Cryotherapy: A Minimal Invasive Procedure in Endodontics

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Abstract: **The field of endodontics is constantly evolving and changing to bring about the best possible treatment for the patient. There is a consistent view of new and emerging therapies to make the patient experience and work of the dentist as comfortable as possible. Cryotherapy is a long-term method used in a variety of fields including endodontics. In the field of endodontics, cryotherapy has been reported to be used after periradicular surgery and during root canal therapy to reduce postoperative pain and inflammation. Another introduction of cryotherapy to endodontics is deep cryotherapy of nickel-titanium (NiTi) endodontic files, providing improved fatigue resistance and reducing possible file separation. Recently, cryotherapy has been successfully tried as a useful adjunct for hemostasis in pulp cryotherapy which is used in conjunction with bioceramic materials. The purpose of this review article was to discuss the concept of cryotherapy, its mechanism and its various applications in the field of endodontics.**

Index terms: **Cryotherapy, Postoperative Endodontic Pain, Root canal irrigants, Vital Pulp Therapy, Endodontic Instruments.**

1. INTRODUCTION

The term “cryotherapy” comes from the word “cryos,” meaning “very cold” or “ice cold” and “therapeia” denoting “cure” in the Greek language. Therefore, cryotherapy refers to treatments that are performed at reduced temperatures. The concept of cryotherapy does not mean cooling the target tissue but rather releasing heat from the tissue at higher temperatures to the point of lower temperature [1].

The Basic Physiological Responses After the Use of Heat or Cold are: (i) Increased or decreased local blood flow, (ii) Stimulation or inhibition of neural receptors in the skin and subcutaneous tissue, and (iii) increased or decreased metabolic cell function [2].

Cryotherapy has been reported to be effective in reducing edema, pain, inflammation, and recovery time through short-term use in orthopaedic, abdominal, gynaecological and hernia operations. An ice pack, gel pack, ice chips, melted ice water, ice cream, pre-packaged chemical ice pack, and ice in a washcloth are the modes of application of cold. Cold application to the skin stimulates thermoreceptors (heat-sensitive receptors), and stimulation of these receptors can inhibit nociception within the spinal cord [3]. According to Van't Hoff's law, cryotherapy causes vasoconstriction and slows down Cellular metabolism reduces biochemical reactions that reduce the rate of tissue damage, thereby reducing the oxygen demand of cells and reducing the production of free radicals in tissues. Vasoconstriction produces antioedema effects, and pain relief is achieved after a decrease in temperature due to inhibition of nerve endings caused by cold application [2][4].

The main cause of postoperative pain is damage to the periapical tissue whether mechanical, chemical or microbiological which leads to inflammation of the periapical tissue known as a flare-up. For pain relief, several techniques have been developed. Using cryotherapy in the dental field was investigated by Felho et al. 2005 in reducing inflammation, pain and trismus after the removal of the third molar [3].

2. VITAL PULP CRYOTHERAPY

When a carious tooth is diagnosed with reversible or irreversible pulpitis and caries excavation leads to direct or indirect pulp exposure, then vital pulp capping or partial pulpectomy is the choice of treatment. Pulpal bleeding may be a clinical sign of the severity of pulpal inflammation. Hemorrhaging in pulps with a pre-treatment diagnosis of mild or reversible pulpitis appears to stagnate and be easily controlled with ice application [5]. Cryo-technique involves the use of sterile water ice shavings over the exposed pulpal tissue. The melted ice should then be removed with a high-speed suction after one minute, followed by irrigation with 17% EDTA [6]. The use of sodium hypochlorite is not advised while performing vital pulp cryotherapy procedures, since it has been shown to destroy pulpal stem cells. The use of EDTA solution is recommended since has been shown to release bioactive growth factors from dentin, thereby stimulating the secretion of the matrix, odontoblastic differentiation, and tertiary dentin formation along with promoting adhesion, migration, and differentiation of dental pulp stem cells [7][8].

After the exposed or indirect exposed pulp was treated with shaved sterile ice and EDTA, it was then covered with a bioceramic material followed by, a permanent restoration. The treated teeth became asymptomatic after 2 weeks after 12–18 months follow up the tooth remained vital, asymptomatic, and functional [6]. Further clinical research was recommended to determine the long-term prognosis for significant Vital pulp cryotherapy.

3. ROLE IN ANTIMICROBIAL ACTION

Various irrigating solutions have been used in endodontics to reduce the bacterial load in the root canal system. Of the available solutions, Sodium hypochlorite (NaOCl) is currently the most commonly used. Yamamoto and Harris [9] have explained the effects of Cryotherapy involving the use of liquid nitrogen over microorganisms. The process of freezing and thawing has been shown to cause cell wall disruption, leakage of intracellular constituents and changes associated with protein structure. The cryogenic fluid has been experimentally used in various studies against the gold standard irrigant, sodium hypochlorite, and has shown more efficacy in antibacterial action as it can reach the desired depth and bring about bacterial freezing and subsequent destruction [10].

4. ROLE IN REDUCING PERIAPICAL INFLAMMATION

Periapical Inflammation has been associated with injury to the periapical tissues before, during or after the endodontic therapy. The result of the periapical extension of pulpal inflammation, excessive instrumentation beyond the root apex during cleaning and shaping of root canals or overextended obturation can lead to periapical injury and result in periapical inflammation with classic signs of increased local temperature, swelling, pain and redness [5].

Vera et al. found that cryotherapy helps to reduce the external root surface temperature during endodontic treatment. The use of cold saline solution (2.5 0 C) as the final irrigant for 5 mins brings about a reduction in external root surface temperature by more than 100C for 4 minutes, which might produce a local anti-inflammatory effect in the periradicular tissues [11]. Inflamed periradicular tissues may be treated with cryotherapy by intracanal irrigation with a cold substance along with a negative pressure irrigation device. The microcannula of the negative pressure system can be applied to the full working length (WL) as well as a continuous flow of the irrigant [11][12].

5. ROLE AS ROOT CANAL IRRIGANT IN REDUCING POST-OPERATIVE PAIN

Various clinical and experimental studies have highlighted the role of cryoirrigation in controlling post-operative pain after endodontic therapy. Following cold therapy, it results in a reduction in the blood flow due to induced vasoconstriction at the application site followed by a reduction in tissue metabolism and oxygen utilization which in turn minimizes oedema and local release of pain mediators. At the same time, leukocytes play a vital role in the inflammatory response of a soft tissue lesion. Therefore, cryotherapy is effective in decreasing the number of leukocytes adhering to the endothelial wall of capillaries, resulting in decreasing in the number of cells migrating to the affected tissues, reducing endothelial dysfunction and inflammation [3].

Keskin et al 2016 [13] evaluated the efficacy of saline solution at a temperature of 2.5 °C when used as the final irrigant on postoperative pain after single-visit root canal treatment in patients with irreversible pulpitis. but they used a side-vented, positive-pressure 31-G Navi Tip needle instead of negative apical pressure. The results revealed that cryotherapy only made a difference in patients diagnosed with apical periodontitis, whereas in patients with only irreversible pulpitis, there was no significant difference in the incidence of postoperative pain between the cryotherapy group and the control group. Gundogdu et al. [14] found that all the cryotherapy applications i.e., intracanal, intraoral, and extraoral applications resulted in lower postoperative pain levels and lower VAS scores pain levels in all the human subjects. Alharthi et al [15] confirmed the ineffectiveness of cryotherapy in previously asymptomatic cases without periapical pathosis. This was in accordance with Jain et al [16] in addition, they recommended the use of cryotherapy for reducing postoperative pain only in symptomatic irreversible pulpitis with apical periodontitis.

Sadaf et al [17] evaluate the effect of intracanal cryotherapy on postoperative pain after root canal therapy in patients with pulpal or periradicular pathosis. They have concluded that Moderate-quality evidence suggests that intracanal cryotherapy (i.e, using cold saline irrigation as a final irrigant) significantly reduces the intensity of pain at 6 and 24 hours after root canal therapy. Duaa S. Bazaid et al [18] studied the effect of cryotherapy on reducing postoperative pain was compared to irreversible pulpitis with and without apical periodontitis It was seen that cold saline used as a final rinse using a 27-G side vented needle had an effect on reduction of postoperative pain degree in patients with irreversible pulpitis with apical periodontitis. But it does not affect patients with irreversible pulpitis without apical periodontitis.

6. EFFECT OF CRYOTHERAPY IN POST SURGICAL MANAGEMENT

Prevention of postsurgical hematoma after periradicular surgery is important in controlling pain but also improving the healing process, reducing the incidence of postoperative complications, and improving outcomes. Postsurgical cold application impedes local blood flow and counteracts the rebound phenomenon, which follows the use of vasoconstrictor-containing local anesthetics. Therefore, reducing the temperature of the surgical site with the cold application has become a recommended protocol for post-surgical support [19].

7. EFFECT OF CRYOTHERAPY AS LOCAL ANESTHETIC

Inferior alveolar nerve block (IANB) is a standard injection technique used to achieve regional anesthesia for mandibular molar teeth. Application for preoperative cryotherapy after IANB did not provide pulpal anesthesia for about 45% of mandibular molars with Symptomatic irreversible pulpitis. However, intraoral cryotherapy may be preferred to increase IANB success rates in patients with symptomatic irreversible pulpitis. Nociceptors are stimulated by various chemical mediators, and these stimuli may cause pain. Cryotherapy slows down neural signals and reduces the release of the chemical mediators responsible for pain conduction. Cryotherapy also induces a local anesthetic effect by lowering the activation threshold of nociceptors and the conduction velocity of pain signals [20]. In addition, a cold application might decrease the activation threshold of tissue nociceptors (specialized nerve endings that are activated after a tissue injury), leading to a local anesthetic effect that is defined as cold-induced neuropraxia [21]. Therefore, the analgesic effect of cooling is produced by a combination of a decreased release of chemical mediators of pain and a slower propagation of neural pain signals. Topçuoglu et al [22] studied the effect of preoperative intraoral cryotherapy application on the success rate of inferior alveolar nerve blocks. They found that the use of intraoral cryotherapy increased the potency of inferior alveolar nerve blocks, especially in teeth with symptomatic irreversible pulpitis. However, supplemental anesthesia techniques may still be required to provide profound pulpal anesthesia in most cases.

8. EFFECT OF CRYOTHERAPY ON ENDODONTIC INSTRUMENTS

Various surface treatment methods have been suggested to improve cutting efficiency, cyclic fatigue resistance, and wear resistance of rotary files. These include boron ion implantation [23], thermal nitridation [24], physical vapor deposition of titanium nitride [25], electropolishing, and cryogenic treatment. Historically, to improve the surface hardness and thermal stability of the metal cryogenic treatment of metal during manufacture had been advocated. It is a supplementary procedure of subjecting superelastic NiTi and stainless steel to subzero temperatures and then allowing the metal to slowly warm to room temperature. It has been classified depending upon the treatment temperature into shallow cryogenic treatment and deep cryogenic treatment. Deep cryogenic treatment (DCT) is more advantageous when compared to traditional shallow cryogenic treatment. Conventional subzero treatments have been tried at temperatures of approximately -80C (shallow cryogenic treatment). However, the life of the instrument is enriched by even lower temperature treatment (deep cryogenic treatment) such as those generated by liquid nitrogen at -185C and -196C. It was seen that deep cryogenic treatment (DCT) had drastically increased the cyclic fatigue resistance with a 24-hour soaking time by 13% and with a 6-hour soaking time of only 1%. Nonetheless, the soaking time did not have the same influence on cutting efficiency [3].

Several mechanisms have been advocated to demonstrate improvement in properties after cryogenic treatment. These include i. A reaction between nitrogen and titanium atoms results in titanium nitride formation on the surface [26]. ii. Nitrogen atom deposition into the interstitial spaces within the atomic lattice of NiTi alloy, causing lattice strain [27]. iii. A more complete martensitic transformation from the austenite phase of the NiTi alloy [28] and iv. Precipitation of finer carbide particles throughout the crystal lattice [29]. The latter two mechanisms have been suggested to account for cryogenic changes in steel alloys [28]. Because there is no carbon present within the NiTi alloy, the fourth mechanism is ruled out immediately [30]. Controversy exists over which mechanism is responsible.

Two studies have been reported in the endodontic literature that investigated cryogenic treatment on stainless steel endodontic instruments. Bramipour et al [28] found no effect of cryogenic treatment on the cutting efficiency of stainless-steel endodontic instruments (Flex R files and Hedstrom files), whereas Berls [31] found no significant increase in wear resistance of the stainless-steel hand instruments (S-type and K-type). Regarding the superelastic NiTi endodontic instruments, Kim et al [30] investigated the effect of cryogenic treatment on microhardness and cutting efficiency. An increase in microhardness was yielded, but this increase was not apparent clinically in terms of the cutting efficiency nor was there a measurable change in the surface or the structural composition. Vinothkumar et al [32] reported that cryogenic treatment of superelastic NiTi files significantly increased the cutting efficiency without affecting the wear resistance. This conflict may be attributed to the method and timing of cryogenic treatment. In the former, instruments were totally immersed in the liquid nitrogen for 10 minutes, whereas in the later dry DCT treatment for 24 hours was used.

Dry DCT treatment significantly increased the cyclic fatigue resistance of superelastic NiTi files compared with untreated files. This positive change in cyclic fatigue was referred to as the complete transformation of the austenitic phase of the alloy to the martensitic phase, which could have occurred at -195^{0}C and thereby decrease the internal stresses within the alloy because of plastic deformation. A residual austenite phase in an alloy decreases hardness and also reduces the wear resistance of the tool [33]. Thus, increasing resistance to wear and reducing the internal stresses can be viewed as the most important benefit of using cryogenic treatment [34]. However, this positive effect of dry DCT on the cyclic fatigue resistance of rotary NiTi files was negated by the study by Yazdizadeh et al [35] in which no improvement in cyclic resistance was reported when the files were totally immersed in -196^{0}C for 24 hours.

9. CONCLUSION

Intracanal cryotherapy can be considered as a simple, inexpensive, and non-toxic therapeutic treatment option for postoperative pain control in single visit RCT cases. Cryotherapy is an innovative and promising method that can be considered to reduce swelling, discomfort and post-operative pain encountered after endodontic treatment and surgeries. It has also shown the potential to control pulpal bleeding in the case of vital pulp therapy and also proven the effectiveness of cryogenic treatment of the recent heat-treated NiTi rotary instrument. However further studies are required to provide strong evidence to prove its therapeutic effect in the field of endodontics.

REFERENCES

[1] Belitsky RB., et al. "Evaluation of the effectiveness of wet ice, dry ice, and cryogenic packs in reducing skin temperature". Physical Therapy 67.7 (1987): 1080-1084.
[2] Knight KL. Cryotherapy in Sports Injury Management. Champaign, IL: Human Kinetics; 1995:60.
[3] Fayyad et al. Cryotherapy: A New Paradigm of Treatment in Endodontics: J Endod. 2020 Jul;46(7):936-942.
[4] Saravana Karthikeyan Balasubramanian and Divya Vinayachandran. "Cryotherapy"– A Panacea for Post-Operative Pain Following Endodontic Treatment". Acta Scientific Dental Sciences 1.1 (2017): 01-03.
[5] Shivangi Vats, Vinod Jathanna; Indian Journal of Forensic Medicine & Toxicology, October-December 2020, Vol. 14, No.4.
[6] Bahcall J, Johnson B, Xie Q, et al. Introduction to vital pulp Cryotherapy. Endod Pract US 2019; 1:14.
[7] Casagrande L, Demarco FF, Zhang Z, Araujo FB, Shi S, Nör JE. Dentin-derived BMP-2 and odontoblast differentiation. J Dent Res. 2010; 89(6): 603-608.
[8] Galler KM, Buchalla W, Hiller KA, Federlin M, Eidt A, Schiefersteiner M, Schmalz G. Influence of root canal disinfectants on growth factor release from dentin. J Endod. 2015; 41(3):363-368.
[9] Yamamoto SA, Harris LJ. The effects of freezing and thawing on the survival of Escherichia coli O157: H7 in apple juice. International journal of food microbiology. 2001 Jul 20;67(1-2):89-96.

[10] Mandras N, Allizond V, Bianco A, Banche G, Roana J, Piazza L, Viale P, Cuffini AM. Antimicrobial efficacy of cryo treatment against Enterococcus faecalis in root canals. Letters in applied microbiology. 2013 Feb;56(2):95-8.
[11] Vera et al; Intracanal Cryotherapy Reduces Postoperative Pain in Teeth with Symptomatic Apical Periodontitis: A Randomized Multicenter Clinical Trial JOE — Volume 44, Number 1, January 2018.
[12] Schoeffel GJ. The EndoVac method of endodontic irrigation, part 2--efficacy. Dentistry today. 2008 Jan;27(1):82-4.
[13] Keskin C, Ozdemir O2, Uzun I, GUler B. Effect of intracanal cryotherapy on pain after single-visit root canal treatment. Aust Endod J 2017; 43:83–8.
[14] Gundogdu EC, Arslan H. Effects of various cryotherapy applications on postoperative pain in molar teeth with symptomatic apical periodontitis: a preliminary randomized prospective clinical trial. Journal of endodontics. 2018 Mar 1;44(3):349-54.
[15] Alharthi AA, Aljoudi MH, Almaliki MN, et al. Effect of intra-canal cryotherapy on post–endodontic pain in single-visit RCT: A randomized controlled trial. Saudi Dent J 2019; 31:330–5.
[16] Jain A, Davis D, Bahuguna R, et al. Role of cryotherapy in reducing postoperative pain in patients with irreversible pulpitis. an in-vivo study. Int J Den Med Sci 2018; 2:43–9.
[17] Sadaf et al.; Effectiveness of Intracanal Cryotherapy in Root Canal Therapy: A Systematic Review and Meta-analysis of Randomized Clinical Trials. J Endod. 2020 Dec;46(12):1811-1823.
[18] Bazaid DS, Kenawi LMM. The effect of intracanal cryotherapy in reducing postoperative pain in patients with irreversible pulpitis: a randomized control trial. Int J Health Sci Res. 2018; 8(2):83- 88.
[19] Laureano Filho JR, de Oliveira e Silva ED, Batista C, Gouveia FM. The influence of cryotherapy on reduction of swelling, pain and trismus after third molar extraction. J Am Dent Assoc 2005; 136:774–8.
[20] Vandana Gade et al, Cryotherapy: An Emerging Trend in the Field of Endodontics International Journal of Drug Research and Dental Science Volume 2 Issue 3,2020 ISSN: 2582-0826.
[21] Nadler SF, Weingand K, Kruse RJ. The physiologic basis and clinical applications of cryotherapy and thermotherapy for the pain practitioner. Pain Physician 2004; 7:395–9.
[22] Topçuoglu HS, Arslan H, Topçuoglu G, Demirbuga S. The effect of cryotherapy application on the success rate of inferior alveolar nerve block in patients with symptomatic irreversible pulpitis. J Endod 2019; 45:965–9.
[23] Lee DH, Park B, Saxeba A, Serene TP. Enhanced surface hardness by boron implantation in Nitinol alloy. J Endod 1996; 22:543–6.
[24] Ruiz-Sanchez C, Faus-Matoses V, Alegre-Domingo T, et al. An in vitro cyclic fatigue resistance comparison of conventional and new generation nickel-titanium rotary files. J Clin Exp Dent 2018; 10:805–9.
[25] Schafer E. Effect of physical vapor deposition on cutting efficiency of nickel-titanium files. J Endod 2002; 28:800–2.
[26] Rapisarda E, Bonaccorso A, Tripi TR, Fragala IL. The effect of surface treatments of nickel-titanium files on wear and cutting efficiency. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000; 89:363–8.
[27] Pogrebnjak AD, Bratushka SN, Beresnev VM, Levintant-Zayonts N. Shape memory effect and super elasticity of titanium nickel alloys implanted with high ion doses. Russ Chem Rev 2013; 82:1135.
[28] Bramipour D, Svec TA, White KW, Powers JM. Wear resistance of cryogenically treated stainless steel files. J Endod 2001; 27:212–3
[29] Huang JY, Zhu YT, Liao XZ, et al. Microstructure of cryogenic treated M2 tool steel. Mat Sci Eng A 2003; 339:241–4.
[30] Kim JW, Griggs JA, Regan JD, et al. Effect of cryogenic treatment on nickel-titanium endodontic instruments. Int Endod J 2005; 38:364–71.
[31] Berls RW. Effect of cryogenic tempering on the wear resistance of two types of stainless-steel files [abstract]. J Endod 2003; 29:300.
[32] Vinothkumar TS, Miglani R, Lakshminarayananan L. Influence of deep dry cryogenic treatment on cutting efficiency and wear resistance of nickel-titanium rotary endodontic instruments. J Endod 2007; 33:1355–8.
[33] Srivastava S. Current strategies in metallurgical advances of rotary NiTi instruments: a review. J Dent Health Oral Disord Ther 2018; 9:00333.
[34] Gavini G, Santos MD, Caldeira CL, et al. Nickel-titanium instruments in endodontics: a concise review of the state of the art. Braz Oral Res 2018;32:67.
[35] Yazdizadeh M, Skini M, Hoseini Goosheh SM, et al. Effect of deep cryogenic treatment on cyclic fatigue of endodontic rotary nickel-titanium instruments. Iran Endod J 2017; 12:216–9.