Cleaning efficacy of a new root canal irrigation solution: a preliminary evaluation

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Abstract

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Aim A new product, electro-chemically activated water, was compared to NaOCl for its cleaning effect on root canal walls.

Methodology Root canal treatment was carried out on two groups of extracted teeth with one of the irrigants being used in each group. The control group received no treatment. All teeth were split and the canal walls viewed in a scanning electron microscope.

Results The canal walls of the control group were covered by debris and bacteria. Sodium hypochlorite produced clean surfaces with the dentinal tubules open in some areas and occluded by the smear layer in other areas; in some areas bacteria were visible inside or under the smear layer. Electro-chemically activated water produced markedly cleaner surfaces, removing the smear layer in large areas.

Conclusions The cleaning efficacy of electro-chemically activated water in root canals was considered to be superior to NaOCl.

Keywords: irrigation, root canal, solutions, ultra-sonic.

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Introduction

Sodium hypochlorite (NaOCl) in a solution of 2.5–5.25%, delivered with either a syringe and needle or an ultrasonic unit, is the irrigant of choice for root canal treatment (Cheung & Stock 1993, Georgopoulou *et al.* 1994, West *et al.* 1994, Gulabivala & Stock 1995, Panighi & Jacquot 1995, Cameron 1995, Walton & Rivera 1996), despite certain problems associated with its use:

1 NaOCl is toxic to living tissue and extrusion of the liquid through the apices of teeth can cause postoperative pain, swelling and necrosis (Brown *et al.* 1995, Cymbler & Ardakani 1994, Çalişkan *et al.* 1994).

2 Because of the corrosive nature of NaOCl (Neal *et al.* 1983), ultrasonic units used in canal irrigation are prone to mechanical breakdown.

3 The taste of NaOCl is unacceptable to patients and the vapour can be an irritant to eyes.

Many investigators have searched for agents to replace NaOCl. Water, disinfectants and various detergents have all been tested and subsequently rejected in favour of NaOCl.

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Russian scientists have developed a process whereby so-called electro-chemically activated water (ECA) is produced with a new and unique anode–cathode system (Leonov 1997). To date, no reference to this system is to be found in Western scientific literature; the only documentation in existence has been translated from the original Russian. ECA is the subject of more than 300 Russian and international patents and many claims regarding its antimicrobial nature have been made. More than 20 000 units producing ECA are in operation in Russian hospitals. It is claimed that ECA is harmless to humans, with patients drinking considerable quantities of ECA and open wounds being washed with it (Leonov 1997, Bakhir 1997).

The physical and chemical nature of ECA is not yet fully understood (Bakhir 1997). The solution supposedly exists in a metastable or disequilibrious state for 48 h after production and contains many free radicals and a variety of molecules. After 48 h the solution returns to the stable state, becoming inactive again. In the metastable state the solutions have a very high oxidation-reduction potential. Two types of ECA solutions are produced.

1 Anolyte, with high oxidation potential (400–1200 millivolts). It is possible to produce acidic, neutral or

alkaline anolyte (pH 2–8). Anolyte is claimed to be highly antimicrobial.

2 Catholyte, an alkaline solution (pH 7–12) with high reduction potential (–80 to –900 millivolts). Catholyte is reputed to have a strong cleaning or detergent effect.

Both these solutions are produced from tap water and saline solutions in a unit which houses a unique flow-through electrolytic module (FEM). The FEM consists of the anode, a solid titanium cylinder with a special coating, which fits coaxially inside the cathode, a hollow cylinder also made from titanium with another special coating. The electrodes are separated by a ceramic membrane.

The anolyte produced at the anode contains Cl_2, HOCl, ClO^-, $ClO\cdot$, $Cl\cdot$, HO_2, $HO_2\cdot$, O_2, $HO\cdot$, O_3, $O_2\cdot$, $^3O_2$, $^1O_2$, $O\cdot$, H_3O^+, $Cl\cdot$, $H\cdot$, H_2O_2, Cl_2O, ClO_2^-, HCl, Cl_2O_7, $S_2O_8^{8-}$, $C_2O_6^{2-}$, HClO, H_2SO_4, and HSO_3Cl. The catholyte produced at the cathode contains OH^-, $H_3O_2^-$, O_2^-, HO_2^-, H_2O_2, H_2, HO, H_2^-, NaOH, KOH, $Ca(OH)_2$ and $Mg(OH)_2$.

Interestingly, the Japanese have reported, favourably, on the use of so-called oxidative potential water (OPW) for the cleaning of root canals in teeth (Hata *et al.* 1996). It is not clear what OPW is, but there is some reason to believe that it may be a copy of ECA being produced from similar technology (Aquacida NDX-250 KH, Nihon Aqua Co. Ltd, Kyoto, Japan). Equivalent technology (Super Mini-Water, Jamix Inc, Atsugi, Japan) was used by another Japanese group in an *in vitro* study on the growth of *Streptomyces* spp. (Hotta *et al.* 1994). It is important to note that the Japanese technology (Super Mini-Water and Aquacida) does not make use of the special patented Russian anode–cathode system with its special membrane.

The purpose of this study was to evaluate and compare, by means of ultrastructural studies, the cleaning efficacy of NaOCl and ECA.

Materials and methods

Twenty-three single-rooted human teeth were collected from the Department of Oral and Maxillofacial Surgery of the Faculty of Dentistry of the University of Pretoria immediately after extraction. The extracted teeth were rinsed under running water and stored in specimen bottles filled with distilled water for 72 h. Three teeth were selected to serve as controls. The pulp chambers of the other 20 teeth were accessed using a fissure bur in an air turbine handpiece and a round bur in a contra-angle handpiece. A size 15 K-type root canal file (Dentsply, Maillefer, Baillaigues, Switzerland) was introduced into each root canal to establish patency. The length of each canal was determined by inserting a file until its tip just appeared through the apical foramen. The silicone rubber stop prefitted to the shaft of the file was adjusted to a coronal reference point, the file withdrawn and the length from file tip to silicone stop was noted. An individual working length for each tooth was calculated by subtracting 1 mm from the measured length. The coronal thirds of all canals were preflared using size 6–3 Gates Glidden burs in a contra-angle handpiece in a stepdown technique (Goerig *et al.* 1982). At this stage the 20 teeth were randomly divided into two groups (group A and group B), each consisting of 10 teeth.

Group A (NaOCl)

The root canals of group A were prepared using a series of K-type files (sizes 15–60) manually in a serial technique and by irrigating with a 2.5% solution of NaOCl from an ultrasonic unit at maximum power, using a size 25 file (Cavitron® ENDOSONIC®, Dentsply, Weybridge, England, UK). Irrigation was performed after every size file for at least 10 s. After the canal was prepared to a size 60, a final flush of irrigation was carried out for a minimum of 30 s. A minimum of 150 mL of 2.5% NaOCl was used in the irrigation process for each tooth.

Group B (ECA)

Electro-chemically activated water was produced from a specially manufactured unit (STEDS™, Radical Waters, Johannesburg, South Africa) as proposed by the Russian scientists. The only raw materials that are fed into the STEDS unit are tap water, electricity and a weak salt solution in water. ECA was produced in the two forms, catholyte and anolyte. Anolyte was produced with a pH of 7.4 and catholyte with a pH of 9.8. These solutions were used to irrigate the canals in group B. Root canals were prepared using the same sizes and types of files and the same manual techniques as in group A. After the use of each size file the canal was irrigated with anolyte delivered with the same ultrasonic unit, also for at least 10 s, at the same power setting and with the same size file. After preparation to a size 60, a final flush of irrigation was carried out for a minimum of 30 s using catholyte delivered with the same ultrasonic unit. A minimum of 75 mL anolyte and 75 mL catholyte was used for each tooth.

Control

The three teeth used as controls were selected on the

basis of their pulpal chambers being invaded by caries. These teeth underwent no root canal treatment procedures but were merely split open to reveal the root canal surfaces. They do not represent a true control group, however they were examined in order to provide some form of baseline reference.

Immediately after preparation and irrigation, the teeth were stored in distilled water for 24 h. Longitudinal grooves were cut on the buccal and lingual surfaces with the aid of a microtome but without penetrating through to the pulpal surfaces. The root was then split longitudinally in two with cutting pliers. Similar horizontal grooves were then cut on the external surfaces, approximately 2 mm apart and the sections fractured from each other. Specimens of the root canal walls of the middle third of the roots were placed into a dust-free incubator and allowed to air-dry for 10 days. The dry specimens were mounted with conductive adhesive onto metal bases and sputter-coated with gold and viewed in a scanning electron microscope (JEOL 5800 LV, Tokyo, Japan) in normal vacuum mode at various magnifications.

Results

Control group: no root canal treatment

The entire root canal surface was covered by debris and bacterial products (Fig. 1). The presence of a dense mat of bacilli in a cobblestone paving appearance covering the entire surface of the root canal walls was clearly seen in certain areas of all specimens (Fig. 2). In parts it was clearly demonstrated that the bacteria were covered by the debris shown in Fig. 1. The dentinal tubules were mostly open in the areas where the bacteria were visible; occasionally bacteria were seen lining the lumen of the tubules. Where debris was present, the dentinal tubules were not visible.

Group A: NaOCl

All surfaces were considered to be free of gross debris (Fig. 3). The typical smear layer formed by the action of the burs and files was generally evident. In no area was there any sign of the smear layer being removed. Some dentinal tubules were open and some were occluded by the smear layer (Fig. 4). Even in areas where the dentinal tubules were open, the surface area between the orifices of the tubules, the intertubular dentine, was covered with a thick smear layer. There was no sign of lateral or accessory canals. A morphologically similar kind of bacteria, seen in the control group, was observed in

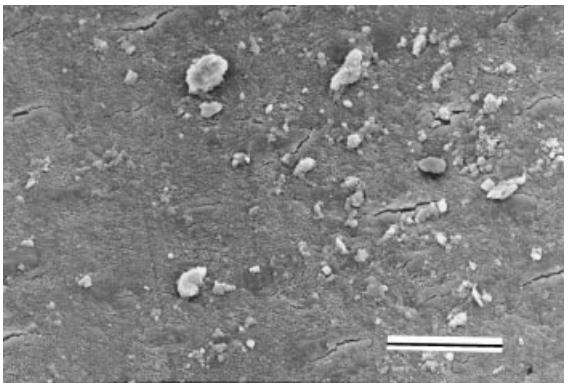

Figure 1 Control group: Untreated surface of infected root canal showing amorphous layer of debris. (Bar indicates 10 μm.)

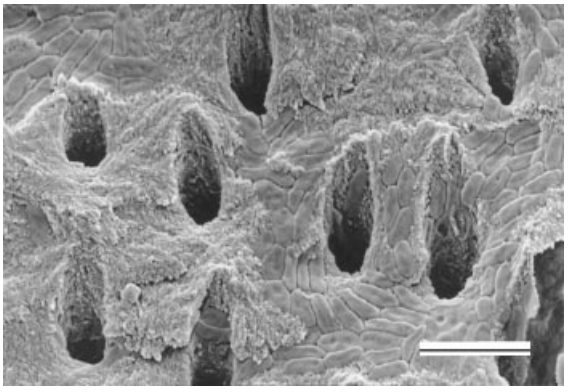

Figure 2 Control group: Untreated surface of infected root canal showing bacilli arranged in cobblestone paving pattern. Note open dentinal tubuli invaded by bacteria. (Bar indicates 5 μm).

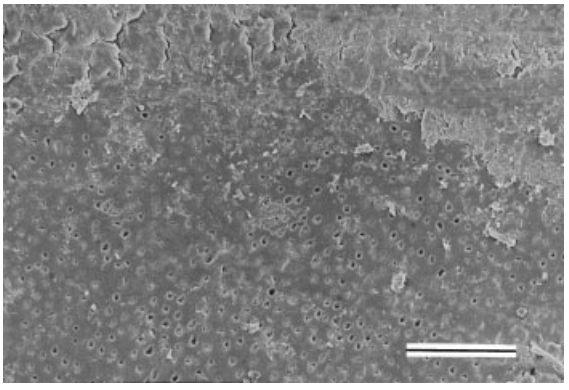

Figure 3 Group A: Surface of root canal walls irrigated by sodium hypochlorite. Note lack of debris and bacteria. (Bar indicates 50 μm).

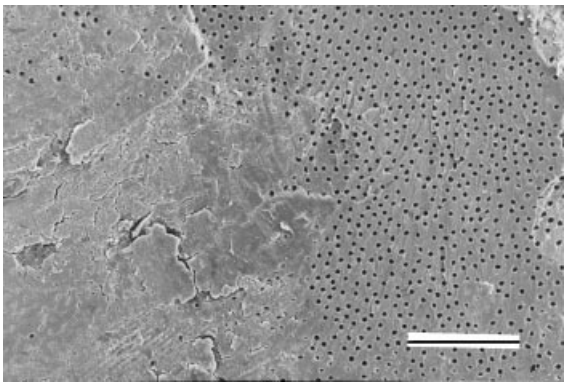

Figure 4 Group A: Surface of root canal walls irrigated by sodium hypochlorite. Note part of specimen with tubuli covered by smear layer in contrast to the rest with tubuli open. (Bar indicates 50 μm).

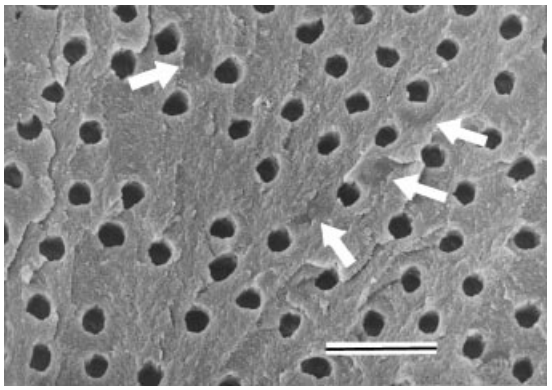

Figure 5 Group A: Root canal walls irrigated with NaOCl, showing smear layer overlying bacteria, indicated by arrows. (Bar indicates 10 μm).

selected areas in or underneath the smear layer overlying the intertubular dentine (Fig. 5).

Group B: ECA

All surfaces appeared to be totally clean and free from debris and bacteria (Fig. 6). Large areas were free of smear layer, exposing the dentinal tubules, collagen fibres and even collagen fibrils underneath (Figs 7, 8). A number of lateral canals or giant tubules, measuring 10–20 μm in diameter were also seen, in certain sections (Figs 6, 9). These canals were seen to branch into two or more, near the root canal surface. There was a distinct difference in appearance and size of these numerous structures and those of the typical dentinal tubules. A typical dentinal tubule had a diameter of 2–3 μm, in contrast to the diameter of 10–20 μm.

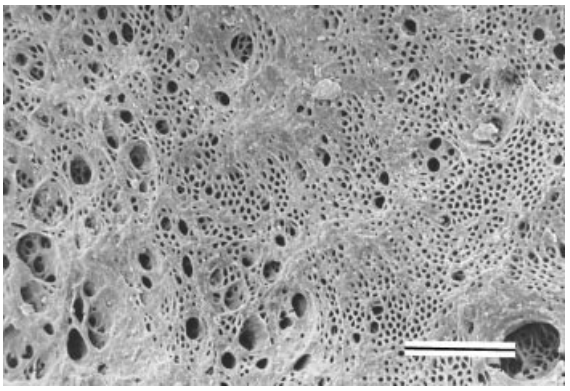

Figure 6 Group B: Surface of root canal walls cleaned by electro-chemically activated water. Note absence of smear layer, debris or bacteria and the open tubuli. Note the larger tubuli measuring 10–20 μm. (Bar indicates 50 μm).

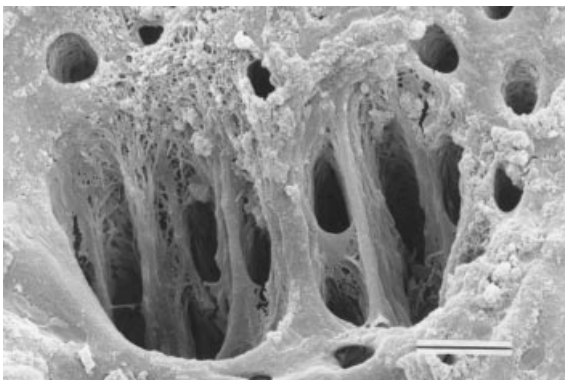

Figure 7 Group B: Larger tubuli in specimen of root canal walls irrigated by electro-chemically activated water. Note collagen fibres, measuring 0.5 μm consisting of collagen fibrils, measuring 50–100 nm (Bar indicates 5 μm).

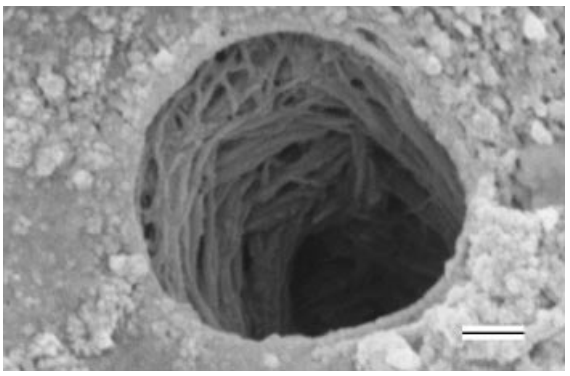

Figure 8 Group B: Higher magnification of small dentinal tubule showing inner structure consisting of collagen fibres. (Bar indicates 0.5 μm).

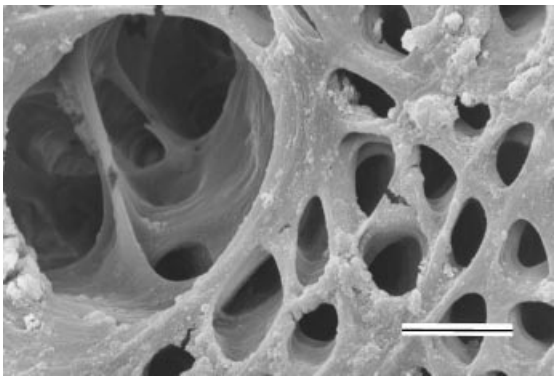

Figure 9 Group B: Detail of larger tubuli showing branching below surface. Note cleanness of surface. (Bar indicates 5 μm).

Discussion

The appearance of the canal walls in the control group with the distinguishing presence of the bacilli type bacteria is significant. It vividly demonstrates the importance of the bio-mechanical approach to root canal preparation. It shows that the predentine was totally covered by a layer of bacteria, which in turn was partly covered by an amorphous layer of debris. Theor-etically all this debris and bacteria should be removed from the root canal system if long-term success is to be achieved. It is one of the aims of root canal preparation to obtain access for an irrigation solution allowing it to come into intimate contact with the bacteria and debris, thereby killing the bacteria and mechanically flushing the debris away.

The cobblestone paving appearance of the bacteria illustrates the importance of treating all surfaces of a root canal, not only part of it. It is imperative to prepare the root canal to a size that allows the free passage of the irrigation solution throughout the entire system, including the apical 2–3 mm. This is potentially a dangerous area, because when an irrigation needle containing NaOCl is introduced to within 2–3 mm of the apical foramen, extrusion can occur. An irrigation solution that is strongly bactericidal, yet harmless to human tissues and cells, would be the ideal irrigating solution, because it would allow for proper irrigation without the toxic effect on periradicular tissues.

The bactericidal potential of NaOCl is not in doubt (Siqueira *et al.* 1998), but the fact that it is highly toxic to human tissues is of concern (Spangberg *et al.* 1973, Lamers *et al.* 1980, Thé & Plasschaert 1980, Pashley *et al.* 1985). As such, its continued use in root canal treatment can be questioned. The removal of the smear layer is still considered somewhat controversial (West *et al.* 1994, Liolios *et al.* 1997), as had been the case in the early years of bonding to dentine. The protagonists of maintaining an intact smear layer wish to keep the dentinal tubules filled with the typical plugs, thereby preventing bacteria from moving into or out of the tubules. Yet, as shown in this and other studies, NaOCl does remove the dentinal plugs from the tubules in certain areas, leaving smear layer intact in the inter-tubular areas. This questions the concept of maintaining the smear layer; there is no advantage in having an intact smear layer over the intertubular dentine if the dentinal tubules themselves are open. In addition, an important finding was that of the bacteria shown in Figure 5, beneath the smear layer over the intertubular dentine. It appeared as if the smear layer was overlying some bacteria in a similar fashion to those shown in the control group (Fig. 2). These bacteria could, arguably, have been shielded by the smear layer from the actions of NaOCl, to survive and multiply. This may offer some explanation for some long- or medium-term failures of root canal treatments. Similarly, bacteria inside the dentinal tubules (Fig. 2) can not be reached by NaOCl, especially when the tubuli are occluded with a smear layer. All these observations add weight to the argument for the removal of the smear layer in root canals.

Electro-chemically activated water cleaned the root canal wall surfaces in a remarkable way, removing the smear layer in large areas. The fact that the collagen fibres and fibrils became exposed (Figs 7, 8) suggests that the dentine was decalcified to some extent, in the way that an etchant would do. Yet, the anolyte used was of a neutral pH and the catholyte of pH 9.8. It should be borne in mind that ECA is produced from nothing more than tap water, salt and electricity, albeit by the use of some unique technology. The fact that such clean surfaces were achieved by this product is remarkable and important.

The appearance of distinctive lateral canals or giant tubules, with a diameter of 10–20 μm (Figs 6 7), is also of interest, because of the numbers of these structures present. In Figure 6 more than 20 of these are visible. The diameter of typical dentinal tubules near the pulpal surface is given as 3–4 μm (Avery 1986), 3 μm (Mjör 1984, Melfi 1988) or 4 μm (Provenza 1988); according to Hess *et al.* (1983), the diameter of accessory canals is in the range of 6–60 μm. It would then appear to be correct to describe these numerous structures as lateral canals. The presence of so many lateral canals in itself would be an interesting phenomenon, although its clinical significance may be unknown at present. At the very least, it would serve to further underline the import-ance of the irrigation phase of root canal treatment.

Lateral canals by their nature can not be negotiated by instruments and can only be cleaned by the action of the irrigation solution. These lateral canals were not macroscopically observed on the external surfaces of the root prior to preparation. And it is possible that they ended blind or 'divided' into dentinal tubules somewhere in the superficial dentine.

Conclusion

Under the conditions of this study, ECA produced cleaner root canal surfaces than did sodium hypochlorite, and removed the smear layer in large areas.

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References

Avery JK (1986) Dentin. In: Bhaskar SN, ed. *Orbans Oral Histology and Embryology*, 10th edn. St Louis, MO, USA: CV Mosby, 103.

Bakhir VM (1997) Electrochemical activation: theory and practice. In: *Proceedings of the First International Symposium on Electrochemical Activation in Medicine, Agriculture and Industry. Moscow, Russia*, 38–45.

Brown DC, Moore BK, Brown CE Jr, Newton CW (1995) An *in vitro* study of apical extrusion of sodium hypochlorite during endodontic canal preparation. *Journal of Endodontics* **21**, 587–91.

Çalişkan MK, Türkün M, Alper S (1994) Allergy to sodium hypochlorite during root canal therapy: a case report. *International Endodontic Journal* **27**, 163–7.

Cameron JA (1995) Factors affecting the clinical efficiency of ultrasonic endodontics: a scanning electron microscopy study. *International Endodontic Journal* **28**, 47–53.

Cheung GS, Stock CJ (1993) In-vitro cleaning ability of root canal irrigants with and without endosonics. *International Endodontic Journal* **26**, 334–43.

Cymbler DM, Ardakani P (1994) Sodium hypochlorite injection into peri-apical tissues. *Dental Update* **21**, 345–6.

Georgopoulou M, Kontakiotis E, Nakou M (1994) Evaluation of the antimicrobial effectiveness of citric acid and sodium hypochlorite on the anaerobic flora of the infected root canal. *International Endodontic Journal* **27**, 139–43.

Goerig AC, Michelich RJ, Schultz HH (1982) Instrumentation of root canals in molars using the step-down technique. *Journal of Endodontics* **8**, 550–4.

Gulabivala K, Stock CJR (1995) Preparation of the root canal. In: Stock CJR, Gulabivala K, Walker RT, Goodman JR, eds *Color Atlas and Text of Endodontics*, 2nd edn. London: Mosby-Wolfe, 97–144.

Hata G-I, Uemura M, Weine F, Toda T (1996) Removal of smear layer in the root canal using oxidative potential water. *Journal of Endodontics* **22**, 643–5.

Hess JC, Culieras MJ, Lamiable N (1983) A scanning electron microscopic investigation of principal and accessory foramina on the root surfaces of human teeth: thoughts about endodontic pathology and therapeutics. *Journal of Endodontics* **9**, 275–81.

Hotta K, Kawaguchi K, Saitoh F, Saitoh N, Suzuki K, Ochi K *et al.* (1994) Antimicrobial activity of electrolysed NaOCl solutions: effect on the growth of *Streptomyces* spp. *Actinomycetologica* **8**, 51–6.

Lamers AC, Van Mullen PJ, Simon M (1980) Tissue reactions to sodium hypochlorite and iodine potassium iodine under clinical conditions in monkey teeth. *Journal of Endodontics* **6**, 788–92.

Leonov BI (1997) Electrochemical activation of water and aqueous solutions: past, present and future. In: *Proceedings of the First International Symposium on Electrochemical Activation in Medicine, Agriculture and Industry, Moscow, Russia*, 11–27.

Liolios E, Economides N, Parissis-Messimeris S, Boutsioukis A (1997) The effectiveness of three irrigating solutions on root canal cleaning after hand and mechanical preparation. *International Endodontic Journal* **30**, 51–7.

Melfi RC (1988) Dentin. In: Melfi RC, ed. *Permar's Oral Embryology and Microscopic Anatomy*, 8th edn. Philadelphia, USA: Lea & Febiger, 111.

Mjör IA (1984) The morphology of dentin and dentinogenesis. In: Linda A, ed. *Dentin and Dentinogenesis*. Boca Raton, FL, USA: CRC Press Inc, 3.

Neal RG, Craig RG, Powers JM (1983) Effect of sterilization and irrigants on the cutting of stainless steel files. *Journal of Endodontics* **9**, 93–6.

Pashley EL, Birdsong NL, Bowman K, Pashley DH (1985) Cytotoxic effects of sodium hypochlorite on vital tissue. *Journal of Endodontics* **11**, 525–8.

Panighi MM, Jacquot B (1995) Scanning electron microscopic evaluation of ultrasonic debridement comparing sodium hypochlorite and Bardac-22. *Journal of Endodontics* **21**, 272–8.

Provenza DV (1988) Dentin. In: Provenza DV, ed. *Fundamentals of Oral Histology and Embryology*, 2nd edn. Philadelphia, USA: Lea & Febiger, 169.

Siqueira JF, Batista MMD, Fraga RC, De Uzeda M (1998) Antibacterial effects of endodontic irrigants on black pigmented gram-negative anaerobes and facultative bacteria. *Journal of Endodontics* **24**, 414–6.

Spangberg L, Engström B, Langeland K (1973) Biologic effects of dental materials 3. Toxicity and antimicrobial effect of endodontic antiseptics *in vitro*. *Oral Surgery, Oral Medicine and Oral Pathology* **36**, 856–70.

Thé SD, Plasschaert AJM (1980) Reactions of guinea pig subcutaneous connective tissue following exposure to sodium hypochlorite. *Oral Surgery, Oral Medicine and Oral Pathology* **49**, 460–5.

Walton RE, Rivera EM (1996) Cleaning and shaping. In: Walton RE, Torabinejad M, eds *Principles and Practice of Endodontics*, 2nd edn. Philadelphia: W.B. Saunders, 201–33.

West JD, Roane JB, Goerig AC (1994) Cleaning and shaping the root canal system. In: Cohen S, Burns RC, eds. *Pathways of the Pulp*, 6th edn. St Louis, MO, USA: CV Mosby, 179–218.