In vivo performance of the new non-instrumentation technology (NIT) for root canal obturation

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Abstract

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Aim The aim of this *in vivo* study was to compare the radiographic quality of root fillings performed by the NIT-obturation method versus conventional mechanical obturation.
Methodology Sixty-six patients needing root canal treatment participated in this study. The treatments were performed by three private practitioners. The root canals were instrumented with K-Flexofiles to a master apical file between sizes 25 and 60, followed by step-back flaring up to size 70. Copious irrigation was used throughout the instrumentation procedure with NaOCl (3%). The teeth were obturated either by lateral condensation, the McSpadden technique (control) or by the new non-instrumentation technology (NIT) with and without using gutta-percha points. In the NIT method, a low pressure was created within the tooth, and AH 26 sealer was sucked into the root canal system. Radiographs of the root-filled teeth were analysed and the length of the root filling, the presence of voids and the area of any other fillings determined.
Results The root canal fillings of the control group (0.1 ± 0.1 mm) and those of the NIT/gutta-percha group (0.3 ± 0.1 mm) were both overextended when taking the apical constriction as a reference point. Root canal fillings of the NIT/gutta-percha group were statistically ($P < 0.05$) significantly longer than those of the NIT without gutta-percha group. The latter showed slightly underextended root canal fillings (−0.14 ± 0.1 mm).
Conclusions The present investigation demonstrated the performance of the NIT-obturation method *in vivo*. Root canals filled by the reduced-pressure-method using sealer combined with gutta-percha cones exhibited equivalent radiographic quality compared to conventionally filled canals.

Keywords: lateral condensation, non-instrumentation technology, root canal obturation, vacuum technique.

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Introduction

Modern methods of root canal treatment are based on mechanical debridement, chemical disinfection and bacteria-tight sealing of the root canals with a filling material. Unfortunately, the intricate anatomy of most canals may be one of the reasons for failure in root canal treatment as mechanical enlargement of the main canals and the removal of infected dentine from the canal walls, may not remove bacteria in those areas which cannot be instrumented. The main function of irrigating solutions is the inactivation of these remaining bacteria and the removal of soft tissue debris.

Buckley & Spångberg (1995) found that 31.3% of root-filled teeth had signs of periapical disease with only 42% of all roots adequately filled. Monfared & Hartwell (1996) reported that 44% of the roots with evidence of periapical pathology were inadequately obturated. Saunders *et al*. (1997) found that root canal fillings judged to be adequate radiographically had a reduced incidence of radiolucencies periapically. Teeth obturated beyond the apex had more radiolucencies than those obturated flush with or within 2 mm of the radiographic apex.

Recently, a method and device have been presented which allow cleansing of root canals without the need for

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manual instrumentation (Lussi et al. 1993, 1995, 1999a). The canals are irrigated with a NaOCl solution under alternating pressure fields producing hydrodynamic turbulence, making the irrigant perfuse even minute ramifications of the root canal system. Experiments have demonstrated that NaOCl concentrations above 1% are best suited for the new device (Lussi *et al.* 1993, 1997b). With this non-instrumentation technology (NIT) the root canals are not enlarged mechanically to standardized dimensions. Therefore, it has become necessary to develop a new method for root canal obturation (NIT), that is, one that can fill entirely the unprepared canal space. The concept was to produce a profound low pressure ('vacuum') within the tooth and thus aspirate sealer into the entire root canal system. It was demonstrated *in vitro* that a reduced (absolute) pressure of 15 hPa (=15 mbar) or less was sufficient to produce radiographically dense root canal fillings (Portmann & Lussi 1994, Lussi *et al.* 1995, 1999b). Negative absolute pressures lower than 10 hPa have already been achieved *in vivo* (Lussi *et al.* 1996, 1997a). However, no clinical studies to demonstrate the performance of the technique were available.

The aim of this study was to compare *in vivo* the radiographic quality of root canal fillings performed by the NIT-obturation method versus conventional mechanical obturation both after cleaning and shaping the canals of the test and the control groups by conventional mechanical methods.

Materials and methods

Sixty-six patients needing root canal treatment participated in this study. The treatments were performed by three private practitioners. The teeth were selected consecutively, applying the following exclusion criteria: no open apices, no cyst (as judged by radiography) present at the time of root canal filling, no apparent communication with the paranasal sinuses or with the mandibular nerve, no primary teeth, no known allergies to material used, no severe or terminal illness.

All subjects participated voluntarily in this study. A written consent form was signed before any treatment was carried out, and all work was approved by the Ethical Committee of the University of Bern, Switzerland.

Patients were assigned either to the control group ($n = 34$, 78 root canals) or to the test group ($n = 32$, 74 root canals) (Table 1).

Control group (conventional techniques)

All root canals were instrumented with K-Flexofiles (Dentsply Maillefer SA, Ballaigues, Switzerland) to a master apical file (MAF) between sizes 25 and 60, followed by step-back flaring up to size 70. Copious irrigation was used throughout the instrumentation procedure with NaOCl (3%). Each operator made a judgement whether a calcium hydroxide dressing was placed in the canals for at least 1 week.

The teeth were filled using AH 26 (De Trey Dentsply, Konstanz, Germany), mixed according to manufacturer's instructions. The sealer was applied to the canal walls with a slowly rotating Lentulo spiral filler (Dentsply Maillefer SA). A master gutta-percha cone fitted to the size and length of the MAF was then seated into the canal. Compaction of the obturation material was achieved either by lateral condensation with a finger spreader and accessory cones (46 root canals) or with the McSpadden technique (Gutta condenser A0242 25 mm, sizes 060 or 080, Dentsply Maillefer SA) (24 root canals). In eight canals only one master gutta-percha cone was seated into the root canal. Following filling, parallel dental radiographs were taken with the aid of a film holder (Hawe Neos Dental, Biaggio, Switzerland).

NIT group

Cleaning and shaping the root canals with conventional instruments up to a MAF between sizes 25 and 50 was carried out and followed by step-back flaring up to size 60. Calcium hydroxide was placed in the canals for at least 1 week.

Table 1 Specifications of the different treatment groups

Group	Instrumentation-irrigation	Obturation sealer	Molars	Bicuspids	Incisors	Canals
Control	Step-back technique NaOCl 3%	AH26 gutta-percha: lateral condensation, McSpadden, single point	18	8	8	78
NIT and no gutta-percha (=NIT group)	Step-back technique, NaOCl 3%	AH 26, no gutta-percha	19	5	8	74
NIT and gutta-percha (=NIT/gutta-percha group)	Step-back technique, NaOCl 3%	AH 26 gutta-percha: points, no lateral condensation	19	5	8	74

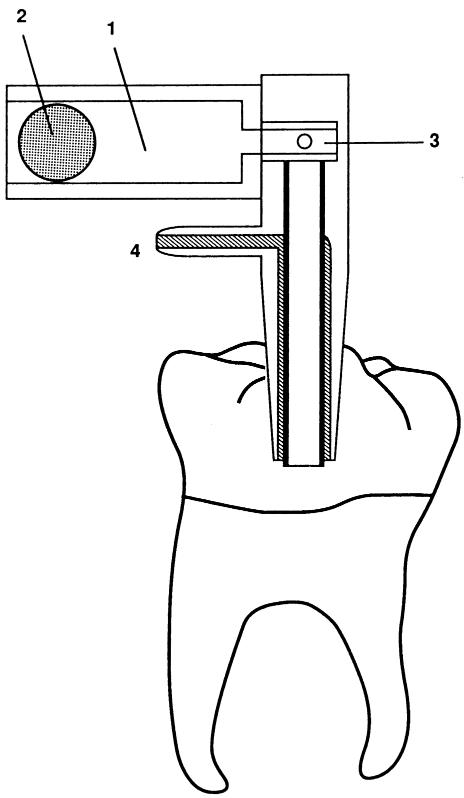


Figure 1 Principle of the new obturation procedure: The connecting piece tightly fitted in the access cavity of the tooth consists of: (1) reservoir for filling paste; (2) a steel ball placed on top of the filling paste; (3) an integrated valve, and (4) a pipe to the vacuum pump (from Lussi *et al.* 1995).

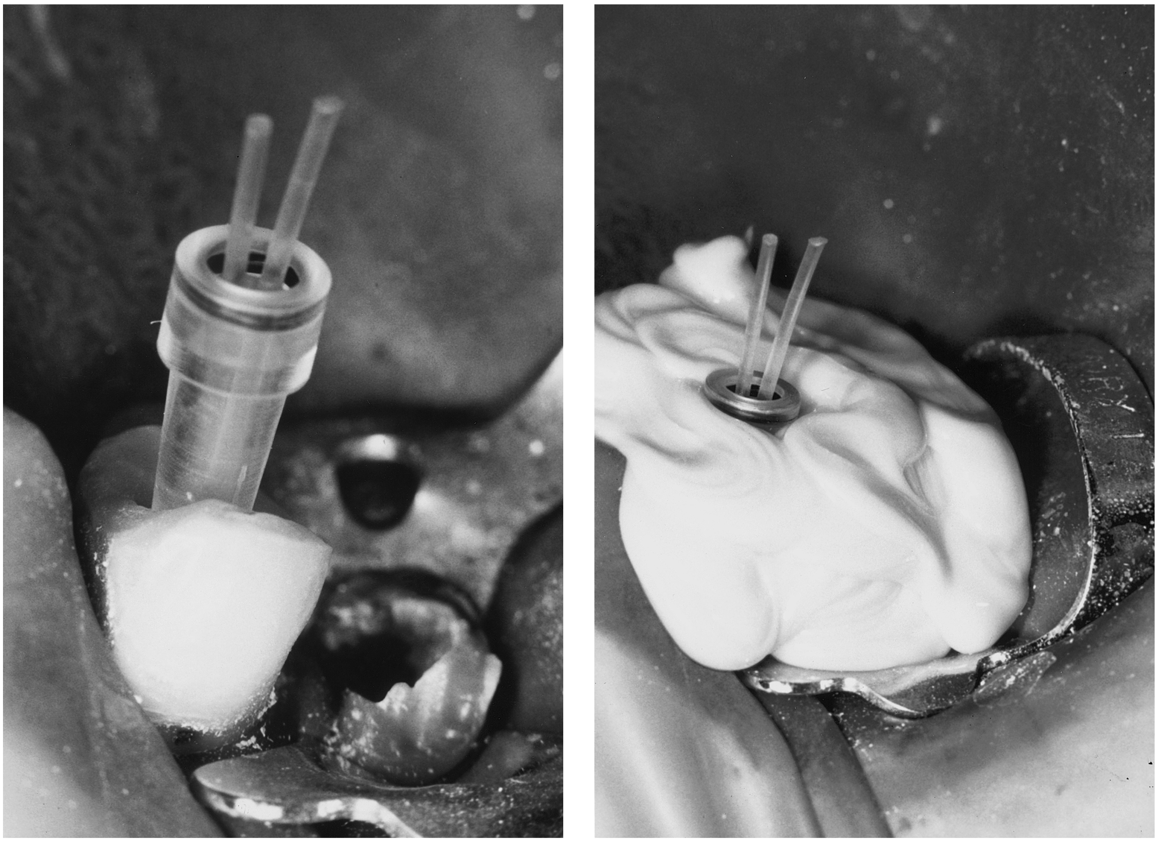
The principle of the new obturation device is shown in Fig. 1. Its mode of function has been described in detail previously (Lussi *et al.* 1995). For obturation, the teeth were connected to the 4-stage vacuum pump via tubing equipped with a valve. The pressure in the canals was reduced to at least 15×10^2 Pa (=15 hPa). In the meantime, AH 26 (DeTrey Dentsply, Konstanz, Germany) was mixed with a powder to resin ratio of 1 : 1 (by volume). This ratio was chosen in order to make it more fluid, yet not change the sealing properties of the material (Barthel *et al.* 1994). In order to reduce trapped air bubbles to a minimum, the mixed sealer was evacuated for 5 min by means of a special vibrating device connected to a vacuum pump. The sealer was placed into a reservoir and then a valve was opened allowing it to be sucked into the pulp space. Since the diameter of the 'tubing' entering the tooth was bigger than that of the tube exiting 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.

The procedure for obtaining a tight fitting attachment to the tooth for the hose to the vacuum pump was as follows (Lussi *et al.* 1996): To keep the orifices of the canals open until obturation, flexible sterile nylon threads were inserted into the root canals. The occlusal ends of the nylon filaments were threaded into the conical connector and the latter held *in situ* whilst the gap between the access cavity and the adaptor sleeve was filled with a fast addition-curing silicone (Jet Bite, Coltène, Altstätten, Switzerland) as shown in Fig. 2(a–d). After sealing and removing the nylon threads, the tooth was connected to the vacuum pump. The required vacuum indicated by a LED-display was usually reached within approximately 10 min (mean 6 min; range 2–14 min). In a few teeth technical problems occurred and an appropriate vacuum could not be reached. This teeth were not obturated by NIT and therefore not included in the study.

Upon completion of the root filling by NIT only, a first radiograph was taken (=NIT group, see Table 1). Then a master gutta-percha cone was inserted in the root canals of the same teeth as above, additional gutta-percha cones were fitted into the root canals without using lateral condensation and the second radiograph was taken (NIT/gutta-percha group, see Table 1).

Assessment

For assessing the two-dimensional quality of the root canal fillings, coded radiographs were projected onto a wall (magnification ×10), traced on paper and then analysed morphometrically (MOP, Kontron, Munich, Germany) (Lussi *et al.* 1995). The root canal curvatures were scored as follows (Lussi *et al.* 1993): deviations 0–5°, straight canal; deviations 5–30°, slightly curved canal; deviations >30°, curved canal. A reference point AC (apical constriction) was defined at 1.1 mm coronally to the radiographic apex (Guldener & Langeland 1993). Then, the apico-coronal extension of the root canal fillings was determined in relation to the reference point. Overextended (in relation to the apical constriction) fillings produced positive, underextended fillings negative readings [mm]. For overextended fillings, the area of the overfilling was measured. Further, the total obturated area was determined in three sections of the root canal: apical (0–2 mm coronal to AC), in the middle (2–4 mm coronal to AC) and coronal (4–7 mm coronal to AC). The periapical region was scored according to the PRI Index (Reit & Gröndahl 1983): PRI 1; periapical destruction of bone definitely not present; PRI 2; periapical destruction of bone probably not present, PRI 3; uncertain, PRI 4; periapical destruction of bone



(a) (b)

Figure 2 Procedure for obtaining a tight filling attachment: (a) Preparation of an access cavity with a standardized conical bur. Flexible sterile nylon threads are inserted and the conical connector put in place. (b) A fast setting silicone is placed over the entire tooth crown. (c) The tooth is connected to the vacuum pump. (d) After reaching the required vacuum, which takes between 2 and 14 min, the filling material is sucked into the root canal system.

probably present, PRI 5; periapical destruction of bone definitely present.

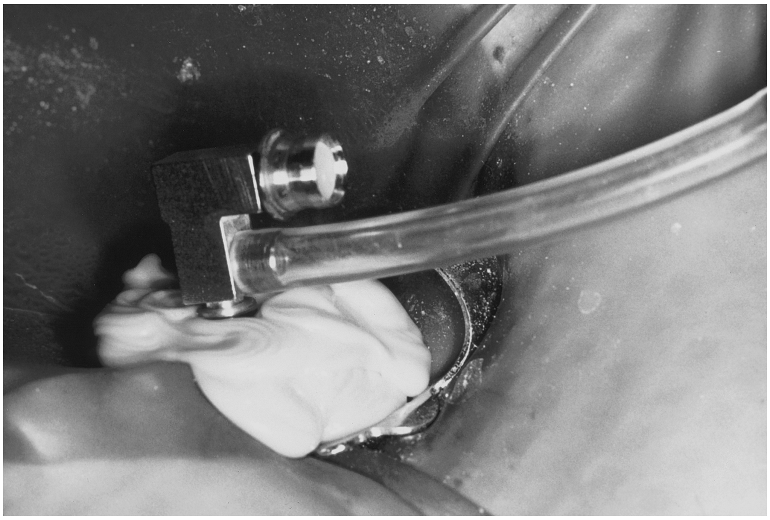
Statistical analysis

The data were first analysed graphically using box plots. As they were not normally distributed, Kruskall–Wallis one-way analysis of variance was used to analyse the data. When the result indicated significant differences between groups, these groups were individually compared by means of the Mann–Whitney *U*-test, adjusting the significance level according to Bonferroni. In the NIT-group the number of gutta-percha cones used was correlated with the extension of the root canal filling by means of Spearman's Correlation. Categorical data (PRI Index and root canal curvature) were compared using the chi-squared test. The level of significance chosen for all tests was $P = 0.05$.

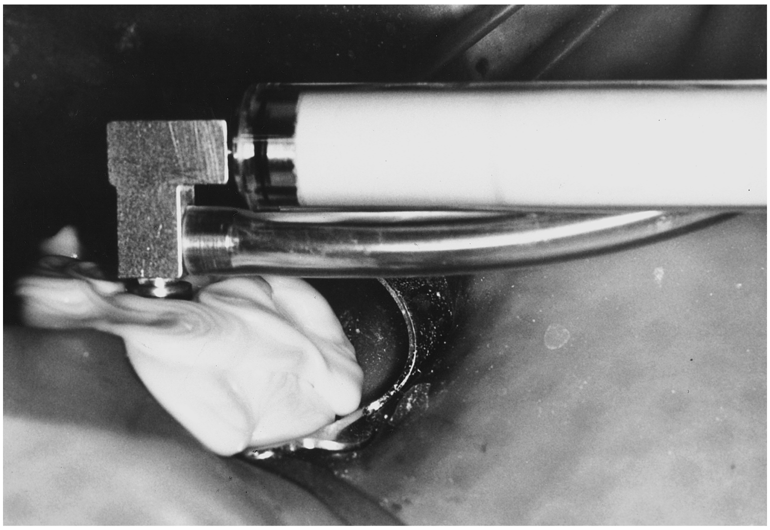
Results

Types of teeth and root canals per tooth (1–4) were equally distributed amongst the various groups ($P = 0.05$). The same was true for the distribution of curved canals ($P = 0.05$). The PRI Index showed no significant difference between the control group and the NIT-groups.

The root canal fillings of the control group (0.1 ± 0.1 mm) (mean ± SEM) and those of the NIT/gutta-percha group (0.3 ± 0.1 mm) were both overextended when taking the apical constriction as a reference point. Root canal fillings of the NIT/gutta-percha group were statistically ($P < 0.05$) significantly longer than those of the NIT-group without gutta-percha. The latter showed slightly underextended root canal fillings (-0.14 ± 0.1 mm) (Fig. 3). The number of gutta-percha cones used with



(c)



(d)

Figure 2 *continued.*

the NIT-obturation technique was weakly correlated with the extension of the root canal filling. Spearman's Correlation revealed a value of 0.29. Eight per cent of the control group were filled more than 2 mm short of the radiographic apex, with 85% for the NIT and 4.1% when gutta-percha was inserted.

The area of obturation material apical to the apical constriction (=AC) was also evaluated. The mean value was 0.3 ± 0.1 mm^2 for the control group. The value found for the NIT/gutta-percha group (1.0 ± 0.4 mm^2) was significantly larger ($P < 0.05$) than that of the NIT-group without gutta-percha (0.1 ± 0.01 mm^2). No significant differences were found between the control group and NIT/gutta-percha group.

Figure 4 illustrates the fillings within three sections of the root. The teeth obturated with the NIT had the least percentage of complete filling ($90.8 \pm 2.8\%$) in the apical part. This result was significantly different from the control group ($97.4 \pm 0.3\%$), as well as from the NIT/gutta-percha group ($99.8 \pm 1.0\%$). In the middle section of the root canal the values for the obturated area ranged from $93.4 \pm 0.4\%$ (NIT-group) to $99.9 \pm 0.2\%$ (NIT/gutta-percha group), the values of these two groups were significantly different ($P < 0.05$). In the coronal section, the control group ($98.2 \pm 0.6\%$) showed significantly lower values than the other groups ($P < 0.05$). As in the apical and middle root sections the NIT/gutta-percha group had the highest scores ($100 \pm 0\%$).

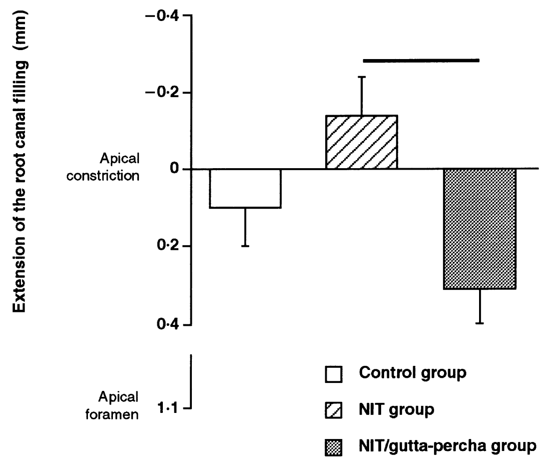


Figure 3 Extension of the root canal filling (mean ± SEM). Reference point (zero) was the apical constriction AC. Positive values are overextended, negative values are underextended fillings. Significant different values are marked with a line.

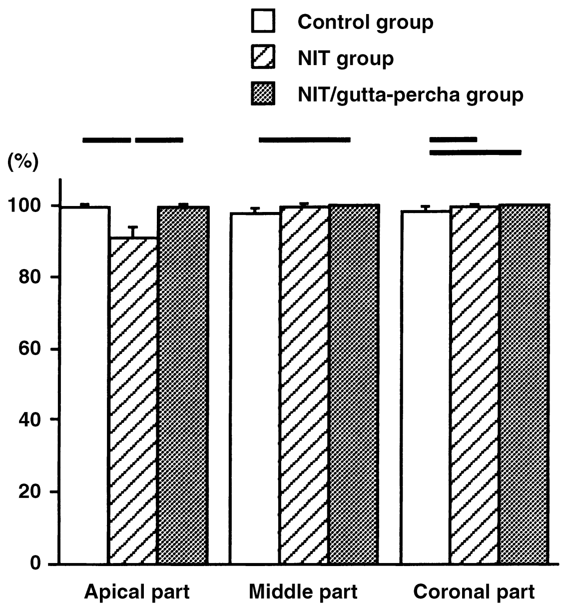


Figure 4 Obturated area in the apical, middle and coronal part of the root canals (mean ± SEM). Significant different values are marked with a line.

Discussion

In this *in vivo* study hand instrumented root canals were obturated using the non-instrumental filling technology (NIT) and the results compared to conventionally obturated canals. The NIT-obturation technique will be required for the obturation of canals cleaned with the hydrodynamic method (NIT), should the latter become applicable *in vivo*. This technique would allow debridement and disinfection of the root canals without the use of traditional endodontic instruments. It does not remove dentine from the canal wall, thus allowing the canals to keep their irregular and often tortuous anatomy. Since it is not possible to obturate canals cleaned by the NIT-technique using traditional techniques, a new method of root canal obturation was required. The concept of this new method was to produce a below ambient pressure within the tooth and thus aspirate sealer into the entire root canal system. It was demonstrated *in vitro* that a reduced (absolute) pressure of 15 hPa was sufficient to produce radiographically dense root canal obturations (Portmann & Lussi 1994, Lussi *et al.* 1999b). The present study has demonstrated that it was possible to reach negative pressures lower than 10 hPa *in vivo* under a routine dental practice setting.

Since the obturation is a purely physical process, it can be assumed that the tightness of the seal *in vivo* would correspond to the results obtained *in vitro*. The new filling method allows obturation of complex root canal systems, including lateral canals. It was demonstrated that internal resorptions (Lussi *et al.* 1997a), C-shaped as well as type-II canals, could be filled completely.

The canals obturated with the new technique were filled to 0.14 mm ± 0.1 mm short of the apical constriction, when no gutta-percha cones were inserted. The insertion of gutta-percha cones is advised in order to facilitate re-entry. The slightly short obturation can be explained using Boyle-Mariotte's law of the behaviour of gases: given a pressure in the root canals of 8 hPa, an ambient pressure of 1000 hPa and an approximate total volume to be filled of 16 mm^3 for hand instrumented and of 8 mm^3 for NIT-cleaned root canals (Lussi *et al.* 1995), the volume under consideration ('rest-volume') would become 0.13 mm^3. The value of 0.13 mm^3 explains why the apical part was not completely filled by the NIT-obturation method alone, i.e. without a gutta-percha point. This volume will be smaller when the root canal system is cleansed with the NIT, because no enlargement of the root canal is carried out.

Hand-instrumented canals usually exhibit a smear layer. We have shown that cleaning with the NIT-method creates no smear layer and that dentine tubules may also account for this 'rest-volume'.

In fact, previous studies have demonstrated that even dentinal tubules and branches could be filled with the new obturation method (Lussi *et al.* 1997a). This phenomenon may explain the better seal *in vitro*, even after artificial ageing of the NIT root-filled teeth (Lussi *et al.* 1999b, Lussi & Imwinkelried 2000). Tightness of the seal of the obturation is important for long-term success of any root canal treatment. This is even more important, with the NIT-method, since potentially infected dentine is not removed and cutting the nutritional supplies for remaining bacteria is important for the success of the treatment.

Two-dimensional radiographic analysis revealed voids in the filling material, especially in their centre. This could be explained by initial curing of the material beginning at the warmer periphery and in the dentinal tubules drawing unset liquid material from the centre to the outer zones, thus creating voids. The NIT/gutta-percha group had fewer voids and were more extended after the obturation process (Lussi *et al.* 1997a). This observation may be explained by the very tight and bubble-free obturation combined with the vacuum in the root canal system and the piston effect gutta-percha points.

At the outset, it was not known whether or not the application of such powerful vacuum would produce discomfort or even pain to the patients. It was interesting to note that this was not the case. No patient received local anaesthesia for the obturation procedure and none reported any sensation or discomfort.

Conclusions

The present investigation demonstrated the performance of the NIT-obturation method *in vivo*. Root canals filled by the reduced-pressure-method combined with gutta-percha cones exhibited equivalent radiographic quality compared to conventionally filled canals.

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