Introduction

The use of chemical substances in order to reduce or eliminate bacteria has always been present in Endodontics. The chemical means (auxiliary chemicals substances) along with the mechanical (action of instruments) and physical means (irrigation and aspiration) form a single and simultaneous process, which is the chemomechanical preparation of root canal.[15]

It is highly desirable that chemical substances selected as endodontic irrigants have antimicrobial and organic tissues dissolution properties besides helping in the debridement of the root canal system and not being toxic to the tissues.[4] Thus sodium hypochlorite (NaOCl) has been chosen as an endodontic irrigating solution for use by the majority of professionals. This is due to the mechanism of action of this solution, which is capable to promote cellular biosynthetic changes, cellular metabolism alterations, destruction of phospholipids as well as for its excellent properties: It has the ability of dissolving organic tissues, antimicrobial action, alkaline pH, promote whitening, is deodorizing and has low superficial tension.[8]

Walker[35] was the first researcher to think of NaOCl as irrigant and according to Spångberg, Engstrom and Langeland,[30] the use of NaOCl at high concentrations has been recommended to degrade protein products present in the root canal. However these high concentrations can cause damage to the periapical tissue.

According to Estrela et al,[10] several irrigating solutions have been proposed to help in the root canal preparation. Nevertheless, according to these authors, an effective solution is crucial to the sanitization process, because it favors the cleaning, preparation and neutralization of septic necrotic content of root canals allowing for its subsequent filling. In reviewing the microbial efficacy of NaOCl it seems to be similar to calcium hydroxide, because of the high pH of NaOCl, which interferes in the integrity of the bacteria cytoplasmic membrane, the cellular metabolism and the degradation of phospholipids present in the root canal. The dissolution of organic tissue can be seen in the saponification reaction that occurs due to the action of NaOCl on lipids and fatty acids.

The NaOCl became the most popular agent for endodontic irrigation, although its ideal concentration is not an universal consensus.[4]

Therefore, this literature review was conduct in order to verify which NaOCl concentration is the most efficient in controlling microorganisms during endodontic treatment.

Literature review

The root canal cleaning not only depends on the mechanical action of instruments, but also on the action of irrigating solutions that lubricates this canal during the cutting action of endodontic instruments, help in removing smear layer and have germicidal potential and solvent action on exudate and pre-dentin.[30] The components of these formulations may cause more or less disinfection of the root canal system, so there is the need to compare the different NaOCl concentrations assessed in studies reported on the literature, distinguishing the results obtained by means of different methodologies and concentrations.

Thus, in this literature review, seven points were highlighted and this division aimed at facilitating the understanding about this subject. The following databases were used for the electronic searches: MedLine, PubMed, BBO, Lilacs, SciELO, Piracicaba Dental School (FOP-UNICAMP) library archives and Ingá Dental School (UNINGÁ) library archives.

1. Ability to dissolve organic tissue

The ability of NaOCl to dissolve organic tissues is directly proportional to its concentration.[2,5,19,31] According to Baumgartner and Cuenin,[1] efficacy of the solvent and disinfectant action of NaOCl solutions at low concentrations can be increased by using higher volume of solution and frequent exchanges.

Fachin, Hahn and Palmini[11] conducted a study on the use of NaOCl solutions in endodontics, analyzing aspects such as: optimal concentration, solvent action, tissue reaction, bactericidal effect and capability of removing organic debris. They observed that at higher concentrations the dissolution of organic tissue is increased.

Spanó et al[31] studied *in vitro* the solvent effect, the level of residual chlorine, pH and surface tension before and after dissolution of tissues, of four concentrations of NaOCl (0.5%, 1.0%, 2.5%, and 5,0%) on bovine pulp tissue. The higher concentrations of NaOCl were more rapid on dissolution of the pulp tissue, and showed lower decrease in chlorine concentration.

Okino et al[21] evaluated the solvent activity of various irrigants on bovine pulp tissue. The tested solutions were 0.5%, 1.0% and 2.5% NaOCl; 2% chlorhexidine gluconate solution and 2% chlorhexidine gel. Chlorhexidine preparations were not able to dissolve the pulp tissue. All NaOCl solutions were effective in dissolving pulp tissue and the dissolution rate varied with the solution concentration.

Following the studies of Cunningham and Balakejian,[5] Sirtes et al[29] evaluated some effects of pre-heating NaOCl solutions. The ability of 1% NaOCl in dissolving human pulp tissue was assessed, *in vitro*, at 45°C and 60°C, and these values compared to 5.25% NaOCl at 20°C. At the concentration of 1% and at 45°C, this substance dissolved pulp tissue with the same efficiency than the 5.25% at 20°C. At 60°C the 1% NaOCl was more effective than the 5.25% at 20°C. Results showed that the solvent capacity is directly proportional to temperature, in other words, the higher the temperature of NaOCl solution the greater is its solvent ability.

2. Effective antimicrobial action

Siqueira et al[28] studied the antibacterial effect of endodontic irrigants in anaerobic Gram negative bacteria and facultative bacteria. The solutions used were: 0.5%, 2.5%, and 4.0% NaOCl; 0.2% and 2.0% chlorhexidine; 10.0% citric acid and 17.0% EDTA. All solutions inhibited the tested bacteria. The 4.0% NaOCl proved to be the most effective antibacterial agent. Both 0.2% and 2,0% chlorhexidine solutions inhibited all bacteria, but were less effective than 2.5% and 4.0% NaOCl.

D'Arcangelo, Varvara and De Fazio[6] analyzed the antimicrobial action of 0.5%, 1%, 3% and 5% NaOCl; 0.2%, 0.3%, 0.4%, 0.5% and 1% liquid chlorhexidine; and 0.2%, 0.3%, 0.4%, 0.5% and 1% Cetrimide on facultative anaerobic microorganisms, microaerophilic and strict anaerobes. Results demonstrated that all substances showed bactericidal effect on all studied microorganisms at all concentrations and after a short contact period.

Vianna[34] evaluated the antimicrobial activity of gel and liquid chlorhexidine in 0.2%, 1%, and 2% concentrations against various strains and compared it with the action of NaOCl in 0.5%, 1%, 2.5%, 4% and 5.25% concentrations. The results led the authors to conclude that the antimicrobial action is related to the concentration, presentation and type of microorganism.

Dametto et al[7] evaluated *in vitro* the antimicrobial activity of 2% chlorhexidine gel against the *Enterococcus faecalis* compared with 2% chlorhexidine liquid and 5.25% NaOCl. The authors observed that the 2% chlorhexidine gel, chlorhexidine liquid and 5.25% NaOCl showed significant antimicrobial reduction immediately after preparation. However, NaOCl was not able to maintain this reduction after 7 days. The results show again[22] the residual effect provided by the chlorhexidine.

Raphael et al[26] performed an *in vitro* study of the antibacterial efficiency of 5.25% NaOCl, used at different temperatures. Extracted human teeth were used, which were sterilized, instrumented and inoculated with *Enterococcus faecalis*, *Pseudomonas aeruginosa* or *Staphylococcus aureus*. The root canals were irrigated with NaOCl at temperatures from 21°C to 31°C and the 0.9% saline solution was used as control. The results showed that there is no direct relation between the NaOCl temperature and its antimicrobial action, since the increase in temperature did not provide difference in the number of negative cultures.

3. Alkaline pH

Pécora[24] proposes a NaOCl solution with 0.5% to 0.6% of active chlorine per 100 ml, with boric acid to reduce the pH, decreasing pH solution near to neutral. The addition of boric acid decrease the pH and provides less free NaOCl, reducing the irritant effect of NaOCl. The author stresses the fact that the proposed solution is unstable, should not be stored for too long, must be packed in amber glass and kept in a cool place with no incident light. The NaOCl with higher pH is more stable and presents slower chlorine release. When the pH is reduced, the solution becomes very unstable and the chlorine release is faster, resulting in a lower life cycle. It is known that concentrated NaOCl solutions are more unstable and if exposed to light, heat and environment, they may present decreased concentration of available chlorine, losing the capacity to dissolve organic tissue.[3,9]

The alkaline content of NaOCl is proportional to its concentration, in other words, the higher the concentration, the higher the pH, since it has greater amount of NaOH molecules. According to Thé, Maltha and Plasschaert,[32] the high pH of these solutions is not a disadvantage, since their action is limited to the surface of the tissue; it may even represent a positive action because, by being alkaline, this pH neutralizes the medium acidity, making it inappropriate for bacterial growth.

4. Deodorant action

The NaOCl solution also acts as a deodorant substance by acting on decomposing matter. According to Gomes, Drucker and Liley,[13] infections caused by anaerobic bacteria often produce strong odor due to the production of short-chain fatty acids, sulfur compounds, ammonia and polaminas. Chlorine through its lethal activity on microorganisms and oxidative action on dead tissues and bacterial products, eliminates the fetid odor produced by necrosis.[18]

According to Estrela et al,[8] NaOCl neutralizes the amino acids forming water and salt. With the output of hydroxyl ions, a reduction in the pH occurs. The hypochlorous acid, a substance present in the NaOCl solution, when in contact with organic tissue, acts as a solvent releasing chlorine — which, combined with the amino group of proteins, forms chloramines. Hypochlorous acid (HOCl) and hypochlorite ions (OCl-) lead to degradation of amino acids and hydrolysis, so the dissolution of organic necrotic tissue can be verified in the saponification reaction when NaOCl degrades fatty acids and lipids, resulting in soap and glycerol and promoting a deodorant effect.

5. Low surface tension

Another factor to be mentioned on the NaOCl solutions is its surface tension, which is similar to the water and somehow prevents a intimate contact of this liquid with the dentin. The reduction in the surface tension of these substances was investigated by Pécora, Guimarães and Savioli.[23]

Lopes, Siqueira Jr. and Elias[14] defined the surface tension as a intrinsic characteristic of each liquid, varying with temperature and the type of surface contacted. It was suggested that in the less concentrated NaOCl solutions, there is a greater interaction of hypochlorous acid (HOCl) with organic matter (reaction 4) and in more concentrated solutions there is a greater interaction of sodium hydroxide (NaOH) with organic matter (reaction 2), leading to greater surface tension reduction in NaOCl solutions with higher concentration.

According to Spanó et al[31], the higher the initial concentration of NaOCl solution, the greater is the reduction in surface tension on the final solution. This can be explained by the fact that the solutions with higher active chlorine concentration and therefore higher sodium hydroxide concentration, provides greater formation of fatty acids salts (soaps). The soaps formed reduced the surface tension of the resulting solutions.

6. Cytotoxicity (toxic to periapical tissues)

Nóleto et al[20] evaluated *in vivo* the irritating potential of different NaOCl concentrations used in root canals irrigation. Were tested the 1.0%, 2.5% and 4.8% concentrations. The authors concluded that the evaluated NaOCl solutions promoted irritation with variable intensity depending directly on the concentration used.

Mehdipour et al[16] and Silva et al[27] reported that the severity of NaOCl cytotoxicity depends on the solution concentration, pH and duration of tissue exposure to the agent. They also say that the highest concentration shows more irritating effects on periodontal ligament.

Farren, Sadoff and Penna[12] advocated, in a case report, that NaOCl can be an extremely cytotoxic material. The leakage of this material during endodontic treatment may cause sequelae such as pain, swelling, bruising and numbness, compatible with a chemical burn.

7. Effectiveness time

Milano et al[17] observed *in vitro* that the pulp dissolution time with different NaOCl concentrations (0.5%, 1%, 2.5% and 5.25%) ranged from 20 minutes to 2 hours.

Radcliffe et al[25] compared the effectiveness time of 0.5%, 1%, 2.5% and 5.25% NaOCl on *Actinomyces naeslundii*, *Candida albicans* and *Enterococcus faecalis*. All concentrations proved effective against *Candida albicans* and *Actinomyces naeslundii* in less than 10 s. But against *Enterococcus faecalis* — which is a species more resistant to NaOCl — there was a variation in cells inactivation time: the 0.5% concentration took 30 minutes; at 1%, took 10 minutes; at 2.5%, 5 minutes; and at 5.25%, 2 minutes to reduce the number of viable cells to zero.

Valença et al[33] evaluated in rats the dissolution time of 60 pieces of conjunctive tissue (dorsum) and skeletal muscle (tongue) by using 1% and 2.5% NaOCl of different brands and observed that the time required for complete dissolution of the fragments ranged between 74 and 335 minutes.

Discussion

Due to its positive and negative aspects described in this paper, the NaOCl solution, in different concentrations, has been used and researched until nowadays.

As presented by Cunningham, Balakejian;[5] Spanó et al;[31] Beltz, Torabinejad, Pouresmail;[2] Naenni, Thoma and Zehnder,[19] the NaOCl ability to dissolve organic tissue is directly related to its concentration. This statement confirms Baumgartner and Cuenin[1] study, which observed that the higher the concentration, the more rapid the tissue dissolution.

Fachin, Hahn and Palmini[11] affirmed that the 0.5% NaOCl concentration is more biocompatible but less stable, allowing us to understand that if open and exposed to intense bright or not stored under refrigeration (6 °C), it becomes inappropriate for use. Radcliffe et al,[25] who also reviewed 0.5% NaOCl, showed that the time required to extinguish all *Enterococcus faecalis* at this concentration is 30 minutes.

According to Borin, Melo and Oliveira,[3] the 1% NaOCl concentration is the most used and studied and it has great action on organic tissues by dissolving 0.43 mg per minute. Examining 1% NaOCl, Radcliffe et al[25] reported that the time needed to inhibit all *Enterococcus faecalis* strains is 10 minutes. Fachin, Hahn and Palmini[11] reported that the 1% NaOCl has stabilizers (sodium chloride) which makes its use more viable at long term because this stabilizers gives greater shelf life, provided it is refrigerated and stored in amber bottle.

The 2.5% NaOCl proved to be a better solution than the others,[17] because it has greater effectiveness than 0.5% and 1% concentrations and has lower cytotoxicity than the 5.25% concentration. The 2.5% NaOCl is capable to inhibit 100% of the *Enterococcus faecalis* in 5 minutes, eliminating the pain of a patient with endodontic urgency, with faster inhibition of bacteria and the shorter time for root canal sanitization.[25]

Regarding the organic tissue dissolution and bacterial inhibition, a 5.25% NaOCl solution is more effective in a shorter time, because its high concentration of hypochlorous acid in contact with organic tissues leads to amino acids degradation and hydrolysis, promoting the death of the root canal bacteria within 2 minutes.[8] Nevertheless — in cases of extravasation — the 5.25% NaOCl can, due to its high cytotoxicity,[11,12] cause sequelae such as pain, swelling, bruising and numbness, which makes its handling a little bit tricky.

Conclusions

1) Based on this literature review it is clear that all NaOCl concentrations mentioned in this paper have limitations, as well as clinical indications. Therefore research on new substances in order to find an ideal irrigant for endodontic treatment should be performed.

2) According to this study, it was observed that 5.25% NaOCl has better effectiveness in dissolving organic tissue, greater antibacterial action, more alkaline pH, and shorter effectiveness time. In contrast is more irritating to the periapical tissues, making its use undesirable.

3) Both 2.5% NaOCl and 5.25% NaOCl have similar properties, but the first on is less cytotoxic, being more indicated for root canals endodontic treatment.

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Dental fracture stabilization for insertion of fiber-reinforced post and tooth-fragment reattachment: 6-month follow-up

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ABSTRACT

Dental fractures in endodontically treated teeth with a great loss of dental structure may be restored using bonding techniques associated with glass fiber post retention of the fragment. The present study reports a weakened and fractured crown restored by dental reattachment after crown stabilization with polyvinilsiloxane matrix, and a glass fiber post cementation for dental fragment retention. The employed techniques enabled the correct dental positioning during reattachment, with a possible increase of resistance. After 6 months follow-up the periodontal tissues showed itself in health condition and functional evaluations maintained the success of the proposed treatment.

Keywords Fracture. Reattachment. Adhesion. Glass fiber post.

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