# Sodium hypochlorite and its use as an endodontic irrigant

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**Abstract**
Sodium hypochlorite has been used as an endodontic irrigant for more than 70 years, and is now one of the most common solutions for this purpose. The chemical properties and production of commercial sodium hypochlorite are reviewed. Domestic bleaches and an infant sanitizer are compared from the point of view of cost and ease of use – Milton being recommended where a 1% solution is required. The cost of syringes and needles for endodontic irrigation is many times greater than the hypochlorite they contain, and total annual practice costs for hypochlorite are low. Brief guidelines for clinical use, storage, handling and disposal are included.

***Key words:*** Sodium hypochlorite, endodontics, domestic bleach, costs.

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## Introduction

Hypochlorites in general are strong oxidizing agents. Commercially they are used as an alternative to chlorine gas for chlorination of domestic water supplies and swimming pools, and in cooling towers of air conditioners and power stations to control biofouling. They corrode most metals except titanium and some forms of stainless steel.[1,2]

## Sodium hypochlorite

Sodium hypochlorite is both an oxidizing and hydrolyzing agent.[3] It is bactericidal and proteolytic. Sodium hypochlorite solutions have been used as wound irrigants since at least 1915,[4] and as an endodontic irrigant as early as 1920.[5] Its use as an infant sanitizer is nearly universal.

Irrigation of root canals with sodium hypochlorite solutions (in concentrations ranging from 1 per cent to 5.25 per cent) is now a widely accepted technique. As an endodontic irrigant, sodium hypochlorite solution is relatively cheap; is bactericidal and virucidal;[6,7] it dissolves proteins, has a low viscosity, and it has a reasonable shelf life. It is not without disadvantages, principally due to its toxicity – it damages all living tissues except keratinized epithelia.[3,8-11] Sodium hypochlorite is extremely corrosive to metals; is strongly alkaline, hypertonic and has a very unpleasant taste. Observance ofcorrect storage procedures is critical to obtaining the expected shelf life. In endodontics most of these disadvantages can be obviated by confining the hypochlorite to the pulp chamber and root canal. Use of rubber dam and careful irrigation techniques are vital.

### *Production and properties of sodium hypochlorite*

Sodium hypochlorite has traditionally been produced by bubbling chlorine gas through a solution of sodium hydroxide (NaOH), to produce sodium hypochlorite (NaOCl), salt (NaCl) and water ($H_2O$).

$$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$$

An alternative method uses electrolysis of a saturated brine solution to produce sodium and chloride ions. The sodium ions diffuse through a membrane, where they combine with water to produce sodium hydroxide. The chloride ions from the first compartment combine to give chlorine gas which is dissolved in the sodium hydroxide to give sodium hypochlorite, salt and water.

Commercial sodium hypochlorite solutions are strongly alkaline, hypertonic, and typically have nominal concentrations of 10 to 14 per cent available chlorine. They deteriorate with time, temperature, exposure to light, and contamination with metallic ions. Excess chlorine in sodium hypochlorite solutions leads to an acid solution which is unstable. More concentrated solutions of

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**Table 1. Properties of sodium hypochlorite products**

| Product name | pH | Available chlorine | Diluent | Surfactant |
|---|---|---|---|---|
| Sno Wite | 13.0 | 4% | Demineralized water | No |
| White King | 13.0 | 4% | Demineralized water | Yes |
| Milton | 11.0 | 1% | PGMP* | No |
| Domestos | 13.2 | 5% | N.R.† | Yes |
| Black & Gold | 11.5 | 1.5% | Brisbane tap water | No |
| Superior | 10.8 | 5% | Demineralized water | No |
| Cyclone Sam | 11.5 | 1.5% | Brisbane tap water | No |
| Home Brand | N.R. | 1% | Melbourne tap water | No |
| Delta West | 11.3 | 0.05% | Water B.P.‡ | No |
| White Magic | 12.0 | 4% | Demineralized water | No |

*PGMP = Water to pharmaceutical Good Manufacturing Practice standards.
†N.R. = No response
‡Water B.P. =

sodium hypochlorite are less stable, and concentrations over about 5 per cent available chlorine require vented containers to prevent build up of the oxygen produced. These chemical changes are summarized in the two equations below.

$$2NaOCl \rightarrow 2NaCl + O_2$$

$$3NaOCl \rightarrow 2NaCl + NaClO_3$$

All sodium hypochlorite solutions will contain some compounds other than sodium hypochlorite itself. Those identified are listed below:

Sodium chlorate – from the breakdown of NaOCl.

Sodium hydroxide – keeps pH high for stability.

Metallic ions – from metal containers and piping.

Chloramines (and perhaps trihalomethanes) – from reaction with organic contaminants.

Perfumes – added to domestic bleaches as a marketing strategy.

Surfactants (usually amine oxides) – to improve cleaning properties.

Fatty acids – give 'body' by forming soap with excess NaOH.

Sodium Chloride – from breakdown of NaOCl.

### *Current status of sodium hypochlorite*

Sodium hypochlorite solutions are used so extensively as endodontic irrigants in Australia, that their use goes largely unquestioned. Milton appears to be widely used, as are solutions of domestic bleach diluted to 1 per cent, although higher concentrations have been suggested.[3,8-16] As the use of dilute domestic bleach is widespread, it seemed appropriate to examine the properties of sodium hypochlorite generally, and of the hypochlorite products on the market, to establish whether it is safe to use domestic bleach in endodontics, and if there is a rational basis for this use.

This article: (1) Reviews a range of sodium hypochlorite products retailed in Australia; (2) Considers the impact of the Therapeutic Goods Act[17] on their use, and (3) Makes some recommendations on choice and handling. Milton was taken as a benchmark, and compared with domestic bleach from the point of view of physical properties and cost. Investigation of hardware costs and overall hypochlorite costs in practices were peripheral investigations, and are included purely to give perspective to the discussion on relative costs for hypochlorite.

## Materials and method

All domestic bleach products available on supermarket shelves and through the local cleaning and packaging wholesaler in the home town of one of the authors were included in this study, along with Milton. Those products containing perfumes were not included in the study because the perfumes themselves make no conceivable therapeutic contribution and are, according to the manufacturers, composed of literally dozens of individual compounds. The authors became aware of the Delta West product through its presence on the register of the Therapeutic Goods Administration.

All data are those provided by the manufacturers either directly or from Materials Safety Data Sheets. An independent analysis was not performed. Written requests were followed up by telephone where necessary to ensure a complete survey. A few cells in the tables could not be completed, that is, in one case where the manufacturer cited commercially sensitive information, and two others where repeated calls failed to contact the responsible person prior to publication. The costs of all products were ascertained on the same day in the same town to ensure valid comparisons. Cost and some other data for the Delta West product were not obtained because its concentration was well below the minimum suggested for endodontics, but it is included in Table 1. Late in the study, the authors approached Johnson & Johnson for data on Johnson's Anti-Bacterial Solution,‡ which is nominally 1.5 per cent sodium hypochlorite. The data provided were variable and incomplete, and also it was not possible to obtain a retail price on the date used for other products, so this product was not included.

Annual costs of hypochlorite used for endodontic irrigation exclusively were obtained from general and specialist endodontic practices to give some idea

‡Johnson & Johnson Australia Pty Ltd, St Leonards, NSW, Australia.

**Table 2. Sodium hypochlorite products studied**

| Product name | Manufacturer | Supplier NaOCl |
|---|---|---|
| Sno Wite | Kiwi Australia, Clayton Sth, Vic., Australia | Kiwi |
| White King | Kiwi Australia | Kiwi |
| Milton | Procter & Gamble Australia Pty Ltd., Parramatta, NSW, Australia | I.C.I. |
| Domestos | Lever Industrial, Marrickville, NSW, Australia | I.C.I. |
| Black & Gold | Steric Pty Ltd, Villawood, NSW, Australia | Elite |
| Superior | National Chemical Vending, Macgregor, Qld, Australia | I.C.I. |
| Cyclone Sam | Steric Pty Ltd | Elite |
| Home Brand | Grocery Wholesalers Pty Ltd, Yennora, NSW, Australia | I.C.I. |
| Delta West | Delta West Pty Ltd, Bentley, WA, Australia | McGuire |
| White Magic | Reckitt & Colman Products, West Ryde, NSW, Australia | N.R. |

N.R. = No response.

of the overall cost impact. It also became evident that hardware costs were more significant than the cost of the hypochlorite, so the costs of a range of disposable plastic syringes and needles typically used for endodontic irrigation were obtained from a single supplier on the one day, again to ensure that cost comparisons were valid. To support the contention that domestic water supplies contain substantial quantities of metallic ions, the Sydney, Brisbane, and Kingaroy local authorities were approached for representative analyses of their water.

## Results

Table 2 lists the names of all the products studied, along with the names of their manufacturers, and the names of their suppliers of bulk commercial sodium hypochlorite (provided by the manufacturer at the time of writing of this paper) where this information was available or forthcoming.

At this stage there are two products which appear on the Therapeutic Goods Register. One is Milton, the other is Delta West, which is a 0.05 per cent solution. Both these solutions were registered under the 'Grandfather Clause' which allowed products currently supplied to register when the Act came into effect in early 1991.

Table 1 gives the pH, concentration of available chlorine, type of water used for dilution from the commercial concentrate, and presence or absence of surfactant, for each product. All products were well below the concentrations of commercial sodium hypochlorite solutions.

From Table 1, these solutions can be divided into five groups.

*Group 1. Bleaches containing surfactant*

White King and Domestos were the only products containing substantial quantities of surfactant, (although bleaches containing perfumes also had small additions of surfactant). Domestos also had the addition of a fatty acid (which would form a soap with the excess sodium hydroxide) to give 'body' – presumably greater viscosity to reduce the tendency to run off vertical surfaces. Domestos was by far the most expensive of the domestic bleach products.

*Group 2. Bleaches diluted with tap water*

Black and Gold and Cyclone Sam were essentially the same product marketed under different names. The concentrated NaOCl was simply diluted with Brisbane tap water to obtain a 1.5 per cent solution. Similarly, Home Brand was diluted with Melbourne tap water to obtain a 1 per cent solution.

*Group 3. Bleaches diluted with demineralized water*

The bleaches produced by diluting commercial sodium hypochlorite with demineralized water, Sno Wite, Superior and White Magic all had higher concentrations (4-5 per cent) of available chlorine than group 2.

*Group 4. Hypochlorite manufactured to pharmaceutical Good Manufacturing Practice (GMP) standard*

Milton was the only product in this group.

*Group 5. Hypochlorite produced under sterile conditions*

Delta West is the only product in this group. It is sterile, isotonic, and marketed in single-use sachets specifically for wound irrigation. Its concentration is 0.05 per cent available chlorine, which is one-tenth of the minimum suggested for endodontic irrigation.

It can be seen from Table 2 that there were only four producers of concentrated commercial NaOCl for all bleaches studied. Kiwi and Elite appeared to use similar production techniques, that is, electrolysis. ICI has two factories which produce sodium hypochlorite, with small differences in concentrations of NaOCl and contaminants.

According to the manufacturers' responses, NaOH concentration in the commercial concentrate from the supplier, varied from 0.3-1 per cent, while chloramines and trihalomethanes were absent from these solutions.

The cost of hardware is greater than the contents by an enormous margin. An examination of Tables 3 and 4 shows that the most expensive sodium hypochlorite solution is one-thirteenth the cost of the cheapest syringe and needle in which it is used. Yearly costs for hypochlorite range between $18 and $37 per practitioner (Table 5).

**Table 3. Calculated costs for 1% solutions of sodium hypochlorite**

| Product name | Cost | Volume | Cost per litre 1% solution* |
|---|---|---|---|
| Sno Wite | $3.17 | 2.5L | $0.58 |
| White King | $4.00 | 2.5L | $0.67 |
| Milton | $5.70 | 1.0L | $5.70 |
| Domestos | $23.36 | 5.0L | $1.21 |
| Black & Gold | $0.99 | 2.0L | $0.45 |
| Superior | $3.99 | 4.0L | $0.48 |
| Cyclone Sam | $2.57 | 4.0L | $0.55 |
| Home Brand | $0.95 | 2.0L | $0.48 |
| White Magic | $3.04 | 2.5L | $0.57 |

*Presupposes dilution with demineralized water costing 35.5 cents per litre. Costs were established in Kingaroy, Qld, on 8 January 1996.

**Table 4. Syringe and needle costs**

| Brand and type | Syringe | Needle | Total | Cost per litre |
|---|---|---|---|---|
| Terumo 5 mL Luer-Lok | $0.28 | $0.21 | $0.49 | $98.00 |
| Terumo 5 mL taper | $0.28 | $0.11 | $0.39 | $78.00 |
| Monoject 6 mL Luer-Lok | $0.48 | $0.14 | $0.62 | $103.33 |

Costs from Commonwealth Dental Supply, Brisbane, Qld, on 12 February 1996.

## Discussion

It is evident from this study that the sodium hypochlorite bleach products on the market have varying concentrations, but all are well below those of commercial hypochlorite (Table 1). It is also apparent that these bleach products contain many compounds other than sodium hypochlorite itself. NaOCl solutions require careful handling to maximize their advantages as endodontic irrigants,[1,8,12-16,18] and their costs vary widely (Tables 3 and 5). These four factors and the associated safety concerns influence the choice of a suitable endodontic irrigant.

### *Extraneous compounds*

Excess sodium hydroxide was present in all products, with a resulting high pH, but the level would appear to be below that likely to cause tissue damage.[19] All sodium hypochlorite products contain some salt from the production process, but Milton contains added salt (16.5 per cent) to change the equilibrium of the breakdown reaction below:

$$2NaOCl \rightarrow 2NaCl + O2$$

This results in a more stable solution.

The endodontic use of hypochlorite requires the removal of dentine debris, the destruction of microorganisms and dissolution of protein. It may be that surfactants would improve the performance of sodium hypochlorite solutions by reducing the surface tension. The lowered surface tension permits 'wetting' of the small particles, allowing them to be suspended in the irrigating solution, and thence removed along with it. For NaOCl this would allow the solution to penetrate finer canals and fins for removal of any contained protein and microorganisms. Cohen and Burns state that the most important factors in reducing dentinal debris are volume and frequency of irrigant used.[20] A lowered surface tension could well be as important, as Cameron[16] showed using household bleach with a fluorocarbon surfactant. Amine oxide surfactants, which are contained in some domestic bleaches, appear to be biologically active materials which are fairly easily degraded,[21] but at this stage, it is not possible to recommend the clinical use of White King and Domestos, which contain amine oxide surfactants, without further investigation.

Both the presence of metallic ions and higher concentrations of available chlorine reduce the shelf life of hypochlorite solutions, and these two factors are interdependent. Products diluted with tap water (Black and Gold, Cyclone Sam and Home Brand), due to contamination by the metallic ion content of municipal water supplies (Table 6) rely on low concentrations to give acceptable shelf life. Group 3 solutions can support higher concentrations of sodium hypochlorite (4-5 per cent available chlorine) because the absence of metallic ions means they deteriorate more slowly. Organic materials are also present in tap water, along with chlorine as NaOCl or gaseous $Cl_2$, and perhaps chloramines and trihalomethanes. Theoretically, further chloramines would be produced by the addition of NaOCl concentrate to any water containing organic material. The concentrations of these chloramines would probably be low. Tank water can be expected to contain organic material to a greater or lesser extent, depending on location, and some metallic ions depending on roof, tank and pipe material. All such contaminants cause sodium hypochlorite solutions to break down more rapidly. Of particular importance is the fact that the internal plumbing of most dental practices is copper, and copper ions cause more rapid deterioration of sodium hypochlorite solutions than other metallic ions.[1]

**Table 5. Sodium hypochlorite costs for endodontics in dental practices**

| Type of practice | Hypochlorite used | No. of dentists | Yearly cost | Cost per dentist |
|---|---|---|---|---|
| Group general | Milton | 1.6 | $30.15 | $18.85 |
| Solo general | Milton | 1 | $37.05 | $37.05 |
| Group specialist | Domestic bleach | 6 | $109.00 | $18.16 |
| Solo specialist | Milton | 1 | $44.00 | $44.00 |

**Table 6. Domestic water analyses**

| Metallic ion concentrations | Brisbane (North Pine) | Kingaroy | Sydney (North Prospect) |
|---|---|---|---|
| Calcium | 17.0 | 34.5 | 7.6 |
| Magnesium | 7.8 | 18.5 | 4.1 |
| Sodium | 60.0 | 46.0 | 11.4 |
| Potassium | 2.9 | 5.1 | 1.58 |
| Iron | 1.1 | <0.02 | 0.12 |
| Aluminium | 0.79 | <0.05 | 0.08 |
| Manganese | 0.51 | <0.02 | 0.007 |
| Copper | 0.12 | <0.05 | 0.01 |

All figures in parts per million. Sydney test date: 20 April 1993. Kingaroy test date: 28 May 1996. Brisbane results are maximum readings for year to June 1996.

The importance of these contaminants is unclear as it is probable that the effects of any contaminants contacting vital tissue would be less harmful than sodium hypochlorite itself.

### *Concentration*

While Delta West produces a 0.05 per cent solution of sodium hypochlorite, it was eliminated as a possible endodontic irrigant, because the concentration is far lower than typically recommended.

Milton which has 1 per cent available chlorine, is manufactured with more controls and at a greater cost than other products except Delta West. More importantly for dentists, Milton contains added salt to change the equilibrium of the breakdown reaction meaning that the sodium hypochlorite does not break down so readily. Milton should be more stable than domestic bleach, diluted or undiluted.

Cameron has shown that concentrations greater than 2 per cent remove protein remnants from root canals when combined with ultrasound, where lower concentrations do not.[22] Where a solution stronger than 1 per cent is judged necessary, a bleach from Group 3 could be recommended subject to some rather rigorous handling criteria. It is important that further dilution should also be with demineralized water, if the solution is to be used over a long period of time.[1] Higher concentrations give more rapid tissue dissolution,[13,15] but are more toxic if they come in contact with vital tissue. Concentrated solutions are less stable, so should be stored for shorter periods before being discarded.

### *Storage and handling*

It would appear from this study and a review of the literature that the following points should be considered when handling sodium hypochlorite:

(1) The stability of hypochlorite solutions is reduced by lower pH, presence of metallic ions, exposure to light, open containers, higher temperatures, and higher concentrations.

(2) To ensure good shelf life, all solutions should be stored in light-proof (opaque glass or polythene), airtight containers, in a cool place.

(3) If diluted, they should be diluted as soon as possible after purchase, because dilute solutions deteriorate less rapidly than concentrated solutions.

(4) Domestic bleach solutions produced and stored in this manner will deteriorate more rapidly than Milton, because they do not have the added salt to give stability.

(5) A practitioner electing to use a Group 3 bleach undiluted, should simply ensure that the bottle is always tightly sealed, and discard by the 'use by' date. Similarly for Milton, as long as the container and lid are intact, the product should be effective until the expiry date.

(6) Frequent opening of the container or failure to close securely, would have an effect akin to an open container, similarly reducing the shelf life.

(7) Metallic containers should never be used for sodium hypochlorite, as the hypochlorite will react with the metal in the containers.

(8) The corrosive nature of sodium hypochlorite must be considered before disposal. As drainage pipes from sinks and dental units may use stainless steel, copper, galvanized steel, PVC, polythene and perhaps other materials, copious quantities of water should be flushed down all drains at the time of disposal to avoid risk of perforation of drainage traps which have undiluted sodium hypochlorite in them for any period.

### *Costs*

Dentistry is a high-cost profession, and choice of materials is one area in which dentists can feel they have some control over these costs. This is true for bleaches; however, the lower intitial cost of domestic sodium hypochlorite solutions compared with Milton must be weighed against the added costs of preparation, storage and handling. Such costs would typically include: (1) Staff time in diluting domestic bleach with demineralized water; (2) Cost of demineralized water; (3) Cost of opaque glass or special polythene containers; (4) Extra space required to store 4-5 times the volume of prepared solution.

The dilution of domestic bleach is the cost-related crux of this paper. Table 3 compares all solutions in the study by calculating the cost per litre at the concentration of the weakest solution. Milton is by far the most expensive at $5.70; but even so, the cost for the contents of a 5 mL syringe is less than 3 cents, or about one-twelfth the average cost of the syringe and needle if they are only used once (Table 4). The annual costs in Table 5, show that a general dentist performing a substantial amount of

endodontics spends less than $20 per year on Milton. Demineralized water costs are always substantial, and for 1 per cent solutions can exceed the cost of the hypochlorite (Table 3). The authors consider that the economic value of diluting domestic bleach solutions is questionable.

It is evident from Table 4 that the cost of syringes is a far greater cost than that of the hypochlorite solution itself. While re-use of syringes may appear to offer cost savings, it can be calculated that a nurse earning $300 per 40 hour week has just 2 minutes 15 seconds to retrieve, flush, sterilize, dry and replace a syringe costing 28 cents, to equal the cost of a replacement – and this assumes the syringe lasts indefinitely.

### *Safety*

Because sodium hypochlorite damages all living tissue except keratinized epithelium,[8] and bleaches most textiles, it must be handled with care. Staff should wear gloves, protective glasses and protective clothing when loading syringes. This is of even greater importance when diluting domestic bleach, due to its higher concentration than that of Milton.

Only Luer-Lok syringes and needles should be considered for use because taper seat needles may dislodge in use, with eye and other tissue damage resulting.[3] During the course of this study it became apparent that syringes for endodontic irrigation are sometimes re-used. It is the opinion of the reviewers that they should be discarded at the completion of the appointment, along with any remaining hypochlorite solution for infection control reasons.

Domestic bleach solutions, both diluted and concentrated, have been used for many years in endodontics, and in endodontic research[8,12,14,23] and there would seem to be no clinical reasons not to continue their use, as long as they are strictly confined to the pulp chamber and root canal system by use of rubber dam and careful irrigation technique. However, general dentists and endodontists choosing to use these solutions (4 per cent to 5 per cent available chlorine) should be aware of the impact of the Therapeutic Goods Act,[17] which appears to regulate the use of sodium hypochlorite solutions as antiseptics, and disinfectants, while sodium hypochlorite solutions for use as infant sanitizers are exempt. If endodontic use of hypochlorite can be considered 'wound irrigation', then strictly speaking, only products registered for this use should be used. Procter and Gamble, manufacturers of Milton state that their product is not suitable for this use, and the Therapeutic Goods Administration states that practitioners should only use a product labelled as being for wound irrigation, but it also points out that regulation of these products occurs at the source, rather than at the point of use. Their concern is that such products conform to two standards: those of the *British Pharmacopoeia,* and pharmaceutical Good Manufacturing Practice (GMP).

## Conclusions and guidelines for use

Sodium hypochlorite solutions are effective endodontic irrigants over a wide range of concentrations, but stale solutions are an expensive combination of salt and sodium chlorate. As with other therapeutic items, timely purchase of the solution in the strength required, storage in the original light-proof container which is kept sealed at all times, and discarding remnants well within the recommended time span will ensure that the product is always effective.

Milton is the solution of choice wherever a 1 per cent solution is judged adequate. The apparent cost savings of diluting domestic bleach to 1 per cent are probably illusory when labour and storage costs are considered. Practitioners requiring a stronger hypochlorite solution should choose one similar to those in Group 3; diluted if necessary with demineralized water and stored with care.

Sodium hypochlorite solution is one of the most economical materials that dentists use. The costs of preparation and associated hardware are greater than the cost of the solution itself.

On the basis of this investigation the following brief guidelines for endodontic use of sodium hypochlorite solutions can be advocated:

1. Always use fresh solutions.
2. Use only demineralized water for dilution.
3. Store solutions in opaque glass, or coated polyethylene containers which are tightly sealed.
4. Use Luer-Lok plastic syringes.
5. Do not inject forcibly, or allow needle to bind in canal.
6. Always use rubber dam during endodontic treatment and ensure that it maintains a tight seal against the tooth and gingiva.
7. Discard syringes and unused solutions at conclusion of appointment, flushing drains with copious quantities of water.

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