0099-2399/99/2501-0009$03.00/0
JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 25, NO. 1, JANUARY 1999

# Comparison of Two Devices for Root Canal Cleansing by the Noninstrumentation Technology

A. Lussi, PhD, DMD, Dipl Chem ETH, P. Portmann, DMD, U. Nussbächer, DMD, S. Imwinkelried, DMD, and J. Grosrey, Dipl Ing

**Optimal cleansing of the root canal system is a prime prerequisite for long-term success in endodontics. Recently, a new method and device were presented providing "automatic" root canal cleansing without the need of endodontic instrumentation. Cleanliness results equivalent to or better than those with conventional methods were achieved in considerably less time. The purpose of the present study was 2-fold: (a) optimization of the device to make it applicable to patients and (b) to measure its effectiveness against the predecessor model. A total of 156 root canals of 66 freshly extracted vital human molars were cleansed with the new device and their cleanliness compared with that of 149 canals of 52 molars cleansed previously with the first apparatus. Data indicated that the smaller new machine produced equivalent or better cleanliness results in the root canal system using significantly less irrigant (NaOCl).**

Proper cleansing and filling of the root canal system is essential for long-term success of endodontic therapy. In an earlier study (1), a novel endodontic technique based on controlled cavitation was proposed. Hydrodynamic turbulence allowed cleaning of root canals automatically without the need of conventional motorized or hand instruments. Overall, the new noninstrumented hydrodynamic technique (NIT) resulted in equal or better cleanliness in all root sections when compared with hand instrumentation.

However, the device presented previously had one major disadvantage: excessive consumption of irrigation solution. Furthermore, because cavitation was not restricted exclusively to the tubings connected to the pulp cavity but was activated in the entire installation, the required operating power was unnecessarily high. A high-quality gear pump and its regulation would have been very expensive.

The purpose of this study was to improve the device in such a way as to overcome these disadvantages and to compare the efficiency of the new device with that of the predecessor model.

## MATERIALS AND METHODS

### Principle of the Hydrodynamic Method

#### FIRST DEVICE

The mode of function was described in detail previously (1). Cleansing of the root canals was achieved with a device building up controlled cavitation outside the mouth. Alternating pressure fields were generated by a piston pump within a reduced pressure environment. First, bubbles were created at a reduced absolute average pressure of $3 \times 10^4$ Pa (= 0.3 bar). A subsequent rapid pressure rise to $9 \times 10^4$ Pa (= 0.9 bar) caused these vapor-filled bubbles to collapse, thus creating cavitation and hydrodynamic turbulence allowing the irrigant to penetrate the entire canal system and to be continously exchanged by new irrigant. The pressure was generated by a positive displacement piston. The frequency was 25 Hz.

A "tube in tube" hose was used to achieve a smooth exchange of irrigant solution. The irrigant fluid was injected through the outer tube while the reflux occurred through the inner tube. This pulsing two-phase system of alternating pressure fields prevented short-circuiting of the irrigant at the orifices of the double hose because, during the higher pressure phase (collapsing of the bubbles), more fluid entered the root canal system than could leave it per unit of time, and vice-versa during the lower pressure phase when the voids were created.

#### SECOND DEVICE

The basic working principle of this device was the same as described, but cavitation was restricted to the tube inside the mouth. Therefore, its dimensions could be significantly minimized because loss of pressure due to long connecting tubes was substantially reduced. The diameter of the tubes and the reduced (absolute) pressure were such that enough irrigant solution (NaOCl) could penetrate the root canal system.

The reduced absolute average pressure to produce vapor-filled bubbles was set at $9.5 \times 10^4$ 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. A pressure rise to close to ambient pressure caused the bubbles to collapse, thus creating cavitation and hydrodynamic turbulences similar to the first device. NaOCl was ex-

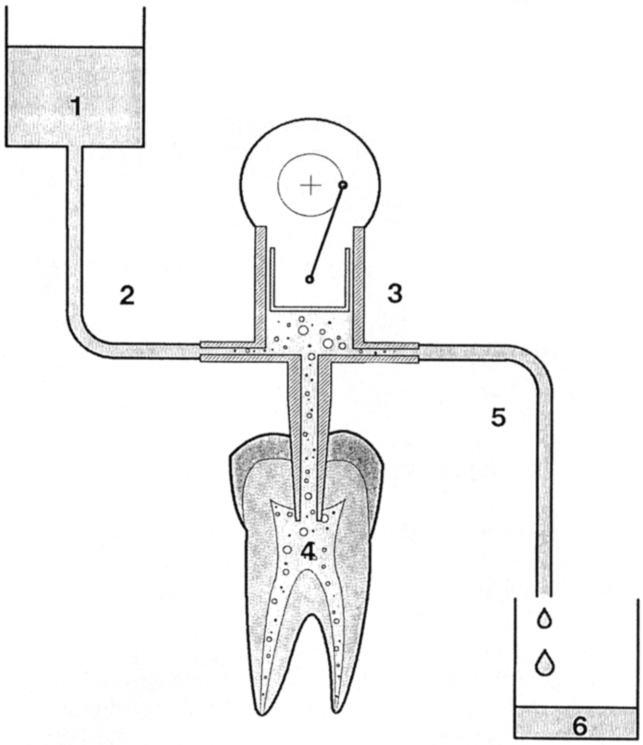


FIG 1. Schematic construction and mode of function of the cleansing machine. From a reservoir *(1)*, the irrigant flows through a heated tubing *(2)* via an alternating pressure generator *(3)* into the tooth *(4)*. Excessive irrigant is conducted via an extra tubing *(5)* into a waste recipient *(6)*.

changed within the root canal system by these hydrodynamic turbulences. The configuration was such that the pressure could not exceed ambient pressure to prevent penetration of irrigant into the periapical region. Cavitation and diameter of the bubbles were controlled by the revolutions of the piston pump. It was set at 230 Hz.

Also, only one tube leading to the tooth was now necessary as the exchange of irrigant in the "closed" endodontic system was maintained by the creation of vapor-filled bubbles and their collapsing immediately afterwards (Fig. 1).

## Procedure

To compare the effectiveness of the new advanced device with that of the machine described previously (1), identical methods of assessment were used in the study presented herein. In summary, after opening the pulp chamber, the roots were covered with a 1.5 mm layer of a zinc phosphate cement (Ultraphos, Woelm, Germany). To obtain a somewhat porous layer, the powder was first mixed with NaCl (1:1) and, once set, NaCl was dissolved out by water. The vial was then filled with a solution with physicochemical properties (viscosity, electrical resistance, and ionic strength) similar to those of blood. Its composition was: 53.0 g of $H_2O$, 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 as indicators monitoring even trace amounts of NaOCl. If NaOCl were to seep beyond the apex, the starch would take on an intensive blue-brown stain from elementary iodine (2) produced according to the following very sensitive chemical reaction: $OCl^- + 2I^- \rightarrow I_2 + O^{2-} + Cl^-$. The temperature was kept at 37 ± 1°C.

Sixty-six freshly extracted molars (immediately deep frozen until use) were cleansed with the new device and compared with 52 molars cleansed with the old machine (1). A total of 118 extracted human molar teeth with 305 canals were therefore treated and assessed by identical methods (except for the machines used) to allow comparison of the two devices. Table 1 gives a summary of the treatment groups.

TABLE 1. *Specifications of the different treatment groups*

| Device | % NaOCl | Treatment Time (min) | No. of Molars | No. of Canals |
|---|---|---|---|---|
| First | 1 | 15 | 19 | 54 |
| First | 2 | 10 | 19 | 56 |
| First | 3 | 10 | 14 | 39 |
| Second | 1 | 15 | 18 | 42 |
| Second | 2 | 10 | 24 | 50 |
| Second | 3 | 10 | 24 | 64 |
| Total | | | 118 | 305 |

## Histological Preparation and Assessment of Organic Debris

After the cleansing, the organic debris remaining in the canals was stained by $AuCl_3$ (3). Then, the root canals were exposed longitudinally by grinding the external root surface with discs and burs under ×2.5 magnification until only a thin layer of dentin remained over the root canal. Finally, this last remaining thin dentin was removed with an explorer. The specimens were then photographed. The residual organic debris in the apical (0 to 2 mm), middle (2 to 4 mm), and coronal (4 to 7 mm) section of the canals was assessed as the percentage of the corresponding total examined length: the total length of residual pulpal tissue was divided by the total examined length of the corresponding section of the canal. The magnifications used were: ×13 for the assessment of the organic debris in the coronal parts of the curvatures and ×33 for the apical and middle sections of the root canals.

First, all data were analyzed by descriptive methods using box pots (Systat 5.2, Systat, Inc., Evanston, IL). Because they were not normally distributed, the Kruskal-Wallis one-way analysis of variance and the Mann-Whitney *U* test were used. For multiple comparisons, the p values were corrected by the Bonferroni adjustment procedure. The significance level chosen for all statistical tests was 0.05.

# RESULTS

Figure 2 illustrates the amount of organic debris left in the root canals as a percentage of the total inspected length of the respective canal section. There were no statistically significant ($p > 0.05$) differences found between the two devices for the apical sections of the root canals, regardless of the concentration of NaOCl irrigating solution used. The values ranged from 19.6 ± 3.8 (mean ± SEM) to 22.1 ± 4.0% for the old and from 10.7 ± 2.4 to 23.6 ± 4.5% for the new device. The apical sections of the canals exhibited the least amount (10.7 ± 2.4%) of organic debris when 3% NaOCl was used with the new device. Statistically, this value was significantly lower than the respective value (23.6%) using 2%

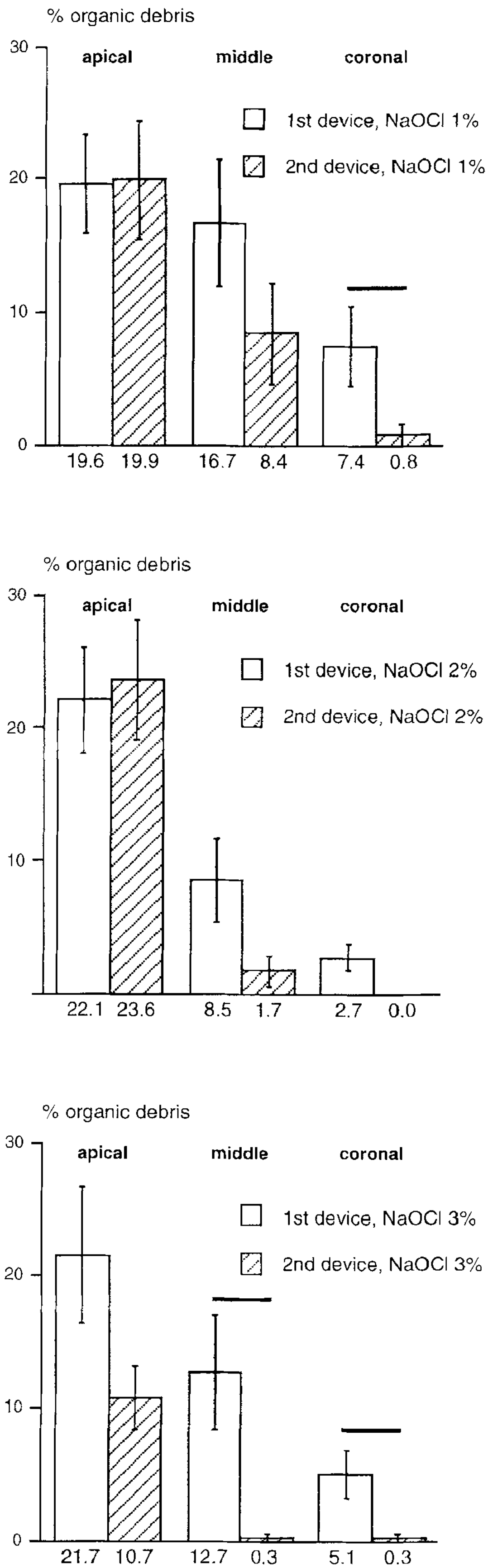


FIG 2. Residual pulpal tissue as percentages of the examined length ± SEM in apical, middle, and coronal root sections. (*Top*) 1% NaOCl: (*middle*) 2% NaOCl; and (*bottom*) 3% NaOCl. Significant differences ($p < 0.05$) within one NaOCl concentration are marked.

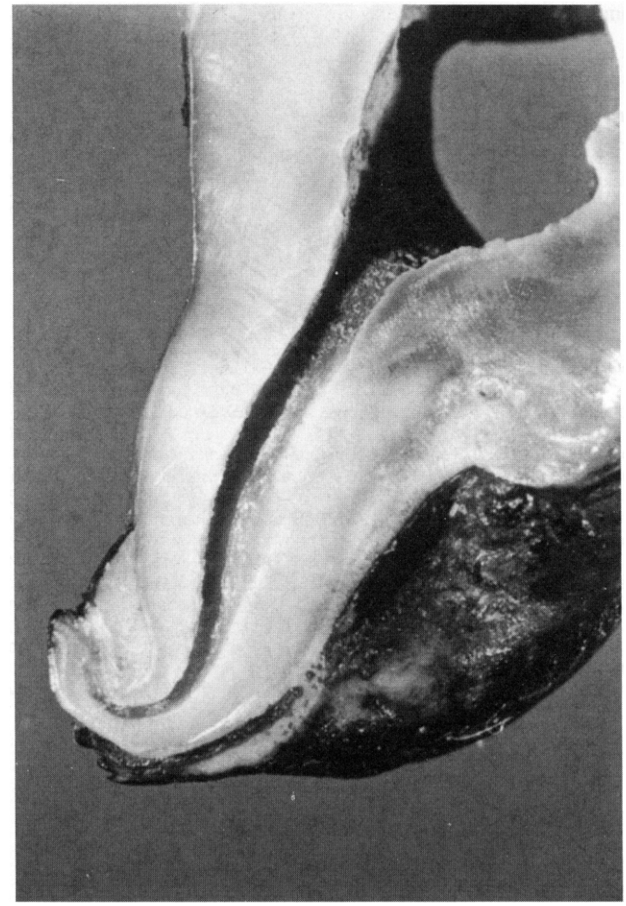

FIG 3. Root canal cleansed for 10 min with the new miniaturized device using 2% NaOCl. No residual pulpal tissue was found.

NaOCl ($p < 0.05$). Generally, the efficacy of the new device was equal or superior to that of the predecessor, although not all differences were statistically significant. The figures for the *middle* sections ranged from 8.5 ± 3.2 to 16.7 ± 4.6% with the old device and from 0.3 ± 0.2 to 8.4 ± 3.8% with the new machine, whereas for the *coronal* sections the respective values went from 2.7 ± 1.0 to 7.4 ± 3.0% with the old and from 0.0 ± 0.0 to 0.8 ± 0.8% with the new device. With all configurations used, the cleansing effect was best in the coronal sections. When the total of organic debris in the three sections of each canal was analyzed, a highly significant ($p < 0.01$) better performance of the new device and 3% NaOCl was found, compared with the old device.

There was no NaOCl found beyond the apex in any of the specimens examined. Figures 3 to 5 show typical root canals cleansed by the new device.

## DISCUSSION

This study showed a better cleansing efficacy in the root canals of the new noninstrumentation technology (NIT), compared with that of its predecessor. However, NaOCl remains indispensable as irrigant (4), and the cleansing performance depended on its concentration. Cleansing efficacy of a 1% solution seemed to be inferior to that of a 3% concentration. Cleansing with the 1% solution was conducted for 15 min, whereas with the 2% and the 3% concentration, this time was reduced to 10 min. Using the old machine, the 1%/15-min procedure did not meet the overall clean-

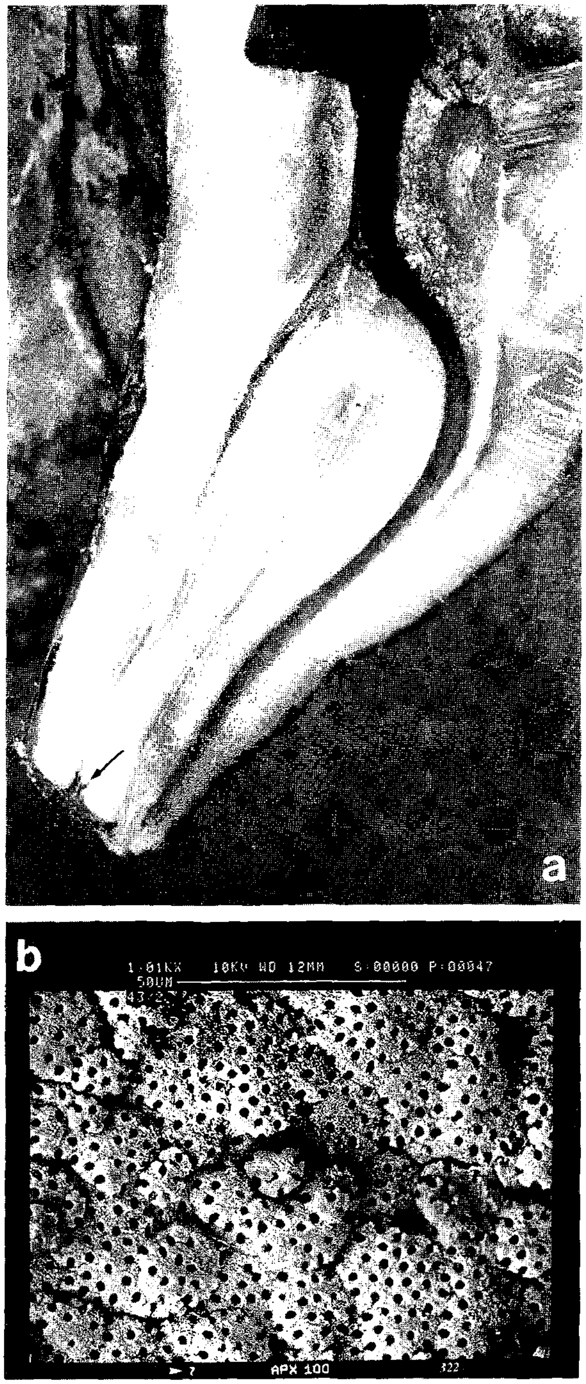


FIG 4. (a) Root canal cleansed for 10 min with the new miniaturized device using 3% NaOCl. Some residual pulpal tissue in the apical part of one canal (*arrow*) is shown. (*b*) The scanning electron microscopic photomicrograph from a clean area shows calcospherites and open dentinal tubules, but not smear layer. (Original magnification ×1010).

FIG 5. Complex root canal cleansed for 10 min with the new miniaturized device using 3% NaOCl.

liness results of the 2%/10-min configuration. With the new device, however, both the 1%/15-min and 2%/10-min method produced comparable results. Furthermore, the new device produced better results with definitely less irrigation solution. The mean consumption of irrigation fluid was reduced by a factor of 20 to now <7 ml/min. This reduction was an absolute prerequisite if the use of the machine was ever to become an office routine. The pressure oscillations created in the pulp chamber by the two machines were different in size and frequency. The older device reduced the average pressure to $3 \times 10^4$ Pa with peaks of up to $9 \times 10^4$ Pa at a frequency of 25 Hz. The bubbles thus produced exhibited a size of between 5 and 50 $\mu$m. Average pressure reduction with the new device was less (i.e. $9.5 \times 10^4$ Pa), but at a frequency of 230 Hz. These conditions produced smaller bubbles. The machine was preset so as not to build up positive pressure at any time, thus preventing irrigation solution from being pressed beyond the apex. The average pressure reduction with the new device ($0.5 \times 10^4$ Pa) was 14 times smaller than that of the old machine ($7 \times 10^4$ Pa) to prevent possible bleeding into the canal in a later in vivo situation. The larger (less negative) base line pressure of the new device ($9.5 \times 10^4$ Pa instead of $3 \times 10^4$ Pa) did not seem to have any negative consequences on cleansing efficacy.

The reduction of treatment time certainly is a major advantage of the new NIT over conventional methods. Previous studies (1, 5) showed an advantage of up to 3.2 times in favor of the new method because treatment time is basically independent of the number of canals to be treated. The major disadvantage of the method is the need of a hermetic seal between the tubing and the pulp chamber to achieve any reduced pressure atmosphere at all. Also, it was necessary that negative pressure ("vacuum") be increased to $1 \times 10^3$ Pa (= 10 mbar) to successfully obturate the root canal system. Our investigations in vivo have demonstrated that a vacuum of said order of magnitude can be successfully achieved either by using seals made of elastomer impression compounds (6) or composit resin core materials with enamel/dentin bondings and adapter capsules (7).

Even though the present study was conducted in vitro, an attempt was made to stimulate in vivo conditions as closely as possible. First, the teeth used in the study were vital before extraction and were then immediately deep frozen until use. Preliminary experiments showed that teeth stored in saline or other solutions would be cleaned better by the machine due to necrotic pulpal tissue. Throughout the experiment, the teeth were stored in a solution closely resembling the physicochemical properties of blood and containing an indicator substance to track even minute amounts of NaOCl. Porous cement was applied onto the root surfaces to simulate the periodontium. The experimental set up allowed checking the hypothesis that, due to permanent negative pressure during the entire cleansing procedure, no NaOCl would penetrate beyond the apex. In fact, during cleansing, no NaOCl was detected outside the pulpal cavity and the root canal. This is a central critical issue regarding future clinical application.

This investigation demonstrated that the improved new model of the noninstrumental root canal cleansing machine (NIT) provided better cleansing with less pressure reduction and with remarkably less irrigation solution than its predecessor. Further studies are needed to evaluate in vivo both the influence on cleansing of injured blood vessels and whether or not the irrigation solution will stay confined to the root canal system under all circumstances and will not seep beyond the apex.

Drs. Lussi, Portmann, Nussbächer, Imwinkelried, and Grosrey are affiliated with the Department of Operative, Preventive, and Pediatric Dentistry, University of Bern, School of Dental Medicine, Bern, Switzerland. Address requests for reprints to Dr. A. Lussi, Klinik für Zahnerhaltung, Freiburgstrasse 7, CH-3010 Bern, Switzerland.

### References

1. Lussi A, Nussbächer U, Grosrey J. A novel non-instrumented technique for cleansing the root canal system. J Endodon 1993;19:549–53.
2. Roth HJ, Blaschke G. Pharmazeutische Analytik. Stuttgart: G Thieme 1978:139–40.
3. Suter B. Endosonic—Eine neue endodontische Aufbereitungs-methode im kritischen Vergleich zur konventionellen Art (Medical Dissertation). Bern, Switzerland, 1985.
4. Lussi A, Schroeder A, Hotz P, Stich H. Cleansing and obturation of the root canal system without conventional instrumentation. Australian Endod Newslett 1997;23:16–9.
5. Lussi A, Messerli L, Hotz P, Grosrey J: A new non-instrumental technique for cleaning and filling root canals. Int Endod J 28:1–6, 1995.
6. Lussi A, Suter B, Grosrey J. In-vivo-Obturation von Wurzelkanälen mit der neuen Vakuumtechnik. Endodontie 1996;3:189–94.
7. Lussi A, Suter B, Grosrey J. Obturation of root canals in vivo with a new vacuum technique. J Endod 1997;23:629–31.