Accidents with sodium hypochlorite in Endodontics: A literature review of clinical cases

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ABSTRACT

O Combating microbial infection and coping with the complexity of the root canal system (RCS) are the major challenges faced by Endodontics. Improvements in instrumentation and irrigation techniques, including the search for the ideal irrigating solutions, allow clinicians to provide effective and painless treatment. This literature review proves sodium hypochlorite as being accepted as an intracanal dressing by a considerable number of clinicians due to its antimicrobial properties, its ability of dissolving organic tissue properties and its low-costs.

On the other hand, it also showed several cases in which the use of sodium hypochlorite is unwanted. We found simple cases of clothes bleaching; however, a case of a patient's death was also found. Unsatisfactory cases induced by the deleterious action of sodium hypochlorite, which is not limited within the RCS, force us to take appropriate measures with a view to minimizing them. Knowing how to address unsatisfactory cases is a sine qua non condition for the development of endodontic therapy.

Keywords: Sodium hypochlorite. Endodontics. Accidents.

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Introduction

Endodontic therapy achieves high success rates provided that treatment protocol is well-grounded on the effective mechanical action of instruments as well as on the sanitizing ability of the solution used to irrigate root canal systems (RCS). It is widely known that not all RCS surfaces are fully touched or reachable by endodontic instrumentation.[1,2,3] Nevertheless, as a result of the chemical and physical action of irrigating solutions, these surfaces have better chances of being disinfected and having by-products resulting from endodontic instrumentation removed. Regardless of the instrumentation technique of choice, the irrigating solution and the best protocol of action should be carefully determined according to the specificities of each case. Mechanical instrumentation alone is not capable of cleaning and disinfecting the RCS effectively. Therefore, with a view to combating microbial infection present inside the RCS as effectively as possible, it is paramount that the choice for the irrigating solution be valued.

According to Estrela et al,[4] the irrigating solution to be used in infected root canals is chosen on the basis of previous knowledge about the microorganisms responsible for infection as well as the properties of the solution itself. Treatment of teeth with asymptomatic apical periodontitis has to overcome numerous hurdles among which are RCS internal anatomical shape, microbial virulence and the host's immune system. Thus, it is paramount that the irrigating solution presents significant antimicrobial activity and exceptional tissue dissolution ability.

According to Torabinejad and Walton,[5] the ideal irrigating solution should have the ability to dissolve organic and inorganic tissues, as well as present antimicrobial action, zero toxicity, low surface tension, and lubricating action. Nevertheless, up to date, no irrigating solution fulfills all the aforementioned requirements.

According to Fregnani and Hizatugo,[6] sodium hypochlorite (NaClO) is the irrigating solution most widely used, particularly because it meets most requirements expected from an irrigant and has the ability to dissolve necrotic tissues and smear layer organic components. Moreover, it presents antimicrobial action while eliminating biofilm and contributing to deactivate endotoxins, all of which is associated with low costs.

A few reports assert that NaClO solutions were first created in 1789 by Berthollet, in Javelle, France. Also known as Javelle water, it consisted of a weak, aqueous solution of NaClO. In 1820, the French chemist Labarraque produced a 2.5% solution used for asepsis of toilets in hospitals and prisons. In 1915, Dakin proposed a concentration of 0.5% active chlorine per 100 ml, neutralizing the pH with boric acid and minimizing the irritant effect used to clean wounds. In 1917, Barret advocated Dakin's solution to be used as a root canal irrigating solution. Since then, it has been extensively researched.

Accidents caused by the use of NaClO lead to unpleasant situations for both patients and clinicians, which might imply inefficiency. The present study focused on raising this issue with a view to warning clinicians about the caustic properties of NaClO solutions and stressing the importance of the care that should be taken to avoid potential complications.

Sodium hypochlorite

Hypochlorite is presented as strong bases and halogen solutions. It is formed by chemical elements that belong to the halogen group in the periodic table (chlorine).

Paiva and Antoniazzi[7] reported that the type of NaClO solution most frequently used can be obtained by means of chemical reactions, such as chemical reaction between sodium hydroxide and chlorine which will result in sodium hypochlorite, water and sodium chloride (manufacturing method); and the chemical reaction between sodium carbonate and calcium hypochlorite which will result in sodium carbonate, calcium carbonate and sodium chloride (laboratory method).

The NaClO solution is found at various concentrations and in the form of several products and additives, namely:

» Dakin's solution: A 0.5% solution (equivalent to 5,000 ppm) neutralized by boric acid to reduce pH (near neutral).

» Dausfrene's solution: A 0.5% solution neutralized by sodium bicarbonate.

» Milton's solution: A 1% solution (10,000 ppm) stabilized by sodium chloride.

» Labarraque's solution: A 2.5% solution (25,000 ppm).

» Chlorinated soda: A solution at concentrations that vary between 4 and 6% (40,000 and 60,000 ppm).

» Bleach: A solution at concentrations that vary between 2 and 2.5% (20,000 and 25,000 ppm).

Lopes and Siqueira Jr.[8] present the NaClO solution with the following properties: antimicrobial activity, ability to dissolve organic matter, deodorant, bleaching, lubricating and of low surface tension. Its solvent activity causes pulp tissue fragments to liquefy, thereby favoring their removal from inside the RCS. All the aforementioned characteristics are influenced by the relationship established between solution volume and organic tissue mass, the contact surface between tissue and solution, the solution time of action, temperature, mechanical agitation, concentration and frequency with which it is changed during irrigation procedures. Thus, the more these factors are present, the greater is the solution ability to dissolve organic tissue, whether living or necrosed. Active chlorine, present in the composition of components such as hypochlorous acid and hypochlorite ion, is responsible for the excellent antimicrobial activity of chlorine solution, even though sodium hydroxide produced as a result of reacting NaClO and water also presents as an effective disinfectant. Infection caused by anaerobic bacteria is usually associated with a foul odor caused by the production of short-chain fatty acids, sulfur compounds, ammonia and polyamines (deodorant action). The same study revealed that low surface tension determines the solution moisturizing and penetration activity, which boosts its effectiveness in cleaning the root canal wall.

Careful consideration should be given to the efficacy of NaClO solution:[9] solutions with pH near neutral produce greater antibacterial effect; however, have their tissue dissolution ability reduced, which might increase cytotoxicity. The lower the pH, the greater is the time required for the solution to dissolve tissues. Solutions with lower pH are unstable and have a shorter life span. NaClO tissue dissolution ability and antimicrobial action are enhanced if the solution is heated. The higher the concentration, the greater the solution tissue dissolution ability and its cytotoxicity. The greater the volume and the frequency of change during irrigation, the more effective the NaClO action. Due to being an unstable solution, special attention should be given to storage conditions and expiration date.

Root canal system irrigation

The mechanical action of endodontic instrumentation should meet the criteria of root canal system cleaning, augmentation and shaping. The cleaning process will only be complete with the irrigant physical (irrigation/aspiration) and chemical action. One of the consequences of introducing the irrigant solution is that the debris produced during endodontic preparation will be eliminated from the root canal system by the physical action of the turbulent-flow effect produced when introducing and aspirating the solution. The aforementioned chemical properties of NaClO solution will also be enhanced if more effective irrigation techniques are employed.

Positive pressure irrigation, which commonly involves the use of syringes and needles, is opposed to negative pressure irrigation, in which the solution flows down the canal when the needle (cannula) is used to aspirate the irrigant. In other words, in positive pressure irrigation, the irrigant is introduced by means of a needle apically positioned in the root canal, while aspiration is carried out by a device cervically placed. Therefore, the irrigant flows from an apical to cervical direction. On the other hand, in negative pressure irrigation, the irrigant is placed in the crown of a tooth while aspiration occurs in the apical direction by means of appropriate cannulae. Therefore, the irrigant flows from a coronal to apical direction.

According to Zuolo and Kherlakian,[10] the properties of an irrigating solution and intracanal irrigation outcomes might be improved by means of incorporating Passive Ultrasonic Irrigation (PUI) to the irrigation protocol. The authors also devote attention to the anatomic complexity of the root canal system which appears in the form of isthmus areas, furcations in the main canal, apical deltas and irregular root canal walls; and might hide tissues, debris, bacteria and filling material residues. The same authors demonstrate that ultrasonic vibration associated with irrigation (auditory flow and cavitation) causes the liquid to continuously move, and is associated with effective cleaning of areas which endodontic instrumentation cannot reach.

It is known that, regardless of the irrigation system, the apical foramen diameter and the distance between the apical foramen and the irrigation/aspiration device, the irrigation solution might overflow

beyond the interior of the root canal system, despite claiming that a given system is safe. Thus, since no irrigation solution is considered as ideal, no irrigation system is said to be completely effective or safe, as the human factor conducting it is always present.

Chemical reactions between NaClO and other irrigants

When combining different irrigant solutions, one should take inter-relation factors into account. Hargreaves and Cohen[11] reported changes in color and precipitation when combining NaOCl and chlorhexidine solutions. The reddish, brown precipitation is also known as parachloraniline (PCA). It is considered toxic and may lead to cyanosis (methemoglobin formation). PCA tends to obstruct the dentin tubules, which might affect root filling sealing. As for reactions between NaClO and EDTA solutions, the authors highlight evidence of the decreased tissue dissolution ability of NaClO. Rossi-Fedele et al[12] reinforce these same conclusions when highlighting the loss of free chlorine available in NaClO solutions when in contact with chelating substances (EDTA and citric acid), thereby decreasing the antimicrobial capacity of NaClO. Basrani et al[13] emphasize the potential toxic and carcinogenic effect of PCA when NaClO reacts with chlorhexidine.

Unwanted situations arising from the use of NaClO

Knowing the unwanted effects of chemical agents is paramount when dealing with them. NaClO has disadvantages such as being an unstable, corrosive, skin and mucosa irritant, odorous and tissue-bleaching solution. Its bleaching action might cause some inconvenience, such as staining patient's clothing.

Researches evince that all disinfectants are toxic to the living cells, as they do not differ the structures it acts upon. Any chemical substance destroying tissues as a result of reaction established with products that are essential to cell survival, transforming proteins and lipids into water (liquefaction) or liquids into solids in a process that promotes cell dehydration (coagulation), is considered a caustic substance.[14] Establishing a balance between the antimicrobial/tissue-dissolving ability of an irrigant and its biocompatibility is hopeless.

Due to being skin and mucosa irritant (even though there have been only a few reports on allergic reactions), NaClO might cause hypersensitivity or dermatitis when in contact with unprotected skin. The studies by Kaufman and Keila[15] as well as Çaliskan et al[16] report the aforementioned possibility.

Another major concern is when NaClO solution spills over patients' eyes. Should that be the case, NaClO might seriously injure the patient's cornea. According to Noia et al[17] and Castellano et al,[18] whenever NaClO contacts one's eyes it causes a chemical burn that requires immediate action, as it might advance at a rapid pace through the ocular tissue, causing further injury that might lead to blindness. For further reading, check the Eye Emergency Manual of the School of Medicine (USP) Clinical Hospital easily available on the internet. It is known that the greater the concentration of NaClO solution, the greater its cytotoxicity and tissue-irritant power. Solutions at high concentrations uncontrollably destroy one's tissues, causing significant postoperative problems.[19]

When in contact with the oral mucosa, due to its caustic action, it provides patients with discomfort (bad taste), a burning sensation and/or wounds (whenever the reaction is prolonged). Should it be swallowed, NaClO might cause a feeling of suffocation, in addition to seriously affecting the tissues and causing necrosis, swelling, hemorrhagic congestion, erosion and/or ulceration. The signs and symptoms of ingestion vary according to NaClO volume and concentration, and might include pain, vomit, sialorrhea, dysphagia and nausea.[14,20]

In 1987, Barbas et al[21] reported a case in which a 52-year-old patient was undergoing endodontic treatment on the right side of the maxilla when she had a cerebrovascular accident and died as a result of NaClO action. Autopsy revealed neither vascular malformation nor the presence of a vascular illness, which supported the hypothesis of NaOCl overflow having caused painful stimuli of the trigeminal nerve, which led to sudden increase in blood pressure, cerebrovascular accident and the patient's death after five days.

The ability to dissolve organic tissue is an important characteristic of NaClO solution. This characteristic, however, is not limited to the dental pulp.

It also occurs in the adjacent dentin as it degrades the collagen present in this type of tissue. With the loss of organic fraction, the tooth loses elasticity and is more likely to fracture.[22] The literature[23] reports experiments on the damaging action of NaClO solution over dogs' bones. It demonstrates holes of demineralization when the animals' femur was exposed to the solution for more than 30 seconds, damaging the cancellous bone. Other studies[24] prove the cytotoxic effects of NaClO over the culture of human osteoblasts at various concentrations.

In Endodontics, the worst damage seems to be that of NaClO overflow beyond the root canal system during irrigation. Previous researches[25,26,27] demonstrate that, regardless of the irrigation technique of choice, the solution will overflow, even though negative pressure irrigation seems to be safer than positive pressure irrigation.

A literature review of clinical cases

There are numerous reports on accidents occurring as a result of using NaClO solution during endodontic therapy. They were due to NaClO overflow through the apical foramen, root perforations, tooth fracture, clinician's lack of attention, exchange of cartridges containing anesthetics for those containing NaClO (both substances are stored in similar containers), among other cases.

Should NaClO contact periapical or periodontal tissues, the oral mucosa, maxillary sinus, skin and ocular tissues, it causes significant complications of which intensity varies according to the concentration, volume and time of response (the ability to diagnose it and react). NaClO is a caustic substance with a pH value that varies between 11 and 12.9. It might cause significant damage to tissues, trigger protein oxidation, as well as damage endothelial and fibroblasts cells. Tissue alterations occur due to the solution rapid penetration into tissues, which hampers the potential for organic defense (the neutrophils do not migrate to the damaged area). Following cell destruction, thrombosis of blood vessels and increased inflammatory reaction might occur, which characterizes tissue necrosis and liquefaction. The signs and symptoms of NaClO overflow are: strong taste of chlorine, burning sensation, severe pain, tissue necrosis, paresthesia, hematoma, ulcer and hemorrhage. Swelling is frequent and allergic reactions, despite being rare, might also occur.

In 1974, Becker et al[29] reported the case of a 23-year-old patient subjected to endodontic therapy in her right upper canine. During the final irrigation procedure (5.25% NaClO solution), the irrigation needle (25G) got stuck inside the root canal, causing the solution to overflow to periapical tissues through the apical foramen. The patient felt immediate severe pain and her right face and lip swelled immediately after 30 seconds. There was immediate hemorrhage through the dental canal, which lasted around six minutes. The patient complained about intense pain which spread to her ear. Swelling evolved to the region of her right eye. Cold compress was applied so as to relieve pain and burning sensation. The patient was advised to take painkillers, antihistamine and antibiotics (tetracycline) drugs. One week later, even though it had reduced a little, swelling and ecchymosis of her right eye remained. Endodontic therapy was finished one month later.

Sabala et al[30] described the injection of NaClO in the periapical tissues of a 58-year-old patient who sought treatment at the Endodontic Clinics of the University of Oklahoma with chief complaint of pain in the left upper second premolar. Five days before, the patient had been subjected to emergency treatment when a #20 file was separated inside the palatal canal of his left upper second premolar. During the new procedure and after irrigation with 5.25% NaClO solution, the patient felt severe pain and quick formation of facial swelling. The procedure was interrupted, and anaesthetic drugs and cold compressions were reapplied in the affected area. Pain was relieved within the next five minutes; however, swelling was spread to the cheeks and infraorbital regions. In spite of that, endodontic therapy was finished within the same session. Due to patient's complaint of pain, a trephination was carried out with a view to placing a drainage tube in the apical area of the palatal root. The patient was advised to undergo physiotherapy with cold compression and to take antihistamine and painkillers. On the following day, the patient presented with significantly increased swelling that now involved the area of the left lower eyelid, submandibular and submental face, and significant ecchymosis.

The authors described the patient's look as dramatic. Secretion was coming out the drainage tube and pain was uncontrolled. At this point, antibiotic drugs were prescribed. Two days later, pain was relieved, but drainage persisted and, despite being severe, swelling had decreased. The drainage tube was removed on the fourth day. Fourteen days later the case presented improvements, and apical surgery was performed to address the separated file that remained inside the root canal.

Reeh et al[31] mention paresthesia caused by NaClO overflow during endodontic intervention of a right central upper incisor. Overflow occurred as a result of unnoticed perforation in the apical third of the root of a 44-year-old patient at the University of Minnesota. During the procedure of removing cement and irrigating the root canal with 1.0% NaClO, the patient complained about severe pain spread to both nasal and premolar area. Pain suddenly vanished and the clinician went on with treatment without exactly knowing what had happened. Subsequently, there was immediate outflow of hemorrhagic discharge from the canal. The clinician immediately interrupted the procedure, dispensed analgesics and left the tooth opened for drainage. On the following day, the patient was referred to emergency treatment, complaining about swelling on the right side of the face in the area below her right eye. Moreover, there was formation of an infraorbital erythema. The patient reported impaired sensitivity at palpation on the region of the nose, including her upper lip. Antibiotics was then prescribed. Four days later, the patient presented with secretion smelling of NaClO coming from ulceration located above her left upper central incisor. She also complained about impaired sensitivity on the right side of her lip and nose. Endodontic therapy was finished 21 days later. After four months, the patient reported a feeling of formication in the region of the right upper lip and a feeling of needling in the region of the nose; however, the patient did not report noticing secretion coming out her nose. After 14 months, the patient's conditions had not returned to normality.

In 1990, Ingram[32] published an article reporting the case of a 15-year-old patient subjected to endodontic therapy of the right lower first molar. During irrigation with 5.25% NaClO applied by means of a Luer-Lok 10-ml syringe and a 25-G needle, the tip of the needle got stuck inside the root canal and suddenly detached from the syringe, causing the irrigation solution to flush and reach the patient's right eye. The patient felt immediate pain and intense burning sensation. The irritation caused by the irrigating solution was evident in the area of the erythema formed in the conjunctiva. The patient was taken to a sink at the clinic room and his eyes were thoroughly washed (tap water). Ten minutes later, the patient showed slight improvements, but with some irritation in his right eye and on the right side of his nose. He was referred to the Department of Ophthalmology which found minor injuries in the patient's eye structures, however, with no further damage. His tooth was provisionally sealed and his eyes were cleaned one more time with saline solution (15 minutes). Antibiotics and specific eye medication were prescribed. Two days later, the patient presented signs of recovery, with no damage to eye function.

Becking,[33] in 1991, also reported three clinical cases of patients referred to the Department of Oral and Maxillofacial Surgery at the Free University of Amsterdam. The first: A 42-year-old patient presented with acute pain and progressive swelling on her left mandible and neck. NaClO overflow occurred as a result of a perforation in the cementoenamel junction of her left lower second molar (the use of absolute isolation was unknown). As a consequence, there was tissue necrosis and mental nerve paresthesia. Intravenous antibiotics and painkiller were dispensed. Pain and swelling were relieved after five days while paresthesia ceased after ten days. However, tissue necrosis was cured after two months, only. The second case: A 31-year-old patient subjected to endodontic therapy in her left upper second molar reported pain on the back and below her left eye after irrigation with NaClO. Pain was spread through her left face, eye and temples. The patient reported feeling a chlorine smell and irritation in her throat. One hour later, swelling was evident in her left face and it was assumed that NaClO had overflown to the maxillary sinus through the apical foramen. The patient was hospitalized (two days) and kept under observation. Two weeks later, she was fully recovered. The third case: A 29-year-old patient was subjected to endodontic therapy of

his left lower second premolar when NaClO solution overflew and caused severe swelling, intense pain and mental nerve paresthesia. Two days later, the patient did not present any signs of inflammation or necrosis. He was treated at a clinic and antibiotic drugs were not necessary. Four days later, secondary infection and tissue necrosis were diagnosed. At this point, antibiotic drugs were prescribed. The case gradually improved, including paresthesia recovery.

In 1991, Gatot et al[34] reported the case of a 32-year-old patient who was in her second endodontic therapy session, treating her right upper central incisor. During final instrumentation procedures, she reported pain in the apical surface of the tooth. Nevertheless, the clinician ignored such an information and went on performing irrigation with NaClO. Severe swelling immediately formed in her upper lip and right cheek, and the patient reported severe pain. A few minutes later, swelling was spread through her right eye. Hydrocortisone and antibiotics were dispensed and the patient hospitalized. Thirty-six hours later, swelling had spread throughout the patient's right face. There was ecchymosis in her right eye and upper lip. The patient reported pain and blurred vision on the right side. Surgical procedures were then carried out. Three days later, the patient presented a wound with minor secretion on her right cheek, which would heal after two weeks, despite leaving a scar. The patient went on reporting paresthesia of the right infraorbital nerve.

Accidental injection of NaClO in the maxillary sinus is also the focus of an article published in 1993 by Ehrich et al.[35] The authors report the case of a 22-year-old male patient referred to endodontic treatment of his right upper first molar one month after the first intervention. Radiographic examination revealed overlapping of molar roots with the maxillary sinus. During the irrigation procedure with 5.25% NaClO in the palatal canal, the patient reported having swallowed the irrigating solution. His oropharynx was rinsed with water and aspirated. A new irrigation procedure with NaClO was performed and, once again, the patient reported feeling a taste of irrigating solution. Meanwhile, a clear liquid was coming out of the patient's right nostril. The patient reported nasal congestion and a burning sensation in the maxillary sinus. He did not present intra/extraoral swelling or intracanal hemorrhage. The palatal canal was irrigated with 30 ml of saline solution with a view to reaching the maxillary sinus. The following medication was prescribed: antibiotics, anti-inflammatory and decongestant. One day later, the patient did not report any discomfort, but reported slight pain and congestion of the right maxillary sinus. A small amount of a brownish-like secretion was observed while the patient blew his nose. Four days later, the provisional restoration was removed, and a serous fluid flowed through the palatal canal. The tooth was instrumented and filled with calcium hydroxide. Endodontic therapy was finished 27 days later.

In 2000, Mehra et al[36] reported hematoma formation in a 51-year-old female patient referred to the Emergency Department of the Boston Medical Center. During the first interview, the patient reported having been subjected to endodontic therapy in her left upper canine two weeks before. She was undergoing Crohn's disease and migraine treatment. Moreover, she was extremely anxious and with significant swelling of soft tissues on the left side of the face as well as in the periorbital and infraorbital regions. Swelling spread up to the angle of the mandible associated with severe ecchymosis around patient's eyes (bilaterally). Swelling was firm, hard, warm and sensitive at palpation. There were no signs of trismus, impaired breathing or swallowing. Intraoral examination revealed ecchymosis around patient's lips. Final diagnosis was of NaClO solution overflow beyond the tooth apex. Antibiotics and painkillers were prescribed in association with ophthalmological follow-up. Despite high levels of drug prescription, pain increased. Because swelling got worse, the patient developed trismus and impaired swallowing. There were no signs of impaired ventilation. The patient was referred to surgical procedures (canine extraction). Two days later, she was discharged from hospital.

According to Serper et al,[37] in 2004, a 54-year-old patient was subjected to endodontic therapy at the Endodontic Clinic of the School of Dentistry at Hacettepe University with chief complaint of pain in her left upper second premolar during emergency pulpectomy. The patient was then referred to therapy complementation. During the last appointment, particularly when irrigation with NaClO was being

carried out, the patient reported a burning sensation in the region below absolute isolation. This fact was ignored by the clinician. NaClO solution overflew on the patient's skin for over two hours and caused an eruption around the chin, a region located below absolute isolation with rubber dam. The situation got worse and the patient's skin seemed to have suffered a chemical burn with the formation of a scab. She was treated with the application of ointment. The clinical presentation gradually improved.

In 2006, Gursoy et al[38] reported the case of 21-year-old, non-smoker patient whose medical history was unalarming. The patient was referred to the Department of Periodontology at Cumhuriyet University with chief complaint of pain in the region of necrosis of the palatal mucosa . He reported having undergone emergency treatment at a private clinic due to pain in the right upper premolar two weeks before. The clinician diagnosed pulpitis and performed pulpectomy in both right upper premolars under local anesthesia. During the procedure, the patient reported feeling pain; for this reason, the clinician decided on a new local anesthesia procedure. Nevertheless, he exchanged the cartridges containing anesthetics for those containing 2.5 % NaClO. The irrigant was then injected in the palatal mucosa, triggering severe and sudden pain that lasted for two days. At the Department of Periodontology, the patient was examined and revealed no painful symptoms. However, there was formation of a wound with necrotic tissue in the region. The wound had neoformed, yellow-whitish connective tissue in its center surrounded by purplish tissue and mild swelling. Tissue debridement and gingival graft were carried out, and the wound healed after 15 days.

In 2008, Pelka et al[39] reported the case of a 54-year-old patient examined for potential implant placement. The patient reported being hypothyroid and allergic to penicillin. During clinical examination, the dentist noted that patient's left upper lateral incisor prosthetic crown was lose. This tooth had a core post and had been subjected to periapical surgery. Radiographic examination did not reveal the presence of endodontic material in the apical third of the root canal, but revealed increased foraminal diameter. While the root canal was being cleaned with 3% NaClO before replacement of the lose core post and crown, the patient felt sudden pain followed by swelling in the infraorbital region on the left side. The clinician administered local anesthesia and went on with irrigation with 0.2% chlorhexidine solution. Cold compression was locally applied in association with antibiotics and painkiller. Over the hours, the patient felt increased pain and swelling and, for this reason, sought medical treatment for further medication. Facial swelling was firm and spread over the lower mandible and the region of the left eye. She had impaired sensitivity on the left of her upper lip and in the left infraorbital region (the infraorbital nerve had been affected). Sensitivity of the buccal branch of the facial nerve was also impaired. Mouth opening and patient's left facial muscle function and esthetics were impaired . Pain and swelling lasted one week with significant discomfort. After 30 days, mouth opening had significantly improved. During an appointment with a neurologist, facial paralysis severity was diagnosed. It caused facial asymmetry and impaired motor skills, as well as chronic hyposensitivity. The patient took legal action against all people involved in the procedures. Five years passed the accident, the patient remained with impaired esthetics and facial motor skills, reduced sensitivity in the infraorbital region, uncontrolled saliva flow due to lack of control of lip muscles, and difficulty drinking.

In 2009, Doherty et al[40] reported the case of a 80-year-old patient referred to Cerdiff University Dental Hospital with facial swelling and severe pain associated with endodontic therapy that had been initiated in his left lower central incisor. The tooth presented with an iatrogenic root perforation through which NaClO solution likely overflew. The patient reported intense pain in the anterior lower region, extraoral chin swelling and intraoral labial sulcus swelling extending from the right lower premolar to the left lower premolar. On the following day, the patient reported paresthesia in the lower lip and chin. One week later, swelling remained visible with the formation of a 5-mm ulcer in the lip mucosa. Healing took three weeks.

In 2009, Baldwin et al[41] reported the case of a 57-year-old patient subjected to endodontic therapy of her left upper canine at Liverpool University Dental Hospital. During the irrigation procedure, with

1.0% NaClO solution applied with a Luer-Lok syringe, needle 27G, the patient reported intense pain in the region of her left eye and cheek. Swelling immediately formed on her left face. Treatment was interrupted and copious irrigation with saline solution was carried out. Antibiotics were prescribed, but the patient was advised to take them only if the symptoms got worse. On the following day, she returned to the hospital with severe swelling. Antibiotics had not been taken. In addition to swelling, there were hematomas around patient's left eye. Clinical examination revealed diffuse generalized swelling on the left side of the face, spreading through the lower edge of the mandible, periorbital tissues and left temple. Sensitivity was impaired in the region of the infraorbital nerve, also on the left side of the face. For this reason, the patient was hospitalized. Total healing occurred 14 weeks later.

In 2009, Motta et al[42] reported accidental NaClO injection in a 56-year-old patient during the procedure of local anesthesia. In this case, the cartridge containing anesthetics was exchanged for that containing NaClO. The patient felt excruciating pain and, for this reason, the procedure was interrupted. Meanwhile, there was immediate swelling formation and the patient had her vision blurred. Anti-inflammatory drugs were prescribed. Two days later, swelling worsened and a necrotic area was formed at the site of injection. The patient reported paresthesia, right lower lip ptosis, intense pain on the right side of the face as well as in her right eye and temples, and chronic visual impairment. Amoxicillin and dexamethasone were administered. The patient presented remission within 60 days; however, lip paresthesia remained after three years.

Sermeño et al,[43] in 2009, treated a 65-year-old patient with medical history of cirrhosis, diabetes mellitus and hypertension. The patient was subjected to examination due to presenting the following signs and symptoms after endodontic therapy of her right upper canine carried out 21 days before: mild pain, ecchymosis and severe swelling on the right side. The patient had already taken antibiotics before endodontic therapy. NaClO (5%) was used as irrigating solution. She reported intense pain during irrigation and noticed the formation of swelling below her right eye. She also had difficulty opening her right eye and had the swelling spread to submandibular and sublingual regions on the right side. The right infraorbital region and the right corner of the upper lip presented with altered sensitivity. Paresthesia of dental nerves was not found, swelling encompassed the compromised tooth and the patient had difficulty in opening her mouth. Radiographic examination revealed increased periodontal ligament space in the apical region probably due to emphysema caused by irrigating solution overflow. One week later, the formation of abscess with fistula and painful symptoms were evident. Endodontic therapy could only be concluded after 15 days.

Braitt et al,[44] in 2010, reported treating a 28-year-old patient who had suffered trauma in the anterior region. Nevertheless, a fracture in the middle third of her left upper central incisor went unnoticed by the dentist. During endodontic irrigation, 1% NaClO was injected out of the root canal and through the fracture. One hour later, the patient sought the authors for treatment of complications arising from NaClO overflow. The patient presented swelling in the gingival tissue and upper lip, in addition to acute pain and irritation. On an emergency basis, medicamentous therapy based on corticosteroid, anti-inflammatory and antibiotics was adopted. Patient's clinical presentation reversed after seven days.

Lam et al,[45] in 2010, reported treating a 37-year-old patient who presented with intense pain and swelling on the right side of her face two hours after being subjected to endodontic therapy in the right upper canine. Within 20 minutes, swelling had spread throughout her right face with formation of ecchymosis. The patient presented normal vital signs with no respiratory impairment. Hydrocortisone and paracetamol were administered, and cold compression was applied in the region of swelling. Because swelling got worse, antibiotics were prescribed. Her case improved within five weeks, with residual edema and mild paresthesia in the right infraorbital region; however, with no facial nerve impairment.

Lee et al,[46] in 2011, reported the case of a 25-year-old patient referred to Mary Immaculate Hospital Dental Clinic (Queens, New York). The patient presented with a certain degree of mental retardation, bipolar disorder, urinary incontinence and impaired verbal communication. For this reason,

treatment was performed under general anesthesia. Radiographic examination revealed the need for endodontic therapy of her left upper central incisor. NaClO and saline solution were used for irrigation. While the patient recovered from anesthesia, there was unexpected formation of unilateral swelling and ecchymosis in the region of her left eye. Due to exacerbation of periorbital swelling, the patient was subjected to medicamentous therapy. Ophthalmological examination was required; however, patient's conditions did not allow proper observation given that she was under a state of irritation due to pain and discomfort caused by swelling. Although the patient had no fever, swelling got worse at night, thereby causing nasolabial obliteration that affected the lower mandibular region. Patient's appearance was described as frightening. She was subjected to surgical intervention for drainage and debridement of necrosed tissue. Apicoectomy evinced endodontic overfilling. One week later, the patient was discharged from hospital.

In 2011, Waknis et al[47] reported complications arising during an anaesthetic procedure carried out in a 33-year-old patient. In that event, the cartridges containing anesthetics were exchanged for those containing 3% NaClO. The irrigant (1.2 ml) was injected in the buccolabial region adjacent to her left lower canine. While being referred to emergency treatment, the patient presented with a wound and ecchymosis in the region where the injection was taken. Inferior alveolar nerve block was performed for pain relief. Corticosteroid was injected around the wound and copious irrigation with saline solution was carried out. The patient was subjected to medicamentous therapy based on antibiotics and nonsteroidal anti-inflammatory drugs for 5 days. A gauze with Povidine was placed over the wound and daily changed for seven days. After four weeks, the patient presented residual wound and mild mental nerve paresthesia. Five years later, even though it had decreased, paresthesia remained, and an extraoral scar tattooed the patient's face.

Bither and Bither,[48] in 2013, reported the complaints of a 65-year-old patient with history of intense pain and swelling in the region of his right upper premolar remaining for four days. Clinical examination revealed intraoral erythema and swelling spreading from the canine eminence to the right upper first molar. There was an open wound with necrotic white pale tissue on the buccal surface of the right upper second premolar through which a purulent discharge drained. Extraoral swelling spread from the right infraorbital edge to the commissure, evolving sideways up to the right malar region. Radiographic examination revealed buccal perforation in the middle third of the right upper second premolar root. The patient had been subjected to endodontic treatment ten days before. During the procedure, there was NaClO overflow affecting the periapical region and the oral mucosa. Patient's medical history revealed regular use of medication for diabetes and hypertension. Furthermore, according to the patient, the clinician had prescribed antibiotics, painkillers and corticosteroid, in addition to drainage through incision. Two days after being referred to treatment, the patient did not present improvements. For this reason, the authors opted for extracting the compromised tooth and surgically treating the wound with gingival tissue grafting.

Discussion

Due to its antimicrobial properties as well as its abilities of tissue dissolution and penetration into isthmus and irregularities, NaClO solution is more effective when used for irrigation during which factors such as solution concentration, volume and renewal are considered. Should techniques promoting ultrasonic agitation be used, the results improve considerably.

As reported by Bramante et al,[49] in 2004, NaClO solutions between 0.5 and 5.25% act by dissolving collagen by means of chlorination of amino acids and saponification of lipids, in addition to promoting necrolytic, antitoxic, bactericidal, deodorant and neutralizing action. Nevertheless, the authors highlight that NaClO solutions produce toxic effects on vital tissues, thereby leading to hemolysis, ulcerations, skin and mucosa necrosis, damage to endothelial cells and fibroblasts, and inhibition of neutrophils migration.

The reports selected for the present study reveal that inadvertent contact with NaClO solution beyond the inner boundaries of the root canal system might cause allergic reactions,[15,16] discomfort as a result of unpleasant taste, burning sensation and/

or damage to the mucosa, asphyxia sensation, tissue necrosis, swelling, hemorrhagic congestion, erosion, ulceration, vomit, sialorrhea, dysphagia and nausea in the event of swallowing the solution.[14,20] The studies also evinced that care should be taken with regard to the patient's eyes and the risk of burns caused by caustic products. Furthermore, the use of protection goggles and proper clothing is also highlighted.

NaClO solution overflow occurs through the apical foramen,[29,30,33-36,41,43,45,46] by means of perforations,[31,33,40,48] root fracture,[44] incorrect use of irrigation syringes and needles affecting the region of patient's eyes,[32] incomplete isolation of compromised tooth allowing solution overflow through the rubber dam,[37] during cementation of the prosthetic post in the attempt to promote root canal cleaning,[39] as a result of careless exchange of cartridges containing anesthetics for those containing irrigating solution.[38,42,47] It also occurs in teeth subjected to apical surgery[39] and under instrumentation.[34,46]

Intense pain occurred in all cases. The roots of certain groups of teeth maintain a close relationship with the maxillary sinus, which was decisive to worsen solution overflow in more than one case.[33,35] Paresthesia, whether more or less intense, was also reported[31,33,34,39,40,41,42,45,47] and, in some cases, did not return to normality. Swelling and ecchymosis are also commonly reported,[29,30,31,33,34,36,39,40-48] in addition to episodes of secondary infection.[31,33,34,41,43,46,48] Two cases pointed out the occurrence of intracanal hemorrhage,[29,31] while others reported the formation of wound with necrotic tissue,[38,40,42,47] extraoral chemical burn,[37] and open wound with secretion and tissue necrosis.[31,34,48]

In addition to reports of motor paralysis and facial asymmetry resulting from NaClO overflow,[39] two articles also reported patient's death.[21]

It is worth citing Hülsmann and Hahn[50] and their research published in 2000. The authors studied the complications arising during root canal irrigation and mention the possibility of the aerosol created by ultrasonic tips damaging the patient's or clinician's clothing, as NaClO is a bleaching substance. Furthermore, with regards to symptoms and potential consequences resulting from accidental injection of NaClO in one's periapical tissues, the authors found out the following: severe and immediate pain, swelling surrounding the affected area, swelling spreading to lips and infraorbital region, copious hemorrhage throughout the root canal, interstitial hemorrhage between the skin and mucosa (ecchymosis), taste of chlorine and throat irritation. After injection of NaClO solution in the maxillary sinus, the authors mention the possibility of finding secondary infection. Potential loss of sensitivity in the affected region or paresthesia are also pointed out as probable sequelae. The authors suggest the following protocol: collect information on the cause and severity of complications; control pain; immediately apply cold compress and one day later apply hot compress; prescribe antibiotics, antihistamine and/or corticosteroids; daily control the evolution of the case; and, in more severe cases, refer the patient to hospital care. It is advisable to exchange NaClO by saline solution or chlorhexidine so as to supplement endodontic therapy.

According to Zuolo and Kherlakian et al,[51] in 2012, a dental prognosis is based on the ability to predict the success or failure of a given intervention or treatment over time. The authors also teach us that, despite variations in individual and regional values, professional training, biological and therapeutic factors and methods, the following criteria might be applied to determine treatment success or failure: clinical, radiographic, histological and tomographic. In addition, it is also important to assess the degree of patient's suffering during and after treatment, since, despite advances, Endodontics coexists with fear, anxiety and potential psychological trauma.

Conclusion

Scientific knowledge and professional training associated with attention to treatment protocol appear to be the key to solving all cases or at least showing the best way to do so. A thorough analysis of information gathered during the first interview in addition to the results of clinical, radiographic and tomographic examinations allow an accurate diagnosis to be made and, as a result, the most appropriate therapeutic protocol to be recommended. Patients often seek treatment in cases of emergency and have usually been treated by other clinicians before. Therefore, care should be taken with regard to the anatomic details of the tooth and surrounding regions, in addition to potential iatrogenesis.

We understand that NaClO solution is widely used in Endodontics due to presenting the following main properties: tissue dissolution, antimicrobial action and low cost. Moreover, the higher the concentration, volume and renewal, the more effective it will be; however, higher concentrations render the solution more cytotoxic. Furthermore, the properties of an irrigating solution might be improved by means of ultrasonic irrigation whenever used in association with other irrigants.

As for the disadvantages of NaClO solution, we have found that it is unstable and corrosive, causes irritation to one's skin and mucosa, bleaches one's clothing, it is toxic and caustic, its tissue dissolution ability does not differ tissues, and, in Endodontics, overflow might be harmful or deadly.

Signs and symptoms commonly reported include excruciating pain, intra and/or extraoral swelling, ecchymosis, tissue necrosis, secondary infection, intracanal hemorrhage and paresthesia. When in contact with one's skin, mucosa and ocular tissues, it causes irritation, allergic reactions and caustic burn.

According to the present study, overflow occurs through the rubber dam and/or apical foramen; due to careless pressure applied over the syringe piston or as a result of irrigation needle placement and inappropriate needle connection; through iatrogenic perforations (mistaken surgery or instrumentation); root fracture; and as a result of disregarding foraminal diameter (teeth subjected to apical surgery, cases of endodontic reintervention and overinstrumentation). Accidents also occur due exchanging the cartridges containing anesthetics for those containing NaClO and inappropriate connection between the needle and the irrigation syringe.

In terms of potential measures to be taken, there is a need to remain calm and win patient's confidence; apply cold compress; apply copious irrigation with saline solution preferably cold and sterilized; and prescribe painkillers, antibiotics, corticosteroid and antihistamine drugs. Moreover, the patient should be notified of potential accidents and the evolution of the case, with appropriate follow-up and, whenever necessary, hospital care.

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