Modern Endodontic Principles Part 4: Irrigation

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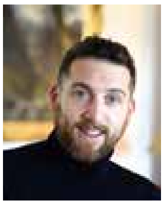

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Modern Endodontic Principles Part 4: Irrigation

Abstract: The complex anatomy of the tooth limits the ability to eradicate pathogens by mechanical means alone. Irrigation is the key to solving this problem. This paper highlights the importance of irrigation, the key irrigants available and methods of improving the performance of irrigants within the canal.

CPD/Clinical Relevance: To provide advice on which irrigants to use, how to use them effectively and safely and what to do if irrigants are extruded beyond the apex.

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Irrigation

During endodontic treatment mechanical debridement alone will not rid the root canals of bacteria,[1] regardless of whether this is done by hand files or rotary instruments.[2] First, instruments do not access the complex shape of the root canal system. (Figure 1).[3-6] Secondly, within these inaccessible regions complex biofilms can develop that are not easily disrupted. Thirdly, instrumentation creates a smear layer that further prevents decontamination of the canal surface dentine and prevents a good adaptation of the obturation material to the canal wall. A sound irrigation regimen can help to deliver antimicrobials to these inaccessible areas of the root canal system, penetrate and remove biofilm and smear layer and even penetrate the dentine.

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Type of irrigant

A recent Cochrane Systematic Review showed no difference between different endodontic irrigants.[7] However, these results should be interpreted with caution. A 'no difference' result is a reflection of the paucity of well-conducted clinical studies rather than taking as fact that no difference exists. The irrigant has several primary goals: dissolution of organic tissue and pulpal remnants, be they vital or necrotic, dissolution of select inorganic components, killing of micro-organisms and neutralization of endotoxin.

Many different irrigants and combinations of irrigants have been used in RCT to achieve these goals. These include:

- Sodium hypochlorite;
- Chlorhexidine;
- Sterilox;
- EDTA;
- Iodine potassium iodide;
- Hydrogen peroxide;
- Local anaesthetic, saline and/or water;
- Mixtures of irrigants (QMIX®).

See Table 1 for a summary of their differing properties.[8] When used alone, very few irrigants offer a complete spectrum of ideal properties.

Sodium hypochlorite

Sodium hypochlorite (NaOCl) was first described as an endodontic irrigant in 1919.[9] It possesses many of the attributes of an ideal antimicrobial agent; it is fast acting, has a broad spectrum of action and is relatively inexpensive.[10] Its activity stems from several key aspects. Hydroxyl ions damage both bacterial lipid membranes and DNA and the high pH created denatures proteins and impairs ideal cell conditions. Chloride ions break peptide bonds dissolving protein and releasing further chloramines that are antibacterial. It remains the gold standard of endodontic irrigants and, although bacteria can still be cultured

	TYPE	ACTION ON FLORA	TISSUE DISSOLUTION	ENDOTOXIN DEACTIVATION	INORGANIC SMEAR LAYER	SUBSTANTIVITY	TOXIC?	ALLERGENIC?	COST
SODIUM HYPOCHLORITE >1%	HALOGEN IONS	✓✓	✓✓✓	✓	X	X	X	-VE	£
CHLORHEXIDINE 0.2%	BISGUANIDE	✓✓	X	✓	X	✓	?	+VE	££
HYPOCHLOROUS ACID		✓✓✓	X	?	X	X	✓	?	££
EDTA	CHELATING AGENT	✓	X	X	✓✓✓	X	✓	-VE	££
IODINE POTASSIUM IODIDE	HALOGEN IONS	✓✓	X	X	X	X	✓	+VE	££
HYDROGEN PEROXIDE	PEROXIDE	✓	X	X	X	X	X	-VE	£
SALINE/WATER/ LOCAL ANAESTHETIC	PLACEBO!	X	X	X	X	X	✓	-VE	£

Table 1. Commonly used irrigants and their key properties. Modified from Zehnder 2006.[8]

following irrigation with hypochlorite, it is nevertheless more effective than saline.[11,12] It should be stored in a cool, dark, air-tight and non-reactive bottle.

Chlorhexidine

Chlorhexidine (CHX) has a broad spectrum activity against both Gram positive and Gram negative bacteria, and is also antifungal. Its antimicrobial activity results from the disruption of bacterial cell walls. Furthermore, it has substantivity; it bonds to dentinal walls, maintaining its antibacterial properties for up to 12 weeks. Chlorhexidine has been used as a substitute for hypochlorite (especially by non-rubber dam users). However, it remains inferior as it does not possess the capacity to dissolve organic matter, and its effect on microbial biofilms is less than that of hypochlorite.[13] Practitioners must also be aware that CHX at 0.2% (found in proprietary mouthwashes) concentrations is only bacteriostatic; to have a bactericidal effect concentrations of 2% must be used. There is also evidence that it can have a negative effect on healing, resulting in an increased odds of failure.[14] In addition, there is a growing concern with CHX and sensitization that may result in anaphylaxis.[15]

Sterilox

Sterilox is a solution that is a safe, non-toxic broad spectrum biocide. The main active ingredient in Sterilox is hypochlorous acid at a concentration of 200ppm of available free chlorine. Hypochlorous acid has been reported to be many times more effective than hypochlorite (bleach) as a biocide. Sterilox solution has approximately 85–98% hypochlorous acid. As a root canal irrigant it has little or no tissue dissolving properties, however, it is non-toxic and safe to use where there may be an open apex and is preferable as an antibacterial agent compared with NaOCl.[16]

EDTA

Ethylenediamine tetra acetic acid (EDTA) (17%) is a chelating agent which removes inorganic debris. It has been found to be beneficial in removing the smear layer and preparing the canal for obturation.[11] EDTA should be used as a final rinse, with no hypochlorite thereafter.[17] In retreatment cases it facilitates the removal of the smear layer and GP residue. It should be used as an adjunct to sodium hypochlorite, not a replacement. It has low toxicity. An alternative is 10–50% citric acid. It too removes the smear layer and is safe.

Iodine-potassium-iodide

Iodine-potassium-iodide (IKI) has been used as an endodontic irrigant. It has excellent antimicrobial activity and low toxicity.[18] It is available in 2% iodine or 4% potassium iodide. Like sodium hypochlorite, it has the ability to penetrate dentinal tubules to a greater extent than chlorhexidine.[19] It can stain dentine and may cause allergic reaction, so it is advisable to take an allergy history of the patient before using.

Hydrogen peroxide

Hydrogen peroxide (H_2O_2) has a long history of use in endodontics. It has been used in concentrations between 3 and 30%.[20] It is active against bacteria, viruses and yeasts.[21] Despite this, the available evidence does not support the use of H_2O_2 over other irrigants and its use is no longer recommended.[22]

Mixtures of irrigants

MTAD and QMIX® have been developed more recently. Both contain surfactants that may lower the surface tension of the irrigant and promote penetration within dentine. MTAD consists of doxycycline, citric acid and detergent. A recent review of this irrigant outlines its properties, and explains that the solution shows promise as an endodontic irrigant in terms of excellent smear layer removal, less concomitant negative effects on dentine, and good biocompatibility.[23] However, there is limited clinical evidence to support the use of MTAD.[24] If used, it should be regarded as an adjunct to NaOCl, not a replacement.[25] QMIX® is a mixture of chlorhexidine, EDTA and a surfactant. As previously highlighted, this solution will not dissolve organic debris and is thus of limited application alone.

a

b

Figure 1. **(a, b)** The CBCT of this UR1 demonstrates three canals in the apical region (marked with *, ** and ***). Question: 'How does one begin to repair this tooth?' Answer: 'You can't!'

Local anaesthetic, saline and/or water

Practitioners using water, saline or local anaesthetic are profoundly misguided in their understanding of endodontics and place themselves at risk of litigation should treatment fail: these irrigants have no antimicrobial properties (Figure 2).

Of the many irrigants on the market, sodium hypochlorite remains the gold standard. It is readily available from dental suppliers and is CE marked. Use of 'thin' household bleach was advocated in the past,[26] letting it down 1 part bleach to 2 parts sterile/distilled water to give a 1% solution. In this increasingly litigious world, however, it would be wise to use only CE marked 'bleach for dental use'. Although other irrigants exist, they should be regarded as adjuncts, not alternatives.

Irrigant mixing

As a rule, the mixing of irrigants should be avoided. Do not mix chlorhexidine and hypochlorite. When mixed they form a precipitate, parachloroaniline which is thought to be carcinogenic, it may stain the tooth and will block the canal and tubules from further irrigant effect[25] (Figure 2). Repeated cycling of hypochlorite and EDTA should be avoided as this will erode dentine and compromise tooth structure.[11] EDTA should be used as a final irrigant once canal preparation has been concluded.[25]

Figure 2. Mixing sodium hypochlorite (left container) and chlorhexidine (middle container) creates a reddish brown precipitate (right container) that is carcinogenic and may impair disinfection.

Activity of irrigant

Concentration

All concentrations of hypochlorite are superior to saline, though there is little difference in efficacy between concentrations.[27] Although 0.5% concentration of NaOCl has been shown to be no different from 5% in terms of bactericidal actions, a concentration of at least 1% (neat Milton is 2%) is required for tissue dissolution.[28] There have been concerns about the safety of concentrations greater than 1%, especially when patency filing. The lower the concentration, the less the risk of a hypochlorite accident. However, no direct link between concentration of hypochlorite and subsequent tissue damage has been made, as a hypochlorite accident is regarded as a scenario with multifactorial aetiology.[29] Chlorhexidine is only bacteriostatic at 0.2% (proprietary mouthwash concentration), but at 2% is bactericidal. Practitioners should be aware of this distinction when considering hypochlorite alternatives.

Temperature

Heating 1% hypochlorite has been shown to improve its properties. A 2.6% solution of NaOCl at 37°C is as effective as 5.2% at 22°C at both tissue dissolution and bacterial killing.[30] Therefore, less cytotoxic concentrations can effectively be used and increasingly practitioners have been heating syringes of hypochlorite in a waterbath prior to use to maximize its effect.

Duration of irrigant use

The longer the irrigant is in contact with root surfaces, the greater the likelihood of successfully killing microbes and reducing the bacterial load. In wider canals, where there is less emphasis on mechanical shaping, longer periods of contact with irrigants are necessary.[11,31] The chlorine component of hypochlorite rapidly

Figure 3. With graduated syringes it is easy to control the flow rate: aim for about 1 ml over 15 seconds.

depletes and may no longer be active after 2 minutes.[32] Constant irrigant exchange throughout treatment is thus essential.

Irrigation rate

It has been shown that exceeding a rate above 4 ml/min does not improve apical clearance but does increase the risk of extrusion;[33] therefore 1 ml increments over 15 seconds give maximum exchange and minimum risk (Figure 3). Further evidence suggests that irrigant does not move further than 1–2 mm beyond the needle tip in the canal irrespective of the pressure applied. Beyond this there is a 'dead zone' and irrigant exchange does not occur, thus consideration must also be given to mode of delivery[34] (Figure 4).

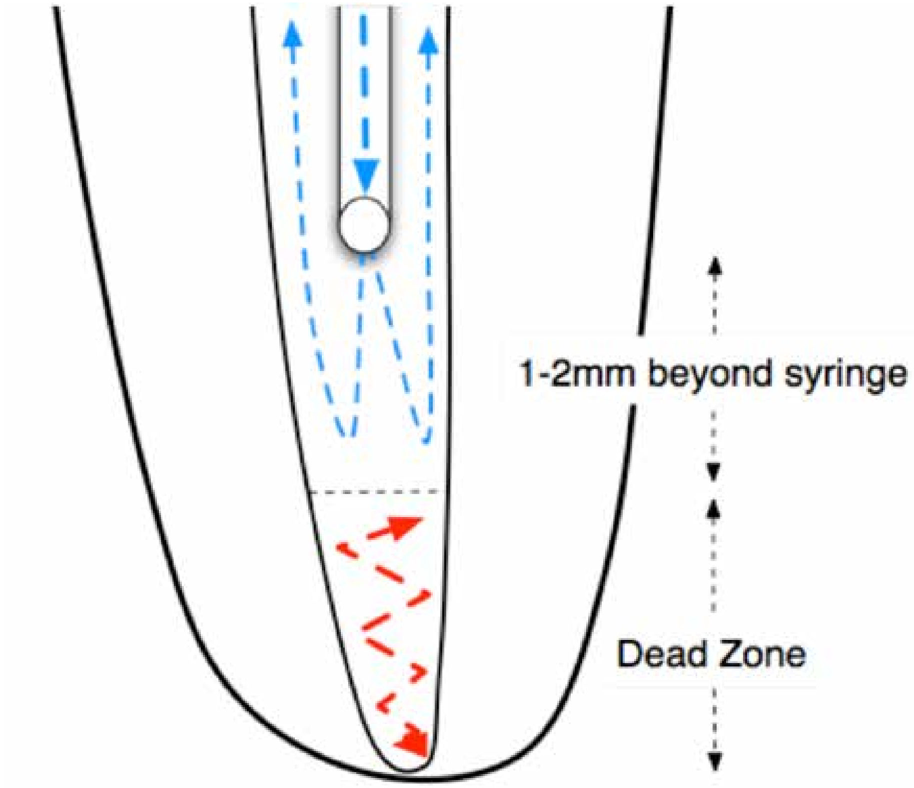

Figure 4. The 'dead zone': there is no exchange of irrigants 1–2 mm beyond the irrigating syringe.

Mode of delivery

An irrigant may not always access anatomical irregularities, remove debris, and eradicate those pathogens embedded in biofilm. Thus, there is growing evidence that irrigant alone may not be adequate and consideration must also be given to exchange and agitation of an irrigant to facilitate decontamination.[35] Circulation and removal of the irrigant and debris are essential components of the cleaning protocol. There are various techniques for ensuring optimal delivery and exchange.

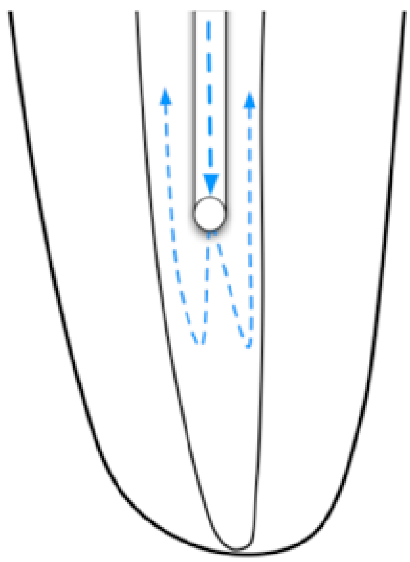

Figure 5. Positive pressure irrigation: irrigant is delivered into the canal via a syringe or cannula.

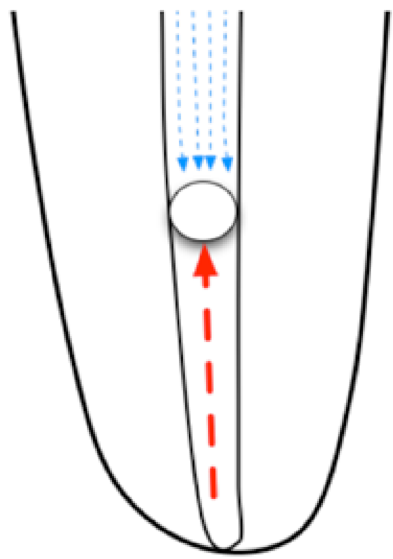

Figure 6. The vapour lock phenomenon: air bubbles apically prevent irrigation beyond.

1. Positive pressure irrigation

Direct injection (positive pressure) is the most common technique for introducing irrigant into canals. A syringe is introduced and pressure applied to deliver irrigant into the canal (Figure 5). The clinician must aim to deliver irrigant to within 1 mm of the apex.[36] Access to the apex is dependent on the size and taper of the canal in question. A 27G needle placed 3 mm from the apex of a canal prepared to 0.3 mm (ISO 30) is sufficient.[37]

An irrigant must not be forced into the root canal system. Forefinger

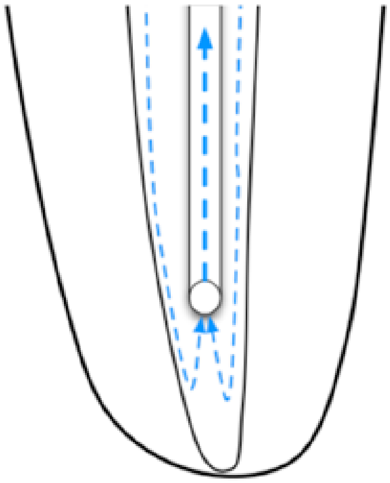

Figure 7. Negative pressure irrigation: an aspirating cannula is inserted into the canal and irrigant introduced coronally. The irrigant is drawn into the canal. This permits the cannula to be introduced further into the canal safely.

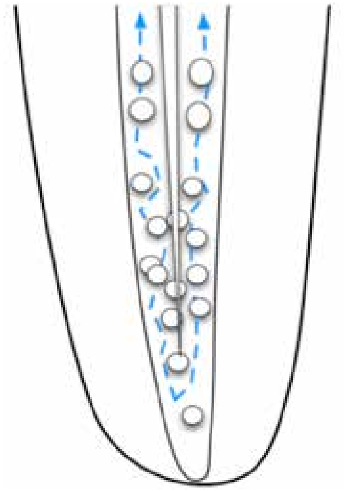

Figure 8. Activation of irrigant with sonic or ultrasonic energy creates acoustic streaming. This disruptive activity promotes disinfection.

a

b

Figure 9. (a, b) The EndoActivator (Dentsply, Tulsa, USA): the disposable tips have depth markings and can be safely introduced into the fluid-filled canal to improve irrigation.

pressure as opposed to thumb pressure is advisable. Although increasing the diameter of the syringe will improve irrigation, this must be balanced with the desire to deliver the syringe tip to within 3 mm of the apex. Do not allow the needle tip to lock in the canal.

Positive pressure irrigation has been associated with two drawbacks:

1. Risk of extrusion; and
2. Inability to irrigate the apical region.

The former can be reduced by a safe irrigating technique, described below. The latter is thought to be due to the formation of bubbles of air within the canal, blocking irrigant penetration; a phenomenon known as vapour lock[38] (Figure 6). This problem can be minimized by using a patency filing technique or negative pressure irrigation.[39] In addition, in narrow curved canals, introduction of a syringe apically may be impossible. Many manufacturers sell flexible tips that can negotiate curved canals more easily.

2. Negative pressure irrigation

The EndoVac (SybronEndo, Orange CA) involves the use of an irrigant delivery cannula combined with a microsuction system (Figure 7). The aspirating cannula draws irrigant into the canal by creating a negative pressure. Thus there is continual irrigant exchange with reduced risk of extrusion. Developed to counteract the difficulties of positive pressure irrigation, this has been shown to improve apical irrigation safely.[40]

This is not without limitations:

1. Debris left *in situ*;[41]
2. Larger apical preparations up to ISO 40 are required to permit introduction of both cannulae (and this may not be[42] possible in curved canals);[43]
3. Cannulae may block with debris;[44]
4. Creating a preparation coronally that allows effective adaptation of the system to the canal can be challenging.

3. Activation of irrigant

Ultrasonic: The application of ultrasonic energy (20–26 kHz) to files within the canal generates acoustic streaming of the irrigant.[45] This increases the turbulence of flow, improving distribution of irrigant, penetration into isthmuses and tissue dissolution. This must be done upon completion of shaping and an ISO 20 or 15 file introduced passively (contact with the canal walls should be avoided as it can remove dentine and create ledges). A protocol of passive ultrasonic irrigation (PUI) has been suggested of 3 x 20 second cycles per canal and the file may be used in an in-out motion.[46] Dedicated systems are available (MiniEndo, Spartan EIE Inc, San Diego CA) but the clinician may simply touch the file with an ultrasonic tip. Though this works well in large straight canals, there is mixed evidence regarding the benefits.[47]

Sonic: The application of sonic energy (1–6 kHz) is thought to have a similar effect to ultrasonic irrigation (Figure 8). The EndoActivator (Dentsply, Tulsa OK) uses disposable polymeric tips with length markings in a battery-powered hand-piece which is theoretically safer to use (Figure 9). Although both sonic and ultrasonic agitation improve cleaning over conventional techniques, they still leave debris within the canal.[48]

Multisonic ultracleaning system

The multisonic ultracleaning system (EMS, Dallas, Texas) uses multiple sonic waves to facilitate irrigation. It will be marketed as 'Gentle Wave' (Sonendo, California USA). It operates using a hand-piece but no component of this is placed within the canal system (Figure 10). The instrument is placed over the pulp chamber, sealing the tooth from the oral cavity and is activated from a computer console. From this a spray of irrigant is delivered at 45 ml/min at 40 °C. (Figure 11). Early *in vitro* results are interesting, with the system showing higher rates of tissue dissolution with differing concentrations of hypochlorite and water[49] (Figure 12).

Manual agitation

Following completion of shaping, the canal is filled with irrigant and the GP master-cone inserted. It is then 'pumped' up and down in rapid 3 mm motions. This can overcome 'vapour lock' and facilitate irrigant exchange close to the FWL, while at the same time disinfecting the GP cone prior to cementation (Figure 13).

Figure 10. (a, b) The Gentle Wave hand-piece and computerized delivery system. (Photos courtesy of Sonendo, California, USA.)

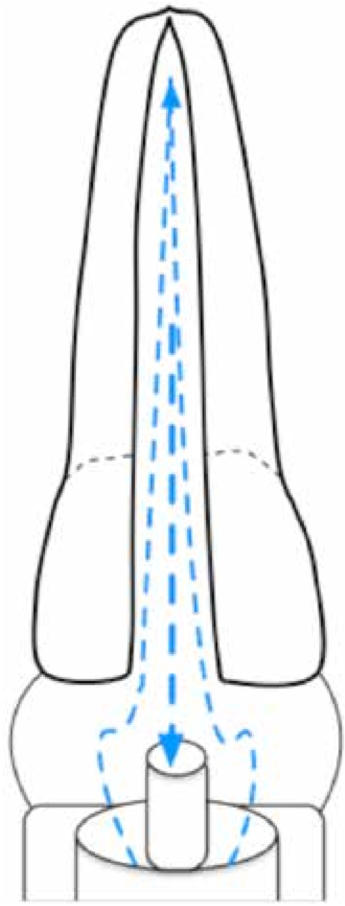

Figure 11. Diagrammatic representation of the Gentle Wave System (Sonendo, California, USA): irrigant is sprayed into the canal system from a hand-piece sealed to the crown of the tooth. An internal aspiration system removes irrigant coronally. No component of the system enters the canal.

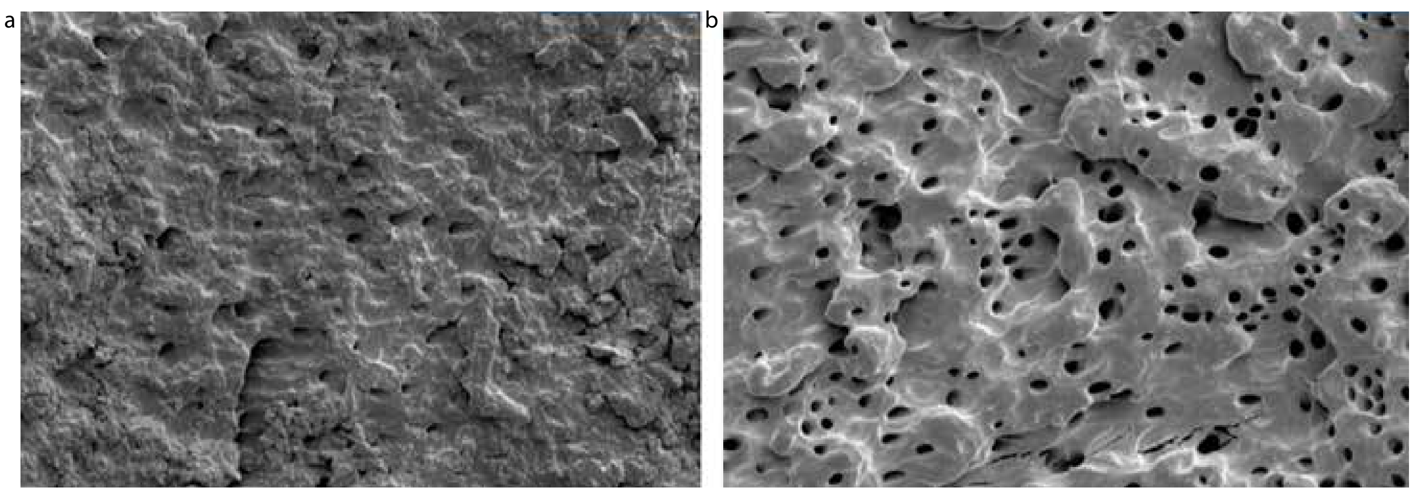

Figure 12. (a, b) Scanning electron micrographs of root canal dentine before and after use of the Gentle Wave System (Sonendo, California, USA) using 3% NaOCl and 8% EDTA. (Photos courtesy of Professor Markus Haapasalo, DDS, PhD, University of British Columbia.)

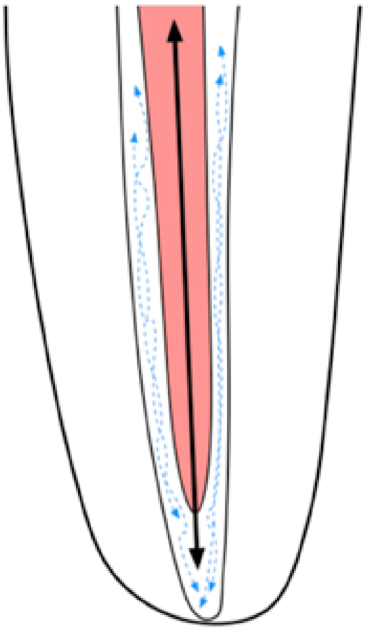

Figure 13. Manual agitation/dynamic pumping: a GP cone is inserted into the irrigant-filled canal and pumped vertically to agitate the irrigant.

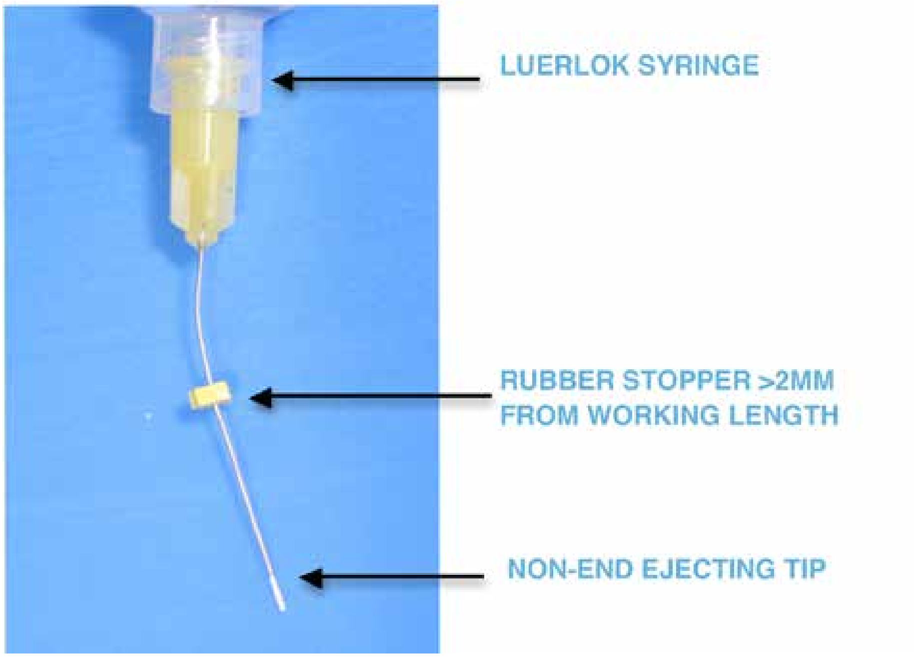

Figure 15. The three essential components of all positive pressure irrigation.

Figure 14. The use of caulking agent (*OraSeal*, Ultradent, Utah, USA) to improve the seal around the rubber dam. This minimizes contamination and prevents hypochlorite leakage.

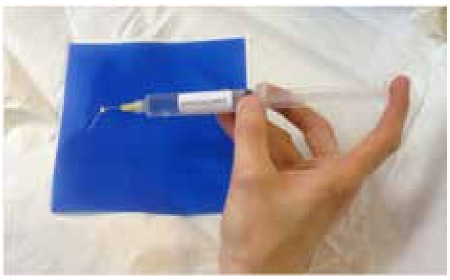

Figure 16. Well labelled syringes prevent mistakes and the use of the forefinger prevents excessive pressure being generated. Never allow the needle to bind in the canal *and* continue digital pressure.

Self adjusting file (SAF)

In the SAF concept (ReDent Nova, Ra'anana, Israel), irrigant is delivered with the filing system to improve penetration and irrigant exchange. Readers are referred to the previous paper for more information about the SAF: it is not currently available in the UK.

Suggested irrigation protocol

Essential – Desirable

- Use 1–2% NaOCl throughout treatment;
- Aim for a minimum of 30 minutes of irrigation time;
- Constantly replenish NaOCl and consider adjunctive methods to improve activity (warming, increased duration, sonic/ultrasonic instrumentation and manual dynamic movement of a close-fitting GP cone);
- Following completion of instrumentation rinse canal with sterile water;
- Rinse with EDTA 17% to remove smear layer.[11]

Hypochlorite accident

Hypochlorite spillages may damage clothing and, though they do not cause physical harm, they may be costly and embarrassing. Personal protective clothing should be worn at all times by both patient and operator. Bibs and safety glasses protect both eyes and clothing. Inadvertent ingestion of irrigants in small quantities is not harmful but may cause minor mucosa irritation and leave a bad taste.[50] Caulking agents can improve the seal around rubber dam and minimize this unpleasant outcome (Figure 14).

With the mantra that 'prevention is better than cure', see Table 2 for a protocol to avoid extrusion (Figures 15 and 16). Although a theoretical risk arises from lateral canals, resorptive or iatrogenic defects or fractures, the majority of case reports pertain to apical extrusion.[51] Should the clinician suspect a hypochlorite accident, action must be swift and communications with the patient honest and sympathetic without panic. Tables 3 and 4 list the common signs and symptoms of extrusion and current guidance on management. There is currently no evidence for the need for supplemental steroids or antibiotics, nor is extraction indicated.[52]

Conclusion

Thorough irrigation of the

Preventing Hypochlorite Injury
■ Aim to preserve an apical stop wherever possible
■ Use lower concentration hypochlorite (1–2%)
■ Use side-vented needles with Luerlok attachment to syringe
■ Don't irrigate > 4ml/min
■ Use a stopper to mark the syringe at a depth 1–2 mm from the apex
■ Never allow the syringe to bind within the canal (or press if there's resistance)
■ Use light finger pressure, not the thumb
■ If you're not sure that you're in the canal: don't irrigate and take a radiograph
■ Keep the syringe moving within the canal

Table 2. Preventing extrusion of sodium hypochlorite.

Symptoms and Signs of Hypochlorite Injury
■ Sudden pain irrespective of presence of LA
■ Profuse bleeding from within the canal
■ Bad taste
■ Extensive oedema
■ *Delayed:* Eccymoses
■ *Delayed:* Secondary infection
■ *Delayed:* Parasthesia

Table 3. Signs and symptoms of hypochlorite accident.

Managing Hypochlorite Injury
■ Irrigate the canal with saline or sterile water
■ Give additional local anaesthetic (preferably longer acting such as bupivucaine)
■ Dress the tooth with non-setting calcium hydroxide: do not leave on open drainage
■ Inform and reassure the patient (anticipate severe oedema and bruising)
■ Prescribe analgesia: Paracetamol 500 mg QDS with Ibuprofen 400–600 mg QDS alternating doses
■ Review within 24 hours and regularly thereafter
■ Prescribe antibiotics only if signs of systemic involvement
■ Refer to A&E if very extensive extrusion or evidence of compromised airway

Table 4. Management of periapical extrusion of sodium hypochlorite.

canal system is essential in endodontics. For those clinicians not using sodium hypochlorite as the principal irrigant it must be acknowledged that, as yet, there is no other irrigant that offers all the benefits of hypochlorite and is as cost-effective. It may be the fear of extrusion that deters practitioners, but it is clear that, with a careful technique, the risk of this complication can be reduced significantly.

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