The effect of a fluorocarbon surfactant on the surface tension of the endodontic irrigant, sodium hypochlorite.

A preliminary report

Jeffrey A. Cameron, BDS

Abstract

A fluorochemical surfactant was used to reduce the surface tension of 4 per cent sodium hypochlorite from 70 mN/m to 27 mN/m. The solution was stable for more than one month when tested for reduced surface tension, available chlorine, and protein solvent ability. No chemical residue remained on the root canal wall when viewed using scanning electron microscopy.

(Received for publication July 1985.)

Introduction

Root canal therapy has been divided into three phases: diagnosis, biomechanical preparation of the root canal, and obturation of the root canal space. Biomechanical preparation can be divided into instrumentation, irrigation, and medication.[1] Instrumentation has been carried out traditionally with hand instruments such as broaches, reamers or files, sometimes in conjunction with mechanical aids such as Peeso reamers or Gates Glidden drills. This instrumentation was designed to remove, or at least loosen, any soft tissue on the root canal surface, and to create a canal shape that would readily accept a root canal filling. The prime function of the irrigant was to remove any debris loosened, but not removed, by the instrumentation. Some irrigants offered chelating, tissue solvent or bactericidal properties. Medication of the root canal is usually in the form of an interappointment dressing, with chelating or bactericidal properties. These medicaments are left in the canal for several days so that the paste, liquid or vapour can either soften the dentine wall, fix remaining tags of tissue, or kill residual infecting organisms.

The efficiency of an endodontic irrigant could be improved by reducing its surface tension, or by increasing fluid flow over the debris on the root canal wall. It is possible that an irrigant could extend its protein solvent capability, or perform the bactericidal function of a medicament if the irrigant could penetrate the uninstrumented areas of the root canal system. A reduction in surface tension could allow the irrigant to flow into these remote areas. The use of ultrasound also has been advocated as a method of increasing fluid flow within the root canal system.[2]

Surface tension is the force between molecules which produces a tendency for the surface area of a liquid to decrease. The diminution takes place not by a contraction of the liquid but by a passage of the surface molecules into the body of the liquid. This force tends to inhibit the spread of a liquid over a surface, or to limit its ability to penetrate a capillary tube. Surface tension diminishes with an increase in temperature until it reaches zero when the liquid turns to vapour.* Surface tension can also be reduced by the use of chemicals known as surfactants.

Abou Rass and Patonai[3] used polysorbate 80 to reduce the surface tension of sodium hypochlorite 5.25 per cent from 79.6 to 69.8 mN/m, sodium hypochlorite 2.6 per cent from 76.7 to 67.2 mN/m and an ethylenediaminetetra-acetic acid (EDTA) solution from 39.7 to 33.7 mN/m.

**Encyclopedia Britannica* 1961;Bk 21:597.

Cunningham and his colleagues[4] mixed equal volumes of sodium hypochlorite with reagent grade ethanol and measured its movement into a glass capillary tube. While the movement of this solution into the capillary tubes indicated a lower surface tension than sodium hypochlorite alone, other experiments indicated that the solution was not stable, and lost most of its available chlorine within 15 minutes.

The purpose of this investigation was to evaluate the effectiveness of a fluorochemical surfactant† sodium hypochlorite solution in four separate areas related to its use as an endodontic irrigant: 1) surface tension, 2) stability of available chlorine, 3) tissue solvent ability, 4) presence of chemical residue on root canal walls.

Materials and method

The sodium hypochlorite used was a household bleach‡ with a stated 4 per cent concentration of available chlorine. Each litre of solution provided two 500 mL samples; one received 0.5 mL surfactant, the other acted as control.

(1) Surface tension

Surface tension readings of experimental and control solutions were obtained using a tensiometer.§ The readings were measured at zero, one hour, one day, one week, and one month. All readings were made in triplicate, corrected for temperature, and recorded in mN/m.

(2) Available chlorine

The concentration of available chlorine in the test and control solutions was determined by titration for free iodine using the sodium thiosulphate, potassium iodide technique. Samples from both test and control solutions were analysed at weekly intervals over a two-month period. They were stored in a cool, stable environment protected from direct light.

(3) Tissue solubility

Ten mL of the test or control solution was placed in a screw-topped 12mL capacity glass container. The pulp was removed in one piece from a freshly extracted, unfixed single-rooted human tooth using a barbed broach; only complete pulps were used.

One pulp was added to each of the two containers. After replacing the cap, the container was shaken briefly then allowed to stand until the pulp dissolved. Six pulps were added to each container over a one-hour period, the time taken for each pulp to dissolve being measured.

(4) Chemical residue

Four freshly-extracted, unfixed human teeth were instrumented to clinical standard through a conventional access cavity. One mL of the 4 per cent sodium hypochlorite 0.1 per cent **FC99** solution was used as irrigant between each instrument size. Two of these teeth were given a conventional irrigation of 2 mL of the test solution, the other two were given one minute of indirect ultrasound irrigation[5] with the test solution. Both groups received 2 mL of anaesthetic solution as the final irrigant to prevent any further tissue solvent action of the sodium hypochlorite. The specimens were prepared for the scanning electron microscope‖ using a diamond wheel under a water spray, dried, and given a minimum thickness gold coating. They were viewed in a scanning electron microscope and the image recorded on film¶ using a roll film back.**

Results

(1) Surface tension

The surfactant reduced the surface tension of 4 per cent sodium hypochlorite from 70 mN/m to 27 mN/m, and this level was maintained without change for a period of one month. Full details of the results are presented in Table 1.

(2) Available chlorine

The test solution showed a stability far superior to previous combinations, losing less than 5 per cent available chlorine in the first month and 26 per cent of the available chlorine in the two-month test period. Full details are given in Table 2. At the completion of these tests the sample containing **FC99** was showing some signs of instability: (1) a colour change from clear, light yellow to a dull brown tinge, (2) a brown deposit had settled at the base of the container, (3) gas in solution gave it a 'spritzig' effect, (4) gas liberated from solution had pressurized the container.

(3) Tissue solvent capability

Under the conditions of this experiment it was not possible to determine accurately when the pulp

†**Fluorad FC99.** 3M, St. Paul, MN, USA.
‡**Zixo.** Ajax Chemicals, Sydney, Australia.
§**Du Noy.** CSC Scientific Co. Inc., Broadview, IL., USA.

‖**JEOL JSM 840. JEOL, Tokyo, Japan.**
¶**Ilford FP4.** Ilford Ltd, Mobberley, Cheshire, UK.
**Mamiya. Mamiya Cameras, Tokyo, Japan.

Table 1. Average surface tension corrected for temperature (mN/m)

Time	4% NaOCl	4%NaOCl 0.1% FC99
Start	69.6	27.3
1 hour	70.2	27.2
1 day	69.7	24.2
1 week	71.9	25.6
1 month	69.7	26.1

Table 2. Available chlorine

Week number	4% NaOCl	4% NaOCl 0.1% FC99
0	3.85	3.81
1	3.85	3.81
2	3.85	3.80
3	3.85	3.80
4	3.84	3.75
5	3.83	3.60
6	3.83	3.50
7	3.82	3.30
8	3.82	3.05
9	3.83	2.84

tissue had completely dissolved. For all 12 samples some tissue was visible after 5 minutes in the test or control solutions, and all the tissue had dissolved by 9 minutes. No difference was noted between the time taken to dissolve the first or sixth specimen in each container, and no difference was noted between the test or control solution.

(4) Chemical residue

Magnifications of up to x 4500 did not reveal any evidence of chemical crystals or unusual smear layer derived from the test irrigant. One specimen presented a well-defined fin leading off the instrumented main canal. All pulpal tissue and predentine had been removed from the fin revealing the calcospherite structure of the dentine surface (Fig. 1). The instrumented surface of the main canal showed a tightly adherent smear layer with a debris free surface. Specimens receiving the ultrasound-activated final irrigation showed clean uninstrumented root surfaces, and evidence of removal or loosening of the smear layer from instrumented areas.

Discussion

With the introduction of ultrasound into endodontics the distinction between instrumentation, irrigation, and medication is not distinct. It is possible that future emphasis will be more on irrigation activated by ultrasound rather than shaping the canal with hand instruments. Even without a reduced surface tension a combination of sodium hypochlorite and ultrasound can remove debris from areas inaccessible to hand instruments and conventional irrigation.[6] It is possible that with a reduced surface tension sodium hypochlorite would be able to exert its tissue solvent action in the fins and interconnecting lacework of the root canal system. Previous attempts to reduce the surface tension of sodium hypochlorite have produced reductions of doubtful clinical significance, or solutions with an available chlorine stability measured in minutes.

Fluorad FC99† is a 25 per cent active solution of amine perfluoroalkyl sulfonates in water. It has a pH of 6-7 as supplied, is considered mildly irritating in conjunctival tests, and practically non-toxic on an acute dermal basis.†† In these experiments **FC99** was used at a concentration of 1 mL per litre of 4 per cent sodium hypochlorite so it is unlikely that it would add to the toxic effects of the sodium hypochlorite. **Fluorad FC99** was chosen as the test surfactant because of its proven ability to withstand aggressive oxidizing or reducing media. Its efficiency as a surfactant in low concentrations ensured minimum dilution of the host solution. Cunningham, Cole, and Balekjiian[4] used ethanol and sodium hypochlorite in equal volumes to produce an irrigant with a reduced surface tension and a concentration of available chlorine diluted from 5.2 per cent in the host solution to 2.6 per cent in the test solution. The **FC99** reduced the surface tension of sodium hypochlorite to that of ethanol alone, without diluting the concentration of available chlorine in the host solution. After two months more than 70 per cent of the original chlorine concentration had been retained. Mixing sodium hypochlorite with ethanol produced an immediate drop of 50 per cent in concentration of chlorine, because of dilution, and further loss of chlorine because of the unstable nature of the mixture. The loss of chlorine from the proposed irrigant could have been caused by the relatively high concentration of **FC99** used in the experiment, or by the introduction of contaminants during the test period. Further experiments are in progress using different sources of sodium hypochlorite, and lower concentrations of the surfactant. The critical concentration of **FC99** needs to be determined. This concentration would produce a clinically significant reduction of the surface tension of

††Technical data sheet. 3M, St Paul, MN., USA.

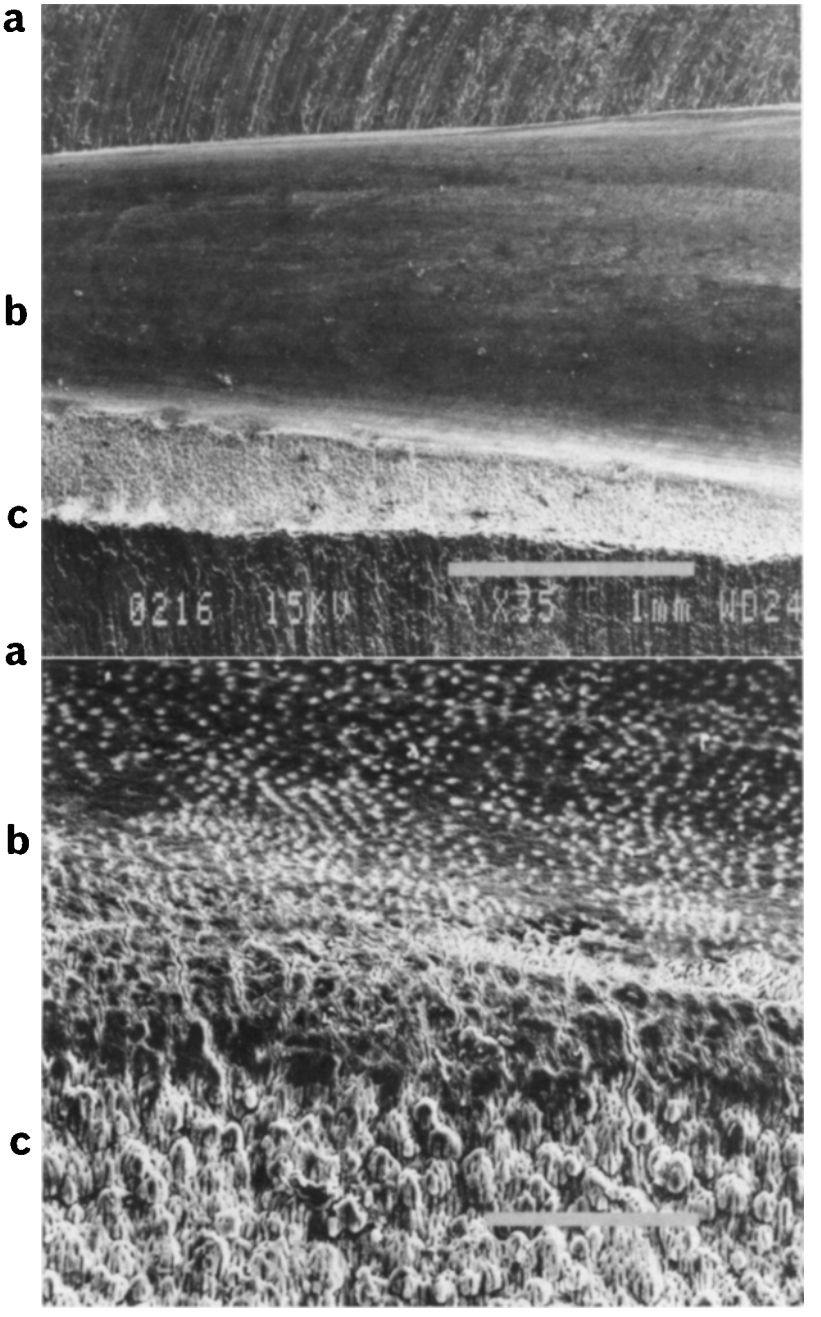

Fig. 1.—*Above.* Scanning electron photomicrographs showing tightly adherent smear layer and well developed fin adjacent to main canal. x 35. a, Canal wall; b, instrumented canal with smear; c, uninstrumented canal showing calcospherites. *Below.* Higher magnification of junction between instrumented and uninstrumented areas. The smear layer is free from debris or chemical deposits; all soft tissue and predentine has been removed from the uninstrumented fin.

sodium hypochlorite but would not affect the stability of available chlorine over a period of several months. The concentration of **FC99** used in this experiment (0.1 per cent) is relatively high as the manufacturers recommend concentrations as low as 0.04 per cent to produce significant reductions in surface tension.

It was not the purpose of this experiment to measure the tissue-solvent capability of sodium hypochlorite, but rather to determine if the surfactant had increased or decreased the solvent effectiveness of the test solution relative to the control. It had not been anticipated that 10 mL of sodium hypochlorite would be capable of dissolving the complete contents of six root canals, and that each pulp sample would dissolve in less than ten minutes without some continuous agitation of the container. The results would tend to indicate that small tags of pulpal tissue would dissolve quickly and easily if the sodium hypochlorite solution could be brought into contact with these tissue tags. This could reduce the need to remove large quantities of root dentine in order to achieve a debris-free root canal. Research into root canal obturation techniques and materials would be needed to take advantage of this minimum instrumentation philosophy.

Some materials introduced into the root canal have left a residue that has proved difficult to remove. Citric acid produced crystals that required large volumes of water for their removal, and the smear layer associated with **RC Prep**‡‡ was resistant to the usual endodontic irrigants. This experiment would indicate that the **FC99**/sodium hypochlorite combination, with or without ultrasound, does not leave a residue within the root canal.

It was felt that the results obtained using the sodium hypochlorite 0.1 per cent **FC99** combination warranted further investigation. These investigations will be the subject of a future report.

‡‡Premier Dental Co., Norristown, PA., USA.

Summary and conclusion

(1) The surface tension of 4 per cent sodium hypochlorite was reduced from 70 mN/m to 27 mN/m by the addition of 0.1 per cent fluorochemical surfactant, **Fluorad FC99.** This reduction was maintained unchanged over the test period of one month.

(2) The concentration of available chlorine decreased by 5 per cent over a one-month period and by 26 per cent over a two-month test period.

(3) The tissue solvent capacity of the sodium hypochlorite was stable over a two-month test period.

(4) No crystalline debris or chemical smear was observed under the scanning electron microscope at magnifications up to x 4500. *In vitro* experiments on extracted teeth will be needed to fully assess the clinical potential of this new irrigant, with special emphasis on the possibility of more conservative root canal instrumentation.

Acknowledgements

The author wishes to thank Brian McLean (Hammersley Chemicals), Joe Micallef (3M), and Gary Weber (SEM unit, University of Newcastle), for their technical assistance.

References

1. Grossman L. Endondontic practice. 10th ed. Philadelphia: Lea & Febiger, 1981:200-2.
2. Moorer WR, Wesselink PR. Factors promoting the tissue dissolving capability of sodium hypochlorite. Int Endod J 1982; 15:187-96.
3. Abou Rass M, Patonai FJ. The effects of decreasing surface tension on the flow of irrigating solutions in narrow canals. Oral Surg 1982;53:524-6.
4. Cunningham WT, Cole JS, Balekjiian AY. Effect of alcohol on the spreading ability of sodium hypochlorite endodontic irrigant. Oral Surg 1982;54:333-5.
5. Cameron JA. The use of ultrasonics on the removal of the smear layer; a scanning electron microscope study. J Endod 1983;9:289-92.
6. Goodman A, Reader A, Beck M, Melfi R, Meyers W. An *in vitro* comparison of the efficacy of the step-back technique versus a step-back ultrasonic technique in human mandibular molars. J Endod 1985;11:249-56.

Requests for reprints:
P.O. Box 101,
Charlestown, NSW, 2290.