Carisolv™: an alternative to NaOCl in immature root canals?

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Abstract

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Aim To test the null hypothesis that Carisolv™ is no more effective than 1% sodium hypochlorite in cleaning uninstrumented, immature root canals.

Methodology A total of 240 uniform, immature ovine incisors were decoronated at the CEJ level and randomly divided into four groups of 60. After gross pulp extirpation, canals were flooded with normal saline (negative control), 1% NaOCl, Carisolv™ or 5% NaOCl (positive control) and incubated for 10 min (group 1), 20 min (group 2), 30 min (group 3) or 30 min, refreshing irrigant at 10 and 20 min (group 4). SEM photomicrographs of canal wall debris in the apical, middle and coronal thirds were scored against a 5-point scale. Internal consistency was assessed by κ statistics. Debris scores for different irrigant regimes at different canal levels were analysed by non-parametric tests ($P < 0.05$).

Results Canals were consistently cleaner in the coronal and middle than apical thirds. NaOCl (5%) was consistently most effective. Carisolv™ and NaOCl (1%) were no more effective than normal saline in group 1 ($P > 0.05$), but significantly more effective than normal saline in groups 2 (middle and apical 1/3), 3 and 4 ($P < 0.05$). Carisolv and NaOCl (1%) had comparable activity in groups 1, 2 (middle and apical thirds) and 3, but NaOCl (1%) was significantly more effective than Carisolv in group 4 (coronal and middle thirds).

Conclusions

1. The ovine incisor model presents opportunities to investigate irrigation regimes under controlled *ex-vivo* conditions.

2. NaOCl (5%) remains the most effective irrigant for rapid debris removal in immature root canals.

3. Carisolv™ cleans pulp debris from the walls of immature root canals as effectively as NaOCl (1%) during static, unrefreshed wall contact for between 20 and 30 min.

4. Refreshment of NaOCl (1%) enhances its cleaning ability above that of Carisolv™.

Keywords: Carisolv™, irrigant, SEM.

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Introduction

Dental trauma is a major cause of pulpal injury in all countries of the world (Andreasen & Andreasen 1993, Welbury 2001). Luxation or avulsion injuries may sever the apical blood flow resulting in sterile avascular pulp necrosis, while pulp exposure to the mouth may cause liquifactive breakdown under the influence of microorganisms. Both forms of pulp necrosis are responsible for the arrest of odontogenesis at the point of pulp death in immature teeth.

The key goals in root canal treatment are to eliminate infection and substrate from the root canal system (Nair *et al.* 1990, Sjogren *et al.* 1997) and to prevent its recurrence. Effective debridement and infection control must therefore underpin every action in root canal treatment from initial assessment of coronal integrity through the operative procedures of canal access, preparation and obturation to the final

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sealing restoration (Saunders & Saunders 1994, Friedman 2002).

Endodontic treatments in immature permanent anterior teeth are complicated by the fact that the apices are open and the walls are thin and often divergent, making controlled debridement and obturation difficult. The primary objective in such cases is to induce apical closure by the formation of mineralized tissue accompanied by the repair of periapical tissues. In the presence of a viable apical pulp stump and Hertwig's epithelial root sheath, continued formation may be achieved (apexogenesis). More often, the development of a cementum-like barrier (apexification) is the best outcome possible.

Conventional root canal treatment includes mechanical instrumentation in combination with antimicrobial and tissue solvent irrigation to dissolve and dislodge debris, and create a clean environment compatible with periapical health. Factors affecting the outcome of root canal treatment have been well documented in the literature (Matsumoto *et al.* 1987, Sjogren *et al.* 1990). The healing effects of preparation alone are recognized (Donnelly 1990) and this has been highlighted as a key determining step. In the case of fragile immature teeth, extensive dentine removal is probably undesirable, placing greater emphasis on irrigants for cleansing.

Sodium hypochlorite is the most widely recommended endodontic irrigant because of its excellent tissue solvent and antimicrobial properties in concentrations between 0.5 and 5.25% (Zehnder *et al.* 2002). The activity of sodium hypochlorite is enhanced by increased concentration, temperature, agitation and volume of application (Abou-Rass & Oglesby 1981, Berutti & Marini 1996). In spite of its excellent track record, many fear to use this potentially irritant agent which is known to cause serious damage when allowed to enter the periradicular tissues in anything but small amounts (Hulsmann & Hahn 2000, Gernhardt *et al.* 2004). For this reason, many reject the use of sodium hypochlorite in immature teeth and employ alternatives without the combination of antimicrobial and tissue solvent action.

Chlorhexidine, a substantive, broad spectrum antimicrobial agent, has been shown to be effective against endodontic pathogens *in vivo* and *in vitro* (Leonardo *et al.* 1999) and is less toxic than sodium hypochlorite, but lacks the tissue solvent activity which may be so critical in debriding immature teeth.

Normal saline and local anaesthetic solutions are bland flushing agents (Whitworth *et al.* 2000), and are effective in eliminating loose debris from the coronal and middle thirds of root canals but have neither antimicrobial nor tissue solvent action (Baumgartner & Mader 1987, Walker & del Rio 1991).

Carisolv™ (MediTeam, Goteborg, Sweden) is a well-researched product which is advocated for chemomechanical removal of infected carious dentine (Banerjee *et al.* 2000). It is presented in two syringes, one containing 0.5% sodium hypochlorite and the other containing 0.1 M amino acids, gel substance, sodium chlorite, sodium hydroxide and a colour indicator (erythrocin). When these components are mixed together, the amino acids bind with chlorine to form high pH chloramine which is a potent disinfectant with tissue solvent activity. The different charges of amino acids attach to different molecular sites of the carious dentine due to electrostatic attraction (Kronman *et al.* 1977). This leads to proteolytic degradation of altered collagen, thus softening the dentine affected by caries and preserving sound dentine (Nadanovsky *et al.* 2001). The potential for Carisolv™ to cleanse immature root canals is that sodium hypochlorite is presented in a gel-form which may be less prone to extrude from the canal than a liquid form. A preliminary study showed that Carisolv™ had the potential to clean immature canals although it was less effective than undiluted house hold bleach (Al-Kilani *et al.* 2003). In this preliminary study it was not tested against weaker concentrations of sodium hypochlorite that may be used more commonly in paediatric dentistry.

Since that study, a new form of Carisolv™ has been introduced (MediTeam). It is claimed to be 25% quicker than the previous gel in caries removal and contains no potentially staining pigment. The canal cleaning activity of improved Carisolv™ has not been tested in comparison with clinically realistic concentrations of sodium hypochlorite, which may typically be 0.5–1% in open apex cases.

This study was designed to test the null hypothesis that new improved Carisolv™ is no more effective than dilute sodium hypochlorite in removing pulp debris from the uninstrumented canals of immature incisors.

Materials and methods

A total of 240 immature incisor teeth were extracted at a single session from freshly culled lambs. The teeth were stored in 0.2% chlorhexidine gluconate (Corsodyl; Adams Health Care, Leeds, UK) at 4 °C until used. Before use, periodontal ligament tissue was removed with a scalpel blade (Swann Morton, Sheffield, UK), and the teeth were decoronated at the CEJ level to yield

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uniform root specimens of approximately 13 mm length. The root specimens were randomly divided into four groups of 60 teeth, which were further divided into four subsets of 15 teeth:

Group 1: For 10 min incubation with:

Set 1: NaOCl 5% (Chlorex, Durham, UK) (positive control).

Set 2: NaOCl 1% (Chlorex).

Set 3: Carisolv™ (MediTeam, Goteborg, Sweden).

Set 4: Normal saline (Fresenius Kabi, Warrington, UK) (negative control).

Group 2: For 20 min incubation in subsets as above.

Group 3: For 30 min incubation in subsets as above.

Group 4: For 30 min incubation, with irrigants refreshed at 10 and 20 min, in subsets as above.

Immediately before investigation, the pulp of each root was grossly removed with a new medium sized barbed broach (Pulpdent, Zurich, Switzerland). The open apical end of each root was then sealed with soft red wax and the specimens in each set mounted upright on stripwax (Metrodent Ltd, Huddersfield, UK).

Aqueous solutions of sodium hypochlorite were prepared freshly from stock solution at room temperature prior to experimentation, and the concentration verified by iodometric titration (Frais *et al.* 2001). Carisolv™ was removed from refrigerated storage 20 min before use and freshly prepared at room temperature for each set of specimens. The concentration of hypochlorite was confirmed by iodometric titration as before. All irrigants were applied at room temperature.

Irrigants were carefully introduced into the canals with a 25-gauge Monoject endodontic needle (Monoject, Gosport, UK) attached to a Luer-Loc syringe. The needle was inserted to the apical limit of the root, and the canal back-filled with irrigant until brim-full. In the case of group 4, canals were rinsed free of agents with sterile water at 10 and 20 min after removing the apical soft wax and resealing them before adding fresh irrigant.

After incubation for the specified time, the canals were rinsed free of agents with 2.0 mL of sterile water from another endodontic needle and the specimens immersed immediately in SEM fixative (2% glutaraldehyde) to preserve canal wall debris for SEM analysis.

Processing for debris scoring

All roots were removed from SEM fixative and grooved longitudinally on opposing sides with a long tapered diamond bur before carefully splitting with a wire cutter and transfer into fresh SEM fixative overnight at 4 °C. The specimens were rinsed with sterile water and sequentially dehydrated in 10, 25, 50, 75, 90 and 100% alcohol at 15 min intervals. Dehydrated specimens were then coded to blind the examiner of the irrigation regime before critical point drying (Tsousimis Samori 780 CPD; Tsousimis Research Corp., Rockville, MD, USA) with absolute alcohol as the intermediate fluid and liquid CO_2 as the transition fluid. The specimens were then mounted on stubs using an electrodag (Achesons Silver Dag; Agar Scientific Ltd, Stansted, UK), and gold sputtered (Polaron E5100 cool sputter coater 12 nm, Hertfordshire, UK) before viewing under SEM (Cambridge S240, Cambridge, UK, 8 kV accelerating voltage, 12 nm working distance). After visualizing canal walls in the apical, middle and coronal thirds, photomicrographs of representative areas were taken at 500× magnification.

Images were captured and saved as JPEG files for scoring. Canal wall debris was then scored against a 5-point debris scale described previously (Al-Kilani *et al.* 2003).

Score 1: Clean root canal wall, only few small debris particles.

Score 2: Light coverage of debris <25% tubules covered.

Score 3: Moderate coverage of debris covering >25% but <50% of the tubules covered.

Score 4: Heavy coverage of debris >50% but <75% tubules covered.

Score 5: Complete or nearly complete root canal wall covered by debris.

Calibration and statistical analysis

An initial sample of 30 images drawn from an earlier study (Al-Kilani *et al.* 2003) was scored independently by two examiners (one being the sole scorer from the previous study) and Cohen's κ scores calculated to determine inter-examiner reliability. Images for the study proper were then read by one examiner only, with 48 randomly selected images re-read 1 week later to determine internal consistency. Debris scores for different irrigants and times of incubation were analysed by the non-parametric Kruskal–Wallis and *post-hoc* Mann–Whitney tests to determine significant differences ($P < 0.05$).

Results

Testing of inter-examiner consistency on 30 previous images yielded a κ score of 0.735, indicating a high

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level of agreement. A total of 720 images were captured for the main study and scored by a single examiner. Re-scoring of 48 random images yielded a κ score of 0.831 indicating a very high level of internal agreement. Debris scores were generally consistent within test sets with few instances of scores in any sets spanning more than two categories. Median debris scores in each treatment sets are shown in Tables 1–4.

Regardless of irrigation regime, canals were consistently cleaner in the coronal and middle thirds than in the apical thirds ($P < 0.05$).

Sodium hypochlorite (5%), the positive control, was consistently more effective than all other irrigants at all canal levels and after all incubation times (Fig. 1). Its cleaning effectiveness was maximal after 30 min static wall contact (group 3), and was not significantly enhanced by further refreshment (group 4).

Carisolv™ and NaOCl (1%) were no more effective than normal saline (the negative control) at any canal level in group 1 ($P > 0.05$) (Fig. 2). The cleaning effectiveness of normal saline did not improve significantly with incubation time or refreshment (Tables 2–4). Carisolv™ and NaOCl (1%) cleaned canals significantly better than normal saline in the middle and apical thirds in group 2, and at all canal levels in groups 3 and 4 ($P < 0.05$). Carisolv and NaOCl (1%) had comparable activity at all canal levels in groups 1 and 3 (Fig. 3), at middle and apical third levels in group 2, and at apical third level in group 4. NaOCl (1%) was significantly more effective than Carisolv™ in the coronal and middle thirds of teeth in group 4 (Fig. 4).

Table 1 Median debris scores for group 1 (10 min incubation)

Canal level	Saline	Carisolv	NaOCl 1%	NaOCl 5%
Coronal	3	3	3	1
Middle	3	3	3	2
Apical	4	4	4	3

Table 2 Median debris scores for group 2 (20 min incubation)

Canal level	Saline	Carisolv	NaOCl 1%	NaOCl 5%
Coronal	3	3	2	1
Middle	4	3	3	2
Apical	4	3	4	3

Table 3 Median debris scores for group 3 (30 min incubation)

Canal level	Saline	Carisolv	NaOCl 1%	NaOCl 5%
Coronal	4	2	2	1
Middle	4	3	3	1
Apical	4	4	4	3

Table 4 Median debris scores for group 4 (30 min incubation, refreshing irrigant at 10 and 20 min)

Canal level	Saline	Carisolv	NaOCl 1%	NaOCl 5%
Coronal	3	3	1	1
Middle	4	3	2	1
Apical	5	3	3	2

Discussion

An ideal root canal irrigant would be non-toxic to host tissues, antimicrobial and possess tissue solvent properties. Issues of toxicity are especially pertinent in open apex cases where a balance has to be maintained between optimal canal cleanliness and safety. While full strength (5%) sodium hypochlorite is regarded by many as the optimal irrigant (Abou-Rass & Oglesby 1981, Zehnder *et al.* 2002) this balance of concerns probably detracts from its use in immature teeth. One clinical response would be to avoid sodium hypochlorite completely and opt for a bland flushing agent.

This study was conducted to test the null hypothesis that a current formulation of Carisolv™, a hypochlorite containing gel, is no more effective than dilute sodium hypochlorite in removing pulp debris from the uninstrumented canals of immature incisors. Positive and negative controls were NaOCl (5%) and normal saline, respectively, with Carisolv™ and NaOCl (1%) as test solutions. Irrigants were prepared freshly and the hypochlorite concentration of NaOCl 1%, 5% and Carisolv™ were confirmed by iodometric titration (Frais *et al.* 2001). Carisolv™ was found to contain 0.46% NaOCl, close to the manufacturer's claim of 0.475%.

The work was undertaken on a uniform sample of immature mammalian incisors which were harvested in a single session and were stored under identical conditions. Such a sample would be difficult to achieve with human teeth and we believe this is a useful model for irrigant evaluation.

The irrigation regime used in the study was based on a range between 10 min (minimalist appointment duration) and 30 min (regarded as a maximum appointment duration a child could reasonably tolerate in the dental chair).

Carisolv™ is a gel which cannot be easily exchanged in volume like a liquid irrigant. Cost and the relatively small volume in which it is presented by the

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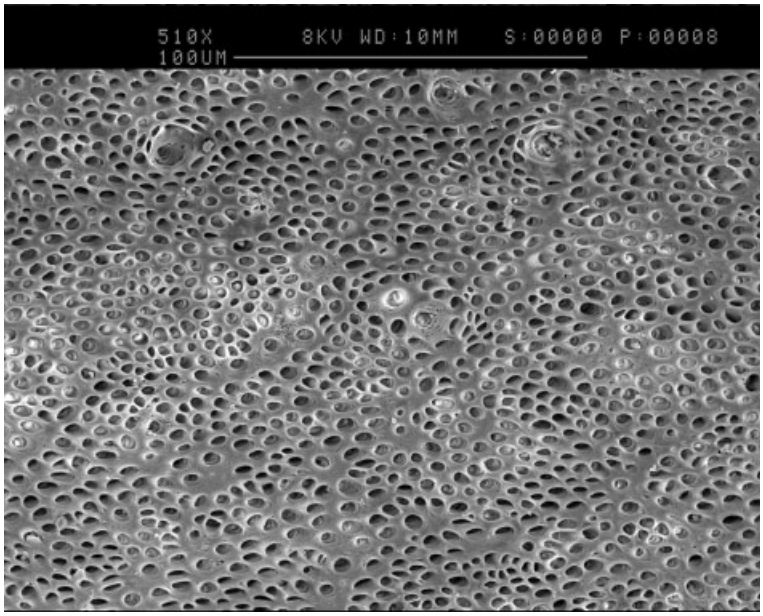

Figure 1 Typically clean canal wall in the middle third after 30 min incubation with sodium hypochlorite (5%): scored 1.

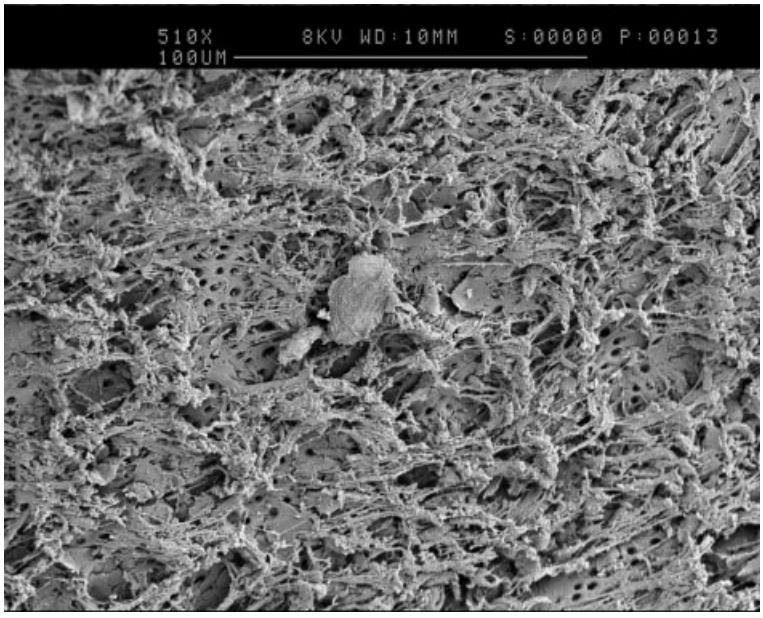

Figure 2 Typical middle third canal wall, covered with debris after 30 min incubation with normal saline: scored 4.

manufacturer also precludes high volume exchange. For these reasons we compared all the irrigants in a comparable way by flooding the canals and allowing them to work on wall debris without further intervention. The irrigants in group 4 were refreshed at 10 and 20 min for 30 min to determine whether this action would enhance activity, as it is known that refreshment, along with agitation and increased temperature enhance the action of sodium hypochlorite (Abou-Rass & Oglesby 1981).

The specimens for SEM analysis were critical point dried to preserve the structure of wall debris by reducing the amount of cell shrinkage which occurs when samples are air dried.

Capture and scoring of the photomicrographs was done by a single examiner. Although this was a

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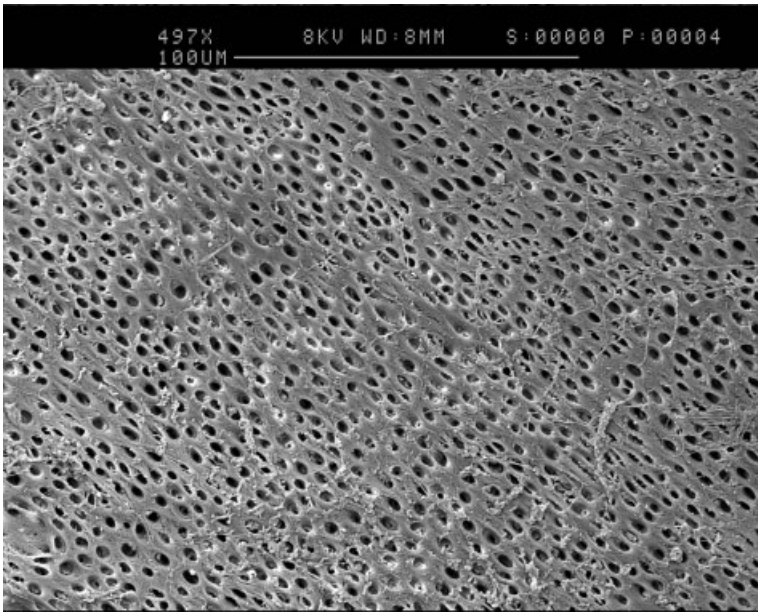

Figure 3 Typical coronal third canal wall with light debris coverage after 30 min incubation to Carisolv™: scored 2.

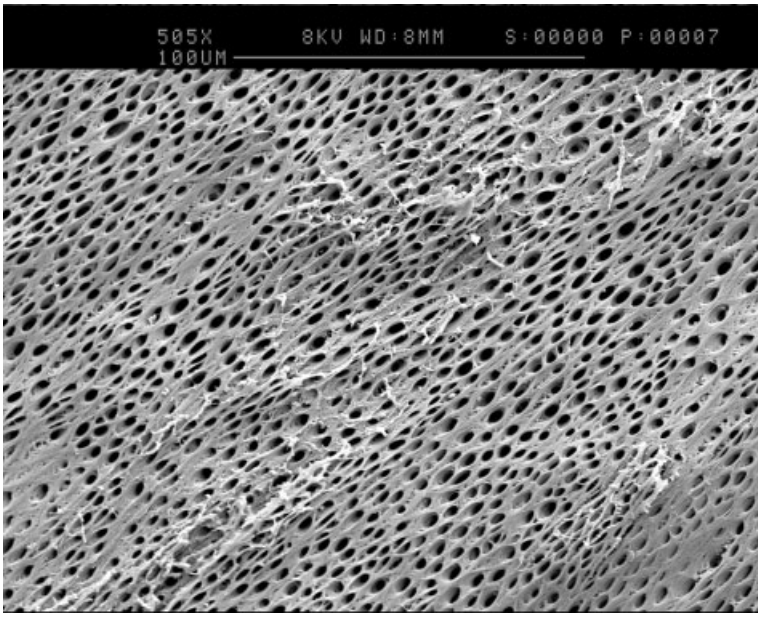

Figure 4 Typical middle third canal wall with light debris coverage after 30 min incubation (refreshing the irrigant at 10 and 20 min) with sodium hypochlorite (1%): scored 2.

potential area for bias, specimens were examined, images secured and scoring conducted blind to the irrigation regime. Kappa scores revealed a high level of consistency with another experienced scorer, and a very high level of internal reliability (Valachovic *et al.* 1986, Chong *et al.* 2003).

The findings of this study confirmed that NaOCl 5% (positive control) is the most effective irrigant in removing pulp debris from root canal walls. Whether this is optimal for clinical use remains in doubt (Spangberg & Haapasalo 2002). The action of sodium hypochlorite was enhanced by incubation time.

Carisolv™ was more effective than normal saline and has the potential to clean canals in a comparable manner to sodium hypochlorite 1%. This corroborates the previous work of Al-Kilani *et al.* (2003) and advances knowledge in relation to a clinically realistic level of NaOCl (1%). The improved effectiveness of

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NaOCl (1%) after refreshment, however, indicates that with irrigation in the customary manner, NaOCl (1%) may prove quicker acting and more effective than Carisolv™. The current formulation of Carisolv™, which is colourless, did not stain; a potential problem identified with its erythrocin-containing predecessor as a cause for concern in a previous study (Al-Kilani *et al.* 2003). In terms of optimal use, Carisolv™ and NaOCl (1%) were no more effective than normal saline after 10 min incubation. This suggests that Carisolv™ and NaOCl (1%) require wall contact for more than 10 min if they are to have a beneficial effect on wall cleanliness. If exchange is not possible, we recommend that Carisolv™ should maintain contact for at least 20 and ideally 30 min. Previous work also suggested that ultrasonic activation may be beneficial (Al-Kilani *et al.* 2003).

This study suggests that Carisolv™ is as effective as NaOCl (1%) in removing debris from the walls of immature root canals, following simple flooding and incubation up to 30 min. It is likely, however that any potential advantages in limiting extrusion may be outweighed by cost and that NaOCl (1%) may be more effective in a more clinically realistic situation of high volume irrigant exchange through the canal system.

Conclusions

1. The ovine incisor model presents opportunities to investigate irrigation regimes under controlled *ex-vivo* conditions.
2. NaOCl (5%) remains the most effective irrigant for rapid debris removal in immature root canals.
3. Carisolv™ cleans pulp debris from the walls of immature root canals as effectively as NaOCl (1%) during static, unrefreshed wall contact for between 20 and 30 min.
4. Refreshment of NaOCl (1%) enhances its cleaning ability above that of Carisolv™.

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