Ability of four irrigating solutions to remove debris after root-canal instrumentation

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_The cleaning and shaping of the root-canal system are considered key requirements for a successful root-canal treatment (RCT). However, limitations in the overall quality of preparations obtained by manual and automated root-canal instrumentation have been reported by numerous researchers.[1,2] Many studies have concluded that neither hand instrumentation nor rotary preparation sufficiently clean the root canal, especially the apical region of curved canals.

Group (*n*=20)	Irrigating solutions during root-canal preparation
A	17 % EDTA (Roth International)
B	2.5 % NaOCl
C	2.5 % MTAD (BioPure MTAD, DENTSPLY Tulsa)
D	2 % chlorhexidine

Table I_ Solutions used during root-canal preparation.

Cleaning and shaping can be easily accomplished in straight canals. However, many canals have moderate, severe or abrupt curvatures that make them susceptible to procedural accidents, such all as ledges, zips, perforations and apical blockages.[3–5]

The removal of pulp tissue, debris, the smear layer and bacteria from the root-canal space prior to obturation is one of the primary aims of RCT. The degree of difficulty experienced during the cleaning and shaping procedure is affected by the canal curvature, access to the canal space, canal length and canal diameter.[6,7] There can be no doubt that micro-organisms that either remain in the root-canal space after treatment or recolonise the filled canal system are the main cause of endodontic failure.[8]

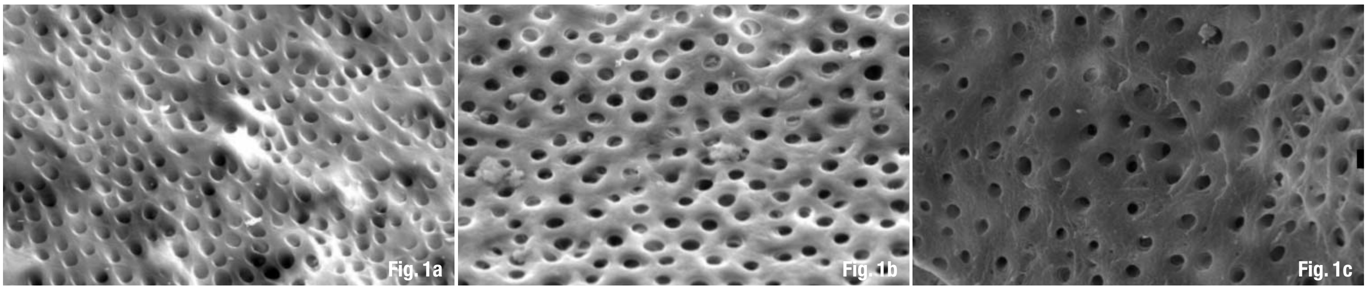
While irrigants, such as sodium hypochlorite (NaOCl), are helpful in dissolving organic debris,[9] thorough instrumentation is a necessity. The efficiency of cleaning the endodontic space depends on both instrumentation and irrigation. Irrigation plays a main role in successful debridement and disinfection. The most widely used irrigant for RCT is NaOCl at concentrations of 0.5 to 5.25 %. The tissue-dissolving capacity and microbicidal activity of NaOCl make it an excellent irrigating solution.[9]

Of all the currently used substances, NaOCl appears to be the most ideal, as it fulfils more of the requirements for endodontic irrigant than any other known compound. Hypochlorite has the unique capacity to dissolve necrotic tissue[10] and the organic components of the smear layer. Inactivation of endotoxins by hypochlorite has been reported;[11,12] the effect, however, is minor compared with that of a calcium hydroxide dressing.[13]

Acid solutions have been recommended for removing the smear layer, including: EDTA, most active at a concentration of 15 to 17 %, and a pH of 7 to 8;[10] citric acid solutions, used at concentrations of 10, 25 and 50 %.[14,15] In addition, calcification hindering mechanical preparation is frequently encountered in the canal system.

Demineralising agents such as EDTA show high efficiency in removing the smear layer.[16,17] In addition to their cleaning ability, chelators may detach biofilms adhering to root-canal walls. This may explain why an EDTA irrigant has proven to be highly superior to saline in reducing intra-canal microbiota,[18] despite the fact that its antiseptic capacity is relatively limited.[19] Antiseptics such as quaternary ammonium compounds (EDTAC)[20] or tetracycline antibiotics (MTAD)[21] have been added to EDTA and citric acid irrigants, respectively, to increase their antimicrobial capacity. The clinical value of this, however, is questionable.

EDTAC shows similar efficacy to EDTA regarding smear layer removal, but it is more caustic.[21] As for MTAD, resistance to tetracycline is not uncommon in bacteria isolated from root canals.[21] Generally speaking, the use of antibiotics instead of biocides such as hypochlorite or chlorhexidine appears unwarranted, as the former were developed for systemic use rather than local wound debridement, and have a far narrower spectrum than the latter.[22]



Figs. 1a–l_Typical SEM photomicrographs showing the cervical, middle and apical thirds of the root-canal dentine surface for 17 % EDTA (a–c), MTAD (d–f), 2.5 % NaOCl (g–i) and 2 % chlorhexidine (j–l; 1,000–5,000x).

MTAD was used to remove the smear layer[21] on coronal leakage of obturated root canals using a dye leakage test.[23]

Chlorhexidine is a strong base and is most stable in the form of its salts. The original salts were chlorhexidine acetate and hydrochloride, both of which are relatively poorly soluble in water.[24] Hence, they were replaced by chlorhexidine digluconate. Chlorhexidine is a potent antiseptic widely used for chemical plaque control in the oral cavity.[25,26] Aqueous solutions of 0.1 to 0.2 % are recommended for such purpose, and 2 % is the concentration of root-canal irrigating solutions usually found in the endodontic literature.[27]

The purpose of the present study was to evaluate the ability of 17 % EDTA, 2.5 % NaOCl, MTAD and 2 % chlorhexidine to remove debris when used as a final irrigant during root-canal instrumentation.

_Material and methods

Tooth selection

Eighty freshly extracted human maxillary central incisors with a single straight root canal extracted from 35- to 60-year-old patients with periodontal disease were randomly selected and radiographed buccolingually and mesiodistally.

The teeth were devoid of caries and cracks, and had not undergone endodontic treatment or restoration. Only teeth with intact and mature root apices were selected. Teeth were placed in individual containers with 2 % formalin and stored in a refrigerator at 10 °C. The average root length was 12 mm. At the time of use, the teeth were removed from formalin and washed in tap water for 30 minutes (Table I).

Root-canal preparation

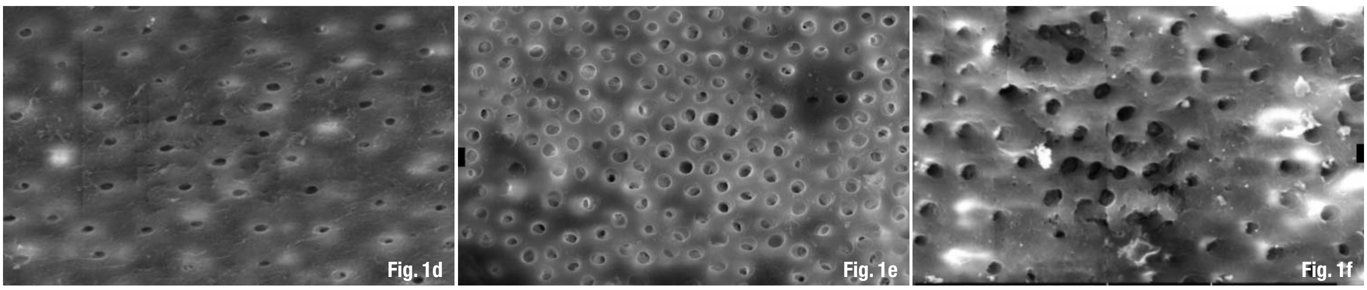
The teeth were de-coronated to a standard root length of 12 mm and randomly divided into four groups ($n = 20$). The working lengths were measured by deducting 1 mm from lengths recorded when the tips of #10 or #15 K-files (DENTSPLY Maillefer) were visible at the apical foramen and confirmed radiographically.

All root canals were then explored and prepared by rotary instrumentation with a size 25 LightSpeed LSX instrument (Discus Dental), in establishing the working length. All working lengths were confirmed radiographically.

Rotary instrumentation was performed with size 25 to 80 LightSpeed LSX instruments in the apical third. They were used at a constant speed of 2,000 rpm using an in-and-out movement. LightSpeed LSX instruments were changed every six canals and the instrumentation was performed according to the manufacturer's instructions. All canals were irrigated with 2 cc of distilled water. Gates Glidden drills (Mani) #1 to #3 were used on the body of the root-canal walls (cervical and middle thirds) before apical preparation.

Irrigation

After cleaning and shaping, all root canals were finally flushed with 30-gauge nickel-titanium needles (Stropko NiTi Flexi-Tip, SybronEndo), which penetrated to within 1 to 2 mm of the working length. The canal was irrigated with 2 ml of the respective irrigating solution: 17 % EDTA (Roth International), 2.5 % NaOCl, MTAD (BioPure MTAD, DENTSPLY Tulsa) or 2.0 % chlorhexidine. The same method was used for all of the 20 teeth in each group, only changing the



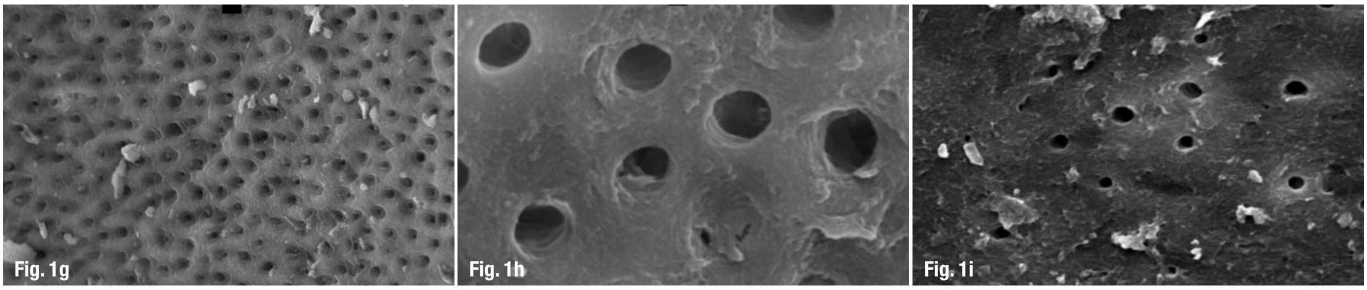


Fig. 1g Fig. 1h Fig. 1i

irrigating solutions tested. After cleaning and shaping, the canals were dried with absorbent paper points (DENTSPLY Maillefer).

SEM examination

To prepare the samples for imaging, all teeth were separated longitudinally and evaluated from the cervical, middle and apical third. Roots were split longitudinally along the buccolingual plane. To facilitate fracture into two halves, all roots were grooved longitudinally on the external surfaces with a diamond disk, avoiding penetration of root canals.

The roots were then split into two halves with a chisel. For each root, the half containing the most visible part of the apex was conserved and coded. The coded specimens were placed on metal stubs with composite, desiccated, sputter coated with gold, and viewed with a SEM (LEO 1430 VP, Carl Zeiss NTS).

The cleanliness of each canal wall was evaluated in each of the thirds and photographed at 1,500 magnification at the same height as the groove that defined each third. The scoring procedure, which did not identify the specimens' groups, was carried out by the authors using the following score system:[4]

Score 1: Clean canal wall; only very few debris particles;
Score 2: Few small conglomerations;
Score 3: Many conglomerations; < 50 % of canal wall covered;
Score 4: > 50 % of canal wall covered;
Score 5: Complete or nearly complete covering of canal wall by debris.

Table II_Results of the debris removal between irrigating solutions ($x \pm s$; x: arithmetical mean, s: standard deviation).

Group/Irrigating solution	apical third	middle third	cervical third
EDTA (*n* = 20)	1.22 ± 0.35 0.545	1.15 ± 033 0.066	1.08 ± 0.10 0.031
NaOCl (*n* = 20)	1.94 ± 0.45 < 0.001	1.76 ± 0.43 0.004	1.76 ± 0.43 < 0.001
MTAD (*n* = 20)	1.54 ± 0.35 0.545	1.55 ± 0.39 0.076	1.69 ± 0.30 0.708
chlorhexidine (*n* = 20)	2.10 ± 0.80 0.064	2.15 ± 0.96 0.330	2.10 ± 0.94 0.082

_Results

The results showed that the increase in the percentage of debris always occurs in the same direction, that is, from the middle region to the apical, no matter which solution is utilised. Table II displays the debris findings and the comparisons among irrigating solutions. Group A (EDTA) demonstrated significant differences to the other groups. EDTA was more effective in debris removal than the rest of the irrigating solutions (Table II).

Statistical analysis

The experimental data used in this study consisted of the four groups and was tested with a Q-Cochran test.[28] The Q-Cochran test showed statistical significance between the four groups. The Kolmogorov–Smirnov test was used for checking the normality of the data distribution. As the data for each group did not follow a normal distribution, the variables were analysed using a non-parametric test. The level of statistical significance was set at $p < 0.05$.

To determine which of the means of the irrigating solutions was significantly different from the others, the complementary Tukey test was used. The Tukey test showed a statistical difference between the means of 2 % chlorhexidine and EDTA. With the Tukey test, we found the means of EDTA and BioPure MTAD to be statistically equal.

Debris was removed mostly at the cervical and middle thirds, but remained visible in the apical third in all cases. The apical third of the root canals showed more debris than the middle third, and none of the irrigating solutions left the root-canal walls entirely free of debris (Fig. 1).

_Discussion

The main purpose of this investigation was to evaluate the ability of 17 % EDTA, 2.5 % NaOCl, MTAD and 2 % chlorhexidine to remove debris when used during root-canal instrumentation. Because debridement in the apical third has always been a challenge, the root canal was analysed and scored by thirds.

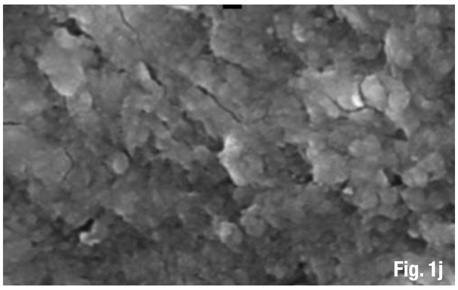


Fig. 1j

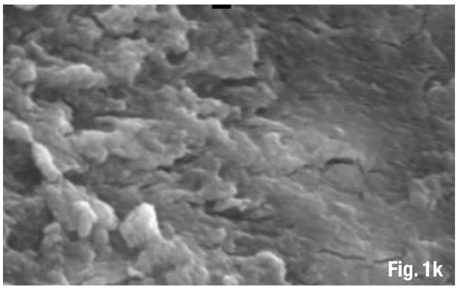


Fig. 1k

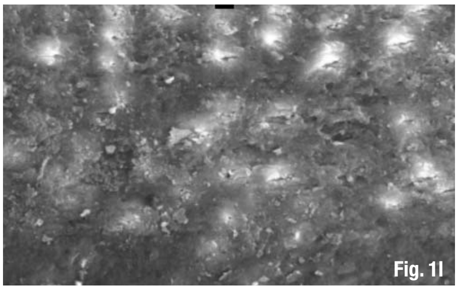


Fig. 1l

The combination of chemical and mechanical preparation forms the key requisite for the success of root-canal instrumentation. The objective of these two interdependent factors consists of the cleaning of the canal and its eventual ramifications removing the largest possible amount of debris in order to establish ideal conditions, which allow a functional recuperation of the dental organ and a regeneration of tissues.

An NaOCl solution remains the most widely recommended irrigant in endodontics on the basis of its unique capacity to disinfect and dissolve necrotic tissue remnants and its excellent antimicrobial potency.[4] However, in this study, NaOCl did not remove the smear layer from the apical third of the canals, which is consistent with the results previously reported by other authors.[29] Numerous studies have compared the performance of irrigating solutions in RCT, including different concentrations of NaOCl, citric acid and EDTA.[30]

EDTA and the different salts from which they are formulated are effective chelating agents for smear layer removal. Numerous authors have reported that alternate applications of NaOCl and EDTA eliminated both organic and inorganic components.[16,19,20]

No significant differences were found by Hülsmann et al.[6,7] in either debris or smear layer removal when they used 3 % NaOCl as initial and final irrigation and 17 % EDTA in the form of a paste after each file and using two rotary instrumentation techniques.

The results obtained in the present study demonstrate that the EDTA and BioPure MTAD solutions were the solutions that left the smallest amount of residue in the interior of the canals, followed by NaOCl and finally chlorhexidine, which left the greatest amount of debris. With the rotary instrumentation technique, the results for EDTA and the rest of the irrigants were similar, as had been found in previous reports,[9] and both solutions (EDTA and MTAD) are recommended.

The finding that the EDTA solution was the best root-canal cleaner confirms the findings of Tanomaru et al.[13] This may be due to the potentiation of the solvent action when energised by temperature.[14] Irrigating solutions used in endodontic treatment not only have an antimicrobial action but also clean the pulp chamber.[11] None of the irrigating solutions studied in the present work was capable of eliminating all of the debris in the root-canal walls, since none of them left the root canals completely free of debris.

In the present study, no significant differences in the presence of debris were observed among root-canal thirds in the manually and rotary instrumented groups irrigated with NaOCl. Similar results were found by Tucker,[31] who compared rotary instrumentation with the hand technique using 1 % NaOCl as irrigating solution.

The removal of debris and the smear layer depends on the irrigation method, as well as on the endodontic instrument, the manner in which the instrument is used, and the preparation technique. The root-canal cleaning capacity of manual versus rotary instrumentation techniques with NaOCl is somewhat controversial.[4]

_Conclusion

1. The apical third showed a greater amount of debris than the middle third, regardless of the solution used.
2. None of the solutions used for irrigation of the root canals allowed complete removal of the debris from the interior of the canal.
3. The 17 % EDTA and BioPure MTAD irrigating solutions left the root canals with less debris than the 2.5 % NaOCl and 2 % chlorhexidine solutions.

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