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REVIEW ARTICLE

Sodium Hypochlorite Irrigation Extrusion in Root Canal Treatment: An Updated Overview

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ABSTRACT

Effective endodontic treatment requires the proper choice of instruments and irrigation techniques in chemo-mechanical preparation. Sodium hypochlorite (NaOCl) is the most employed irrigant in endodontic practice, known for its efficiency in disinfecting the root canal system and dissolving organic debris. However, its cytotoxicity poses a drawback, potentially causing acute harm when extruded beyond the apex, a situation referred to as a NaOCl accident. While this occurrence is rare globally, NaOCl extrusion during root canal therapy can lead to severe aftereffects in addition to acute symptoms like pain and swelling. This review paper aims to guide dental clinicians in the early detection and diagnosis of NaOCl accidents, providing appropriate management strategies. The discussion encompasses the prevalence, risk factors, management, complications, and prognosis of NaOCl extrusion beyond the root apex. Recommendations and preventive measures for safely using sodium hypochlorite irrigation during endodontic therapy are also highlighted to ensure better management of hypochlorite accident symptomatology.

INTRODUCTION

Sodium hypochlorite (NaOCl) is the most commonly utilised irrigating solution in endodontic procedures, typically found in concentrations ranging from 0.5 to 5.25%

(Baumgartner & Cuenin, 1992). Its ability to dissolve tissue and its antibacterial properties have made it the preferred choice for cleaning root canals in endodontic therapy (Zehnder, 2006). These attributes allow for effective disinfection when used within the root canal, and no other solution has demonstrated the same level of effectiveness as NaOCl. However, it is essential to note that its cytotoxicity is a well-recognized concern that can result in acute harm if it reaches the periapical area (Guivarc'h et al., 2017). When NaOCl comes into contact with vital tissues, it induces oxidation of the surrounding tissues, leading to rapid hemolysis, ulceration, inhibition of neutrophil migration, and damage to endothelial and fibroblast cells (Pashley et al., 1985).

Wearing the proper personal safety equipment, using a fitted rubber dam, and using high-power suction are preventive methods (Clarkson & Moule, 1998). These precautions help to avoid skin and eye damage, as well as prevention from ingestion and aspiration. The Health Protection Agency Compendium of Chemical Hazards provides management for these injuries. Nevertheless, there remains a potential for the inadvertent release of sodium hypochlorite (NaOCl) into the periapical and soft tissues during root canal therapy.

The extrusion of NaOCl during root canal therapy (RCT) is known as a "hypochlorite accident," and it causes sudden severe symptoms as well as the possibility of catastrophic consequences (Farook et al., 2014). The prevalence of such incidents is uncertain because they are not regularly reported and cannot be diagnosed retrospectively (Guivarc'h et al., 2017). With several randomised control trials conducted worldwide, it is a relatively infrequent event. However, the research found that nearly half of the endodontic practitioners report experiencing at least one NaOCl accident during their work (Kleier et al., 2008).

The intricate anatomy of the head and neck region makes numerous vital structures susceptible to NaOCl accident injuries (Farook et al., 2014). Therefore, general dentists and endodontists need to be well-versed in the risk factors and the management of patients with NaOCl extrusion injuries.

REVIEW

Sodium hypochlorite irrigants

Sodium hypochlorite is an alkaline irrigant with a pH of 11-12. In water, NaOCl ionises to form Na+ and the hypochlorite ion, OCl, which are in equilibrium with hypochlorous acid (HOCl). Chlorine predominates as OCl at high pH levels of 9 and above, while HOCl predominates at acidic and neutral pH levels (McDonnell & Russell, 1999). The antibacterial activity is caused by hypochlorous acid; the OCl ion is less potent than the undissolved HOCl. Hypochlorous acid interferes with several of the microbial cell's vital functions, leading to cell death (McKenna & Davies, 1988). It is a potent agent with effectiveness against many bacteria and can dissolve both living and dead tissue (Senia et al., 1975).

The solution concentration affects NaOCl's capability to dissolve tissue, antibacterial effectiveness, and cytotoxicity. The more concentrated the solution, the more toxic it is to cells (Pashley et al., 1985). More significant cytotoxicity was seen with 5.25% NaOCl solutions than 0.5% or 1% NaOCl solutions (Pashley et al., 1985). However, the irrigant's concentration is still up for debate and is still controversial; many authors suggest using sodium hypochlorite at a concentration of 5.25%, whereas others prefer a lower concentration of 3% or even 0.5% (Harrison, 1984). Due to its toxic impact on living tissues, sodium hypochlorite can lead to adverse effects such as hemolysis, skin ulceration, and necrosis. Therefore, it is crucial to exercise caution to prevent the extrusion of NaOCl beyond the root apex (Pashley et al., 1985). For this reason, (Hauman & Love, 2003) recommended utilising larger quantities of low-concentration sodium hypochlorite (e.g., 0.5–1%) instead of employing highly concentrated solutions (5.25%).

Types of sodium hypochlorite accident

While many studies have commonly referred to the extrusion of sodium hypochlorite (NaOCl) beyond the apex as a "hypochlorite accident" (Guivarc'h et al., 2017), it is essential to note that various other mishaps during root canal irrigation have been documented in the dental literature. According to Hulsmann et al. (2007), these incidents can include damage to the patient's clothing, splashing of the irrigant into the patient's or operator's eye, accidental ingestion of irrigants, extrusion beyond the apex, air emphysema, allergic reactions to the irrigant, and unintentional use of an irrigant as an anaesthetic solution.

Additionally, it is worth mentioning that Zhu et al. (2013) categorised sodium hypochlorite (NaOCl) extrusion accidents into three distinct types. These categories encompass careless iatrogenic injections, such as unintentionally administering NaOCl as a local anaesthetic, the extrusion of NaOCl into the maxillary sinus, and the extrusion or infusion of NaOCl beyond the root apex into the periradicular regions.

Prevalence and incidence of sodium hypochlorite accident

According to a study by Kleier et al. (2008), female patients with a clinical history of pulp necrosis and periapical radiolucency were found to be at a significantly higher risk of experiencing accidents involving maxillary premolar and molar teeth. The study's findings indicated that such accidents occurred more frequently in the maxillary region (accounting for 73% of cases, or n=122) than in the mandibular region (21%, or n=35). Furthermore, these accidents predominantly occurred in the molar or premolar areas (70%, or n=107) compared to the incisor or canine regions (30%, or n=46). When considering the gender of the patients, accidents were more commonly reported among females (69%, or n=99) than males (31%, or n=44). These results align with a recent systematic review by Guivarc'h et al. (2017), which found that sodium hypochlorite (NaOCl) accidents were most frequently observed in females and maxillary teeth.

Aetiology and risk factors of sodium hypochlorite accident

Factors such as open apices, either iatrogenic or anatomic (Becker et al., 1974), undiagnosed perforation (Reeh & Messer, 1989), needle wedging (Balto & Al-nazhan, 2002), and close approximation with surrounding structures such as antral tooth (Becking, 1991) may increase the risk of NaOCl extrusion.

It is crucial to adhere to the apical constriction during the root canal system's apical preparation. The breakdown of apical constriction in situations when this has been over-prepared will elevate the possibility of hypochlorite extrusion (Spencer et al., 2007). A larger apical foramen may also result from root resorption (Hülsmann & Hahn, 2000). It has been observed in NaOCl accidents that the reactions become more severe when NaOCl concentrations are increased (Kleier et al., 2008). This has led to the debate about the ideal concentration of NaOCl.

The precise positioning of teeth about the alveolar bone is of utmost importance, particularly when the root apex might be shielded by thin bone or soft tissue (de Sermeño et al., 2009). In such instances, even a tiny amount of irrigant extrusion can result in symptoms that have the potential to propagate. Compared to men, the lower bone density in women and the thinness of the cortical bone covering the buccal roots of maxillary teeth could explain why NaOCl may extend into nearby soft tissues (Kleier et al., 2008). An explanation for the potential extrusion of NaOCl into the maxillary sinus was provided by Hauman and Love (2003) in their review, where they mentioned that the alveolar bone tends to become thinner with age, particularly around the tooth apices.

Besides that, the high flow rate of irrigant, needle depth insertion, apical fenestration, horizontal root fracture, and presence of periapical lesion may also contribute to the risk of NaOCL accident (Boutsioukis et al., 2013).

Until now, most clinical case documentation has been unsystematic, with specific important details omitted (Guivarc'h et al., 2017). This finding is by the study done by Boutsioukis et al. (2013), who reviewed the factors influencing NaOCl extrusion during RCT, and they concluded that the available literature did not allow for the establishment of conclusive findings but instead led to speculation about the risk factors.

Complications

Allowing sodium hypochlorite to settle on vital tissues can lead to a chemical burn. Short exposure may trigger a minimal inflammatory response. In contrast, prolonged exposure or using a higher concentration solution can result in a more significant inflammatory reaction, ultimately causing necrosis in the affected tissue.

Typical clinical manifestation of sodium hypochlorite accident (Hülsmann & Hahn, 2000; Phillip et al., 2022; Spencer et al., 2007):

i. Sever, sudden pain with a burning sensation.
ii. Rapid swelling of nearby soft tissues, with the possibility of spreading to the upper lip, infraorbital region, and bruising on the side of the face.
iii. Continuous bleeding from the root canal
iv. Profound internal bleeding leading to skin and mucosal haemorrhaging (ecchymosis)
v. A taste resembling chlorine and discomfort in the throat after injecting into the maxillary sinus.
vi. Risk of subsequent infection.
vii. The possibility for reversible anaesthesia or paraesthesia.

Sequelae of symptomatology by Khandelwal & Ajitha (2020):

i. Patients present with sudden, intense pain and swelling.
ii. Swelling typically begins minutes to hours after the incident and can be extensive, spreading within and outside the affected tooth area. In some cases, it may even hinder the ability to open the eye on the same side.
iii. Hematomas, tissue necrosis, and infections are typically the subsequent symptoms that may emerge hours or days after the extrusion. Hematomas on the face often result from extensive internal bleeding caused by haemolysis. Consequently, neurological signs like sensory and motor impairments can be expected after an extrusion.
iv. Ophthalmic symptoms such as eye pain, blurred vision, double vision, and coloured patches on the cornea may manifest. These symptoms are commonly associated with the canine and central incisor in the upper jaw.

Other complications include:

i. iTissue necrosis from the chemical burn caused by NaOCl can lead to a secondary healing phase, ultimately forming scars. (Hulsmann et al., 2007).
ii. Acute sinusitis is likely due to endodontic therapy involving the maxillary sinus. Therefore, the congestion of the maxillary sinus is a critical indicator of irrigant damage to the sinuses. Symptoms can range from the taste and smell of sodium hypochlorite to severe sinus congestion and intense discomfort (Ehrich et al., 1993)
iii. Neurological complications such as paraesthesia and anaesthesia may arise, affecting the trigeminal nerve's infraorbital, inferior dental and mental branches. NaOCl can cause permanent nerve damage, resulting in a loss of motor or sensory function. (Chaudhry et al., 2011) (Pelka & Petschelt, 2008)
iv. upper airway obstruction is risky (Bowden et al., 2006).

Ecchymosis and its anatomical relationship
Swelling and ecchymosis are typically the characteristics of NaOCl extrusion into the periradicular tissues. Swelling could be perceived as a defensive tissue reaction when a hyperosmotic and cytotoxic solution is extruded into the periradicular tissues (Zhu et al., 2013). The cytotoxicity of NaOCl caused ecchymosis as a potent solvent for organic materials, which resulted in the blood vessel walls' disintegration and subcutaneous soft tissues' haemorrhage.

It is interesting to note in various literature regarding the location of ecchymosis following incidents of NaOCl extrusion, precisely the absence of ecchymosis in the soft tissues immediately above the endpoint of the tooth affected by the extrusion. According to numerous case reports by Zhu et al. (2013), ecchymosis commonly appears around the mouth's angle and the periorbital region (both upper and lower eyelids). This ecchymosis often follows the path of superficial venous blood vessels. The extent of ecchymosis can vary depending on the quantity and concentration of NaOCl that enters the venous system and the specific location of the affected venous components and associated tissues. In more severe cases, ecchymosis may extend into other body parts, such as the neck and chest regions (Zhu et al., 2013).

It is essential to know how NaOCl extrusion could enter the venous vasculature. According to a new hypothesis by Zhu et al. (2013), the apical pressure produced by positive-pressure irrigation delivery systems at the periapex must be greater than the venous pressure in the neck's superficial veins. When this apical fluid pressure surpasses the venous pressure in the facial veins, the irrigant can enter a portal of entry within the facial venous vasculature. It is important to note that normal central venous pressure typically has a much lower average value (ranging from 1 to 7 mmHg, with a mean of approximately 5.88 mmHg) as reported by (Baumann et al., 2005). Consequently, extruded NaOCl would naturally flow into a vein via the path of least resistance, following the principles of pressure gradients.

Prognosis and healing

As stated by Becking (1991), patients typically require a few weeks to recover from the initial indications and persisting symptoms such as pain, swelling, hematoma, and tissue necrosis. However, discomfort and swelling can persist for as long as 30 days, and in certain instances, as Markose et al. (2009) reported, it may take up to 4 months for the swelling to entirely subside. Mucosal healing might extend to 60 days (Hülsmann & Hahn, 2000), and in some scenarios, it might even result in fibrosis and scar tissue formation, potentially leading to disfiguring scarring. In cases of paraesthesia, complete resolution may take several months.

Management of sodium hypochlorite accident

Addressing NaOCl extrusions seemed to rely mainly on empirical approaches (Guivarc'h et al., 2017). The lack of a documented standard treatment protocol may be due to the rare occurrence of these complications (MS, 2016). It is fascinating to note that most guidelines for managing NaOCl accidents are from the oral maxillofacial department. Therefore, as the first operator, general dental practitioners and endodontists need to know the management and clinical signs of NaOCl extrusion to allow fast and proper management to reduce the severity of the complications.

The first step in managing a NaOCl accident is to elucidate the situation to the patient (MS, 2016). This stage is crucial when managing the aftermath of such an incident. Additionally, record every aspect of the incident, such as the type of irrigation needle used, the usage of a rubber dam, the duration of the work, and the volume and concentration of NaOCl. Consider taking medical photos to support these notes.

The course of treatment will be decided based on the seriousness of the situation (Farook et al., 2014). Long-acting local anaesthetics and analgesics, such as nonsteroidal anti-inflammatory medications and paracetamol, could alleviate pain (Chaugule et al., 2015; Phillip et al., 2022). For the management of severe pain, a flexible prescription that alternates between ibuprofen and paracetamol at intervals of four hours may be helpful. Prescription of a prophylactic antibiotic is advised to avoid secondary infections that could arise as a result of tissue necrosis or hematoma in the affected tissues (Farook et al., 2014). Steroid usage may be suggested to regulate the acute inflammation process (Chaugule et al., 2015).

Advise the patient to apply cold compression on the first day to reduce swelling and warm compression the following day to increase circulation (Hulsmann et al., 2007). Hospitalisation is advised in the event of an obstruction of the upper airway. It will be required to intubate the patient and give them steroids and antihistamines intravenously (Farook et al., 2014).

A summary of the management of NaOCl accidents by Hulsmann et al. (2007) and (Phillip et al., 2022): Patient education regarding the cause, nature, and severity of the problem

i. Promptly flush the canal with saline solution to effectively dilute and rinse away any residual hypochlorite in the canal.
ii. Pain management through the use of analgesics and local anaesthesia.
iii. In extreme situations, consider referring to the hospital.
iv. Applying cold compresses externally to reduce oedema.
v. After a day, switch to warm compresses and regularly gargle with warm water to enhance localised systemic circulation.
vi. Provide daily instructions for managing the recovery process.
vii. Antibiotics may be considered, mainly when there is a high risk of infection or signs of secondary infection
viii. The use of antihistamines and corticosteroids is discretionary.
ix. Typically, it is possible to continue endodontic treatment using sterile saline or chlorhexidine as irrigants.

Preventive measures

The existence of any risk factor that could predispose to the formation of a NaOCl accident, such as perforations, resorption, immature apices, or any other circumstances, must be adequately investigated by the clinician (Ehrich et al., 1993). Previous studies have suggested various precautions to reduce the potential side effects of using NaOCl. The recommended preventive measures are replacing NaOCl with another irrigant, using a lower NaOCl concentration, and avoiding wedging the needle into the root canal. Aside from that, the irrigation needle should be 1-3 mm shorter than the working length, a side-vented needle should be used for root canal irrigation, and excessive pressure should be avoided during irrigation (Kleier et al., 2008; Phillip et al., 2022; Spencer et al., 2007).

According to Boutsioukis et al. (2013), a literature search on factors affecting NaOCl extrusion during RCT regarding the pressure during irrigation causing extrusion is very subjective. It is interesting to explore the fluid dynamics of NaOCl irrigants to know the relation between the flow rates and pressure driven by the fluids. A study by Park et al. (2013) presented a simulated root canal model to measure the magnitude of apically-directed fluid pressure associated with using different needle delivery systems. This study reported that the apical fluid pressure increased with fluid flow rates.

A new hypothesis by Zhu et al. (2013) concluded that the use of a 30G close-ended side-vented needle with a positive pressure irrigant delivery approach, inserted 1 mm short of the working length, resulted in producing positive fluid pressures at the tooth apex that escalated non-linearly with increasing irrigant flow rate. When the irrigant flow rate remains below 3.4 ml/min, the fluid pressure generated remains below the average blood pressure value within the intraosseous space, around 30 mmHg. In other words, even when there is a patent apical foramen and variations in the facial venous vasculature anatomy, using a non-binding side-vented needle with an irrigant flow rate below 3.4 ml/min is unlikely to lead to a classic NaOCl accident. Conversely, using the same needle at flow rates exceeding 3.4 ml/min can create a more significant pressure gradient than the intraosseous space, which could lead to the extruded NaOCl entering a facial vein.

Summary of preventive measures (Phillip et al., 2022):

i. Employing a rubber dam consistently.
ii. Accurately measuring files to the appropriate working length.
iii. Placing stoppers for irrigation syringes slightly short of the working length (1-2mm).
iv. Utilizing needles with safe ends (side-vented needles).
v. Employing the index finger, not the thumb, to depress the syringe plunger.
vi. Ensuring the syringe is not lodged in the canal by employing an in-and-out motion during irrigant dispensing.
vii. Facilitating the passive movement of the syringe to enable the irrigant to flow around the needle, back into the access cavity, and subsequent aspiration.
viii. Instruct the patient to inform the operator or nurse if they experience an unpleasant taste during treatment.
ix. Opt for a lower concentration of sodium hypochlorite (between 0.5% and 5.25%) to mitigate potential adverse reactions.

Recommendations

As a recommendation for the prevention of NaOCl accidents, the use of a negative pressure irrigation system such as the EndoVac system or modified apical negative pressure (mANP) was proven to minimise the risk of extrusion of root canal irrigant (Farhana et al., 2023; Jamleh et al., 2016; Rahman et al., 2023). Standardising the data information in future case reports is also recommended for further analysis of sodium hypochlorite accidents. Guivarch et al. (2017) proposed a template that can fulfil this goal and clarify the way for greater comprehension of the factors, management, and prognosis of hypochlorite accidents.

CONCLUSION

Even though the extrusion of NaOCl during root canal treatment is rare, its consequences can be severe. Therefore, assessing teeth before initiating root canal treatment is essential to identify potential risks that could lead to extrusion accidents, enabling the implementation of appropriate preventive measures. Understanding the mechanics of a typical NaOCl accident will empower clinicians to make informed decisions regarding irrigation delivery techniques during root canal disinfection. Additionally, this knowledge can guide manufacturers in developing and improving their irrigation systems to ensure the utmost safety and efficiency in root canal irrigation procedures.

CONFLICT OF INTEREST

The authors affirm that they have no conflicts of interest, whether financial or of any other nature.

ABBREVIATIONS

NaOCl – Sodium hypochlorite
RCT – root canal treatment
HOCl – hypochlorous acid
OCl – hypochlorite ion

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