation technique used coronally in Group 2. The reason for this became evident when the routes of dye penetration, or leakage, were examined under the stereomicroscope.

The possible routes of dye penetration through filled root canals are:

Fig. 4.–Routes of dye penetration in a sectioned specimen from Group 2 (AH-26). The gutta percha root filling has been covered by a layer of AH-26 and the dye penetrated between the sealer and the dentine.

(a) between the sealer and dentine

(b) between the core material (gutta percha) and sealer

(c) through the core material or

(d) through the sealer.

Stereomicroscope examination of the sectioned specimens showed that leakage was via the first two routes for the Ketac-Endo specimens. In the coronal 3 mm the dye leaked between the solid mass of Ketac-Endo and the dentine which was similar to that reported by De Gee *et al*.[21] However, apical to this level, the leakage occurred between the sealer and the gutta percha (Fig. 2). The leakage within the coronal 3 mm appeared to be due to shrinkage of the Ketac-Endo which occurred during the setting reaction (Fig. 3) despite being stored in 100 per cent humidity which is in contrast to the claims of the manufacturer. Examination of the remainder of the obturated specimens demonstrated bonding of Ketac-Endo to the radicular dentine wall with leakage between the sealer and the gutta percha (Fig. 2). It appears that the strength of the setting contraction of comparatively large masses of Ketac-Endo is greater than the strength of the bond obtained between the sealer and dentine when it is used in a thin layer where Ketac-Endo demonstrated a better bond to dentine than to gutta percha. These findings suggest that, in its current form, Ketac-Endo is not a suitable material to be used with a single cone gutta percha technique or as a retrograde filling material without gutta percha due to the greater mass of sealer and possible setting contraction. Furthermore, the clinical relevance of the increased resistance to root fracture reported by Trope and Ray[14] using Ketac-Endo as a sealer must be questioned since their study achieved this result utilizing a single cone technique on dry teeth.

The AH-26 specimens leaked between the sealer and the dentine – which suggests that the sealer appeared to bond more effectively to gutta percha than to dentine (Fig. 4) – and this was more obvious in the coronal end of the canal. This finding also suggests that it may have been interesting to have filled the coronal 3 mm of these canals with just the AH-26 sealer to examine whether the coronal microleakage could be reduced further since apical dye leakage studies have demonstrated that AH-26 when used without gutta percha allows very little, if any, dye penetration.[23,24]

The setting times and flow characteristics of AH-26 have been well documented[24] and Ketac-Endo demonstrated similar handling properties in this study. The setting time of the capsulated material was more than adequate for obturation of a single canal in this *in vitro* setting, although in a clinical situation it may set too rapidly to allow sufficient time to condense gutta percha and to check the root filling radiographically. This implies that the Ketac-Endo may set before any alterations could be made or before the root filling could be removed if the radiographic control demonstrated an initially unsatisfactory root canal filling. A further disadvantage noted in this study was that the heat used to soften and remove excess gutta percha appeared to cause the Ketac-Endo to set more rapidly. When filling teeth with multiple root canals, a separate capsule would probably be required for each canal which would introduce extra expense to the overall procedure. Similar concerns have also been noted by other authors.[6,20]

Conclusions

It may be concluded from this study that Ketac-Endo will give a similar apical and coronal seal to that obtained with AH-26 when used in conjunction with lateral condensation of gutta percha. However, there were important observations made about some of the physical properties of Ketac-Endo which suggest that this material is not an ideal root canal sealer in its current form and further investigations of these properties are indicated. Furthermore, the importance of an adequate coronal restoration cannot be underestimated in the light of the high coronal microleakage demonstrated with both sealers used in this study.

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