Original Article

A preliminary study on the effect of photobiomodulation with diode laser on direct pulp capping of cariously exposed teeth

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Abstract

Background: Vital pulp therapy has gained significant attention in modern clinical practice. However, direct pulp capping (DPC) success rates remain low due to bacterial contamination.

Aims and Objectives: This study explored novel techniques of preoperative disinfection and photobiomodulation with diode laser to enhance outcomes.

Materials and Methods: Forty patients were divided into two groups: Group A: Calcium hydroxide pulp capping, Group B: Preoperative disinfection with sodium hypochlorite (one minute) + photobiomodulation with diode laser + composite restoration.

Statistical Analysis: Cochran's Q Test compared pain, tooth sensibility, and radiographic changes at 1, 3, and 6 months ($p<0.05$).

Results: The study yielded success rates of 80% and 90% for groups A and B, respectively. Group B showed increased success rates, although not statistically significant which can be attributed to the laser's biostimulation properties.

Conclusion: This study suggests that combining preoperative disinfection and photobiomodulation with diode laser may improve DPC success rates, offering a promising approach in vital pulp therapy. Further research is warranted to confirm these findings.

Keywords: Calcium hydroxide; diode laser; direct pulp capping; photobiomodulation

INTRODUCTION

Direct pulp capping (DPC) is a vital pulp therapy procedure used for treating pulp exposure caused by caries, trauma, or mechanical cavity preparation. This treatment involves applying a medicament over the exposed pulp to promote dentin bridge formation, prevent bacterial contamination, and maintain pulp vitality.[1-3]

Common medicaments for DPC include formacresol, resins, glass ionomer cement, calcium hydroxide, mineral trioxide aggregate, and calcium silicate-based cements. These medicaments should ideally induce dentin bridge formation and possess biocompatibility and antibacterial properties. Calcium hydroxide, a longstanding pulp capping material, has the longest clinical track record in vital pulp therapy.[4]

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Literature highlights a lower success rate for pulp exposures attributed to caries with bacterial contamination being a key factor in unfavorable outcomes.[5] Success in DPC hinges on maintaining a sterile environment at the pulp exposure site and using a restorative material that ensures an effective seal, promoting optimal conditions for dentin bridge formation.[6] In this study, we emphasize the importance of asepsis in DPC. We assessed the effectiveness of rigorous tooth disinfection before DPC, combined with laser irradiation as an adjunct. Low-level laser therapy (LLLT) with a diode laser has been shown to increase the proliferation of dental pulp stem cells. The diode laser offers advantages like decontamination, biostimulation, and coagulation at the exposure site, and its soft-tissue interaction, with strong absorption by melanin and hemoglobin, facilitates precise treatment with deep tissue penetration.[6,7]

Although existing studies have explored the coagulative properties of diode lasers in pulp capping, this study specifically investigates their photobiomodulation potential in DPC. Thus, we designed this study to compare the efficacy of conventional DPC with diode laser-assisted DPC.

MATERIALS AND METHODS

This study was approved by an Institutional Ethical Committee after which 40 patients (ages 18–40 years) with deep caries close to pulp tissue were selected. The selection criteria were as follows.

Inclusion criteria

1. Permanent teeth with closed apices (both genders)
2. Carious pulp exposure ≤2 mm in diameter
3. Nonpersistent exaggerated response to cold test and preoperative diagnosis of reversible pulpitis
4. Caries involving three-fourth or more dentin thickness
5. Controlled pulpal bleeding within 10 min of pulp exposure
6. Tooth suitable for restoration with resin composite or amalgam.

Exclusion criteria

1. Presence of pain, swelling, pus exudate, fistula, or abnormal mobility
2. Periapical changes, root resorption, calcification, or pulp canal obliteration.

Statistical analysis

G Power (available for Windows XP, Vista, 7, 8, 10 and 11) analysis with 80% power and effect size 0.5 yielded a sample size of 32 teeth. Considering the 20% attrition rate 32 + 7 = 39, so the sample size was fixed at 20 per group.

Methodology

Patients were explained about the treatment protocol after which written informed consent was signed by them. Based on computer-generated random sequence allocation, patients were randomly allocated into two groups of 20 patients each. Group A received conventional calcium hydroxide pulp capping. Rubber dam isolation and local anesthesia were administered. Caries was excavated with sterile rotary and hand instruments, followed by bleeding control with 3% sodium hypochlorite-dampened cotton pellet. Calcium hydroxide paste (Dycal Radiopaque Calcium Hydroxide) was placed gently on the exposed pulp tissue. This was followed by permanent restoration with composite, occlusion was adjusted, and patients were recalled for follow-up [Figure 1a-d].

In Group B, teeth were disinfected using 3% sodium hypochlorite for 1 min before caries excavation. Bleeding control was achieved in the same manner as in Group A, followed by diode laser photobiomodulation (wavelength of 635 nm, fiber diameter of 400 μm, 0.1W power, and continuous wave for 1 min) over the exposed pulp before calcium hydroxide application and composite restoration [Figure 2a-e].

Participants returned at 1, 3, and 6 months for clinical and radiographic follow-ups [Figure 2f-i]. This 6-month study evaluated three parameters:

1. Pain perception
2. Pulp sensibility
3. Radiographic outcome.

Success was defined as the absence of pain, positive cold test response, and no periapical changes on the radiograph. Treatment was unsuccessful if there was pain, a negative response to a cold test, or radiographic evidence of periradicular changes. Failed cases were managed with endodontic therapy.

Statistical analysis

Data were analyzed using Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., with Cochran's Q-test examining changes in pain, tooth sensibility, and radiographic outcomes over three-time points (1, 3, and 6 months). A comparison of outcome between both the groups at 6 months was done using the Chi-square test. The level of significance was set at $P < 0.05$.

RESULTS

Group A showed gradual pain reduction [Table 1] (15%, 11%, and 0%), whereas Group B maintained stable, low pain levels (5%, 5.3%, and 0%).

Group B had no vitality loss, whereas Group A saw a slight decline [Table 1] (5%, 11%). Radiographically,

Figure 1: (a) Preoperative radiograph of 46 showing deep carious lesion. (b) One month postoperative radiograph of 46 treated with conventional calciumhydroxide pulp capping. (c) Three month post-operative radiograph of 46. (d) Six month postoperative radiograph of 46

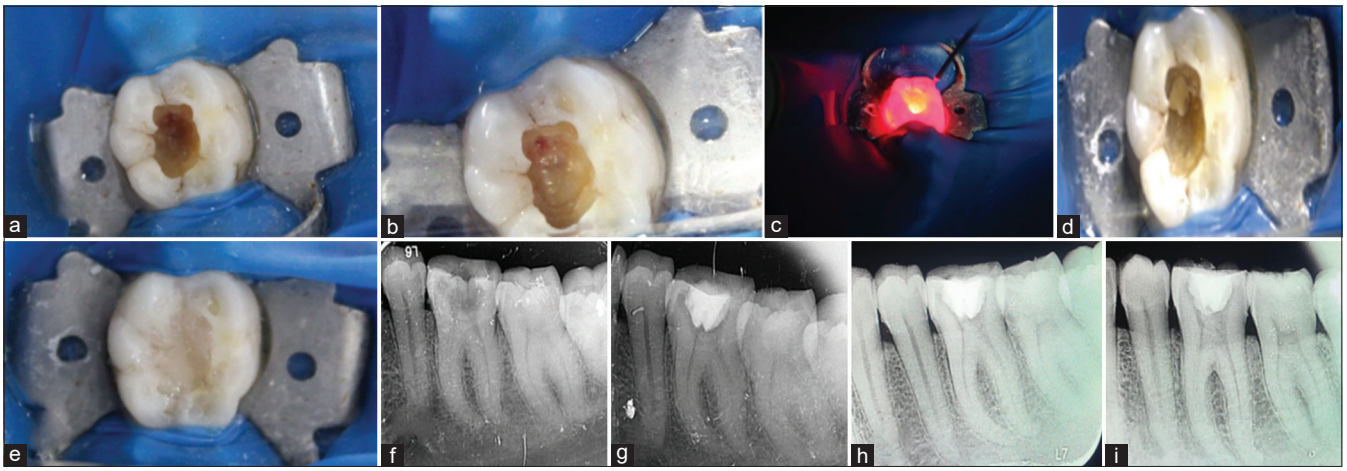

Figure 2: (a) Caries excavation of 36 done under rubber dam isolation. (b) Pin point pulp exposure of 36. (c) Diode laser irradiation (photobiomodulation) of exposed pulp. (d) Calcium hydroxide placed over exposed pulp. (e) Composite restoration placed. (f) Preoperative radiograph of 36 showing deep carious lesion. (g) One month post-operative radiograph of 36. (h) Three month post-operative radiograph of 36. (i) Six month postoperative radiograph of 36

Table 1: Comparison of pain perception, pulp sensibility and radiograhic outcomes over three time points -1, 3 and 6 months of group A and B with cochran's Q-test

Comparison of the presence of pain between different time intervals in each group using Cochran's *Q*-test					
Group	Pain	1 month, *n* (%)	3 months, *n* (%)	6 months, *n* (%)	*P*
Group A	Present	3 (15.0)	2 (11.1)	0	0.18
	Absent	17 (85.0)	16 (88.9)	16 (100.0)	
Group B	Present	1 (5.0)	1 (5.3)	0	0.43
	Absent	19 (95.0)	18 (94.7)	18 (100.0)	
Comparison of pulp sensibility between different time intervals in each group using Cochran's *Q*-test					
Group	Vitality	1 month, *n* (%)	3 months, *n* (%)	6 months, *n* (%)	*P*
Group A	Present	19 (95.0)	16 (88.9)	16 (100.0)	0.15
	Absent	1 (5.0)	2 (11.1)	0	
Group B	Present	20 (100.0)	19 (100.0)	18 (100.0)	-
	Absent	0	0	0	
Comparison of the presence of radiographic changes between different time intervals in each group using Cochran's *Q*-test					
Groups	Radiographic changes	1 month, *n* (%)	3 months, *n* (%)	6 months, *n* (%)	*P*
Group A	Present	1 (5.0)	2 (11.1)	0	0.65
	Absent	19 (95.0)	16 (88.9)	16 (100.0)	
Group B	Present	1 (5.0)	1 (5.3)	0	1.00
	Absent	19 (95.0)	18 (94.7)	18 (100.0)	

Group B experienced minimal changes [Table 1] (5%, 5.3%), whereas Group A showed a slight increase (5%, 11%). No significant differences were found in pain, pulp sensibility, or radiographic changes over time in either group.

The Chi-square test was employed to compare the outcomes between Group A and Group B at 6 months, yielding success rates of 80% and 90%, respectively [Table 2]. There was a relatively increased success rate observed in Group B compared to A;

Table 2: Comparison of outcomes between 2 groups at 6-month period using Chi-square test

Variable	Category	Group A, *n* (%)	Group B, *n* (%)	*P*
Outcome	Success	16 (80.0)	18 (90.0)	0.38
	Failure	4 (20.0)	2 (10.0)	

however, there was no significant difference in success rate in both the groups.

DISCUSSION

Management of deep caries lesions in dentistry has undergone a paradigm shift from aggressive endodontic therapy to a conservative approach of vital pulp therapy.[8] The efficacy of vital pulp therapy is well-established in dental practice, with a robust body of literature validating its effectiveness.[9] Exposure of the pulp with a diagnosis of reversible pulpitis during caries excavation can be effectively managed by DPC.[10] Among the array of pulp-capping agents documented in literature, calcium hydroxide stands out as the gold standard, with a proven clinical track record which prompted its selection for pulp capping in the present study.[11] Calcium hydroxide has antibacterial properties and induces dentin bridge formation by the release of bioactive molecules which are proteins. These proteins include bone morphogenetic protein and transforming growth factor-beta one which help in dentin matrix formation.[4]

The present study employs two novel therapeutic approaches, preoperative disinfection of the involved teeth and photobiomodulation of the exposed pulp using a diode laser.

Treatment failure occurred in four Group A participants, with associated outcomes including pain ($n = 4$), negative pulp sensibility, and radiographic alterations ($n = 3$). Several predictors of treatment failure include compromise in the seal between pulp capping material and restorative material, anatomical variations, and age-related characteristics.

Group B had only two failures with the presence of pain and radiographic changes compared to Group A, with better overall performance, despite no statistical difference in success rates.

Literature analysis indicates that bacterial contamination significantly compromises the effectiveness of DPC in treating carious pulp exposures.[5,12]

This emphasizes the fact that lowering the bacterial load at the exposure site should be considered during this procedure. Group B participants received an innovative preoperative treatment, involving 1-min disinfection with 3% sodium hypochlorite, a method not previously explored, along with photobiomodulation using a diode laser. Unlike studies that used high-power diode lasers for coagulation, our study used photobiomodulation or LLLT for biostimulation.

Although no statistically significant difference was observed between groups, Group B demonstrated favorable trends in pain perception, pulp sensibility, and radiographic evaluation. The study yielded success rates of 80% and 90% for Groups A and B, respectively. The improved outcomes in Group B suggest that photobiomodulation, facilitated by laser therapy, and rigorous preoperative tooth disinfection may have contributed to enhanced treatment efficacy.

The laser parameters used herein (diode laser parameters for photobiomodulation – 635 nm, 400 μm fiber diameter, 0.1W, continuous wave, and 1-min duration) were in agreement with the established standards of AlGhamdi and Bernardi. LLLT irradiation refers to the use of red-beam or near-infrared lasers with a wavelength of 600–1100 nm and an output power of 1–500 mW in continuous wave or pulsed light. Studies confirmed that laser irradiation (600–1200 nm) with energy fluence (0.05–10 J/cm^2) induces biostimulation, enhancing cell proliferation.[13-17]

The application of diode laser causes biostimulation of injured pulp tissue triggering a cascade of beneficial effects, including anti-inflammatory and analgesic effects, promotion of cellular growth and migration, odontoblastic differentiation, and formation of reparative dentin.

LLLT utilizes photobiomodulation to interact with cellular photoreceptors, converting light energy into biochemical energy. This process enhances cellular function, proliferation, and repair while reducing pain, edema, and inflammation. Specifically, LLLT modulates tissue metabolism through "laser biostimulation," promoting healing and restoring function in damaged areas.[18,19] The favorable outcome observed in Group B could be attributed to the therapeutic properties of the laser.

CONCLUSION

Based on the results of the present study, it can be concluded that low-level diode laser irradiation (photobiomodulation effect) before placement of calcium hydroxide medicament over exposed pulp shows favorable outcomes when compared with conventional pulp capping procedure. Although the results obtained were not statistically significant among both the groups, the laser group performed better.

Our preliminary study explored the effect of preoperative disinfection with sodium hypochlorite and

photobiomodulation and yielded a positive outcome. This is constrained by a small sample size and brief follow-up period, highlighting opportunities for enhancement in subsequent investigations.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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