International Journal of Applied Dental Sciences 2017; 3(2): 193-196

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2017; 3(2): 193-196

www.oraljournal.com
Received: 02-02-2017
Accepted: 03-03-2017

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Pulp tissue dissolution in endodontics- A review

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Abstract
Meticulous shaping and cleaning of the root canals is of utmost importance to the success of endodontic therapy. A combination of mechanical instrumentation with appropriate chemicals is conventionally used for thorough cleaning and disinfection of the complex root canal system. Ideally, an irrigant should be antimicrobial, biocompatible, dissolve pulp tissue, mechanically flush debris and help to remove smear layer. The capacity to dissolve pulp tissue, both vital and necrotic, is of paramount importance, as the solution can help clean areas of the root canal that are inaccessible to mechanical instrumentation. This paper reviews various irrigants with respect to their pulp dissolution capacity.

Keywords: Pulp tissue, dissolution, irrigant

Introduction
The main objectives of endodontic treatment are thorough shaping and cleaning of the pulp spaces followed by complete obturation with an inert material. The root canal system is complex, and canals may branch and divide. Variations in anatomy such as fins, isthmi and C-shaped canals may be present [1]. Studies have shown that approximately 35-40% of the canal walls remain uninstrumented because of these complexities [2]. Geometrically symmetrical instruments used for shaping root canals will not be able to reach these anatomically complex, inaccessible areas [3]. Therefore, there is a need to supplement mechanical preparation with chemicals which can dissolve the tissue remnants and disinfect the canal system. The mechanical action of instruments and chemical effect of irrigants occur simultaneously, referred to as chemomechanical preparation. Ideally, an endodontic irrigant must be antimicrobial, dissolve pulp tissue remnants and remove the smear layer. It should be non-irritating to the periapical tissues, non-antigenic, non-toxic, and non-carcinogenic [4]. Pulp tissue remnants may provide a source of nutrition for surviving bacteria, may cause severe pain, and may interfere with proper obturation, thereby leading to endodontic treatment failure [5]. Therefore, tissue dissolution is one of the most important properties that are required of an endodontic irrigant.

Methods used to assess tissue dissolution *in vitro*
Different methods have been used to measure the dissolution process *in vitro*- analysis of the hydroxyproline content in the residual tissue (a measure of dissolution of collagen in the tissue), analysis of hydroxyproline in the irrigant, measurement of available chlorine in the solution after dissolution process, assay of radioactive iodine in the irrigant, scanning electron microscopy, measurement of weight loss of tissue over a specified time, and assessment of the time needed for complete dissolution of the specimen [6-8]. Of these, measurement of weight change and time to complete dissolution are the most widely accepted and used methods. However, it is difficult to ascertain the end-point of complete dissolution as a large number of bubbles are formed due to saponification reaction as in the case of irrigant like sodium hypochlorite [6, 7]. Measuring the weight change in a particular time interval is more relevant to the clinical scenario as compared to evaluating the time taken for complete dissolution.

Commonly used and potential irrigants investigated for organic tissue dissolution capacity
Sodium hypochlorite
Sodium hypochlorite (NaOCl) is an excellent antimicrobial and tissue dissolving agent. It is the most widely used endodontic irrigant, at concentrations ranging from 0.5-6%.

This chemical has been extensively investigated with respect to its mechanism of action and factors which affect its properties [1]. However it is extremely toxic. Contact of NaOCl with organic matter like dentin and pulp results in the formation of organochlorine compounds which may be carcinogenic [9].

Mechanism of action of NaOCl

Estrela *et al.* [10] described the mechanism of action of NaOCl with respect to its tissue dissolving and antimicrobial properties. NaOCl in aqueous medium exhibits a dynamic balance as shown by the reaction:

$NaOCl + H_2O \leftrightarrow NaOH + HOCl \leftrightarrow Na^+ + OH^- + H^+ + OCl^-$

Three types of reactions take place due to the interaction of NaOCl with organic matter. These reactions take place mostly at the surface, and occur simultaneously and synergistically.

Saponification reaction- NaOCl functions as an organic and fat solvent, degrading fatty acids and converting them into fatty acid salts (soap) and glycerol (alcohol), and reduces surface tension of the remaining solution [10].

Amino acid neutralization reaction- NaOCl reacts with amino acids to form salt and water, with a reduction of pH and exit of hydroxyl ions [10].

Chloramination reaction- Hypochlorous acid (HOCl) present in NaOCl solution is an organic tissue solvent. It releases chlorine, which form chloramines on reaction with amino group of proteins. Hypochlorous acid and hypochlorite ions (OCl-) cause amino acid degradation and hydrolysis [10].

Factors affecting tissue dissolution

Organic tissue dissolution is significantly influenced by tissue type, concentration and pH of the solution, time of exposure and rate of replenishment, temperature, amount of organic matter relative to the volume of solution, frequency and intensity of agitation, available surface area of tissue, canal preparation size, and mechanical action [11, 12].

i. Type of tissue

A vast variety of tissues have been used in studies assessing tissue dissolution - porcine muscle, porcine palatal mucosa, porcine pulp, bovine muscle, bovine pulp, human pulp, rabbit liver, and rat connective tissue [7]. Human pulp tissue has been used only in a few studies. Tissues other than pulp have been used due to their easy availability and the relative ease to standardize the various parameters that affect dissolution such as surface area, volume and weight of tissue [13]. However, a study revealed that NaOCl solution took approximately three times longer to dissolve porcine palatal mucosa completely when compared to human pulp [14].

ii. Concentration and pH of the solution

Higher concentrations of NaOCl produce greater dissolution of organic tissue [11]. Higher bactericidal activity is demonstrated by solutions with lower pH. However tissue dissolving activity is enhanced with increase in pH and concentration [12]. This can be explained by the fact that higher the concentration and pH, greater is the number of NaOH molecules, which play a considerable role in tissue dissolution. After dissolution, pH decreases, and the dynamic equilibrium is shifted towards increased formation of HOCl and decreased dissolution velocity [15].

iii. Time of exposure and rate of replenishment of solution

Initial reaction between NaOCl and organic matter occurs relatively fast, followed by a slower phase of dissolution. The reaction occurs mainly on surface of the tissue, and molecules of NaOCl are consumed in the reaction, leading to their local depletion. Most of the activity of NaOCl is lost after two minutes of contact with organic tissue. Frequent replenishment of the solution is therefore essential to ensure availability of active molecules for further reaction and to remove remnants of dissolved tissue [7, 11].

iv. Temperature

Dissolution capacity of NaOCl increases with increase in temperature [16, 17].

v. Amount of organic matter in relation to volume of solution

For optimum activity of an irrigant, volume of the solution should be in excess compared to the amount of tissue to be dissolved. Excess organic matter depletes available chlorine in NaOCl and causes pH to drop, thereby decreasing its activity [7, 11]. Therefore, continual replenishment with fresh irrigant is essential during instrumentation.

vi. Frequency and intensity of agitation

Mechanical agitation is an important factor in promoting tissue dissolution, as it influences the fluid flow [1].

vii. Surface area in contact with the solution

Dissolution mainly occurs on the surface of tissue in contact with the solution. In the clinical situation, the irrigant comes in contact with only a small portion of the pulp tissue, unlike in studies conducted *in vitro*, where the tissue is usually immersed in the solution. Several studies have used bovine and porcine muscle, or porcine palatal mucosa, in order to obtain samples of uniform surface areas. Human pulp tissues present a major challenge to obtaining uniform samples.

viii. Surface tension

In less concentrated NaOCl solutions, there is greater interaction of HOCl with organic matter. In more concentrated solutions, there is greater interaction of NaOH, leading to greater reduction of surface tension. Higher the initial concentration of NaOCl, greater is the surface tension reduction. This is due to the fact that solutions with higher active chlorine concentration, and therefore higher NaOH concentration, provide greater formation of soaps, which reduce the surface tension. Greater dissolution capacity of NaOCl has been noted in the presence of surfactants. This may be due to the better contact of the solution with the tissue [18, 19].

ix. Stability of NaOCl

Solutions of NaOCl are unstable. The amount of available chlorine deteriorates with time, exposure to heat and light, and on contact with air, metals, metallic ions and organic matter. To ensure good shelf life, the solution should be stored in light-proof opaque glass or polythene airtight containers, in a cool place [4].

x. Effect of dentin

Dentin is found to have a detrimental effect on tissue dissolution potential of NaOCl [20, 21].

xi. Effect of other irrigants

Presence of EDTA and hydrogen peroxide adversely affected dissolution by NaOCl [21, 22].

xii. Ultrasonic activation

Passive ultrasonic irrigation promotes tissue dissolving effects of NaOCl [23].

xiii. Effect of lasers

The effect of Er:YAG laser irradiation has been investigated and it was concluded that laser activation of NaOCl at 200 mW output led to effective dissolution [24].

xiv. PIPS

Photon-initiated photoacoustic streaming technique of irrigant activation was found to increase the dissolution potential of NaOCl [25].

xv. Ozone

HealOzone was found to increase speed of dissolution by NaOCl [26].

Calcium hydroxide

Calcium hydroxide has minimal pulp dissolution potential. Calcium hydroxide paste causes better dissolution of necrotic remnants, but not the solution [13, 27].

Hydrogen peroxide

Combination of hydrogen peroxide with NaOCl was found to delay dissolution by NaOCl [22].

Chlorhexidine

Chlorhexidine, though an excellent antibacterial, is ineffective as a solvent of pulp tissue [14, 28, 29]. However 2% chlorhexidine gel associated with 8% papain gel was found to dissolve pulp tissue [30].

Ethylene diamine tetraacetic acid (EDTA)

EDTA exhibits minimal dissolution of organic tissue [31, 32]. Furthermore it adversely affects the dissolution potential of NaOCl [33].

MTAD

MTAD is not an effective solvent of organic tissue [29].

Chlorine dioxide

Different concentrations of chlorine dioxide have shown ability to dissolve pulp tissue, but to a lesser extent than NaOCl [34-36].

Peracetic acid

Pulp dissolution has been reported with 5% peracetic acid, though significantly less than NaOCl [37].

Papain gel

8% papain gel was found to dissolve pulp tissue, both alone and in combination with chlorhexidine gel [30].

Calcium hypochlorite

5% and 10% solutions of calcium hypochlorite were assessed and found to be good solvents of pulp tissue [36, 38].

Maleic acid

7% maleic acid was found to have minimal dissolution potential when compared to NaOCl [32].

Apart from these, several other chemicals have been tested for their tissue dissolving abilities. Citric acid [14], dichloroisocyanurate [14], super-oxidized water [26], octenidine [39], garlic extract [40] etc. have been investigated but found to be ineffective.

Conclusion

Over the years, several chemicals and combinations have been investigated for potential use as endodontic irrigant. Sodium hypochlorite, though toxic, is the most commonly used irrigant as it is an excellent antimicrobial agent and solvent of organic tissue. Despite extensive research, an ideal irrigant with all the required properties is yet to be identified. Some chemicals have shown optimistic results as far as pulp dissolution is concerned. Further research should be directed towards understanding their mechanism of action on pulp tissue and thereby the various methods which would enhance pulp dissolution.

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