

# Sodium hypochlorite as an endodontic irrigant and its effect on dentine: a review of literature

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## SUMMARY

Successful endodontic treatment is achieved by a combination of factors which include acceptable instrumentation, optimal irrigation and disinfection of the root canal system. It is vital that a suitable antimicrobial agent be used during irrigation and sodium hypochlorite emerges as the optimal agent to be used as it complies with most of the criteria of an ideal irrigant. Sodium hypochlorite is a popular choice as an endodontic irrigant due to its solvent activity as well as its antimicrobial action. The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants, refreshment and/or activation cycles of solution, as well as the surface area of exposed tissue.

During irrigation, radicular and coronal dentine and enamel are exposed to solutions used during irrigation. Irrigation with sodium hypochlorite during debridement may result in changes to the mineral content of dentine, as it has an effect on the chemical composition, physical and mechanical properties of dentine structure. Irrigants can thus alter surface characteristics of dentine. These changes may influence the integrity and longevity of the tooth. The impact of sodium hypochlorite on the dentine matrix is of particular importance when investigating changes in the dentine matrix. Due to the alterations in dentine structure and mechanical properties of dentine, the effect of sodium hypochlorite can affect the interactions of these surfaces with obturation materials and as well as coronal restorations. Irrigation solutions provide lubrication of root canal walls and thus ease of canal preparation. The effect of sodium hypochlorite to alter dentine surface and chemical structure allows for a change in microhardness, which facilitates ease of root canal preparations.

## AIM OF REVIEW

To offer an overview of existing literature on sodium hypochlorite as an endodontic irrigant.

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The author declares there is no conflict of interest.

## SODIUM HYPOCHLORITE AS AN ENDO-DONTIC IRRIGANT

### Aim of canal irrigation

The mainstay of successful endodontic treatment involves the optimal cleaning and shaping of root canals to enable adequate irrigation and disinfection of the root canal system.<sup>1,2,3</sup> Due to the complex anatomy of root canal systems, host defences and different levels of virulence in microorganisms, irrigating solutions must have crucial tissue dissolving ability as well as antimicrobial action. Although root canals are shaped mechanically either by hand or rotary instrumentation, the eradication of microorganisms is completed by adequate irrigation.<sup>4,5,6</sup> The combination of mechanical debridement and the use of an adequate canal irrigant results in an even greater decrease of the microbial population.<sup>7,8,9,10</sup> Sodium hypochlorite, as the irrigant, is responsible for the dissolution of organic pulpal tissue.<sup>11,12,13</sup> With current instrumentation techniques, 40-50% of the root canal may remain untouched and tissue may remain for microorganisms to survive and flourish, thus the aim of irrigation is to optimise root canal disinfection.<sup>14,15</sup> Irrigation is currently the best method for the removal of necrotic tissue and dentinal debris.<sup>16,17</sup> The antibacterial effect, tissue dissolution ability, cleaning and chelating are important features of irrigation during root canal preparation.<sup>17,18,19</sup>

### Ideal properties of a root canal irrigant

An antimicrobial agent should have the following properties:

- Have an expansive antimicrobial spectrum and capacity to eradicate anaerobic and facultative microorganisms<sup>6,20,21,22</sup>
- Inhibit bacterial growth<sup>21</sup>
- Ability to penetrate the infection site<sup>23</sup>
- Have a low toxicity level<sup>20,23</sup>
- Dissolve necrotic pulp tissue remnants<sup>6,20,21</sup>
- Inactivate the endotoxin<sup>22</sup>
- Should have adequate concentration to have an antimicrobial effect<sup>9</sup>
- Microorganisms should not be able to develop resistance to the antimicrobial agent<sup>20,23</sup>
- Prevent smear layer formation during instrumentation and/or possess the ability for dissolution of the smear layer once it has formed<sup>21,22</sup>

### Sodium hypochlorite as an endodontic irrigant

An important objective of antibacterial irrigation is the effective bacterial disinfection as well as the promotion of debridement of necrotic pulpal tissue and debris from the root canal.<sup>24,25</sup> While anaerobes are easily eliminated, the eradication of facultative bacteria like streptococci, enterococci and lactobacilli proves to be more difficult which requires the use of an adequate antibacterial agent; and thus sodium hypochlorite emerges as the

ideal agent to be used due to its antibacterial and solvent ability.<sup>6,20,21,22,26</sup>

The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants, and surface area of exposed tissue.<sup>14,15,16</sup>

In addition, the temperature of the sodium hypochlorite solution as well as refreshment and activation of the solution influences the tissue dissolving ability of sodium hypochlorite.<sup>27</sup>

#### The sodium hypochlorite reaction

The dynamic balance of sodium hypochlorite is demonstrated by the following reaction:



Sodium hypochlorite acts as a solvent by degrading fatty acids and converting the fatty acids into fatty acid salts (soap) and glycerol (alcohol), which causes the reduction of surface tension of the remaining solution.<sup>6,20,22</sup> Sodium hypochlorite neutralises amino acids by forming water and salt. Due to the exit of the hydroxyl ions, there is a decrease in pH. Hypochlorous acid, which is present in sodium hypochlorite solution, acts as a solvent when interacting with organic tissue. This reaction results in the release of chlorine which combines with the protein amino group to form chloramines. Hypochlorous acid and hypochlorite ions results in degradation of amino acids and hydrolysis.

Chloramines are formed due to the reaction between chlorine and the amino group, which then interfere with cell metabolism. Chlorine will lead to antibacterial action by suppressing bacterial enzymes which leads to irreversible oxidation of sulphhydryl groups of essential bacterial enzymes. Sodium hypochlorite (with a pH of more than 11) is found to have detrimental biological effects on bacterial cells. Enzymatic sites are located in the cytoplasmic membrane of bacteria and are essential for functions such as metabolism, cell division and growth. The high pH when hydroxyl ions are released changes the integrity of the cytoplasmic membrane which leads to chemical death. Thus, the key mechanism of sodium hypochlorite depends on the saponification reaction (formation of soap and alcohol), amino acid neutralisation and chloramination reactions that occur when microorganisms are present which progresses to the antimicrobial and tissue dissolution effect.<sup>6,20</sup>

#### Efficacy of sodium hypochlorite

The path of the sodium hypochlorite reaction is determined by the amount of the organic matter present and the amount and concentration of sodium hypochlorite used.<sup>16,21,28</sup> The second characteristic of the reaction is that there is an initial fast reaction, which is then followed by a slower second reaction. This means that an excess of organic matter can diminish the irrigant of most of its activity and cause a great drop in pH within minutes.<sup>21</sup> The efficacy of sodium hypochlorite means that it needs to respond rapidly and be in excess of the organic matter. Therefore, to ensure the efficacy and maintain a greater ratio of irrigant to organic matter there should be regular use of fresh irrigant and/or increasing the concentration of the sodium hypochlorite solution.<sup>21,26</sup>

#### Bactericidal action of sodium hypochlorite

The penetration of dentine by sodium hypochlorite is confirmed by the bleaching action of sodium hypochlorite on dye-impregnated dentine and the bactericidal effect of sodium hypochlorite can be observed at depths of 300µm.<sup>29</sup> At deeper layers 3% sodium hypochlorite is able to reduce the amounts of viable bacterial cells when compared to 0.5% sodium hypochlorite, thus the bactericidal effect of sodium hypochlorite reaches a greater depth in dentinal tubules at a higher concentration.<sup>29,30</sup>

#### Capacity to dissolve organic matter

Tissue dissolving ability depends on the frequency of agitation, the volume of organic matter in proportion to the amount of irrigant and surface area of remaining tissue. Greater concentrations of sodium hypochlorite provide faster dissolution of tissues. Sodium hypochlorite is a strong proteolytic agent, which demonstrates maximum tissue dissolution.<sup>20,31</sup>

#### Factors which influence the efficacy of sodium hypochlorite

The tissue dissolving ability of sodium hypochlorite depends on its concentration, volume, contact time of solution with tissue remnants and surface area of exposed tissue. Efficacy of sodium hypochlorite for dissolution of tissues can be increased by activation with sonics or ultrasonics, increasing the pH and temperature of the sodium hypochlorite solution, multiple cycles of refreshing solution and increasing the working time.<sup>15,27,32</sup>

##### *i) Altering /adjusting the pH*

When sodium hypochlorite is added to water, hypochlorous acid is formed and dissociates into a hypochlorite ion (OCl<sup>-</sup>). At a pH of 10 most of the available chlorine is in the hypochlorite ion form and at a pH of 4.5 most available chlorine is in the hypochlorous form.<sup>33</sup> Sodium hypochlorite with a pH of more than 11 is found to have damaging effects on microbial populations.<sup>6,20,26</sup>

##### *ii) Temperature of sodium hypochlorite*

An increase in the temperature of sodium hypochlorite can increase its effectiveness. A preheated solution of sodium hypochlorite has the following positive effects: short-term stability of sodium hypochlorite, improved tissue dissolving capacity and antimicrobial efficacy.<sup>20,34</sup> Preheated sodium hypochlorite solution removed organic debris from dentine shavings more successfully than an unheated solution. The tissue dissolving capability of sodium hypochlorite is increased by maintaining a temperature of 36°C.<sup>34,35</sup> The tissue dissolution ability of 1% sodium hypochlorite at 45°C is equal to that of 5.25% sodium hypochlorite at 20°C.<sup>34</sup> Sodium hypochlorite solutions need to be disposed of, following increase in temperature, and clinicians should bear in mind to limit the heating of sodium hypochlorite to 50°C.<sup>36</sup>

##### *iii) Agitation of sodium hypochlorite*

The efficacy of sodium hypochlorite has been established by its antibacterial activity when it comes into contact with bacterial biofilms, especially in the coronal and middle third of the root canal. The apical third of the root canal has always been challenging concerning sodium hypochlorite penetration and efficacy.<sup>37</sup> The agitation of irrigant solutions is used to increase the efficacy of irrigants.

These techniques can involve manual agitation with hand instrumentation, manual agitation with gutta percha points, mechanical agitation with plastic instruments and sonic and ultrasonic agitation.<sup>37,38,39</sup> The use of ultrasonic activators to agitate 5.25% sodium hypochlorite within the canal, especially the apical third, increased the efficacy of sodium hypochlorite.<sup>37</sup> The use of negative pressure devices such as EndoVac® is especially valuable during the chemical debridement of the apical third of root canals as it allows for better penetration of the sodium hypochlorite solution into the root canal system.<sup>40</sup>

#### *iv) Volume of sodium hypochlorite*

During mechanical canal preparation, the root canal space that has been prepared is where irrigating solutions are placed. The efficacy of the irrigating solution is dependent on the dimensions of the prepared canal space, as it determines the irrigant's volume.<sup>41</sup>

#### *v) Concentration and time*

Although sodium hypochlorite is widely used, no consensus has been reached with regard to the ideal concentration to be used.<sup>42</sup> The ideal concentration should have a low toxicity level and adequate antibacterial action. Canal preparation is done in a short time period; therefore the antibacterial efficacy of the irrigant will be influenced by the concentration of the solution.<sup>31,43,44,45</sup> Organic matter present in canals that come into contact with sodium hypochlorite will consume the available chlorine and the antibacterial efficacy is reduced. With the use of sodium hypochlorite at a lower concentration, this phenomenon is evident. With a higher concentration of sodium hypochlorite a reserve would be created to maintain the antibacterial activity.<sup>45</sup>

Studies on sodium hypochlorite concentration and time exposure varies from 2-30 minutes and a concentration of 0.5%-5.25%.<sup>46,47</sup> The most effective regimen is found to be a sodium hypochlorite concentration at 5.25% at 40 minutes, especially to remove *Enterococcus faecalis*. Irrigation with sodium hypochlorite at a lower concentration for an equivalent period of time period is less effective in removing *Enterococcus faecalis*. Antimicrobial agents require adequate exposure time in the root canal system to yield results.<sup>46</sup> The negative effect of using concentrated solutions is the tissue irritation and damage that may be caused when irrigant is inadvertently forced into the periapical tissues.<sup>22</sup>

### **The effect of sodium hypochlorite on root canal dentine**

Irrigation with sodium hypochlorite has an effect on mechanical effects of dentine including flexural strength, microhardness and elasticity.<sup>4</sup>

#### **Effect of sodium hypochlorite on flexural strength**

The ability of a material to resist deformation under load is defined as flexural strength. A decrease in flexural strength would indicate a decreased force is needed for the cohesive bonds within dentine to fragment.<sup>48</sup> Exposure of dentine to sodium hypochlorite results in decreased flexural strength and the modulus of elasticity of dentine. The overzealous use of sodium hypochlorite may increase the risk of fracture in endodontically treated teeth.<sup>29</sup> The dentine surface structure degrades after sodium hypochlorite exposure and this could contribute to the decrease of flexural strength.

The exposure of dentine to sodium hypochlorite (at a concentration of 3% and higher) for one hour resulted in changes in dentine flexural strength.<sup>50</sup>

#### **Effect of sodium hypochlorite on microhardness of dentine**

The mineral content as well as the hydroxyapatite concentration in the intertubular spaces determines the hardness profile of dentine. A positive relationship is present between dentine hardness and mineral content of dentine.<sup>51</sup> Evaluating the microhardness of dentine can impart information pertaining to mineral loss or gain in dentine. Microhardness values may vary with regard to location, with the value decreasing closer to the pulp. This can be due to the presence of open dentinal tubules closer to the pulp, and these tubules would have less resistance.<sup>19,51,52</sup>

Dentine microhardness (which is determined by the amount of calcified matrix per mm<sup>2</sup>) is inversely correlated to tubular density. Determination of microhardness only provides indirect evidence of mineral loss or gain in dental tissues.<sup>53</sup> No consensus/agreement is available in the current literature on the ideal amount of dentine microhardness reduction to facilitate mechanical instrumentation and, at the same time, avoid excessive mineral loss which could lead to weakening of dentine structure.<sup>54</sup> The reduction of microhardness is caused by a reduction of stiffness of the intertubular dentine matrix. This is caused by varied distribution of the mineral phase within the collagen matrix.<sup>55</sup> The dentine microhardness evaluated next to the root canal lumen is higher, where the dentinal tubuli are dense compared to the peripheral area where the tubuli are less crowded.<sup>55</sup> The degree of mineralisation and the hydroxyapatite content in the intertubular substance affects the intrinsic dentine hardness, where a decrease in dentine microhardness may be observed as well as an increase in surface roughness of the root canal dentine.<sup>57</sup> This was observed with concentrations of sodium hypochlorite of 2.5% to 5.25%.<sup>48</sup> Studies have shown that 1% of sodium hypochlorite may decrease dentine microhardness. A Vickers hardness test was used and researchers found that lower Vickers hardness values were obtained at 500µm from pulp. Dentine microhardness is location related, and the value of dentine microhardness decreased as the indentations were closer to the pulp. This can be attributed to the open dentinal tubules (free of peritubular dentine), which are closer to the pulp.<sup>19</sup> Various studies confirmed that sodium hypochlorite significantly decreased dentine microhardness. It was found that although the different areas of the root (cervical, middle and apical) are structurally different, all the root thirds displayed the same results with regard to decrease in dentine microhardness.<sup>19,56,56</sup>

#### **Concentration of sodium hypochlorite and microhardness**

The greater efficacy of sodium hypochlorite at greater concentrations has influenced clinicians to use higher concentrations of sodium hypochlorite during root canal preparation. However, this may have a deleterious effect on dentine properties.<sup>57</sup> The concentration of sodium hypochlorite has an effect on microhardness where both concentrations of 2.5% and 6% sodium hypochlorite rendered a decrease in microhardness; however, 6% sodium hypochlorite rendered a greater decrease in microhardness than 2.5% sodium hypochlorite.<sup>55</sup> Weight loss of dentine

after immersion in sodium hypochlorite was greater at a higher concentration of sodium hypochlorite.<sup>19</sup>

#### Contact time of sodium hypochlorite and dentine microhardness

The decalcifying effect of sodium hypochlorite is influenced by the irrigation period and will therefore have an effect on dentine microhardness.<sup>58,59</sup> During contact with sodium hypochlorite a reduction in dentine microhardness was found in the first 10 minutes. After 20 minutes' contact time there was no statistical significance. The initial decrease may be due to the initial removal of the organic matrix from the dentine during the first 10 minutes.<sup>60</sup>

#### Effect of sodium hypochlorite on mineral composition of dentine

Dentine comprises approximately 22% organic material which is made up mostly of type I collagen, and this constituent influences the mechanical properties of dentine.<sup>61</sup> Sodium hypochlorite is a nonspecific oxidising agent and deconstructs long peptide chains and chlorinates protein terminal groups which leads to the breakdown of N-chloramines into other species. This leads to adverse consequences for dentine structure.<sup>60</sup> Sodium hypochlorite dissolves both collagen components of dentine and magnesium and phosphate ions and increases dentinal carbonate.<sup>48,51</sup> Research studies has shown that sodium hypochlorite solutions with concentrations varying from 1% to 6% may cause a reduction in dentine microhardness. Sodium hypochlorite can also alter the calcium to phosphate ratio of root dentine which leads to the conclusion that these changes in the mineral content can affect the hardness profile of dentine.<sup>48</sup> The exposure of dentine with 6% sodium hypochlorite for a period of 5 minutes has shown a decrease in dentine microhardness. The decalcifying effect of sodium hypochlorite largely depends on application time, the pH and concentration of the solution as well as the hardness of dentine.<sup>58</sup> Sodium hypochlorite has also demonstrated maximum reduction in microhardness compared to other acids such as carbonic citric and tartaric acid. Sodium hypochlorite at 5.25% concentration caused the maximum reduction of microhardness, which could be attributed to the degradation of the organic dentin components.<sup>58</sup>

#### Effect of sodium hypochlorite on the modulus of elasticity of dentine

Sodium hypochlorite has the ability to deproteinise and disintegrate the organic dentine matrix. Disintegration of the organic dentine matrix results in a reduction in the elastic modulus and flexural strength of dentine. Sodium hypochlorite also increases the permeability of the altered intertubular dentine with a 5% sodium hypochlorite concentration altering the peripheral dentine matrix.<sup>55</sup> The modulus of elasticity of dentine after irrigation with sodium hypochlorite can be determined using ultrasonic wave propagation measurements. To determine changes to the modulus of elasticity of dentine following exposure to sodium hypochlorite, the 3-point bend test and ultrasonic investigation can be used. The results demonstrated a reduction of the modulus of elasticity by 3%. As dentine is anisotropic and varies in thickness, a reduction of 3% can have an effect on dentine. At regions of stress concentrations this reduction in elasticity can lead to the propagation of microcracks.<sup>56</sup> Fracture loads were found to be less, with significant deformation of the dentine bars

before complete fracture. Although a range of disparity in the behaviour of dentine bars was observed, there was enough significant statistical difference to indicate that both 3% and 5% sodium hypochlorite caused a decrease in the modulus of elasticity and flexural strength.<sup>45</sup>

#### Effect of sodium hypochlorite on tooth surface strain

Tooth surface strain is measured at the cervical margin of a tooth by using electrical strain gauges during cyclic loading. Sodium hypochlorite at a concentration of 5% has demonstrated an increase in strain value under cyclic loading. The actions of sodium hypochlorite may produce surface flaws in the dentine and subsequent cyclic loading during function may allow crack propagation through fatigue. Tooth tissue loss (demineralisation) causes a reduction of the force required by the tooth to strain and this may lead to crack development and fractures.<sup>57</sup> Dentine exposed to 5.25% sodium hypochlorite displayed a significant decrease in flexural strength and rigidity and a decrease in elastic modulus. This may be attributed to the decrease of the organic matrix within dentine. In addition, an increase in tooth strain may result in changes in stiffness of the tooth which may predispose the tooth to fracture. Increase in tooth strain after sodium hypochlorite irrigation was 15.9% tensile strain and 3.5% compressive strain.<sup>57</sup>

#### Dentine permeability and penetration

The effect of irrigating solutions may be affected by the permeability of dentine, which may favour or decrease their effect. The floor of the pulp chamber consists of primary and secondary dentine which allows for more uniform penetration of ions. Alternatively, reparative dentine is more amorphous in structure, less tubular and the route of fluids may be obstructed. Thus, the dentine permeability will have an effect on sodium hypochlorite penetration.<sup>59</sup>

Knowledge of the depth of sodium hypochlorite penetration into dentine and factors which may influence the depth of penetration can be beneficial when practicing one appointment endodontic treatment. The penetration of sodium hypochlorite into dentine is outlined by measurement in micrometres. The depth of sodium hypochlorite penetration into the dentinal tubules was recorded as between 77 and 300µm. Factors such as sodium hypochlorite concentration, exposure time and temperature have an effect on sodium hypochlorite efficacy and it stands to reason that these variables can impact sodium hypochlorite penetration.<sup>28</sup>

## CONCLUSION

Various studies indicate that sodium hypochlorite is the irrigant of choice of the majority of dentists due to its antibacterial effect, tissue dissolution capacity and acceptable biologic compatibility in less concentrated solutions. The concentration of the sodium hypochlorite varies due to the clinician's preference. Greater efficacy of sodium hypochlorite is observed at higher concentrations of sodium hypochlorite, and thus it is tempting in the clinical situation to use a higher concentration of sodium hypochlorite.

There is also evidence in literature that connects the concentration-dependant effect on mechanical properties of dentine when dissolution of organic dentine occurs. Thus the concentration, exposure time and temperature should



be taken into consideration during endodontic visits. This is particularly important when practicing single or multiple endodontic visits. The changes to dentine structure and mechanical properties may influence the interaction of the root canal dentine with obturation materials, coronal restorations and cements in the case of post core crowns. There is, however, no consensus with regard to optimal concentration or irrigation time of sodium hypochlorite to eliminate microbial populations in root canal systems.

More research is required in this field to investigate the ideal time, concentration and temperature of sodium hypochlorite use in endodontics.

## REFERENCES

- Torabinejad M, Walton RE. Endodontics Principles and Practice, 4th ed. St. Louis: Saunders, 2009: 264-265
- Albahiti MH. Knowledge and practices of decontamination during root canal treatment by dentists in Jeddah. Saudi Dent J. 2020; 32(4): 213-218
- Khandelwal A, Janani K, Teja K, Jose J, Battineni G, Riccitiello F, Valletta A, Palanivelu A, Spagnuolo G. Periapical Healing following Root Canal Treatment Using Different Endodontic Sealers: A Systematic Review. Biomed Res Int. 2022; (8): 1-9c
- de Souza RA, de Castro FP, Pires OJ. Research of the major methods and clinical outcomes of irrigation in endodontics: a systematic review. J Health Med Sci. 2022; 15(3): 1-5
- Raducka M, Piszko A, Piszko PJ, Jawor N, Dobrzynski M, Grzebieluch W, Mikulewicz M, Skoskiewicz-Malinowska K. Narrative review on methods of activating irrigation liquids for root canal treatment. Appl Sci. 2023; 30(13):7733
- Estrela C, Estrela CRA, Barbin EL, Spanó JOE, Marchesan MA, Pécora JD. 2002. Mechanism of action of sodium hypochlorite. Braz Dent J. 2002; 13(2): 113-117
- Paixão S, Rodrigues C, Grenho L, Fernandes MH. Efficacy of sonic and ultrasonic activation during endodontic treatment: A Meta-analysis of in vitro studies. Acta Odontol Scand. 2022; 80(8):588-595
- Moukarab, DAA. Evaluation of antimicrobial activity of manually agitate (nanochitosan and nano-propolis) against Enterococcus faecalis in comparison with sodium hypochlorite: an in-vitro study. Egypt Dent J. 2020; 66(1):587-596
- Young GR, Parashos P, Messer HH. The principles of techniques for cleaning root canals. Aust Dent J. 2007; 52(1): S52-S63
- Baugh D, Wallace J. The role of apical instrumentation in root canal treatment: A review of the literature. J Endod. 2005; 31(5): 333-340
- Abraham S, Raj JD, Venugopal M. Endodontic irrigants: A comprehensive review. J Pharm Sci Res. 2015; 7(1):5
- Topcu KM, Karatas E, Ozsu D, Ersoy I. Efficiency of the Self Adjusting File, WaveOne, Reciproc, ProTaper and handfiles in root canal debridement. Eur J of Dent. 2014; 8(3):326-329
- Gulabivala K, Patel B, Evans G, Ng Y-L. Effects of mechanical and chemical procedures on root canal surfaces. Endod Topics. 2005; 10(1): 103-122
- Li Q, Zhang Q, Zou X, Yue L. Evaluation of four final irrigation protocols for cleaning root canal walls. Int J Oral Sci. 2020; 12(1):29
- Slutzky-Goldberg I, Hanut A, Matalon S, Baev V, Slutzky H. The effect of dentin on the pulp tissue dissolution capacity of sodium hypochlorite and calcium hydroxide. J Endod. 2013; 39(8): 980-983
- Ruksakiet K, Hanák L, Farkas N, Hegyi P, Sadaeng W, Czumbel LM, Sang-Ngoen T, Garami A, Mikó A, Varga G, Lohinai Z. Antimicrobial efficacy of chlorhexidine and sodium hypochlorite in root canal disinfection: a systematic review and meta-analysis of randomized controlled trials. J Endod. 2020; 46(8):1032-41
- Karunakaran JV, Kumar SS, Kumar M, Chandrasekhar S, Namitha D. The effects of various irrigating solutions on intra-radicular dentinal surface: A SEM analysis. J Pharm BioAllied Sci. 2012; 4(6): 125-130
- Wu D, Ma YZ, Jia J, Xin BC, Wang DS, Sun DG, Wang LX. Removal of the root canal smear layer using Carisolv III and sodium hypochlorite. J Med. 2020; 99(22): e20372
- Oliveira LD, Carvalho CAT, Nunes W, Valera MC, Carmango CHR, Jorge AOC, dos Campos SJ. Effects of chlorhexidine and sodium hypochlorite on the microhardness of root canal dentin. Oral Surg Oral Med Oral Pathol Oral Radiol. 2007; 104(4): e125-e128
- Mohammadi Z. Sodium hypochlorite in endodontics: an update review. Int Dent J. 2008; 58(6): 329-341
- Moorer WR, Wesselinck PR. Factors promoting the tissue dissolving capability of sodium hypochlorite. Int Endod J. 1982; 15(4): 187-196
- Zehnder M. Root canal irrigants. J Endod. 2006; 32(5): 389-398
- Haapasalo M, Shen Y, Wang Z, Gao Y. Irrigation in endodontics. Br Dent J. 2014; 216(6): 299-303
- De-Deus G, Garcia-Filho P. Influence of the NiTi rotary system on the debridement quality of the root canal space. Oral Surg Oral Med Oral Pathol Radiol. 2009; 108(4): e71-e76
- Kaur P. Role of Irrigants in Endodontics. J dent problems solutions. 2020; 9(7):100-4
- Ghorbanzadeh S, Loodaricheh SA, Samizade S, Zadsirjan S. Irrigants in endodontic treatment. Int j contemp dent med rev. 2015; 11: p12
- Macedo RG, Verhaagen B, Wesselinck PR, Versluis M, Van Der Sluis LWM. 2014. Influence of refreshment/activation cycles and temperature rise on the reaction rate of sodium hypochlorite with bovine dentine during ultrasonic activated irrigation. Int Endod J. 2014; 47(2): pp.147-154
- Zou L, Shen Y, Li W, Haapasalo M. Penetration of sodium hypochlorite into dentine. J Endod. 2010; 36(5): 793-796
- Wong DT, Cheung GS. Extension of bactericidal effect of sodium hypochlorite into dentinal tubules. J Endod. 2014; 40(6): 825-829
- Trautmann E, Attin T, Mohn D, Zehnder M. Hydrogen peroxide versus sodium hypochlorite: all a matter of pH? J Endod. 2021; 47(2): 297-302
- Srinivasan S, Kumarappan SK, Ramchandran A, Honap MN, Kadandale S, Rayar S. Comparative evaluation of pulp tissue dissolution ability of sodium hypochlorite by various activation techniques: An in vitro study. J Conserv Dent. 2020; 23(3): 304
- Petridis X, Busanello FH, So MV, Dijkstra RJ, Sharma PK, van der Sluis LW. Factors affecting the chemical efficacy of 2% sodium hypochlorite against oral steady-state dual-species biofilms: Exposure time and volume application. Int Endod J. 2019; 52(8):1182-95
- Kandaswamy D, Venkateshbabu N. Root canal irrigants. J Conserv Dent. 2010; 13(4): 256-264
- Sirtes G, Waltimo T, Schaetzle M, Zehender M. The effects of temperature on sodium hypochlorite short-term stability, pulp dissolution capacity, and antimicrobial efficacy. J Endod. 2005; 31(9): 669-671
- Yared G, Ramli GA. Antibacterial ability of sodium hypochlorite heated in the canals of infected teeth: An ex vivo study. Cureus. 2020; 12(2): 1-6
- landolo A, Abdellatif D, Amato M, Pantaleo G, Blasi A, Franco V, Neelakantan P, Clarkson RM, Moule AJ, Podlich HM. The shelf-life of sodium hypochlorite irrigating solutions. Aust Dent J. 2001; 46(4): pp.269-276
- Paragiola R, Franco V, Fabiani C, Mazzoni A, Nato F, Tay FR, Breschi L, Grandini S. Final rinse optimization: influence of different agitation protocols. J Endod. 2010; 36(2): 282-285
- Al-Ali M, Sathorn C, Parashos P. Root canal debridement efficacy of different final irrigation protocols. Int Endod J. 2012; 45(10): 898-906
- Aveiro E, Chiarelli-Neto VM, de-Jesus-Soares A, Zaia AA, Ferraz CC, Almeida JF, Marciano MA, Feres M, Gomes BP. Efficacy of reciprocating and ultrasonic activation of 6% sodium hypochlorite in the reduction of microbial content and virulence factors in teeth with primary endodontic infection. Int Endod J. 2020; 53(5):604-18
- Wahjuningrum DA, Kandow R, Rulianto M, Prayogo K. Irrigation solution pattern in root canal treatment (Irrigation solution pattern in root canal between negative pressure system by Endovac and sonic activation by Eddy System). J Int Dent Med Res. 2020; 13(1): pp.111-115
- Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: A scanning electronic microscopic study. J Endod. 2011; 37(6): 871-874
- Basudan, S.O. Sodium hypochlorite use, storage, and delivery methods: A Survey. Saudi Endod J. 2019; 9(1): pp.27-33
- Sassone LM, Fidel RA, Murad CF, Fidel SR, Hirata Jr R. Antimicrobial activity of sodium hypochlorite and chlorhexidine by two different tests. Aust Endod J. 2008; 34(1): 19-24
- Ferraz CC, Gomes BP, Zaia AA, Teixeira FB, Souza-Filho FJ. Comparative study of the antimicrobial efficacy of chlorhexidine gel, chlorhexidine solution and sodium hypochlorite as endodontic irrigants. Braz Dent J. 2007; 18(4): 294-8
- Siqueira JF, Rôças IN, Faveri A, Lima KC. Chemomechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1%, 2.5%, and 5.25% sodium hypochlorite. J Endod. 2000; 26(6): 331-4
- Retamozo BR, Shabahang S, Johnson N, Aprecio RM, Torabinejad M. Minimum contact time and concentration of sodium hypochlorite required to eliminate Enterococcus faecalis. J Endod. 2010; 36(3): 520-523
- Du T, Wang Z, Shen Y, Ma J, Cao Y, Haapasalo M. Effect of long-term exposure to endodontic disinfecting solutions on young and old Enterococcus faecalis biofilms in dentin canals. J Endod. 2014; 40(4): 509-14
- Pascon FM, Kantovitz KR, Sacramento PA, Nobre-dos-Santos M, Puppini-Rontani RM. Effect of sodium hypochlorite on dentine mechanical properties. A review. J Dent. 2009; 37(12): 903-908
- Grigoratos D, Knowles J, Ng YL, Gulabivala K. Effect of exposing dentine to sodium hypochlorite and calcium hydroxide on its flexural strength and elastic modulus. Int Endod J. 2001; 34(2): 113-9
- Marending M, Luder HU, Brunner TJ, Knecht S, Stark WJ, Zehnder M. Effect of sodium hypochlorite on human root dentine- mechanical, chemical and structural evaluation. Int Endod J. 2007; 40(10): 786-93
- Aslantas EE, Buzoglu HD, Altundasar E, Serper A. Effect of EDTA, sodium hypochlorite, and chlorhexidine gluconate with or without surface modifiers on dentine microhardness. J Endod. 2014; 40 (6): 876-9
- Ari H, Erdemir A, Belli S. Evaluation of the effect of endodontic irrigation solutions on the microhardness and the roughness of root canal dentin. J Endod. 2004; 30(11): 792-5
- Kumar, G.A. and Anita, G. Evaluation of the Effect of EDTA, EGTA and Citric Acid on the Microhardness and Roughness of Human Radicular Dentin-An In Vitro Study. Natl J Integr Res Med. 2014; 5(6):24-30
- Ulusoy OI, Görgül G. 2013. Effects of different irrigation solutions on root dentine microhardness, smear layer removal and erosion. Aust Endod J. 2013; 39(2): 66-72
- Slutzky-Goldberg I, Maree M, Liberman R, Heling I. Effect of sodium hypochlorite on dentin microhardness. J Endod. 2004; 30(12): 880-2
- Tartari T, Silva e Souza Pd-AR, de Almeida BVN, Silva Júnior JOC, Pessoa OF, Silva e Sousa Junior MH. A new weak chelator in endodontics: Effects of different irrigation regimens with Etidronate on root dentin microhardness. Int J Dent. 2013; 1-6
- Sim TPC, Knowles JC, Ng YL, Shelton J, Gulabivala K. Effect of sodium hypochlorite on mechanical properties of dentine and tooth surface strain. Int Endod J. 2001; 34(2): 120-132
- Butt N, Talwar S. In-vitro evaluation of various solvents for retrieval of mineral trioxide aggregate and their effects on microhardness of dentine. J Conserv Dent. 2013; 16(3): 199-202
- Zaparolli D, Saquy PC, Cruz-Filho AM. Effect of sodium hypochlorite and EDTA irrigation, individually and in alternation, on dentine microhardness at the furcation area of mandibular molars. Braz Dent J. 2012; 23(6): 654-8
- Marending M, Paqué F, Fischer J, Zehnder M. Impact of irrigant sequence on mechanical properties of human root dentin. J Endod. 2007; 33(11): 1325-28
- Hart PS, Hart TC. Disorders of human dentin. Cells Tissues Organs. 2007; 186(1): pp.70-77
- John C, Löst C, Elayouti A. Ultrasonic monitoring of the effect of sodium hypochlorite on the elasticity of dentine. Int Endod J. 2013; 46(5): 477-482
- Sobhani OE, Gulabivala K, Knowles J, Ng Y-L. The effect of irrigation time, root morphology and dentine thickness on tooth surface strain when using 5% sodium hypochlorite and 17% EDTA. Int Endod J. 2010; 43(3): 190-199