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SODIUM HYPOCHLORITE AND ITS PROPERTIES
Mokshi .R. Jain*
Saveetha Dental College & Hospitals, 182, Ponamalle high road, Chennai-600077.
Email: mokshi.jain.007@gmail.com
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Abstract

**Aim:** The aim of this article is to write a literature review on sodium hypochlorite and its properties.

**Objective:** This review aims to provide elaborate details about sodium hypochlorite and its various properties.

**Background:** The use of sodium hypochlorite (NaOCl) as an endodontic irrigant began in the early 1920s and is now the most commonly used solution for this purpose. A 0.5% to 5.25% solution of NaOCl is the medicament of choice due to its efficacy against pathogenic organisms and pulp digestion. At low concentrations it dissolves mainly necrotic tissue; at higher concentrations it also dissolves vital tissue and additional bacterial species. Longer time exposure and warming the solution also increases its effectiveness in removing soft tissue and bacteria within the root canal chamber. It is also used as a stain removal in cases of dental fluorosis, as a disinfectant and bleach. However, escape of the solution into the periodical space due to excessive pressure applied on syringe may lead to sever pain, edema, haematoma and ecchymosis.

**Reason:** As sodium hypochlorite is used extensively in the current scenario, it is important to know about its properties and adverse effects to ensure efficient treatment.

**Keywords:** antimicrobial, dissolution, endodontics, irrigant, pulp

**Introduction**

A successful root canal treatment requires a complete debridement of the root canal system. Microbes and their by-products are the main causes of pulpal and peri-radicular lesions. Pulpal tissue remaining in the root canal serves as a source of nutrition for further microbial growth. In order to eliminate these sources of pulpal infection, various mechanical and chemical methods have been proposed. Due to the complex anatomy of the root canal system, mechanical instrumentation alone is not effective in reducing the number of microorganisms. As a result, the use of chemical solutions which have the ability to traverse the areas which are inaccesible by instruments and remove all
the remnant tissue as well as microbes has become significant. Chemical agents can be divided into irrigants, rinses and inter-visit medicaments. One such chemical irrigant used is sodium hypochlorite (NaOCl), which is an excellent non-specific proteolytic and antimicrobial agent[1].

The use of sodium hypochlorite as a wound irrigant began in 1915 and as an endodontic irrigant in 1920[2]. Concentrations of NaOCl ranging from 1% to 5.5% are used for irrigating root canals. The properties of NaOCl are based on the solution’s concentration, temperature and pH. NaOCl has low superficial tension and has antimicrobial action, the ability to reduce endotoxic load, and the capacity to dissolve organic tissue [3]. Sodium hypochlorite reacts with the fatty acids and amino acids of the dental pulp to produce liquefaction. This mechanism relies on its concentration, volume, and contact time of the solution but also on the surface area of the exposed tissue. However, high concentrations are potentially toxic for periapical tissue [4]. The main disadvantages of sodium hypochlorite are that it is highly corrosive to metals, strongly alkaline, hypertonic and has a very unpleasant taste.

**Mechanism of Action**

The properties of sodium hypochlorite are manifested by the following chemical reaction:

\[
NaOCl + H2O \leftrightarrow NaOH + HOCl \leftrightarrow Na^+ + OH^- + H^+ + OCl^-
\]

It transforms the organic and fat degrading fatty acids into fatty acids (soap) and glycerol (alcohol) that reduces the surface tension of the solution [5]. Amino acids are neutralised by the formation of water and salt. Reduction in pH is seen with the release of hydroxyl ions. Hypochlorous acid present in the NaOCl solution acts as a organic tissue solvent and releases chlorine. Chlorine, being a strong oxidant inhibits the bacterial enzymes by irreversibly oxidising the sulphhydryl groups and acts as a strong antimicrobial agent [5].

The antimicrobial effectiveness of NaOCl is based on its high pH contributed by hydroxyl ions. The high pH interferes in the cytoplasmic membrane integrity with an irreversible enzymatic inhibition, biosynthetic alterations in cellular metabolism and phospholipid degradation observed in lipid peroxidation. The formation of chloramines by chloramination reaction with protein amino groups interferes with the cellular metabolism [5].

Enzyme inactivation occurs by three mechanisms:

- Displacement of hydrogen ions with chlorine.
- Chloramination reaction
- Irreversible oxidation of sulphhydryl groups.
Grossman and Meiman, observing pulpal tissue dissolution capacity, reported that 5% NaOCl takes 20 minutes to 2 hours to dissolve the tissue. Pulpal dissolution occurs by saponification reaction when NaOCl degrades fatty acids and lipids resulting in soap and glycerol [6].

**Antibacterial Activity**

**In vivo studies:** Studies were conducted by Bystrom and Sundqvist [7] using 0.5% NaOCl on fifteen single rooted teeth. Each tooth was treated at five appointments and the presence of bacteria in the root canal was studied at each occasion. The results showed that no bacteria was recovered from 12 out of 15 teeth when 0.5% NaOCl was used. However, only 8 out of 15 root canals could be successfully cleaned using saline solution as irrigant. Investigations by Vianna *et al* [8] revealed that the degree of microbial reduction after chemo-mechanical preparation of root canals containing necrotic pulp tissue was greater in NaOCl group than Chlorhexidine group.

**In vitro studies**

5% solution of NaOCl as a root canal irrigant was introduced by Walker [9] in 1936. Similar studies by Siqueira *et al* and Gomes *et al* have shown the effectiveness of varying concentrations of sodium hypochlorite in eliminating *Enterococcus faecalis* [10]. Berber *et al* [11] found that 5.25% concentration of NaOCl was the most effective solution followed by 2.5% concentration. Thus it can be concluded that NaOCl, in both *in vitro* and *in vivo* conditions, exhibits excellent antibacterial activity.

**Anti Fungal Activity**

*Candida albicans* is the most commonly found fungal species in both healthy (30–45%) and medically compromised (95%) individuals. Fungal infections are predominantly seen in root canals of obturated teeth in which treatment has failed [1]. Sen *et al* stated that C. albicans are more resistant in the presence of smear layer. When smear layer was absent, NaOCl started to display antifungal activity after 30 minutes [12].

**Sodium Hypochlorite and Biofilms**

Free floating bacteria existing in an aqueous environment form thin layered condensations on various surface structures. Such biofilms get established on any organic or inorganic substrate where planktonic microorganisms prevail [13]. In the oral cavity, free bacteria in the saliva serve as the source of biofilm formation. Reports state that microorganisms found in biofilms are 2-1,000 fold more resistant than corresponding planktonic form [14]. Studies have proved that NaOCl is most effective followed by iodine in removal of such biofilms. Dunavant *et al* [15] established that a significant relationship exists between concentration of test agent and percentage kill of the bacteria.
The results of percentage kill were reported as 6% NaOCl (>99.99%), 1% NaOCl (99.78%), SmearClearTM (78.06%), 2% CHX (60.49%), REDTA (26.99%) and BioPure TM (16.08%). NaOCl is claimed to be the only endodontic irrigant that can disrupt and remove microbial biofilm from the infected root canals.

**Tissue Solubility of NaOCl**

The ideal qualities of an endodontic irrigant are: antimicrobial activity, non-toxicity to periapical tissues, water solubility and capacity to dissolve organic matter inside the root canal system. According to Moorer and Wesselin [16], tissue dissolution is dependent on three factors: frequency of agitation, amount of organic matter in relation to amount of irrigation in the system and surface area of tissue that was available. In a study conducted by Naenni et al [17], the necrotic tissue dissolution capacity of 1% (wt/mol) sodium hypochlorite, 10% chlorhexidine, 3% and 30% hydrogen peroxide, 10% peracetic acid, 5% dichloroisocyanurate and 10% citric acid. Standardised necrotic tissue samples obtained from pig palates were incubated in these solutions and their weight loss was measured over time. None of the test solutions except sodium hypohlorite had any substantial tissue dissolution capacity. NaOCl is a strong proteolytic agent, which exhibits the best tissue dissolving ability as an endodontic irrigant at higher concentrations.

**Effect of NaOCl on Endodontic Instruments**

An essential requirement during canal preparation is a continuous and progressively tapered shape, so as to allow NaOCl to be delivered to the apical section of the canal and perform its bactericidal action and dissolve organic debris. NaOCl contacts the surface of nickel titanium instruments during root canal instrumentation and causes removal of nickel from the surface due to its corrosive nature. The resultant micropitting can lead to areas of stress concentration and crack formation, weakening the instrument [18].

O'Hoy et al [19] detected significant corrosive phenomena when Ni-Ti were exposed to 1% NaOCl for upto 10 cleaning cycles. However, no change in mechanical properties was observed. Berutti and Marini [20] concluded that if NiTi rotary instruments were operated immersed in a NaOCl solution contained in the pulp chambers of teeth restored with metals or alloys having different electrochemical nobility values, galvanic corrosion may occur.

**Effect of Heating**

The effectiveness of low concentration NaOCl can be improved by increasing the temperature of the solution. The removal of organic debris from dentin shavings is more efficient by heated hypochlorite solutions. The bactericidal rates of sodium hypochlorite solutions are more than doubled for every 5°C rise in temperature in the range of 5-60°C.
The capacity of a 1% NaOCl at 45ºC to dissolve dental pulps was found to be equal to that of a 5.25% solution at 20ºC. However, no clinical studies are available to support the use of heated NaOCl.

**Effect of NaOCl on Dentin**

**I. Effect on Composition and Structure of Dentin:** 22% of the dentin by weight is contributed by type I collagen which is responsible for the mechanical properties of dentin [22]. Hypochlorite causes degradation of organic dentin components by fragmenting long peptide chains and formation of N-chloramines.

Mountouris [23] et al reported that 5% solution NaOCl treatment reduced the organic matrix when applied with a rubbing action on the smear layer covered and acid etched human coronal dentin surfaces.

Marending [24] et al found that NaOCl caused a concentration dependent reduction of elastic modulus and flexural strength in human root dentin. A significant reduction in carbon and nitrogen content with an alteration in the permeability of intertubular dentin of the was reported.

**II. Effect on Bonding to Dentin**

The reaction of Sodium hypochlorite solution results in generation of oxygen which interferes with the polymerisation of bonding resin [25]. The bond strength of the resin following NaOCl treatment before etching decreased [26]. This reduction in bond strength can be improved by using ascorbic acid or sodium thipsulphate solution which removes NaOCl by oxidation-reduction reaction [27].

**Haemostatic Property of NaOCl**

Biocompatibility of NaOCl with exposed pulp tissues favours in controlling tissue amputation haemorrhage. Hafez [28] et al stated that 3% solution of NaOCl is an effective haemostatic agent as pulp treated with this concentration shows no evidence of pulpal necrosis after 7 and 27 days. NaOCl can be used for the disinfection and chemical amputation of operative debris and clot and coagulum debris as well as for the establishment for dentin-pulp interface free of organic biofilm before adhesive capping [1].

**Toxicity of Sodium Hypochlorite**

As already stated, increase in the temperature or concentration of sodium hypochlorite solution improves the antimicrobial and tissue dissolving properties. This poses the risk of toxicity and at higher concentrations, NaOCl is prone to cause tissue irritation on contact [29]. Heggars [30] et al examined wound healing to relative irrigation and bactericidal properties of NaOCl in vitro and in vivo models. They concluded that 0.025% solution of NaOCl was the safest to use because it was bactericidal but not tissue toxic.
Most complications of sodium hypochlorite occur due to apical extrusion which causes adverse tissue reactions like pain, swelling and haemorrhage followed by secondary infection and parasthesia [29]. Therefore, utmost care should be taken prior to the use of sodium hypochlorite irrigant by checking the condition and health of the root and periodontium.

**Complications of Accidental Spillage of Sodium Hypochlorite**

1. **Damage to clothing**

   Sodium hypochlorite is a popularly used bleaching agent. Even minute quantities can cause irreversible bleaching of clothing. Spillage can occur while transferring a syringe full of NaOCl into the oral cavity or due to the aerosol from the ultrasonic devices used during root canal irrigation [31]. Protective wear should be used for the safety of both the doctor and the patient.

2. **Damage to the eye**

   Immediate pain and mild burns occur due to alkaline nature of NaOCl which reacts with the corneal epithelium and forms a soap bubble which penetrates the corneal stroma which eventually may cause endophthalmitis and subsequent loss of vision [32].

   Ingram recorded a case of accidental spillage of 5.25% NaOCl into the patient's eye followed by severe pain, intense burning, epiphora and eythema [33].

   Accidental spillage should be followed by immediate ocular irrigation with large amounts of water. The patient should be referred to the nearest opthalmologist. Using protective eye wear is the best way to prevent such untoward complications.

3. **Damage to skin and oral mucosa**

   Surface injury is mainly caused by the saponification reaction between the alkali and protein or fat.

4. **Allergic reactions to sodium hypochlorite**

   Hypersensitivity reactions have been reported by Kaufman and Keila [34] in a patient where a confirmation was made using a skin patch test. In a case where 1% NaOCl was used for a patient allergic to it, severe pain, burning sensation, swelling of lips, cheeks and infraorbital area followed by ecchimosis and profuse haemorrhage of the root canal.

   Treatment for allergic reactions includes immediate administration of systemic corticosteroids and antihistamines intravenously [35].
Complications Due To Extrusion of Hypochlorite Beyond Root Apex

1. Chemical burns and tissue necrosis
Extrusion of sodium hypochlorite beyond the root apex is generally rare but when it occurs, it is characterised by a chemical burn leading to localised or extensive tissue necrosis. A severe acute inflammatory reaction develops giving rise to an intraoral or extraoral swelling which may be oedematous or haemorrhagic or both [36]. Onset of pain is a hallmark for tissue damage and may occur immediately or after several hours [37].

Involvement of maxillary sinus will cause sinusitis [38]. Associated bleeding into the interstitial tissues results in bruising and ecchymosis of the surrounding area [36]. A necrotic ulceration of the mucosa adjacent to the tooth may occur as a direct result of chemical burn [39].

2. Neurological complications
The major neurological complications include parasthesia and anaesthesia affecting the mental, inferior dental and infraorbital branches of the trigeminal nerve which may take several months to completely resolve [40]. Sensory and motor nerve deficit are not commonly associated with acute dental abscesses.

3. Upper airway obstruction
Inadequate isolation can lead to leakage of the solution into the oral cavity and ingestion and inhalation by the patient. Throat irritation is most commonly seen with upper airway obstruction in severe cases [40]. Fibre optic nasal tracheal intubation followed by surgical decompression is required to manage airway compromising swelling arising within three hours of accidental exposure [41].

Ways to Minimize Risk of Complications
One of the most important aspects of providing the best treatment to the patient includes the safety of the patient from chemicals and hazardous substances. Detailed plans and procedures to deal with accidents and emergencies have to be laid out.

Using protective gear like eye wear, face mask, gloves and plastic apron significantly reduces the risk of exposure. The sodium hypochlorite solution which is prepared should be stored in a light-proof, non-metallic container. Patient's clothing should be protected using a bib which is impermeable to liquid.

Rubber dam isolation should be done effectively. Side venting needles should be used to irrigate the root canal as it reduces the risk of accidental inoculation into the soft tissues [42]. Saline should be used as an irrigant for immature teeth with open apices [43].
By maintaining a high safety standard and following the protocol will result in a better endodontic therapy by eliminating the possible complications and ensuring patient comfort throughout the treatment.

**Conclusion**

In summary, this review discusses the various properties of sodium hypochlorite, the most popular endodontic irrigant. The mechanism of action followed by the antimicrobial, tissue dissolving and haemostatic property are highlighted. The interaction of sodium hypochlorite with the tooth structure, most importantly the human coronal dentin has also been explained. The followin conclusion can be drawn from the article:

- Sodium hypochlorite has a wide spectrum of activity against bacterial species.
- It is the strongest antifungal agent used in root canal therapy.
- NaOCl is the only endodontic irrigant which can destroy the biofilm effectively.
- The effect of sodium hypochlorite on endodontic instruments is controversial.
- It is an effective oxidising agent with tissue dissolution capacity.
- Antimicrobial and tissue dissolving capacity is improved at higher temperatures.
- It degrades the dentin and effects the mechanical and chemical properties.
- Haemostatic activity of sodium hypochlorite enhances the prognosis of vital pulp therapy.
- It is highly tissue toxic at high concentrations.
- Various complication have been reported due to accidental spillage or extrusion beyond the root apex.
- Preventive measures should be taken to ensure the safety of the operator and the patient.

**References**


**Corresponding Author:**

Mokshi .R. Jain*

**Email:** mokshi.jain.007@gmail.com