

Obturation quality after four years of storage using the non-instrumentation technique

Abstract

The aim of this *in vitro* study was to compare the sealing quality of three root canal filling materials after four years of ageing. Obturation with the non-instrumentation technique (NIT) was compared with cold lateral condensation of gutta-percha.

Seventy-six canals were endodontically treated with traditional hand instrumentation and cold lateral condensation (control) whereas 77 canals were cleansed and obturated with NIT. Three different sealers were used: AH 26, AH Plus and Apexit. After obturation, the teeth were stored for four years at 37 °C. Coronal dye penetration was evaluated after the teeth were made transparent. The teeth cleansed and filled with the new method showed significantly less dye penetration than the hand-instrumented teeth ($p < 0.001$). Within the hand-obturated group, Apexit showed significantly more dye penetration (4.7 ± 0.71 mm) ($p < 0.01$) than AH Plus (1.83 ± 0.57 mm) or AH 26 (1.16 ± 0.4 mm). No significant differences were found within the NIT groups. This study showed NIT to produce root canal fillings with significantly less coronal leakage compared to the conventional technique after four years of storage *in vitro*.

Keywords: coronal dye penetration, endodontics, leakage, non-instrumentation technique

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Introduction

Thorough debridement of the root canal system is considered to be essential for successful treatment. However, many studies have shown that current methods do not clean the entire root canal system, with all its ramifications and anatomical irregularities. This is true for both hand instrumentation and mechanical instruments (CYMERMAN et al. 1983, SUTER et al. 1986, WALKER & DEL RIO 1989).

Recently, a new method for root canal treatment – the non-instrumental technology (NIT) – was introduced, allowing debridement, disinfection and obturation of the root canals without the use of traditional endodontic instruments (LUSSI et al. 1993, LUSSI et al. 1995). The canals are cleansed by irrigation with NaOCl under alternating pressure. Hydrodynamic turbulence allows the irrigation fluid to penetrate all root canal ramifications. This new non-instrumental cleaning technique does not enlarge the root canal system at all, nor are the irregularities of the walls removed. It is therefore not possible to obturate canals prepared in this way using traditional techniques.

Obturation of the root canals is performed using a vacuum pump, which produces an absolute pressure of at least 20 hPa (= 20 mbar, = 15.2 mm Hg). Comparative studies showed the NIT to produce equivalent or better results than hand instrumentation regarding cleanliness of canals and quality of obturation (LUSSI et al. 1993, PORTMANN & LUSSI 1994, LUSSI et al. 1995, LUSSI et al. 1999a, 1999b).

Furthermore, after ageing for six months and subsequent thermocycling 5000 times between 5 °C and 40 °C the NIT-cleaned and filled root canals showed better sealing (LUSSI et al. 2000). However, there are no data available concerning the long-term behaviour of root canals obturated by the NIT method. The aim of the present study was to compare the quality of sealing by three root canal filling materials after ageing for four years. Obturation with NIT was compared to cold lateral condensation of gutta-percha.

Materials and Methods

Tooth selection, equilibration and grouping

A total of 77 extracted and immediately deep-frozen molars were used for the study. To assess the curvature of the roots, standardised radiographs were taken of all the teeth (SEPIC et al. 1989). A mould for each tooth was made from a condensation-cured silicone impression material (Optosil, Heraeus, Kulzer, Dormagen, Germany) in such a way as to be able to project the most prominent curve of the root on the radiograph. The roots were transcribed from the radiograph onto a transparent film and the curvature of each root was determined (SCHNEIDER 1971). The teeth were arranged in an ascending order of their curvatures and divided into pools. One tooth after another was then selected randomly from each pool and attributed to one of the treatment groups. This procedure led to an equilibrated distribution of root curvature in the treatment groups (LUSSI et al. 1999a).

Seventy-six canals of 40 teeth were endodontically treated by traditional hand instrumentation and cold lateral condensation (control) whereas 77 canals of 37 teeth were cleansed and obturated by the non-instrumentation technique (NIT). Three different sealers were used: AH 26 (De Trey Dentsply, Konstanz, Germany), AH Plus (De Trey Dentsply) and Apexit (Vivadent, Schaan, Liechtenstein).

Hand instrumentation and cold lateral condensation of the canals

In the control group the root canals were instrumented by seven endodontically trained dental practitioners with reamers and K-Flexofiles (Maillefer SA) to a master apical file (MAF) No. 35. The working length was determined by placing a No. 08 file into the canal until the tip of the file was just visible at the apical foramen and then it was drawn back 1.0 mm. Irrigation with 3% NaOCl was used throughout the instrumentation procedure. Step-back flaring of the canal at 1, 2, 3, 4 and 5 mm short of the

established working length was accomplished by instrumenting in a sequential manner up to five files larger than the MAF.

The following procedure was used for obturation of the lateral condensation group. A standardised master gutta-percha cone fitted with the length of the MAF was selected. AH 26, AH Plus and Apexit were mixed according to the manufacturer's instructions. The resin was placed onto the canal walls with a slowly rotating Lentulo No. 1 (Maillefer SA). The apical part of the master gutta-percha cone was also coated with sealer and inserted into the canal up to the working length. A finger spreader size B (Maillefer SA) was set in the canal as far as possible but not nearer than 1 mm from the working length. Accessory cones coated with sealer were laterally condensed. Excess material was removed with a heated hand-excavator.

Cleansing and obturation using the new method

Cleansing of the root canals was achieved with the new non-instrumentation technique (NIT) (LUSSI et al. 1993, 1995). The NIT generated alternating pressure fields within an overall reduced pressure environment. This procedure created hydrodynamic turbulences, allowing the irrigant (3% NaOCl) to perfuse the entire canal system and the polluted fluid to be exchanged within the root canal system. The reduced absolute average pressure to produce vapour-filled bubbles was set at 9.5×10^4 Pa (0.95 bar). It was maintained by the constant hydrodynamic pressure between the two vials (irrigant reservoir and waste reservoir) resulting in a flow rate of the irrigant of 7.0 ± 0.6 ml/min. This configuration prevented the pressure from exceeding ambient pressure to prevent penetration of the irrigant into the periapical region. Diameter of the bubbles was controlled by the revolutions of the piston pump which was set at 230 Hz. The device used for cleansing the root canals in this study was described by LUSSI et al. (1999a) as the "new device".

The roots were covered with a 1.5 mm layer of cementum to imitate alveolar bone (De Trey Zink Zement, De Trey Dentsply). This cementum was first mixed with NaCl in order to create a porous layer (1:1). Once set, the NaCl was dissolved in water. The vial was then filled with a solution whose physicochemical properties are comparable to blood in viscosity, electrical resistance, and ionic strength. The composition of this solution was as follows: 53.0 g of H₂O, 44 g of 85% glycerol, 2.45 g of NaCl, 1.5 g of KI, and 10 drops of starch (1%). Starch and KI were added to monitor trace amounts of NaOCl (LUSSI et al. 1993). When NaOCl extends beyond the apex the following reaction takes place: $\text{OCl}^- + 2\text{I}^- \rightarrow \text{I}_2 + \text{O}^{2-} + \text{Cl}^-$. This reaction is very sensitive. Iodine then changes the colour of starch to blue-brown (ROANE et al. 1985). At no time during cleansing with the NIT such a colour change was detected. The temperature was kept at 37 ± 1 °C. The root canal system was then cleansed using 3% NaOCl as irrigant for 15 min.

Since the debridement with the NIT does not produce an enlargement of the root canals, obturation by conventional means is impossible. Therefore, an appropriate method had to be used, namely root filling by vacuum. Following completion of the cleansing, the teeth were prepared for the obturation procedure as described previously (PORTMANN & LUSSI 1994, LUSSI et al. 1995, 1999b). To do so, the tooth was connected to a vacuum pump via a tubing equipped with a valve. The pressure in the canals was reduced to 10 hPa. The valve of the paste reservoir was then opened and the respective sealer sucked into the root canals system. Since the diameter of the "filling tube" was bigger than the one of the tube evacuating the tooth the obturation paste flowed into the tooth first. Evacuation was stopped as soon

as sealer appeared in the evacuation tubing from the tooth to the pump. Subsequently, gutta-percha cones (Maillefer SA) were placed into the root canal as far as possible to ensure retreatment or preparation of post space in a later in vivo application of the technique. The equipment used for root canal filling in this study was described by PORTMANN & LUSSI (1994) and by LUSSI et al. (1995).

AH Plus and Apexit were mixed according to the manufacturer's instruction. To increase fluidity AH 26 was mixed with a powder to resin ratio of 1:1. This did not have any influence on the sealing properties of the material (BARTHEL et al. 1994, PORTMANN & LUSSI 1994). Prior to the filling procedure the pulp canal sealers were evacuated for 5 minutes with a vacuum pump to avoid bubbles.

Ageing and coronal dye penetration

After obturation, the teeth were placed into coded vials at 37 °C and 100% humidity for four years. The vials were changed monthly. Then, the crowns of the teeth were removed using an Isomet 111180 low-speed saw (Buehler Ltd, Evanston, IL, USA) under cooling with glycerine 85%, leaving roots ~10 mm of length. With the exception of the ground coronal surface the teeth were completely coated with boxing wax (Kerr, Emeryville, CA, USA).

An extra tooth that was endodontically instrumented, but not filled, was added as a control (= second control) to each of the six experimental groups.

All specimens including the controls were placed in a horizontal position, immersed in black ink (Schwarze Kunstschrifttusche, Pelikan AG, Hannover, Germany) and exposed to a reduced pressure atmosphere of 66.5 hPa for 2 h. After releasing the negative pressure the teeth were left in the ink for another 88 h (SAUNDERS & SAUNDERS 1995) before they were rinsed with water. The wax coating was removed with a scaler. The teeth were rendered transparent so that the obturation of the canal and possible dye penetration became visible (ROBERTSON et al. 1980). Each root was oriented in such a way as to make the largest extent of the dye penetration visible through a microscope. The extent of coronal dye penetration was measured using an Olympus SZ-stereo-microscope (Olympus Optical AG, Volketswil/Switzerland) at $\times 20$ magnification by a person not involved in the obturation procedure. One of the eyepieces was equipped with a measuring scale (G10XSP, Olympus Optical AG). Starting at the ground coronal surface (SAUNDERS & SAUNDERS 1995), dye penetration was measured to the nearest 0.1 mm by means of the measuring eyepiece. For further calculations the mean was taken. The Spearman correlation coefficient for the two measurements was 0.88.

Since the data did not follow a normal distribution, they were analysed using the Kruskal Wallis or Mann-Whitney U Test in order to reveal differences between the obturation methods on one hand and the materials on the other. The level of significance was set at $p \leq 0.05$. For multiple comparisons the p values were corrected by the Bonferroni adjustment procedure (Systat 1992, Evanston, IL, USA).

Results

Due to the equilibration procedures no statistically significant differences of curvature scoring were found between the groups.

The following numbers of root canals were analysed: AH 26; 24 root canals in the control group, 28 root canals in the NIT-group,

AH Plus; 23 root canals in both groups, Apexit; 29 root canals in the control group and 26 root canals in the NIT group.

The teeth cleansed and filled with the new method showed statistically significantly less dye penetration than the hand-instrumented teeth ($p < 0.001$) (Fig. 1). Within the hand-obtured group, Apexit showed significantly more extensive dye penetration (4.7 ± 0.71 mm) ($p < 0.01$) than AH Plus (1.83 ± 0.57 mm) or AH 26 (1.16 ± 0.4 mm). No significant differences were found within the NIT groups. All unfilled control teeth (= second control) exhibited complete dye penetration from the coronal ground surface up to the apex. Figure 2 shows a tooth after ageing, cleaning and filling by the NIT.

Discussion

A long-term success in root canal treatment can only be achieved if proper cleansing of the canal system is possible and if the sealing of the root canal system is tight. This may be difficult to achieve since root canals are morphologically complex systems with many irregularities, ramifications and grooves. Current methods are based on chemo-mechanical root canal preparation. In order to remove remaining bacteria, dentin and pulp debris, the common disinfectant is NaOCl. Many studies have shown that a complete cleansing of the root canal system cannot be achieved by mechanical debridement due to its complexity (SENIA et al. 1971, SALZGEBER & BRILLIANT 1977, WALKER & DEL RIO 1989). Conventional hand instruments or rotary instruments have a limited area of action. BARBIZAM et al. (2002) showed that neither succeeded in completely cleaning the surface of flattened root canals. Irrigation of the root canal with antibacterial agents without removing dentin apically is efficient in the reduction of the intracanal bacteria when the coronal flare is sufficient to allow access to the apical part (COLDERO et al. 2002). The NIT-method is able to irrigate root canals to the apex without mechanical enlargement (LUSSI et al. 1993).

Conventional methods for the filling of root canals recommend the use of relatively viscous sealers to be applied with lentulo

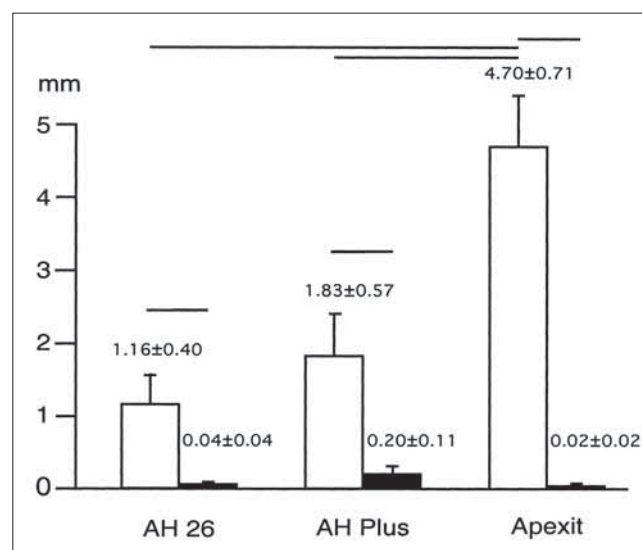


Fig. 1 Coronal dye penetration (mean \pm SEM) after four years of storage using three different sealers (AH 26, AH Plus and Apexit) and two preparation techniques. Open columns: manual cleansing and lateral condensation. Black columns: cleansing and obturation with the NIT. Significantly different values are marked with a line.



Fig. 2 Tooth after ageing, cleaned and filled by the NIT using AH Plus. (Original magnification $\times 5$)

spirals or other appropriate means, followed by one or several gutta-percha points or cold lateral condensation. This procedure could lead to trapping of air bubbles. Along such paths coronal leakage could occur. Bubbles may not only be formed when applying the sealer to the canals, but also during the mixing of the sealer. The NIT method, however, aspirates the obturation material into the main canal as well as into side canals and into the dentinal tubules. Previous degassing removes bubbles having formed in the filling paste.

So far, machine-filled teeth have been examined for tightness of the seal in short-term experiments or after artificial ageing only (PORTMANN & LUSSI 1994, LUSSI et al. 1995, 1996, 1997, 1999b). Assessment of the sealing properties of root canal obturations has been attempted using various methods. The most widely used technique has been the measuring of the linear dye penetration along the root canal filling (WU & WESSELINK 1993).

The study evaluated coronal dye penetration, as there exists only poor correlation between apical dye penetration and clinical success (OLIVER & ABBOTT 2001). Coronal leakage seems to have an influence on periapical health as well; DUGAS et al. (2003) showed in a cross-sectional *in vivo* study that the risk of developing apical periodontitis was three times larger for teeth with adequate tooth fillings but inadequate restorations than for teeth with both adequate root fillings and restoration. This may be explained by the restoration's inadequate ability to prevent for-

mation of pathways for microbial ingress into the root canal system.

Dye penetration is used in many laboratories in order to compare different obturation techniques (SAUNDERS & SAUNDERS 1995). Extrapolation to the clinical performance and bacterial leakage is not possible.

Several studies demonstrated that entrapped air bubbles can exert a negative influence on passive dye penetration. Therefore, methods were developed to eliminate the effect of entrapped air bubbles using reduced pressure conditions (GOLDMAN et al. 1989, SPANGBERG et al. 1989, OLIVER & ABBOTT 1991, SAUNDERS & SAUNDERS 1995) and aqueous perfusion of the root filled teeth before exposure to dye (WU et al. 1994). For the control group hand instrumentation and irrigation with 3% NaOCl was chosen as this was the standard procedure used by the dental practitioners participating in this study in 1996. Nowadays different irrigation fluids like EDTA may be used to remove the smear layer. Opinions differ on the effect the removal of smear layer has on microleakage. TIMPAWAT et al. (2001) even found an increased amount of microleakage after removal of the smear layer. Different sealer types may require different dentine pretreatment for optimal adhesion as reported by SALEH et al. (2002). They found that pretreatment with EDTA showed no effect (Apexit) or produced weaker bonds (AH Plus).

EDTA is more efficient to remove smear layer than NaOCl, but even ultrasonic agitated irrigation with EDTAC (= EDTA with 1% Cetavlon) did not always completely remove the smear layer (GUERISOLI et al. 2002). Also GAMBARINI & LASZKIEWICZ (2002) showed after treatment with GT rotary instruments that root canal walls were left covered with smear layer, particularly in the apical third even after irrigation with EDTA. NIU et al. (2002) reported that more debris, but also more dentine was removed from the wall of the root canals when irrigation with EDTA was followed by NaOCl.

In the control group, the sealer was placed with a lentulo spiral. WIEMANN & WILCOX (1991) and KAHN et al. (1997) found the lentulo spiral to be the most effective method or at least equal to other means when evaluating sealer placement. HALL et al. (1996) compared the wall coverage of different sealer placement techniques before and after obturation with gutta-percha. The best coverage of the root canal wall with sealer was obtained with a lentulo spiral (90.2% wall coverage). After obturation no difference was found between the methods (62.5% average wall coverage). Also WU et al. (2000b) reported that sealer might be removed from the canal wall by the condensation procedures. They found that the wall coverage with sealer was significantly higher after single cone technique (no condensation) than after lateral or vertical condensation. In the present study there was no condensation with gutta-percha in the NIT-group, so the wall coverage with sealer is probably superior to the lateral condensation groups. Further investigation has to be undertaken to evaluate the wall coverage with sealer using the NIT-method.

The NIT-method does not produce a smear layer on the wall of the root canal (LUSSI et al. 1993); therefore NaOCl only was used as irrigant in this group. Using the NIT-method, STOJAN (2000) found a higher penetration of the sealer in the dentinal tubuli of the root canal compared to the conventionally filled control group. Further investigation is necessary concerning the amount of penetration of the sealer in the dentinal tubuli when no smear layer is present on the wall of the root canal as well as the possible impact on microleakage. Calcium hydroxide is advocated as an interappointment therapeutic dressing because of its anti-

bacterial effect. However, removal is often difficult with conventional irrigation (GOLDBERG et al. 2002). Further investigation has to be undertaken to show whether the NIT-method is also efficient in removing calcium hydroxide.

The effect of tissue fluids or macrophages on the apical seal were not taken into account in this study, as it was concerned with coronal leakage only. Dissolution of sealer or smear layer in the apical region may be more important in vivo. The dissolution of the sealer can theoretically occur when roots are stored in a solution. SAUNDERS & SAUNDERS (1995) stored teeth in saline solution for one year. There was no significant difference in leakage between Apexit and Sealapex when lateral condensation had been used.

In the present study, teeth were stored in vials at 37 °C and 100% humidity to simulate the situation on the coronal end of the root canal in the oral cavity.

In the present study AH 26, AH Plus and Apexit showed significantly more dye penetration within the hand-obtured group than when NIT was used. Significant differences between the two techniques were also found by LUSSI et al. (1999b) using the same sealers after seven days of storage. After six months of ageing, LUSSI et al. (2000) could only show significantly less leakage for the NIT group when Apexit was used as a sealer. No significant difference between NIT and the hand-obtured group was found when using AH Plus as a sealer.

Using NIT, no significant differences were found between AH 26, AH Plus and Apexit. This is also true for LUSSI et al. (1999b) and LUSSI et al. (2000).

One factor may be the smaller volume of the NIT group: PETERS et al. (2003) showed increased volumes between 26.6% (palatal root canals) and 71.9% (distobuccal root canals) using ProTaper instruments. In a smaller volume, dimensional changes are less distinct than after enlarging the root canals with conventional instruments.

A possible explanation for the better performance of AH 26 and AH Plus in the present study, both for lateral condensation and NIT may be the initial expansion of the sealer. ORSTAVIK et al. (2001) showed initial expansion of 4–5% in the first four weeks for AH 26, expansion up to 0.9% after 48 weeks for AH Plus. Apexit showed only minor variation around the baseline value, after four weeks 0.14% shrinkage was found, then the material expanded up to 0.19%. It seems that when LUSSI et al. (1999b) measured dye penetration after seven days, expansion of AH 26 and AH Plus was not completed and this may have led to larger dye penetration in the lateral condensation group with the larger canal volume. In the lateral condensation group expansion of gutta-percha could also contribute to a better seal after four years of storage. WU et al. (2000a) showed that expansion of gutta-percha takes place in the first six months. After six months of ageing (LUSSI et al. 2000) no significant difference between NIT and lateral condensation was found when AH Plus was used as sealer.

This study showed NIT to produce root canal fillings with significantly less leakage compared to conventional technique even after four years of storage in vitro.

Clinical success of the NIT cleansing technique has not been investigated so far. First results using the NIT filling technique in vivo are however encouraging (LUSSI et al. 2002).

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Zusammenfassung

Das Ziel dieser In-vitro Studie war es, die Qualität dreier Wurzelkanal-Füllmaterialien zu vergleichen, nachdem Wurzelfüllungen während vier Jahren gelagert wurden. Obturation mit NIT wurde mit konventioneller, lateraler Kondensation verglichen. Sechundsiebzig Kanäle wurden mit Handinstrumenten und lateraler Kondensation (Kontrolle) behandelt, während 77 Kanäle mit der nichtinstrumentellen Technik (NIT) gereinigt und obturiert wurden. Drei unterschiedliche Sealer wurden benutzt: AH 26, AH Plus und Apexit. Nach Obturation wurden die Zähne für vier Jahre bei 37 °C gelagert. Koronale Farbstoffpenetration wurde ausgewertet, nachdem die Zähne transparent gemacht wurden. Die Zähne, die mit der neuen Methode gereinigt und gefüllt waren, zeigten erheblich weniger Farbstoffpenetration als die Kontrollgruppe ($p < 0,001$). Innerhalb der Kontrollgruppe zeigte sich bei Apexit deutlich mehr Farbstoffpenetration ($4,7 \pm 0,71$ mm) ($p < 0,01$) als bei AH Plus ($1,83 \pm 0,57$ mm) oder AH 26 ($1,16 \pm 0,4$ mm). Keine signifikanten Unterschiede wurden innerhalb der NIT-Gruppen gefunden. Nachdem die Wurzelkanäle dieser Studie in vitro vier Jahre gelagert wurden, zeigten die mit NIT behandelten Wurzelkanäle signifikant weniger koronale Penetration als solche, die mit der konventionellen Technik aufbereitet wurden.

Résumé

Le but de cette étude *in vitro* était de comparer l'étanchéité de trois matériaux d'obturation canalaire après les avoir soumis à un vieillissement durant quatre ans. Des obturations canales effectuées selon une technique dite «non-instrumentelle» (non-instrumentation technique, NIT) ont été comparées à des obturations réalisées selon une technique manuelle conventionnelle. Soixante-seize canaux radiculaires ont été traités selon une technique de préparation manuelle traditionnelle et condensation latérale (groupe contrôle), tandis que soixante-dix-sept canaux étaient nettoyés, puis obturés selon la technique NIT. Trois différents matériaux d'obturation canalaire («sealer») ont été utilisés: AH 26, AH Plus et Apexit. Après l'obturation les dents ont été stockées durant quatre ans à 37 °C. La pénétration coronaire d'un colorant a été évaluée après avoir rendu les dents transparentes. Les dents nettoyées et obturées selon la nouvelle technique ont montré significativement moins de pénétration de colorant que les dents traitées selon la technique manuelle traditionnelle ($p < 0,001$). Parmi les groupes de dents traitées selon la technique manuelle, Apexit montrait significativement plus de pénétration de colorant ($4,7 \pm 0,71$ mm) ($p < 0,01$) que AH Plus ($1,83 \pm 0,57$ mm) ou AH 26 ($1,16 \pm 0,4$ mm). Aucune différence significative n'a été trouvée à l'intérieur des groupes NIT. Cette étude a montré que la technique NIT, comparée à une technique conventionnelle, produisait des obturations canales avec significativement moins de perméabilité après stockage durant quatre ans.

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