Heat treatment of Sodium Hypochlorite : A Comprehensive Review

Saurabh Rathi[1], Pradnya Nikhade[2], Manoj Chandak[2], Anuja Ikhar[3], Nidhi Motwani[1], Meghana Deshpande[4], Madhulika Chandak[1]

[1]Post Graduate Student, [2]Professor, [3]Professor, [4]Associate Professor, Department of Conservative Dentistry and Endodontics, Department of Conservative Dentistry and Endodontics, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Medical Sciences (Deemed University), [6]Post Graduate Student, Department of Pedodontics and Preventive Dentistry, Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Medical Sciences (Deemed University)

Abstract

Introduction - The primary objective of root canal therapy is reduction of the bacteria in the root canal. The effective debridement depends on thorough cleaning and shaping of the complex root canal system. Chemical débridements can be optimally achieved using various irrigants and intracanal medicaments. The primary irrigant of choice is Sodium Hypochlorite. It has excellent tissue dissolving ability along with antibacterial property. The purpose of this review is to discuss the need to heat Sodium Hypochlorite, techniques to heat Sodium Hypochlorite, effect of Sodium Hypochlorite on tissue dissolution, antibacterial efficacy, penetration into dentinal tubules, viscosity, and effect on Ni-Ti alloy and temperature rise on external surface of root.

Method- An electronic search was carried out using the certain keywords: “sodium hypochlorite”, “heated sodium hypochlorite”, “prewarmed sodium hypochlorite”, “intracanal heating of sodium hypochlorite”, to collect literature available on Heat treatment of Sodium hypochlorite.

Result- Fourty One articles published between 1936-2020 were selected. Four main categories of data were highlighted: Sodium Hypochlorite and Heat, the need to heat Sodium Hypochlorite, different techniques to Heat Sodium Hypochlorite, effect of Sodium Hypochlorite on various parameters.

Conclusion- The efficacy of lower concentration of sodium hypochlorite can be effectively enhanced by increasing its temperature. It enhance the pulp dissolution, antibacterial efficacy and flow without any adverse effect on periodontal ligament or outer surface of the root.

Keywords: *“heat treatment of sodium hypochlorite”, “sodium hypochlorite”, “prewarmed sodium hypochlorite”, “intracanal heating of sodium hypochlorite”, “heating sodium hypochlorite”.*

Introduction

The primary goal of root canal therapy is the reduction/elimination of the bacteria and their by-products from the infected root canal space and to prevent the apical periodontitis.[1,2] This issue is addressed by disinfection of the root canal and subsequent sealing of the canal space. The canal is cleaned by the chemico-mechanical method. However, the root canal system posses the most complex anatomy in the human body, and thus, it is impossible to completely clean the canal with the conventional endodontic instrumentation.[3,4] The newer mechanical instruments and techniques though effective, cannot clean the root canal completely. Various studies dictate that large area of the canal is left untouched and unprepared, whatever might be the equipment used. This large area left untouched and

Corresponding author:
Dr. Saurabh Rathi
B.D.S, Post Graduate Student, Department of Conservative Dentistry and Endodontics
Sharad Pawar Dental College and Hospital, Datta Meghe Institute of Medical Sciences (Deemed University), Sawangi (M), Wardha ,Maharashtra 442001. e-mail address- saurorathi@gmail.com
Contact Number- 7709947624.

unprepared harbors a large number of bacteria.[5,6,7] These shortcomings can be overcome by the use of irrigants. The irrigant can penetrate the uninstrumented area and effectively debride the root canal system. The irrigant can reach the delicate intricacies of canal space and clean the areas of webs, apical deltas, fins, isthmus, and anastomosis present in the root canal.[8] From past to present, variety of irrigants have been used from normal saline, hot water, anesthetic solutions, urea, urea peroxide, hydrogen peroxide to EDTA, Chlorhexidine, Hypochlorite, Qmix, and MTAD.[9]

Sodium Hypochlorite - Sodium hypochlorite is currently the most preferred irrigant for a maximum endodontist in the endodontic therapy. It would not be an overstatement to say that 'endodontic irrigation is incomplete without hypochlorite.' Sodium hypochlorite is a chlorine compound that was frequently used as a disinfectant or bleaching agent. Labarraque, in 1820, prepared sodium hypochlorite by chlorination of caustic soda. It was extensively used for irrigation of wounds by ' chemist Henry Drysdale Dakin and surgeon Alexis Carrel' at the time of First World War.They promoted the use of buffered '0.5 % sodium hypochlorite solution', later called as 'Dakin's Solution.' Hypochlorite showed necrotic tissue dissolving abilities, a wide spectrum of action, bactericidal and virucidal properties. These favorable properties enhanced the use of hypochlorite as the main endodontic irrigant in the 1920s.[10,11,12]The efficacy of sodium hypochlorite is not based on a single factor, but it is an interplay of multiple variable factors like - pH, temperature, contact time, concentration, and time. The currentlyavailable literature focuses majorly on the concentration, volume, pH, contact time, and ultrasonic activation method of the irrigant, but the review discussing the interaction of heat and hypochlorite is scarce. To our knowledge this is the first review to discuss heat treatment of Sodium Hypochlorite. Hence, this review aims to shed light on this seldom discussed facet of irrigation.

Material and Method - An electronic search was carried out using the following keywords: "sodium hypochlorite", "heated sodium hypochlorite", "prewarmed sodium hypochlorite", "intracanal heating of sodium hypochlorite", to collect literature available on till date. The abstracts and full text of relevant articles were obtained to collect comprehensive update on heating of sodium hypochlorite.

Discussion

This review is discussed under following headings -

Sodium Hypochlorite and Heat.

The need to heat Sodium Hypochlorite.

Different techniques to Heat Sodium Hypochlorite.

Effect of Sodium Hypochlorite on various parameters.

Sodium Hypochlorite and Heat -

Present data suggest numerous techniques to enhance/increase the efficacy of Sodium hypochlorite during in the root canal procedure.[13] The initial groundwork on heating of sodium hypochlorite can be traced back to 1980s. Cunningham and Balekjian (1980) stated that rise in temperature of hypochlorite from 22°C-37°C enhanced its tissue dissolution activity. Cunningham and Joseph (1980) stated that increasing the temperature also increases the antibacterial efficacy of hypochlorite. Elio Berutti and Marini (1996) mentioned about the action of hypochlorite to debride pulp tissue at various temperatures. Piskin and Turkun (1995) assessed the stability of hypochlorite at different temperatures and concluded that it was stable at higher temperatures.[14,15,16,17].

The need to heat Sodium Hypochlorite -

Chemical reaction rates are directly proportional to the temperature, pressure, and concentration of hypochlorite. Also, the intracanal pressure cannot be increased, and concentration beyond the certain limit of 6 percent is not advisable, and thus, it is thought to increase the temperature of the irrigating solution. The efficacy of hypochlorite is increased by heating the solution. The chemical reaction is accelerated and its effect is enhanced.[18] The heated hypochlorite solution can provide the same benefits as with the higher concentration, thus reducing the risk associated with using higher concentration hypochlorite.[19]

Different techniques to Heat Sodium Hypochlorite -

Sodium Hypochlorite can be heated either outside the canal / prewarmed or inside the canal. It can be heated outside / prewarmed using a beaker on a hot plate, or kettle or with a baby bottle warmer.[20,21,22]and then introduced in the canal. The extraoral heating was ineffective as it could not maintain the rised temperature of the preheated hypochlorite inside the canal and attains the equilibrium within seconds.[21] The prewarmed irrigant inside the root canal will attain a neutral temperature between room and body temperature.[15] Ebtissam M. Al-Madi (2008) stated that heating can be effectively done with a fresh solution. He recommended preparing a stock solution and store them at low temperatures for chairside use.[23,24] The efficacy of a preheated hypochlorite decreases with few minutes and thus, if preheated hypochlorite is to be used, it should be replenished inside the canal continuously.[15] However, due to its short term efficacy or inadequacy, the new technique has evolved that heats the hypochlorite inside the canal. Dr. Woodmansey (2005) first advocated the technique for intracanal heating of sodium hypochlorite using Buchanan System B plugger. The plugger fit is verified by placing it within 3 mm of the apex. It should fit passively and not contact the canal wall. System B Heat Source is set to a power setting of 10 and a temperature of 200°C and placed in the canal for 3 to 5 seconds, with 5- second interval. This above technique was revised by Simeone M et al. They changed the temperature, plugger size, and the time. The temperature of the carrier was decreased from 200 to 150°C (boiling temperature of sodium hypochlorite is between 96 and 120 degree), plugger size 30/04, activation cycle of 10 sec (with an interval 10 sec,5 cycles) and the heat carrier makes a short up-down movement of 2 mm to shake the irrigant.[25] Recently, Prof. Angelo Putigano created a battery-based device called " Endowarmer ", having a thin 1 mm. probe with a temperature range of 45 to 60°C.[26]

Effect of sodium hypochlorite on various parameters -

1. Effect of Heat on the stability of sodium hypochlorite - Chemical stability of hypochlorite is generally measured by the amount of chlorine in the solution. Cunningham and Balekjian (1980) found that the available chlorine titer did not decrease at 37°C for up to 4 hours. However, he stated that deterioration of the warmed solutions does occur at 37°C if heated for an extended time.[14] Similar results were reported by Pişkin B and Türkün M (1995). Gambirini G et al (1998) showed that heating of NaOCl to 50°C did not affect its chemical stability.[27] Sirtes G et al. (2005) showed that the concentration of chlorine was not decreased for up to 60°C. Sodium hypochlorite retained 100 percent chlorine at the temperatures of 20°C, 45°C, and 60°C. [28] Trisha Dash et al. (2017) reported that both heated and nonheated solution showed similar chlorine concentration.[29]

2. Effect of Heat on tissue dissolution property of sodium hypochlorite -

It is a common consensus that heat increases the tissue dissolution efficacy of hypochlorite irrigant. Initially, this finding was confirmed by Cunningham and Balekjian (1980), and Abou-Rass & Oglesby (1981). Sirtes G (2005) reported that 1% hypochlorite at 45°C was equally effective as 5.25% at 20°C to dissolve the pulp.[28] Rossi-Fedele and De Figueiredo (2008) stated that the highest tissue dissolution occurs at 60 to 75 degrees. Sonja Stojicic (2010) showed that heated hypochlorite increased the organic matter dissolution by 30% to 300%. [31] Basaiwala AK (2018) reported a similar finding.[32] Furthermore, Kamburis JJ (2003) concluded that heated hypochlorite solutions are better in comparison to the unheated solution to remove organic debris from dentin shavings.[34] Amato M (2018) stated that pulp dissolution in lateral canals can only be achieved with intracanal heating followed by ultrasonic activation.[33]

3. Effect of Heat on antibacterial efficacy of sodium hypochlorite -

Costigam GM (1936) reported that hypochlorite heated to 60°C can kill M. Tuberculosis in a small time.[35] Cunningham and Joseph (1980) initially reported the increased bactericidal property of 2.6 % hypochlorite at 37°C against different planktonic bacteria.[15] Dychdala GR. (1991) reported that for every 5°C rise in temperature till 60 degrees, the antibacterial efficacy of hypochlorite is doubled.[36] Sirtes G et al. (2005) concluded that heating of hypochlorite by 25°C increased its efficacy by a factor 100.[28] Poggio C et al. (2010) compared the antibacterial property of different types of hypochlorite based irrigating solutions in unheated state versus solution preheated at 45 degrees. They concluded that a pre-warmed solution at 45°C was more effective than the unheated solution.[37] Rakesh RR (2011) studied the antibacterial effect of different temperatures at of hypochlorite against E. faecalis and reported that 5% sodium hypochlorite at 45°C was more effective than 24 and 37°C.[24] Giardino L et al (2016) stated that hypochlorite at 45°C showed the lowest colony-forming unit with E. faecalis.[38] Yared G and Ramli GA (2020) was the first to study the ex vivo effect of hypochlorite heating on E.faecalis. They showed a significant reduction in the bacterial count when intracanal heating with System B at 150°C.[39]

4. Effect of Heat on viscosity, surface tension, and penetration of sodium hypochlorite -

Heat treatment of hypochlorite increases its temperature, which leads to the increase in kinetic energy of the molecules. This kinetic energy is greater than the intermolecular forces allowing the sodium hypochlorite to become more fluid (decrease in viscosity), less surface tension, more penetration into the dentinal tubules and thus greater reach to deeper situated microorganism.[53] Priyanka A et al. (2013) assessed the effect of heat on the viscosity of hypochlorite. The dynamic viscosity was evaluated at 25, 45, and 60°C. Irrigating solution molecules undergo thermal agitation on heating, which increases its flow properties. They said that heat application decreases the viscosity, thus increasing the flow characteristic which aids the penetration of irrigants into delicate spaces and canal complexity.[40] Kanfantari N (2019) compared the effect of heated hypochlorite at 20°C, 60°C, and 80°C. They found that the storage modulus was were reduced by 4.3 - 6.8 GPa and 5.1 - 9.7 GPa at 60°C and 80°C respectively.[22] Semra Sevimay et al. (2010) stated that the surface tension of hypochlorite decreases with an increase in temperature.[41] Ling Zou et al. (2010) measured the penetration of hypochlorite at 20°C, 37°C, and 45°C. They reported that the least penetration of 77 microns was seen with 1% for 2 minutes at room temperature and maximum penetration of 300 microns with 6% for 20 minutes at 45°C. Apart from temperature, time duration plays an important role concluding that longer exposure time was associated with deeper penetration with heated hypochlorite.[42] Yaghi A (2016) compared the penetration of heated and non-heated NaOCl by apical negative pressure irrigation into lateral canals of the root. They showed better penetration with heated irrigant and apical negative pressure and heated irrigant did not penetrate better in lateral canals.[43] Landolo A et al. (2019) in a study stated that heating of hypochlorite preceded by ultrasonic activation showed higher penetration of irrigant into dentinal tubules at both 3 mm levels and 5 mm levels. Intracanal heating of ultrasonically activated irrigation resulted in significantly cleaner canals than syringe-and-needle irrigation.[44] He conducted the similar study in 2018 that showed intracanal heating of NaOCl resulted in significantly less debris on the root canal walls, compared to irrigation with pre-heated NaOCl.[13] Similar results were reported by Semra Sevimay.[41]

5. Effect of heated sodium hypochlorite on the rotary instrument -

Endodontic files are used with the irrigant placed inside the canal. However, the fatigue life of NiTi instruments is also influenced by the irrigant used, its concentration, and temperature. The Ni-Ti rotary instruments at a lower temperature can be easily deformed which improves its fatigue crack growth resistance, flexibility and instrument have higher resistance to cyclic fatigue. However, the temperature inside the root canal is higher than room temperature (close to body temperature) and heating of irrigant might influence the properties of Ni-ti alloy. The heated hypochlorite when in contact with the Ni-Ti instrument causes microstructural defects.[45] Jamleh A (2015) stated that cyclic fatigue resistance decreases with an increase in temperature.[46] Demiral M et al (2017) reported similar results with the OneShape instrument. They stated that the number of rotations required to failure was less for NaOCl at 50°C compared to NaOCl at 37°C.[47] Huang X (2017) conducted a similar study with Distilled Water and hypochlorite at 22°C, 37°C, and 60°C. The results of their study were in accordance with others, but they found no significant difference between the two solutions.[48] Alfawaz et al. (2018) stated that at a higher temperature of NaOCl, the cyclic fatigue resistance of the Ni-Ti file decreased. This was more evident at higher concentration of 5.25% NaOCl, rather than 2.5%.[49] Keles A et al. (2019) studied the effect of preheated hypochlorite on thermal-treated Reciprocating files. They showed similar result as other studies. Preheated solution adversely affected the cyclic fatigue resistance.[50]

6. Effect of heated hypochlorite on the periodontal ligament and external surface of root surface -

The critical temperature on the external surface of root that affects the cells of the periodontal ligament was found to be 47°C-56°C because the alkaline phosphatase is denatured at this temperature. The cells of the periodontal ligament are adversely affected at this temperature. Temperature greater than 60°C may stop permanent blood flow and bone necrosis.[51] Macedo RG et al. (2014) stated that the highest temperature measure on the outer surface of the root was 39°C with heated hypochlorite.[52] Simeone M et al. showed that heating of hypochlorite inside the root canal till 150°C-200°C did not raise the temperature on the external root surface by more than 42.5°C.[25]

Conclusion

The efficacy of sodium hypochlorite can be increased by either using the pre-warmed irrigant or heating the hypochlorite inside the canal. The efficacy of lower concentration of sodium hypochlorite can be effectively enhanced by increasing its temperature. It enhance the pulp dissolution, antibacterial efficacy and flow without any adverse effect on periodontal ligament or outer surface of the root.

Source of Funding: - None.

Conflict of Interest: None to declare.

Ethical Clearance: Obtained from Institutional Ethical Committee.

References

1. Chugal NM, Clive JM, Spångberg LS. Endodontic infection:some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(1):81-90.
2. Happasalo M, Endal U, Zandi H, Coil JM. Eradication of endodontic infection by instrumentation and irrigating solutions. End Topics 2005;10:77-102.
3. Barbizam JV, Fariniuk LF, Marchesan MA, Pecora JD, Sousa-Neto MD. Effectiveness of manual and rotary instrumentation techniques for cleaning flattened root canals. J Endod2002;28(5):365-6.
4. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30(8):559-67.
5. Siqueira Junior JF, Rocas ID, Marceliano-Alves MF, Pérez AR, Ricucci D. Unprepared root canal surface areas: causes, clinical implications, and therapeutic strategies. Braz Oral Res 2018;32.
6. Stavileci M, Hoxha V, Görduysus Ö, Tatar I, Laperre K, Hostens J, Küçükkaya S, Muhaxheri E. Evaluation of root canal preparation using rotary system and hand instruments assessed by micro-computed tomography. Med Sci Monit Basic Res 2015;21:123.
7. Manker A, Solanki M, Tripathi A, Jain ML. Biomechanical preparation in primary molars using manual and three NiTi instruments: a cone-beam-computed tomographic in vitro study. Eur Arch Paediatr Dent 2019;5:1-1.
8. Wilson N and Sikri V. Essentials of Endodontics. J Conserv Dent 2012;15(3):305.
9. Basrani B, Haapasalo M. Update on endodontic irrigating solutions. Endodontic topics 2012;27(1):74-102.
10. Ponzano GP. Sodium hypochlorite:history, properties, electrochemical production. InDisinfection by Sodium Hypochlorite: Dialysis Applications. Karger Publishers 2007;154:7-23.
11. Mohammadi Z. Sodium hypochlorite in endodontics: an update review. Int Dent J 2008;58(6):329-41.
12. Zehnder M. Root canal irrigants. J Endod 2006;32(5):389-98.
13. Landolo A, Amato M, Dagna A, Poggio C, Abdellatif D, Franco V, Pantaleo G. Intracanal heating of sodium hypochlorite:Scanning electron microscope evaluation of root canal walls. J Conserv Dent 2018;21:569-73
14. Cunningham,W. T., and Balekjian, A. Y .: Effects of Temperature on Collagen-Dissolving Ability of Sodium Hypochlorite Endodontic Irrigant. ORAL SURG 1980;49:175-177.
15. Cunningham WT, Joseph SW. Effect of temperature on the bactericidal action of sodium hypochlorite endodontic irrigant. Oral Surg Oral Med Oral Pathol1980;50(6):569-71.
16. Berutti E, Marini R. A scanning electron microscopic evaluation of the debridement capability of sodium hypochlorite at different temperatures. J Endod 1996;22(9):467-70.

17. Pişkin B, Türkün M. Stability of various sodium hypochlorite solutions. J Endod 1995;21(5):253-5.

18. Woodmansey KF. Intracanal heating of sodium hypochlorite solution: an improved endodontic irrigation technique. Dent Today2005;24(10):114-6.

19. Rossi-Fedele, G., & De Figueiredo, J. A. P. Use of a bottle warmer to increase 4% sodium hypochlorite tissue dissolution ability on bovine pulp. Aust Endod J 2008;34(1):39–42.

20. Frais S, Ng YL, Gulabivala K. Some factors affecting the concentration of available chlorine in commercial sources of sodium hypochlorite. Int Endod J 2001;(3):206-15.

21. Landolo A *et al*. 3D cleaning, a perfected technique: Thermal profile assessment of heated NaOCl. G Ital Endod 2017;2;001

22. Kafantari, N., Gulabivala, K., Georgiou, G., Knowles, J., & Ng, Y.-L. Effect of Heated Sodium Hypochlorite on the Viscoelastic Properties of Dentin Evaluated Using Dynamic Mechanical Analysis. J Endodn 2019;45(9):1155-1160.

23. Ebtissam M. Al-madi. Effect of intermttent PUI and rotary instruments on microbial colonies of infected root canal. Saudi Dent J. 2008;20(1):10-16.

24. Rakesh RR. Effect of Irrigation of Sodium Hypochlorite at Different Temperatures and Concentration on the Elimination of Enterococcus Faecalis from Rootcanals: An In Vitro Study (Doctoral dissertation, JKK Nataraja Dental College, Komarapalayam).

25. Simeone, M., Valletta, A., Giudice, A., Di Lorenzo, P., & Iandolo, A. The activation of irrigation solutions in Endodontics: a perfected technique. G Ital Endod 2015;29(2):65–69.

26. Prof. Angelo PUTIGNANO and his colleagues. UNIVERSITÀ POLITECNICA DELLE MARCHE, FACULTY OF MEDICINE AND SURGERY. Available from www.diagram.it.

27. GambariniG, De LucaM, & Gerosa R. Chemical stability of heated sodium hypochlorite endodontic irrigants.J Endodn2009;24(6):432–434.

28. SirtesG, Waltimo T, Schaetzle M, & Zehnder, M. The Effects of Temperature on Sodium Hypochlorite Short-Term Stability, Pulp Dissolution Capacity, and Antimicrobial Efficacy. J Endodn 2005;31(9):669–671.

29. Dash T, Mohan RP, Mannava Y, Thomas MS, Srikanth N. Effect of storage temperature and heating on the concentration of available chlorine and pH of 2.5% sodium hypochlorite. Saudi Endod J 2017;7:161-5.

30. Abou-Rass, M., & Oglesby, S. W. The effects of temperature, concentration, and tissue type on the solvent ability of sodium hypochlorite. Journal of Endodontics 2108;7(8):376–377.

31. Stojicic S, Zivkovic S, Qian W, Zhang H, Haapasalo M. Tissue dissolution by sodium hypochlorite: effect of concentration, temperature, agitation, and surfactant. J Endodn 2010;36(9):1558-62.

32. Basaiwala AK, Shetty K, Nath KS. Comparative evaluation of temperature changes on tissue-dissolution ability of sodium hypochlorite, calcium hypochlorite, and chlorine dioxide. Saudi Endod J 2018;8:208-11

33. Amato M, Pantaleo G, Abtellatif D, Blasi A, Gagliani M, Iandolo A. An in vitro evaluation of the degree of pulp tissue dissolution through different root canal irrigation protocols. J Conserv Dent 2018;21(2):175.

34. Kamburis JJ, Barker TH, Barfield RD, Eleazer PD. Removal of organic debris from bovine dentin shavings. J Endod 2003;29:559 – 61.

35. Costigan SM.Effectiveness of hot hypochlorites of low alkalinity in destroying mycobacterium tuberculosis. J Bacteriol1936;32:57-63.

36. Dychdala GR. Chlorine and chlorine compounds. In: Block SS, ed. Disinfection, sterilization and preservation. Philadelphia: Lea & Febiger1991:131–51.

37. Poggio, C., Arciola, C. R., Dagna, A., Chiesa, M., Sforza, D., & Visai, L. Antimicrobial Activity of Sodium Hypochlorite-Based Irrigating Solutions. Int J Artif Organs 2010;33(9):654–659.

38. Giardino L, Mohammadi Z, Beltrami R, Poggio C, Estrela C, Generali L. Influence of temperature on the antibacterial activity of sodium hypochlorite. Braz Dent J. 2016;27(1):32-6.

39. Yared G, Ramli GA. Antibacterial Ability of Sodium Hypochlorite Heated in the Canals of Infected Teeth: An Ex Vivo Study. Cureus 2020;12(2).

40. Velayutham Gopikrishna PA, Kumar AP, Narayanan LL. Influence of temperature and concentration on the dynamic viscosity of sodium

hypochlorite in comparison with 17% EDTA and 2% chlorhexidine gluconate: An in vitro study. J Conserv Dent. 2014;17(1):57.

41. Sevimay S, Oğan-Hasçiçek C, Tarımcı N. Evaluation of surface tensions and cleansing ability of sodium hypochlorite and chlorhexidine solutions at different concentrations and temperatures. Balkan Journal of Stomatology 2010;14(2):72-8.

42. Zou L, Shen Y, Li W, Haapasalo M. Penetration of sodium hypochlorite into dentin. J Endod 2010;36(5):793-6.

43. Yaghi A, Kaloustian H. Penetration of heated and non-heated sodium hypochlorite into lateral canals by apical negative pressure irrigation. International Arab Journal of Dentistry2016(10);7(2).

44. Landolo, A., Abdellatif, D., Amato, M., Pantaleo, G., Blasi, A., Franco, V., & Neelakantan, P. Dentinal tubule penetration and root canal cleanliness following ultrasonic activation of intracanal□ heated sodium hypochlorite. Aust Endod J. 2019.

45. Haïkel Y, Serfaty R, Wilson P, et al. Mechanical properties of nickel-titanium endodontic instruments and the effect of sodium hypochlorite treatment. J Endod1998;24:731-735.

46. Jamleh, A., Yahata, Y., Ebihara, A., Atmeh, A. R., Bakhsh, T., & Suda, H. Performance of NiTi endodontic instrument under different temperatures. Odontology 2015;104(3):324–328.

47. Demiral M, Keskin C and Inan U. Effect of Sodium Hypochlorite Activated by Heating on the Cyclic Fatigue Resistance of OneShape Rotary Instruments. J Dent App. 2017;4(1): 372-375.

48. Huang, X., Shen, Y., Wei, X., & Haapasalo, M. Fatigue Resistance of Nickel-titanium Instruments Exposed to High-concentration Hypochlorite. J Endod 2017;43(11), 1847–1851.

49. Alfawaz, H., Alqedairi, A., Alsharekh, H., Almuzaini, E., Alzahrani, S., & Jamleh, A. Effects of Sodium Hypochlorite Concentration and Temperature on the Cyclic Fatigue Resistance of Heat-treated Nickel-titanium Rotary Instruments. J Endod 2018;44(10):1563-1566.

50. Keles A, Ozyurek EU, Uyanik MO, Nagas E. Effect of temperature of sodium hypochlorite on cyclic fatigue resistance of heat-treated reciprocating files. J Endod 2019;45(2):205-8.

51. Eriksson, A. R., & Albrektsson, T. Temperature threshold levels for heat-induced bone tissue injury: A vital-microscopic study in the rabbit. J Prosthet Dent1983;50(1):101–107.

52. Macedo RG, Verhaagen B, Versluis M, van der Sluis L. Temperature evolution of preheated irrigant injected into a root canal ex vivo. Clin Oral Investig. 2017;21(9):2841-50.

53. Bukiet F, Soler T, Guivarch M, Camps J, Tassery H, Cuisinier F, Candoni N. Factors affecting the viscosity of sodium hypochlorite and their effect on irrigant flow.J Endod 2013;46(10):954-61.