Effect of Photobiomodulation Therapy following Direct Pulp Capping on Postoperative Sensitivity by Thermal Stimulus: A Retrospective Study

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Highlights of the Study

- Cold sensitivity is one of the most common complications after the pulp capping procedure, which is an unpleasant situation for both patients and doctors.
- Photobiomodulation therapy can help decrease discomfort and inflammation formed in the pulp following pulp capping procedures and manage patients' pain during the posttreatment period.

Keywords

Biostimulation · Direct pulp capping · Photobiomodulation therapy · Thermal stimulus

Abstract

Objective: The aim of this study was to investigate the effect of photobiomodulation therapy (PBMT) on postoperative pain provoked by thermal stimulation in direct pulp capping (DPC). **Subjects and Methods:** A retrospective study was performed using the records of patients who received DPC using mineral trioxide aggregate. Teeth irradiated with a laser were assigned as the PBMT group, and nonirradiated teeth were considered as the control group. Before treatment and 6 h, 1 day, and 7 days after treatment, tooth sensitivity to a cold stimulus was recorded using a visual analog scale. **Results:** From a total of 123 documented DPC procedures, only 72 directly capped permanent teeth met the inclusion criteria. Age, gender, and tooth location were comparable between the groups. A statistically significant difference was found in sensitivity to cold stimulus between groups on day

7 ($p = 0.007$), but no difference was found at the preoperative, 6 h, and day 1 time points ($p = 0.055$, $p = 0.132$, and $p = 0.100$, respectively). In the intragroup evaluation, a significantly greater decrease in sensitivity to cold stimulus was detected in the PBMT group than that in the control group, although both groups showed a reduction in discomfort throughout the follow-up period ($p = 0.000$). **Conclusion:** PBMT is an effective method for enhancing patient comfort by reducing thermal sensitivity following DPC procedures.

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Introduction

Profound dentin caries may progress and cause pulpal inflammation that results in necrosis, abscess, and even tooth loss [1]. The purpose of direct pulp capping (DPC) is preserving and maintaining pulp health in teeth with pulp exposure due to trauma, caries, or restorative treatment [2]. DPC is performed in deciduous and young per-

manent teeth, in which the pulp has been mechanically or traumatically exposed, with no history of spontaneous pain or inflammation, in which bleeding can be controlled, and no radiographic pathology has been observed [3]. Depending on different types of pulp exposure, low and high success rates have been reported following carious and traumatic exposures, respectively [4]. Several factors beyond the type of exposure may influence the prognosis of DPC, such as the diameter and location of pulp exposure, the status of the pulp, patient age, and the pulp capping material used [5].

Pulp capping materials should be biocompatible, non-toxic, and antimicrobial to induce the differentiation of odontoblast-like cells and support the regeneration of the dentin-pulp complex [6]. Mineral trioxide aggregate (MTA) introduced in the 1990s as a novel cement is routinely used for root canal repair and as a DPC material. Clinicians have reported superior treatment outcomes, and various research reports have shown that this material is biocompatible; stimulates bone, periodontal ligament, and pulp repair; and has proper sealing in fluid penetration studies [7]. The success rates of DPC have been reported to be between 67% [8] and 97% [9] after both short- and long-term follow-ups for MTA.

Cold sensitivity is one of the most common complications after the pulp capping procedure, which is an unpleasant situation for both patients and doctors. Although several methods are recommended to decrease sensitivity following pulp capping procedures, an optimal strategy for pain relief has not yet been found. Thus, an appropriate, effective, and practicable way to overcome this complication is required.

In photobiomodulation therapy (PBMT), electromagnetic radiation in the visible wavelengths (380–700 nm) or in the near-infrared range (700–1,070 nm) is used, which reaches 3–15 mm depth of penetration in hard and soft tissues [10]. PBMT has been used in dentistry and medicine due to its anti-inflammatory, biomodulatory, and pain relief effects as well as its important role in wound healing [11, 12]. In addition, laser irradiation has been shown to induce hard tissue formation in dental pulp cells. It has been found that laser therapy can stimulate odontoblasts to release tertiary dentin and create a dentin bridge at the pulp exposure site in pulp capping treatments [13]. PBMT may be beneficial in reducing any damage or inflammation in the pulp following a pulp capping procedure because of its biostimulatory capability, leading to increased patient comfort. Besides, clinicians can better manage patient pain during the posttreatment period.

A search of the literature on low-power lasers used in pulp capping procedures revealed no publications directly related to the biostimulation effect of PBMT in DPC. The main goal of this study was to ascertain whether PBMT can be used to eliminate postoperative pain in DPC. We analyzed the effect of PBMT on postoperative pain provoked by thermal stimulation in pulp capping. In addition, the PBMT and control groups were compared in terms of clinical success rates in DPC.

Subjects and Methods

Patient Selection

Participants for this study were obtained from the pool of patients who attended for routine treatment at the Department of Endodontics at the Ordu University Hospital between October 2017 and October 2018. The patients had received DPC treatment by a single operator. The goal was to standardize the samples with a similar number of clinical cases for each of the groups. The study protocol was approved by the Ethics Committee of Clinical Research of Ordu University (Ref. 2019/122). In total, 123 teeth of 123 patients were examined. Cases that fulfilled the following criteria were included in the outcome analysis: (1) mandibular and maxillary permanent molars with pulpal exposure between 0.5 and 1.0 mm, (2) periodontally healthy teeth (no more than 3 mm probing depth), (3) pulpal exposure occurring only on the occlusal side of the tooth, (4) systemically healthy participants aged 15–45 years, (5) participants who signed the written consent form, (6) patients who have not used an analgesic or antibiotic in the past 2 weeks, (7) patients whose data are fully and accurately recorded, and (8) patients who do not use immunosuppressive drugs and do not need antibiotic prophylaxis. The following subjects were excluded from this study: (1) patients needing a second anesthetic, (2) the presence of a previous restoration of the tooth, (3) patients using psychiatric or sedative medication, (4) patients who had a DPC treatment on several teeth, (5) patients with tooth pain and in whom this pain was unable to be localized, (6) patients taking pain medication within 1 week of the procedure, (7) patients with a lack of data during the follow-up, and (8) teeth treated without the clinical procedures listed later.

Clinical Procedures

All participants were asked to sign a declaration of informed consent to take part in the study. Medical and dental anamnesis was obtained from all participants, and preoperative radiographs (Fig. 1a) were taken following the clinical examination. Baseline preoperative pain levels were recorded by a thermal test (Coltene/Whaledent Inc., Mahwah, NJ, USA). Local anesthesia (4% articaine and epinephrine 1: 100,000; Ultracain DS Fort, Aventis, Istanbul, Turkey) and rubber dam isolation were achieved. The decay was removed with a sterile bur (Meisinger, Germany). In the cases of pulpal exposure by caries removal, a saline-soaked cotton pellet was used for bleeding control for 5 min. If bleeding from the exposed pulp continued for longer than 5 min, irreversible inflammation of the pulp tissue was considered, and a root canal treatment was performed. After controlling the hemorrhage, the pulp exposure area was capped with MTA (ProRoot MTA; Maillefer, Dentsply, Switzerland), which was mixed according to the manu-

Fig. 1. **a** Preoperative radiograph showing deep caries. **b** Immediate postoperative radiograph. **c** Dentin bridge formation in the 6-month recall radiograph.

facturer's instructions. A glass ionomer cement (3M ESPE, St Paul, MN, USA) was placed over the MTA, and the permanent restoration was finished with a resin-bonded composite (3M ESPE, St. Paul, MN, USA). Control radiographs were taken at the end of the treatment (Fig. 1b).

Laser Application

An Nd-YAG laser (DEKA, Calenzano, Italy) with a fiber optic phototherapy probe (600 μ m) was used for laser irradiation under the following parameters: continuous wave mode, 1,064 nm wavelength, energy 100 mJ, frequency 10 Hz, power output 1 W, time 60 s, and 1 mm distance from the target tooth. Clinicians and patients were protected with glasses against any possible harm during laser application. The nonirradiated patients were assigned as the control group.

Follow-Up Evaluation

Similar to the baseline measurement, postoperative sensitivity was assessed with a cold spray and documented by a visual analog scale (VAS). The VAS consisted of a 10-cm line represented at one end by a sign for "no pain" and at the other end with "unbearable pain." Patients were instructed to record the pain intensity at home for 6 h, until the effect of anesthesia on postoperative sensitivity had disappeared. Patients were informed that the scoring must be performed only for sensitivity induced by cold beverages (e.g., ice water). Patients were also seen 1 day and 1 week postoperatively to indicate the degree of pain on the VAS as they had before. Teeth were examined clinically and radiographically at 1 and 6 months (shown in Fig. 1c). Failure was indicated by signs of inflammation (i.e., swelling, sinus tract, abscess, and pain that could not be controlled by an analgesic), presence of periapical lesions, and pulp necrosis. Patients were referred for root canal treatment in the case of any of the symptoms stated earlier or in the case of persistent severe pain.

Statistical Analysis

The normality and homogeneity of the data were tested. The data were analyzed by using the Mann-Whitney U, Wilcoxon signed-rank, Friedman, and ANCOVA tests. The analysis of clinical

success for each group was performed by using the χ^2 test. SPSS (Statistical Package for the Social Sciences, version 22.0, Chicago, IL, USA) was used for the statistical analyses. A p value ≤ 0.05 was accepted as statistically significant.

Results

From a total of 123 documented DPC, only 72 directly capped permanent teeth met the inclusion criteria. The patient distribution is shown in Figure 2. The baseline characteristics of the subjects were evaluated to assess the comparability between the PBMT and control groups. Age, gender, and tooth location were comparable between the groups (Table 1). Table 2 presents the mean and standard deviation of preoperative and postoperative sensitivity at the follow-up time points (6 h, day 1, and day 7) in the PBMT and control groups. Lower pain scores were observed at the 3 postoperative follow-up periods in the PBMT group than the control group (Fig. 3). This difference was significant for sensitivity to cold stimulus between the groups at day 7 ($p = 0.007$), but no difference was found at the preoperative, 6 h, and day 1 time points, respectively ($p = 0.055$, $p = 0.132$, and $p = 0.100$). In the intragroup evaluation, a significantly greater decrease was detected in the PBMT group than in the control group, while both groups showed a reduction in discomfort throughout the follow-up period, as shown in Table 2 ($p = 0.000$). The PBMT group showed a success rate of 97.2% (35/36), and the control group had a success rate of 86.1% (31/36). The overall success rate was 91.6% (66/72). Six cases failed, that is, one in the PBMT group and 5 in the control group. No statistically significant dif-

Fig. 2. Summarizing patients eligible for the study. PBMT, photobiomodulation therapy.

Table 1. Baseline characteristics of the included study participants in the PBMT and the control groups

	PBMT (n = 36)	Control (n = 36)	p value
Age, years			
Mean±SD	23.27±1.37	19.63±0.81	0.030
Gender, n (%)			
Female	23 (63.9)	20 (55.6)	0.099
Male	13 (36.1)	16 (44.4)	
Tooth location, N			
Maxilla	14	14	0.096
Mandible	22	22	

Statistical significance ($p < 0.05$). SD, standard deviation; PBMT, photobiomodulation therapy.

ference was observed in the success rates between the groups ($p = 0.201$).

Discussion

This retrospective study indicated that PBMT following the DPC procedure is a potent method to increase the comfort of patients with cold sensitivity. Lower pain scores were observed at the 3 postoperative follow-up periods in the PBMT group than in the control group. At day 7, the PBMT group showed significantly lower pain scores than the control group. When the difference in VAS scores between the pretreatment and each follow-up period was compared between the 2 groups, the PBMT group showed a significantly higher degree of pain relief than the control group.

Fig. 3. Comparison of tooth sensitivity between the PBMT and control groups before treatment and at the 3 examination periods after treatment. PBMT, photobiomodulation therapy; VAS, visual analog scale.

Table 2. Mean and SD regarding preoperative and postoperative sensitivity in PBMT and control groups at different evaluation points

	Preoperative (mean ± SD)	Postoperative (mean ± SD)			p value
		6 h	day 1	day 7	
PBMT	2.57±0.35	1.27±0.33	1.41±0.31	1.20±0.38	0.000*
Control	1.92±0.34	2.14±0.33	1.99±0.31	1.84±0.28	0.975
p value	0.055	0.132	0.100	0.007*	

SD, standard deviation; PBMT, photobiomodulation therapy. * Statistical significance ($p < 0.05$).

Generally, 2 methods are preferred in laser application. In the first technique, the laser is applied directly to the wound surface to achieve hemostatic and antiseptic effects. In the second method, low-power lasers are used to obtain a biostimulatory effect by stimulating the tissues [14]. In some studies, lasers have been used with different parameters for irradiation of the exposed pulp tissue, as mentioned in the first method, and have reported higher success rates. In a study by Moritz et al. [15], a carbon dioxide laser (10,600 nm) was used as a supplement to DPC.

Santucci [16] investigated the exposed pulp of teeth treated with calcium hydroxide (CH) and laser therapy and treated with CH alone. They reported significantly higher success rates in teeth treated with lasers. Olivi and Maturro [17] used an Er-YAG laser as an adjunct to DPC at different power parameters and different durations. Contrary to other studies, no significant difference was found in terms of success rates. Based on the results of our study, as separate groups, the success rate of DPC was 91.6%. Furthermore, the success of DPC in the PBMT and con-

trol groups was 97.2 and 86.1%, respectively. There was no statistically significant difference between the groups in terms of treatment success.

To the best of our knowledge, there are no studies on patients with postoperative pain induced by a cold stimulus following DPC using different variables such as pulp capping material, parameters of irradiation, and type of tooth. Thus, the results of the present study could not be compared to previous studies. However, a study by Moosavi et al. [11] assessed the effect of PBMT on reducing the postoperative sensitivity of restored teeth; 62 teeth of 31 patients were included and assigned in 2 groups, namely, laser and placebo. PBMT was applied shortly before the placement of resin composite on class V cavities and prior to treatment, and tooth sensitivity to a cold stimulus was recorded using the VAS on days 1, 14, and 30 after treatment. Significantly lower pain scores were found in patients irradiated with a low-power laser than in the placebo application. In the present study, although a different technique was used for laser application, we detected a significantly lower pain level in the PBMT group on day 7, similar to the previous study. The intra-group evaluation showed a significant decrease in pain levels in the PBMT group, but no significant difference was found in the control group.

Different wavelength and power settings of lasers may influence the treatment outcome. Some researchers have stated that PBMT can be performed with devices with a wavelength of 700–1,070 nm at 250–500 mW power [18, 19]. However, Kara et al. [20] operated PBMT in cell culture using an Nd-YAG laser at 0.5, 1, 2, and 3 W power and reported that the optimum energy was 1 W for cell proliferation. Therefore, in this study, the laser was applied at 1 W for 60 s, aiming at the pulp tissue, which is surrounded by enamel and dentin. Additionally, a biostimulation probe was used to avoid any potential tissue damage caused by thermal shock during the process. Contrary to other studies, we applied the laser to the external surface of the enamel and dentin for biostimulation of the pulp tissue. The purpose of this type of application was to determine whether cold-induced sensitivity can be reduced by PBMT without any intervention to the filling. The reason for using the Nd-YAG laser in this study was to ascertain whether successful results could be achieved in terms of eliminating postoperative sensitivity after DPC.

The type of pulp capping agent can also influence the outcome of DPC [21]. Although CH is the gold standard for DPC among all pulp capping agents, it has recently lost its popularity due to a lack of sealing ability, the presence of degradation over time, and inefficient biocompatibility

[6]. Studies have reported the clinical success rate of CH as 13% after 10 years [22]. In one study, mechanically or cariously exposed pulps were capped with MTA or CH; 80 and 68% success rates were found in the MTA and CH groups, respectively, after 2 years of follow-up [23]. Kundzina et al. [24] investigated the outcome of DPC using MTA and CH. They found a significantly higher success rate in the MTA group than in the CH group. In contrast, some researchers declared that CH showed similar satisfactory clinical outcomes to MTA [25, 26]. In recent years, MTA has been preferred in DPC due to its favorable properties including increased transcription factor levels, dentin bridge formation, excellent biocompatibility, sustained alkalinity, less leakage, and better sealing ability [27, 28]. In the present study, MTA was used in DPC procedures to provide standardization because of its higher success rate than CH in long-term outcomes.

A significantly higher grade of pain relief was detected in the PBMT group than in the control group but only on day 7. The setting mechanism of MTA can explain why no differences in VAS scores were found between the 2 earlier postoperative time points (6 h and day 1) between the 2 groups. MTA, which absorbs moisture from the pulp while hardening, could have suppressed hyperemia in the early period after DPC [29]. Therefore, postoperative pain might not have occurred in the first days when MTA hardening was ongoing in both groups, but by day 7, when the MTA was set and hyperemia in the pulp reappeared, laser application might have reduced this pain. The statistical difference between the 2 groups only on day 7 can be explained by this.

This study represents a new approach for minimizing postoperative sensitivity regarding a cold stimulus after DPC. PBMT should be considered as a safe and simple option for decreasing discomfort after DPC. Longer follow-up periods and applications with different parameters are required to demonstrate the benefits of PBMT as an adjuvant therapy to eliminate the discomfort of pulp capping procedures.

Patient age may have a role in the success of DPC. Researchers have stated that DPC is more successful in patients younger than 40 years [30, 31]. Therefore, we selected patients between the ages of 15 and 45 years for our study. Also, age was statistically different between the groups in our study. Although the mean age of the patients in the PBMT group was greater than the mean age of the patients in the control group, their pain on day 7 was less. To the best of our knowledge, there are no available data about this issue in the literature. Consequently, the findings of our study cannot be directly compared.

Because of the nature of the retrospective study, no sample size calculation was made, and all appropriate patients who had received both laser application and DPC or DPC alone during the stated study duration were included. Due to the retrospective nature of this study, the distribution of samples was not randomized, which is another limitation. Also, different wavelengths and different capping materials were not evaluated in the present study.

Conclusion

This study indicates that PBMT is effective in enhancing patient comfort by reducing thermal sensitivity following DPC procedures. On the basis of the results of the present study, randomized clinical studies with different wavelengths for PBMT and different capping materials are justified.

Statement of Ethics

This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and the 1964 Helsinki Dec-

laration and its later amendments or comparable ethical standards. The Ethics Committee of Clinical Research of Ordu University approved this study. Informed consent was obtained from all participants included in the study and has been registered retrospectively with the number "NCT04367324" on clinicaltrials.gov on April 29, 2020.

Conflict of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this article.

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Author Contributions

Adem Günaydın: conceptualization, data curation, writing, reviewing, and editing. Elif Bahar Çakıcı: visualization, investigation, supervision, and validation.

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