CONSORT RANDOMIZED CLINICAL TRIAL

The Effect of Novel Cryotherapy Technique on Postoperative Pain for Pulpotomy in Permanent Molars with Symptomatic Irreversible Pulpitis: A Randomized Controlled Trial

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ABSTRACT

Introduction: The purpose of this study was to evaluate the effect of cryotherapy application on postoperative pain in permanent molars with symptomatic irreversible pulpitis after full pulpotomy procedures. **Methods:** Sixty-two patients with permanent maxillary and mandibular molars diagnosed with symptomatic irreversible pulpitis were included in the study. The teeth were randomly divided into 2 groups: the control group ($n = 32$) and the cryotherapy group ($n = 30$). In both groups, cotton pellets moistened with 2.5% sodium hypochlorite were used to achieve hemostasis. In the cryotherapy group, after hemostasis was achieved, the pulpotomy area was irrigated with saline solution at 2.5°C for 5 minutes. Then, in both groups, the pulp chamber was covered with Bio mineral trioxide aggregate+ (Cerkamed Company, Poland) and the composite restoration of the teeth (Clearfil Majesty Posterior, Kuraray Medical Inc., Tokyo, Japan) was completed. The participants were asked to rate the intensity of their postoperative pain via a Visual Analog Scale at 6, 12, 24, 48, and 72 hours. The data were analyzed using the Shapiro–Wilk, Levene's, Student t, Repeated Measures ANOVA and the Chi-square test. **Results:** The basic demographic data and analgesic intake of the 2 study groups were similar. Compared with those in the control group, the postoperative pain scores at 6 and 12 hours were significantly lower in the cryotherapy group ($P < .05$). The postoperative pain scores at 24, 48, and 72 hours were similar in both study groups. **Conclusions:** During vital pulp treatment, the cryotherapy application after hemostasis reduced postoperative pain in permanent molars with symptomatic irreversible pulpitis in the early period. *(J Endod 2025;51:547–553.)*

KEY WORDS

Cryotherapy; irreversible pulpitis; postoperative pain; pulpotomy; vital pulp treatment

SIGNIFICANCE

The use of cryotherapy for pain control following vital pulp therapy may be beneficial because of its ease of application, lack of toxic effects on tissues, and cost-effectiveness.

Many different classification systems have been developed on the basis of clinical and histopathologic findings in pulp diseases. As a result, different histologic diagnoses of the same clinical condition have emerged. Clinically, pulp inflammation can be categorized as "reversible" or "irreversible" on the basis of the presumed healing capacity of the pulp[1]. The American Association of Endodontists defines irreversible pulpitis as "a clinical diagnosis based on subjective and objective findings indicating that the vital inflamed pulp is incapable of healing and that the root canal treatment is indicated."[1] One of the classic symptoms of irreversible pulpitis is severe pain that occurs in response to hot or cold stimuli. Patients often report dull, throbbing and spontaneous pain[2,3]. However, in teeth exhibiting these symptoms, inflammatory changes are often limited to the coronal pulp tissue adjacent to carious lesions, whereas the radicular pulp tissue remains uninflamed. As a result, there is an emerging understanding

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https://doi.org/10.1016/j.joen.2025.01.020

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that extensive removal of inflamed pulp tissue may allow preservation of the remaining noninflamed pulp tissue, potentially reversing pulpitis.

In the literature, formerly the preferred treatment option for teeth with symptomatic irreversible pulpitis was root canal therapy[4,5]. Although root canal therapy has a high success rate of approximately 89%, complications during canal shaping, such as ledge, zipping, strip perforation and instrument fractures play a significant role in treatment failure[6]. However, the emergence of new evidence indicating that clinical symptoms may not accurately reflect the histological status of the pulp tissue, along with new information regarding the reparative capacity of the pulp tissue and the development of biocompatible materials, has encouraged the application of vital pulp therapies (VPT) as alternatives to root canal treatment in recent years.

The management of postoperative pain in endodontic practice is important. Various studies aimed at controlling postoperative pain have utilized various treatment strategies, including the use of analgesics, antihistamines and corticosteroids, occlusal reduction, low-level laser therapy, and local anesthetic applications[7-10].

Cryotherapy has recently gained popularity as a technique for reducing postoperative pain in endodontic practice. The term cryotherapy is derived from the Greek word "cryos," which means "cold."[11] The aim of cryotherapy is to reduce the temperature of the tissue, thereby decreasing the nerve conduction velocity[12,13]. In this way, inflammation, bleeding, edema, and the number of leukocytes adhering to the endothelial walls of the capillaries are reduced[14]. The aim of this study was to evaluate the effect of the application of cryotherapy with cold saline on postoperative pain after full pulpotomy procedures in patients with symptomatic irreversible pulpitis in permanent molars. The null hypothesis of this study was that there would be no difference in postoperative pain between the cryotherapy group and the control group.

METHODS

This study is a single-blind, randomized controlled clinical trial. Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Cukurova University Faculty of Medicine (reference no. IRB/144/2024). The study protocol was registered with the ClinicalTrials.gov (NCT06644703).

This study included 42 females and 24 males aged 14-60 years who were systemically healthy and had permanent molars with symptomatic irreversible pulpitis. Informed written consent was obtained from all participants involved in the study.

Inclusion Criteria

- First and second maxillary or mandibular molars with moderate or severe pain according to the VAS (no pain (0 mm), mild pain (1–3 mm), moderate pain (4–6 mm), and severe pain (7–10 mm))
- Teeth that responded positively to the cold test and electric pulp test
- Teeth that responded negatively to percussion and palpation tests
- Teeth without periapical pathosis

Exclusion Criteria

- Teeth with requiring postcore restoration
- Teeth that have periapical pathosis radiographically
- Teeth that have poor periodontal status (pocket depth $>$ 4 mm),
- Teeth that responded negatively to the cold test and electric pulp test
- Teeth with no pulp exposure after caries removal
- Patients who have no preoperative pain or mild pain according to the Visual Analog Scale (VAS) score
- Patients with bleeding disorders, immunosuppressive diseases, or systemic conditions such as diabetes

Sample Size Calculation

The sample size calculation was based on the previous study[9] using a G*Power v.3.1.9.2 (Heinrich Heine, Dusseldorf University, Dusseldorf Germany) with a 80% power, a 5% α error, and an effect size of 0.5. The minimum sample size was calculated to be 48. Considering patients lost to follow-up, a total of 66 teeth from different patients were included in this study.

Group Randomization

Patients were randomly assigned to the control group or the cryotherapy group. Randomization was performed using online software with a block randomization technique of four block sizes to ensure equal distribution between the groups (www.randomizer.org).

Access Cavity Preparation

All endodontic procedures were performed by a single operator (K.G.) under magnification (3x loupes) and illumination. The teeth were isolated with a rubber dam after anesthesia was administered to the relevant teeth using 4% articaine hydrochloride with 1:1,00,000 adrenaline (Ultracain D-S; Sanofi, Paris, France). Before caries removal, the teeth were disinfected with a 2% chlorhexidine digluconate solution. Caries tissues were removed with high-speed sterile diamond burs under water cooling.

Pulpotomy Procedures

The coronal pulp tissue was completely removed with high-speed sterile diamond bur under water cooling. The procedural steps according to the study groups were as follows:

Control group (n = 32): The exposed pulp tissue was irrigated with 5 ml of 2.5% sodium hypochlorite (NaOCl). Cotton pellets moistened with 2.5% NaOCl were used to achieve hemostasis.

Cryotherapy group (n = 30): The exposed pulp tissue was irrigated with 5 ml of 2.5% sodium hypochlorite (NaOCl). Cotton pellets moistened with 2.5% NaOCl were used to achieve hemostasis. After hemostasis was achieved, the pulpotomy area was irrigated for 5 minutes with normal saline solution, which was kept in a cooler set to 2.5°C and verified with a digital thermometer to ensure that the temperature was 2.5°C. During irrigation, the irrigation needle was placed 1–2 mm above the root canal orifices, and irrigation was performed via continuous circular motions.

In both experimental groups, if hemostasis could not be achieved within 8 minutes after the removal of the coronal pulp tissue, root canal treatment was performed on the teeth, as it was considered that the radicular pulp tissue was irreversibly inflamed, and these patients were excluded from the study. After hemostasis was achieved, the canal orifices and pulp chambers in both study groups were covered with 2–3 mm thick Bio mineral trioxide aggregate (MTA)+ (Cerkamed Company, Poland). A moist cotton pellet was placed on the MTA, and after completing a 10-minute setting time, resin-modified glass ionomer cement (Equia Forte HT with Equia Coat, GC America) was applied on MTA, followed by composite restoration (Clearfil Majesty Posterior, Kuraray Medical Inc., Tokyo, Japan) of the teeth at the same visit (Fig. 1). Patients in both groups were prescribed 400 mg of ibuprofen after treatment and were instructed to use it if necessary. Patients were informed that they should consult an endodontist in cases of severe postoperative pain that does not respond to analgesics.

Postoperative Evaluation

A blinded researcher (K.Y.) performed the observation of postoperative pain in this study. A questionnaire was administered to all participants on the basis of the VAS score,

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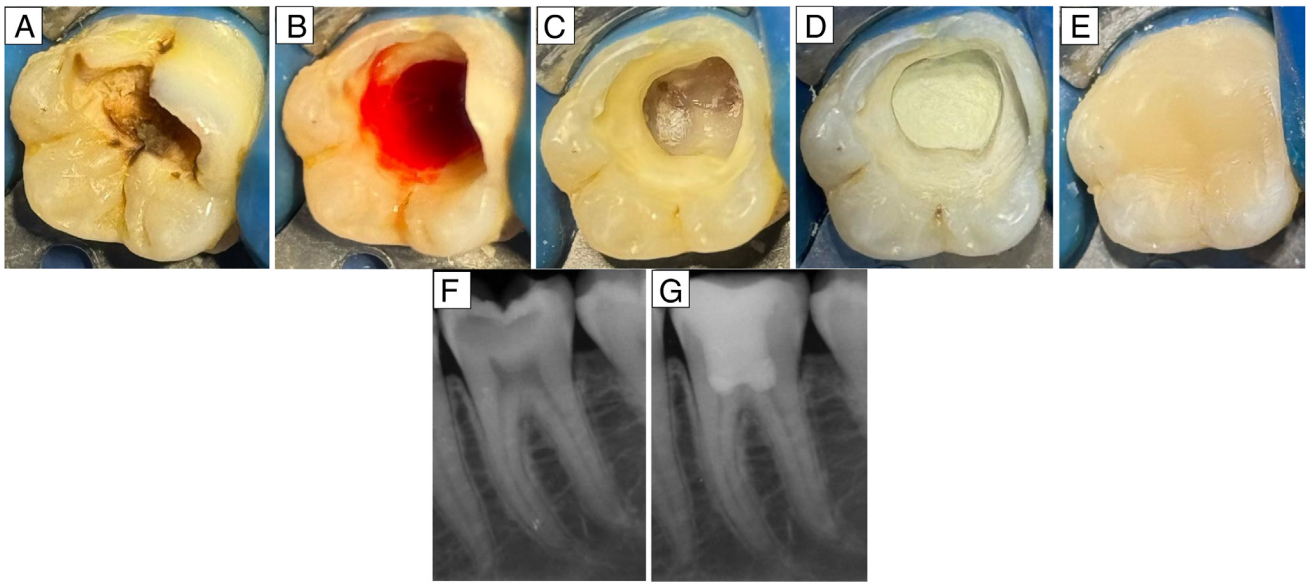


FIGURE 1 – Cryotherapy Group Clinical Photographs (*A*) Preoperative appearance (*B*) Complete removal of coronal pulp tissue (*C*) Hemostasis achieved (*D*) Placement of 2–3 mm thick layer of MTA (*E*) Final restoration (*F*) Preoperative periapical radiography (*G*) Postoperative periapical radiography. MTA, mineral trioxide aggregate.

which revealed their pain levels and analgesic intake at 6, 12, 24, 48, and 72 hours postoperatively. Patients were asked to complete the form. Patients were called for a clinical examination 72 hours after treatment, and those who were clinically asymptomatic were scheduled for long-term follow-up appointments.

Statistical Analysis

SPSS 22.0 software (IBM Corp, Amork, NY) was used for statistical analysis of the obtained data. The pain scores data were normally distributed according to the Shapiro–Wilk test. The homogeneity of the data was assessed with Levene's test. Student t test was used between the groups for pain scores. Pain values at different hours (6, 12, 24, 48, and 72 hours) for each group were analyzed via Repeated Measures ANOVA and multiple-comparison test with Bonferroni correction (α = 0,05) at significance level of $P < .05$. The Chi-square test was applied to compare demographic data and analgesic intake across the 2 groups. The level of significance was set at $P < .05$.

RESULTS

A total of 84 teeth were evaluated for eligibility, and for 66 teeth, the diagnosis of vital inflamed pulp was confirmed after exposing the pulp tissue for all included teeth (n = 66)." None of the teeth had an intraoperative diagnosis of pulp necrosis. Owing to failure to achieve hemostasis within 8 minutes, one tooth from each group was excluded from the study. The remaining 64 teeth were randomly divided into 2 groups and full pulpotomy treatment was performed. Two patients were excluded from the cryotherapy group during the follow-up period (Fig. 2).

The basic demographic data and preoperative pain scores of the two study groups are shown in Table 1. There were no statistically significant differences in the preoperative pain scores between the control and cryotherapy groups ($P > .05$). A total of 40 female and 22 male patients with 26 maxillary and 36 mandibular molars underwent full pulpotomy. There were no statistically significant differences between the control and cryotherapy groups in terms of demographic data (gender and location) ($P > .05$) Compared with those in the control group, the postoperative pain scores at 6 and 12 hours were significantly lower in the cryotherapy group ($P < .05$). Postoperative pain scores at 24, 48, and 72 hours were similar in both study groups. In the control group, there were significant differences in the postoperative pain scores between 6 and 24, 48, and 72. In the cryotherapy group, there were significant differences in the postoperative pain scores between 6 and 48, and 72 hours (Table 2) (Fig. 3). In the control group, 5 patients used analgesics during the postoperative period, whereas in the cryotherapy group, 2 patients used analgesics. There were no statistically significant differences in analgesic intake between the control and cryotherapy groups ($P > .05$) (Table 3).

DISCUSSION

Irreversible pulpitis, classified under traditional pulp disease classification, is a pulp condition in which the pulp is damaged beyond recovery and presents clinically with severe spontaneous pain in patients. According to this classification system, for many years, teeth diagnosed with irreversible pulpitis have been treated with root canal therapy, which is based on clinical symptoms. However, on the basis of similar studies in the literature, both partial and full pulpotomy have begun to be applied in these patients[15,16]. The advantages of the VPT include a lower risk of complications than does the root canal treatment, the ability to maintain pulp health and vitality, and consequently, the continued development of roots in the immature teeth. For this purpose, we preferred VPT as a current alternative to root canal treatment in permanent molars with symptomatic irreversible pulpitis.

In addition to an accurate clinical diagnosis, the selection of pulp capping material is an important factor in the success of VPT. High success rates have been achieved using MTA in full pulpotomy applied to teeth with symptoms and signs of symptomatic irreversible pulpitis[17,18]. MTA has excellent sealing ability, as well as remarkable marginal adaptation, biocompatibility, and outstanding clinical outcomes[19]. Additionally, recent studies have shown that compared with calcium hydroxide, MTA achieves better and more complete dentin bridge formation as a pulpotomy agent[20,21]. In the present study,

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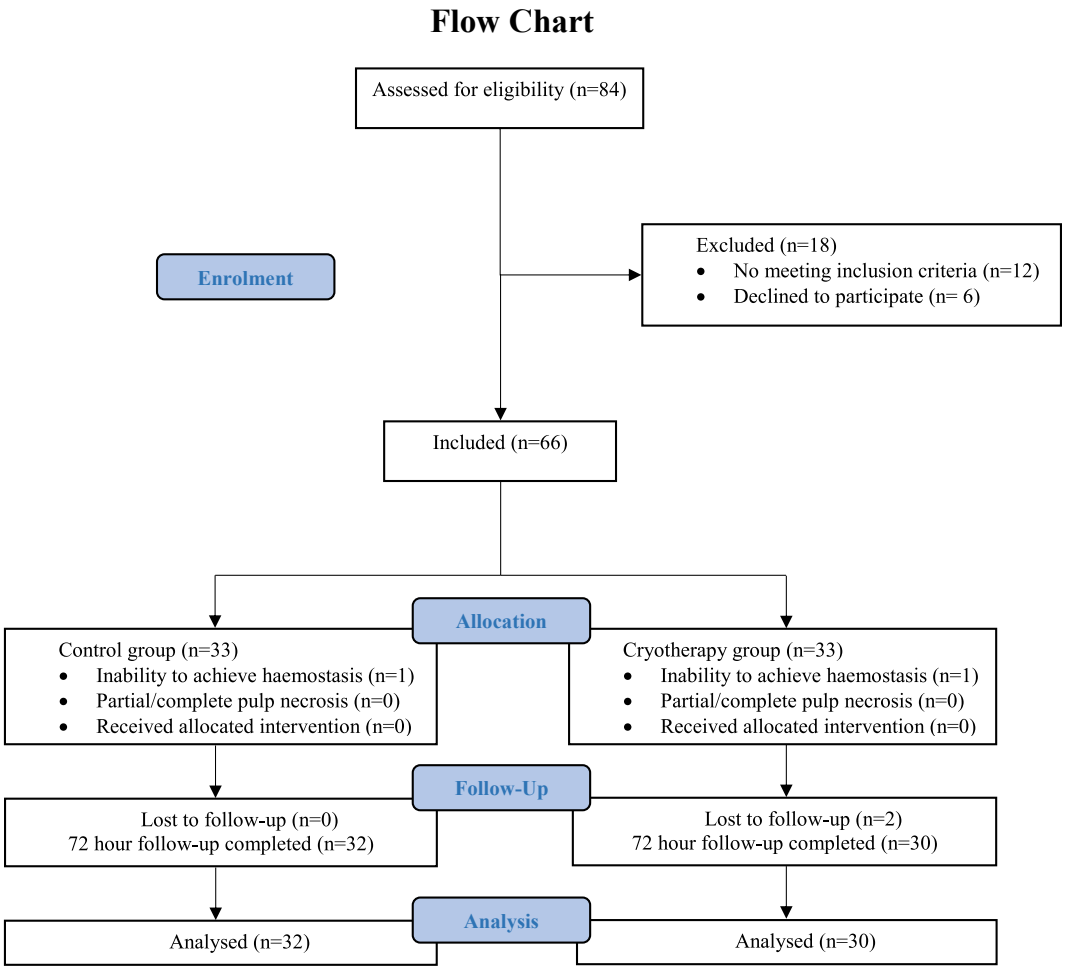


FIGURE 2 – The flowchart of participants throughout the trial

MTA was chosen as the pulp capping material because its properties, such as biocompatibility, the ability to be placed in sufficient volume, and the immediate formation of a coronal seal under rubber dam isolation, contribute to high success rates.

The age of the patient is a controversial topic in the literature regarding VPT. It has been suggested that the greater fibrous and less resistant structure of the pulp in older patients may reduce its ability to heal damage. In immature permanent teeth, the pulp can provide greater resistance to bacterial infection because of its rich collateral circulation and strong defense mechanisms[22]. Although VPT should be performed only on young patients with permanent teeth[23], successful results have also been achieved in patients up to 70 years of age[4,24]. Therefore, we included patients aged between 14 and 60 years in our study.

In teeth undergoing endodontic treatment, the reasons for postoperative pain include not only the materials and techniques used during the procedure but also the preoperative pain levels of the patients, which are known to be significant factors. In teeth indicating moderate to severe preoperative pain on the basis of VAS scores, the frequency and intensity of postoperative pain are greater than those in teeth that are only mildly painful or pain free prior to the procedure[25]. For this reason, in our study aimed at evaluating postoperative pain, we included permanent molars with symptomatic irreversible pulpitis that had moderate to severe preoperative pain.

TABLE 1 - Preoperative Pain Scores and Baseline Demographics

		Gender				Location			
	Preoperative pain	Female		Male		Maxillary		Mandibular	
Study groups	(Mean ± SD)	*n*	%	*n*	%	*n*	%	*n*	%
Control (n = 32)	7.124 ± 2.132	22	68.8	10	31.3	14	43.8	18	56.3
Cryotherapy (n = 30)	6.986 ± 1.927	18	60	12	40	12	40	18	60
P value	.402*	.650†				.967†			

*Student t Test.
†$\chi 2$ test.

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TABLE 2 - Mean (± Standard Deviation) Postoperative Pain Score Values at 6 h, 12 h, 24 h, 48 h, and 72 h (VAS) in the 2 Groups

	6 h	12 h	24 h	48 h	72 h
Study Group	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Control	3.500 ± 2.271[a]	1.750 ± 1.849[ab]	1.00 ± 1.796[b]	0.437 ± 0.715[b]	0.375 ± 0.793[b]
Cryotherapy	1.933 ± 1.874[a]	0.866 ± 1.224[ab]	0.866 ± 1.279[ab]	0.466 ± 0.899[b]	0.533 ± 0.899[b]
P value	.005*	.032*	.739	.888	.464

Different superscript letters indicate significant differences in each row ($P < .05$).
*$P < .05$, statistically significant.

When vital pulp therapy is used for teeth with irreversible pulpitis, the patient's medical history, clinical findings, and relevant radiographic findings should be examined. The aim of this study was to assess the degree of inflammation of the affected tooth and to determine the prognosis of the tooth after VPT. Hemostasis time is among the indicators used to determine the state of inflammation in the pulp. Teeth in which hemostasis cannot be achieved are those with irreversible inflamed pulp or those from which sufficient tissue could not be removed to reach healthy pulp tissue. The literature reports that hemostasis times between 5 and 10 minutes after coronal pulp amputation indicate that healthy pulp tissue has been reached and that the inflammation in the pulp is reversible[26]. In our study, we also chose an 8 minute hemostasis time, referencing similar studies.

The steps of the root canal treatment aim to reduce the microbial load both within the root canal and in the periapical tissues, thereby decreasing inflammation levels[27]. The success rate of VPT, which we applied as an alternative to the root canal treatment in our study, depends on the state of inflammation in the pulp and the levels of inflammatory biomarkers within the pulp. Among these biomarkers are Substance P, IL-6, IL-8, MMP-9, TNF-α, and PGE2[28]. These biomarkers are also among the factors that determine the level of postoperative pain following VPT[29]. There are only a few studies in the literature examining the extent to which cryotherapy affects the levels of biomarkers in inflamed pulp and its impact on the prognosis of inflammation[30,31]. Therefore, in our study, we aimed to evaluate the effect of cryotherapy in VPTs on postoperative pain in permanent molars with symptomatic irreversible pulpitis.

According to the results obtained in our study, the VAS scores at 6 and 12 hours were significantly lower in the vital pulp therapy group than in the group that did not receive cryotherapy ($P < .05$). At 24, 48, and 72 hours, significant reductions in the VAS scores were observed in both groups; however, no statistically significant difference was found between the two groups ($P > .05$). Akhil et al investigated the effect of cryotherapy on postoperative pain in mandibular molars with symptomatic irreversible pulpitis and reported that the VAS scores in the cryotherapy group were significantly lower at 24 and 48 hours than those in the conventional pulpotomy group. The authors attributed this result to the removal of infected coronal pulp tissue during the VPT and the reduction in local tissue pressure. Additionally, they reported that the application of cryotherapy resulted in a decrease in the temperature of the surrounding tissues by 7°C and 3°C, respectively, leading to the deactivation of myelinated A-δ fibers and unmyelinated C fibers, which contributed to the reduction in postoperative pain[30]. There are no other studies in the literature with which we can directly discuss our results apart from this study.

Keskin et al reported in their study on symptomatic and asymptomatic maxillary and mandibular teeth that the application of cryotherapy resulted in a significant reduction in postoperative pain. The authors stated that cryotherapy induces vasoconstriction in blood vessels, reducing the blood flow rate and limiting the metabolic rate due to decreased

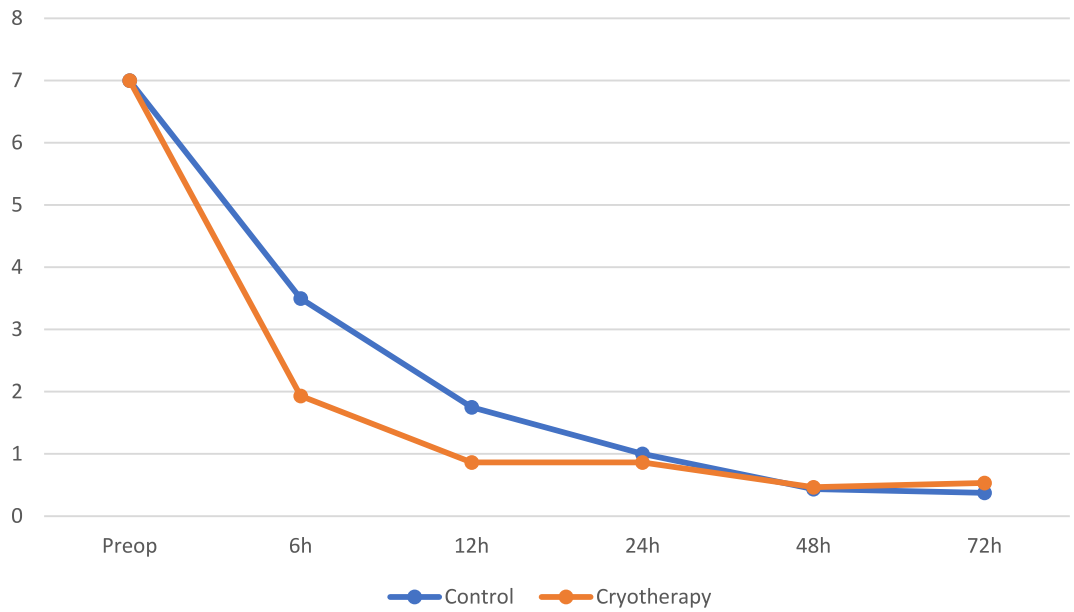


FIGURE 3 – Plots for pain score values at baseline, 6 h, 12 h, 24 h, 48 h, and 72 h (VAS) in 2 groups. VAS, Visual Analog Scale.

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TABLE 3 - Frequency and Percentage of Analgesic Intake According to Group

	Control ($n = 32$)	Cryotherapy ($n = 30$)	Total ($n = 62$)	*P* value
Analgesic intake				
Yes	5 (15.6)	2 (6.7)	7 (11.3)	.427*
No	27 (84.4)	28 (93.3)	55 (88.7)	

*$P > .05$, statistically not significant.

oxygenation in the tissues[32]. Vera et al demonstrated in their *in vitro* study that irrigating root canals with a 2.5°C cold saline solution for 5 minutes reduced the temperature of the external root surface by more than 10°C and maintained this temperature for 4 minutes. Similar to the results of our study, these findings indicate that a decrease in temperature on the external surface of the root reduces inflammatory reactions, leading to a decrease in the release of mediators that cause pain and a reduction in periapical edema[11].

The medical literature also reports that cryotherapy reduces the use of narcotic medications during the postoperative period[33]. According to the results of the present study, the number of patients who used analgesic anti-inflammatory medications after the procedure was greater in the control group but there were no statistically significant differences between the 2 groups.

The fact that we determined the degree of inflammation in the pulp of the teeth included in our study on the basis of clinical symptoms and those biomarkers such as TNF-α, IL-6, IL-8, and MMP-9, which could indicate pulp health, were not evaluated can be considered limitations of our study. Additionally, the fact that the randomization of the study groups was performed prior to treatment and that the syringes used for the cold saline solution in cryotherapy were cold, making it impossible for the endodontists to remain blinded, can also be considered limitations of the study.

In conclusion, we believe that the use of cryotherapy for pain control following VPT may be beneficial because of its ease of application, lack of toxic effects on tissues, and cost-effectiveness. However, further studies are needed to determine the long-term effects of cryotherapy on vital pulpal teeth.

CONCLUSION

During VPT, the cryotherapy application after hemostasis reduced postoperative pain in permanent molars with symptomatic irreversible pulpitis in the early period.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Kübra Gürler: Clinical procedures, Investigation, Writing – review & editing. **Koray Yilmaz:** Investigation, Methodology, Supervision, Writing – review & editing.

ACKNOWLEDGMENTS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

The authors deny any conflicts of interest related to this study.

REFERENCES

1. Glickman GN. AAE consensus conference on diagnostic terminology: background and perspectives. J Endod 2009;35:1619–20.
2. M T. Pulp and periradicular pathosis. In: Walton RE, Torabinejad M, editors. Principles and practice of endodontics. 3rd ed. Philadelphia: WB Saunders Co; 2002.
3. Glickman GN MAK, Levin LG, Fouad AF, Johnson WT. Glossary of endodontic terms. 7th ed. Chicago: American Association of Endodontists; 2003.
4. Aguilar P, Linsuwanont P. Vital pulp therapy in vital permanent teeth with cariously exposed pulp: a systematic review. J Endod 2011;37:581–7.
5. Alqaderi H, Lee C-T, Borzangy S, Pagonis TC. Coronal pulpotomy for cariously exposed permanent posterior teeth with closed apices: a systematic review and meta-analysis. J Dent 2016;44:1–7.
6. Asgary S, Eghbal MJ, Ghoddusi J, Yazdani S. One-year results of vital pulp therapy in permanent molars with irreversible pulpitis: an ongoing multicenter, randomized, non-inferiority clinical trial. Clin Oral Investig 2013;17:431–9.
7. Mehrvarzfar P, Abbott PV, Saghiri MA. Effects of three oral analgesics on postoperative pain following root canal preparation: a controlled clinical trial. Int Endod J 2012;45:76–82.
8. Pochapski MT, Santos FA, Andrade EDD. Effect of pretreatment dexamethasone on postendodontic pain. Oral Surg 2009;108:790–5.
9. Parirokh M, Rekabi AR, Ashouri R, Nakhaee N. Effect of occlusal reduction on postoperative pain in teeth with irreversible pulpitis and mild tenderness to percussion. J Endod 2013;39:1–5.
10. Yıldız ED, Arslan H. Effect of low-level laser therapy on postoperative pain in molars with symptomatic apical periodontitis: a randomized placebo-controlled clinical Trial. J Endod 2018;44:1610–5.

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11. Vera J, Ochoa-Rivera J, Vazquez-Carcaño M. Effect of intracanal cryotherapy on reducing root surface temperature. J Endod 2015;41:1884–7.
12. Hubbard TJ, Denegar CR. Does cryotherapy improve outcomes with soft tissue injury. J Athl Train 2004;39:278–9.
13. Modabber A, Rana M, Ghassemi A, Gerressen M. Three-dimensional evaluation of postoperative swelling in treatment of zygomatic bone fractures using two different cooling therapy methods: a randomized, observer-blind, prospective study. Trials 2013;14:238.
14. Laureano Filho JR, de Oilva e Silva ED, Camargo IB. The influence of cryotherapy on reduction of swelling, pain and trismus after third-molar extraction: a preliminary study. J Am Dent Assoc 2005;136:774–8.
15. Asgary S, Eghbal MJ, Ghoddusi J. Two-year results of vital pulp therapy in permanent molars with irreversible pulpitis: an ongoing multicenter randomized clinical trial. Clin Oral Investig 2014;18:635–41.
16. Taha NA, Khazali MA. Partial pulpotomy in mature permanent teeth with clinical signs indicative of irreversible pulpitis: a randomized clinical trial. J Endod 2017;43:1417–21.
17. Witherspoon DE, Small JC, Harris GZ. Mineral trioxide aggregate pulpotomies: a case series outcomes assessment. J Am Dent Assoc 2006;137:610–8.
18. Qudeimat MA, Alyahya A, Hasan AA. Mineral trioxide aggregate pulpotomy for permanent molars with clinical signs indicative of irreversible pulpitis: a preliminary study. Int Endod J 2017;50:126–34.
19. Alqaderi HE, Al-Mutawa SA, Qudeimat MA. MTA pulpotomy as an alternative to root canal treatment in children's permanent teeth in a dental public health setting. J Dent 2014;42:1390–5.
20. Chailertvanitkul P, P J, Sooksantisakoonchai N, et al. Randomized control trial comparing calcium hydroxide and mineral trioxide aggregate for partial pulpotomies in cariously exposed pulps of permanent molars. Int Endod J 2014;47:836–42.
21. Barrieshi-Nusair KM, Qudeimat MA. A prospective clinical study of mineral trioxide aggregate for partial pulpotomy in cariously exposed permanent teeth. J Endod 2006;32:731–5.
22. Takahashi K. Changes in the pulpal vasculature during inflammation. J Endod 1990;16:92–7.
23. Ward J. Vital pulp therapy in cariously exposed permanent teeth and its limitations. Aust Endod J 2002;28:29–37.
24. Mente J, Geletneky B, Ohle M, et al. Mineral trioxide aggregate or calcium hydroxide direct pulp capping: an analysis of the clinical treatment outcome. J Endod 2010;36:806–13.
25. ElMubarak AHH, Abu-bakr NH, Ibrahim YE. Postoperative pain in multiple-visit and single-visit root canal treatment. J Endod 2010;36:36–9.
26. Tan SY, Yu VSH, Lim KC, et al. Long-term pulpal and restorative outcomes of pulpotomy in mature permanent teeth. J Endod 2020;46:383–90.
27. Barbosa-Ribeiro M, Arruda-Vasconcelos R. Effectiveness of calcium hydroxide-based intracanal medication on infectious/inflammatory contents in teeth with post-treatment apical periodontitis. Clin Oral Investig 2019;23:2759–66.
28. Duncan HF, El-Karim I, Dummer PMH. Factors that influence the outcome of pulpotomy in permanent teeth. Int Endod J 2023;56(Suppl 2):62–81.
29. Wieckiewicz M, Boening K, Wiland P, et al. Reported concepts for the treatment modalities and pain management of temporomandibular disorders. J Headache Pain 2015;16:106.
30. Akhil VS, Kumar V, Aravind A, et al. Novel cryotherapy technique for pulpotomy in mature permanent teeth with symptomatic irreversible pulpitis-a randomized controlled trial. Clin Oral Investig 2024;28:1–14.
31. Keskin C, Aksoy A, Kalyoncuoğlu E. Effect of intracanal cryotherapy on the inflammatory cytokine, proteolytic enzyme levels and post-operative pain in teeth with asymptomatic apical periodontitis: a randomized clinical trial. Int Endod J 2023;56:932–42.
32. Keskin C, Özdemir Ö, Uzun İ, Güler B. Effect of intracanal cryotherapy on pain after single-visit root canal treatment. Aust Endod J 2017;43:83–8.
33. Watkins AA, Johnson TV, Shrewsberry AB. Ice packs reduce postoperative midline incision pain and narcotic use: a randomized controlled trial. J Am Coll Surg 2014;219:511–7.

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