

Case Report

Photobiomodulation-assisted pulp capping using nano-hydroxyapatite and mineral trioxide aggregate: Report of two cases

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ABSTRACT

Direct pulp capping (DPC) aims to preserve pulp vitality following carious or mechanical pulp exposure. While calcium hydroxide and mineral trioxide aggregate (MTA) are widely used, biomimetic materials, such as nano-hydroxyapatite (nHA), have shown promising bioactivity. Adjunctive photobiomodulation therapy (PBMT) may enhance pulpal healing by modulating inflammation and stimulating reparative dentinogenesis. Two cases of reversible pulpitis in mandibular molars with carious pulpal exposures were managed using PBMT-assisted DPC. In Case 1, nHA powder was used, and in Case 2, MTA was used. Both cases received PBMT with a diode laser. Clinical and radiographic follow-up at 3, 6, and 12 months demonstrated resolution of symptoms, maintenance of pulp vitality, and evidence of dentin bridge formation. PBMT-assisted DPC using both nHA and MTA provided favorable clinical and radiographic outcomes, suggesting potential benefits of combining bioactive capping materials with PBMT in vital pulp therapy.

Keywords: Direct pulp capping, MTA, Nano-hydroxyapatite, Photobiomodulation

INTRODUCTION

Preservation and conservation of the tissues are the cornerstones of minimally invasive treatment approaches. Vital pulp therapy (VPT) is a minimally invasive treatment designed to preserve the vitality of the pulp tissue, thereby prolonging the natural lifespan of the patient's teeth.^[1] Direct pulp capping (DPC) is one such biologically driven VPT procedure designed to protect the exposed pulp and stimulate the formation of a dentin bridge, thereby maintaining tooth vitality.^[2]

Since its inception, the concept of DPC has evolved significantly and has come a long way from using a gold foil to calcium hydroxide for covering the exposed pulp. Today, researchers have shifted their focus to bioactive and biomimetic materials, which possess conductive properties that facilitate the formation of hard tissues. Mineral trioxide aggregate (MTA), a

bioactive, calcium silicate-based cement, has gained widespread acceptance as a DPC material owing to properties like superior sealing ability, low solubility, and initiation of reparative dentin formation through the hard tissue-forming cells. Numerous DPC studies have demonstrated that MTA promotes dentin bridge formation with minimal to no inflammation and improved success rates in maintaining pulp vitality over extended periods.^[3]

Hydroxyapatite (HA), the primary component of bone, as well as tooth enamel and dentin, is a known bone-filling material, owing to its high osteoconductive ability and biocompatibility.^[4] Nano-hydroxyapatite (nHA) has been reported to exhibit higher osteoconductive ability than conventional hydroxyapatite (HA).^[5] Although it has been observed that nHA-coated titanium implants facilitate osseointegration after dental

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implantation compared to microroughened titanium implants, studies regarding their use as a vital pulp therapy agent in human permanent teeth are still limited.^[6] Owing to its structural similarity to tooth mineral, holds promising potential in pulp capping procedures.

Photobiomodulation (PBM) or low-level laser therapy (LLLT) has gained attention due to its ability to penetrate tissues, promote healing, and reduce pain with minimal side effects. It uses a red or near-infrared laser with an energy output of up to 500 mW and a wavelength range of 600–1000 nm. It has the ability to stimulate tissue repair through cellular biostimulation.^[7,8] Recent experimental studies indicate that photobiomodulation therapy (PBMT) can improve the healing potential of vital pulp therapies.^[9] The effect of PBM on human dental stem cells has been studied in vitro, and it shows that it can induce human dental stem cells to differentiate into odontoblast cells.^[10,11]

With this background, this report aimed to combine, for the first time, the cellular-healing properties of PBM with the hard-tissue-forming abilities of nHA and MTA. Two clinical cases of PBMT-assisted DPC in mandibular molars are presented, one using nHA powder and the other using MTA, along with PBM therapy. The cases were completed in accordance with the PRICE 2020 guidelines for reporting endodontic cases. Written informed consent was taken from the patients for the treatment plan and for the publication of the clinical and radiographic images.

CASE PRESENTATIONS

Case 1

A 22-year-old male presented with pain in the lower left first molar (#37). The pain was mild, intermittent, and provoked by cold stimuli but subsided within a few seconds of stimulus removal, with no spontaneous or unprovoked pain. Clinical examination revealed a deep carious lesion on the occlusal surface. The tooth responded positively to cold testing (Endo-Frost, Coltene/Whaledent, Switzerland) and electric pulp testing, with no lingering pain. Intraoral Periapical radiograph showed a deep carious lesion approximating the pulp, but without periapical changes. These clinical signs, symptoms, and radiographic findings were consistent with a diagnosis of reversible pulpitis for tooth 37.

After local anesthesia and rubber dam isolation, caries excavation resulted in pinpoint pulp exposure (~0.5 mm). Hemostasis was achieved using cold 2.5% hypochlorite-moistened cotton pellets pressed over the exposed pulp for 5 minutes. A 660 nm diode laser was applied in contactless continuous mode, 100 mW output, for 120 seconds over the exposed pulpal site externally at the occlusal surface. Nano-

hydroxyapatite powder (Sigma-Aldrich, Bengaluru, India) mixed with normal saline to form a paste consistency was carefully placed over the exposure site, followed by a light-cured resin-modified glass ionomer liner. The tooth was then finally restored with a composite resin restoration [Figure 1]. At 3, 6, and 12 months, the patient was asymptomatic, with normal pulp sensibility tests and no radiographic evidence of any periapical lesion [Figure 2].

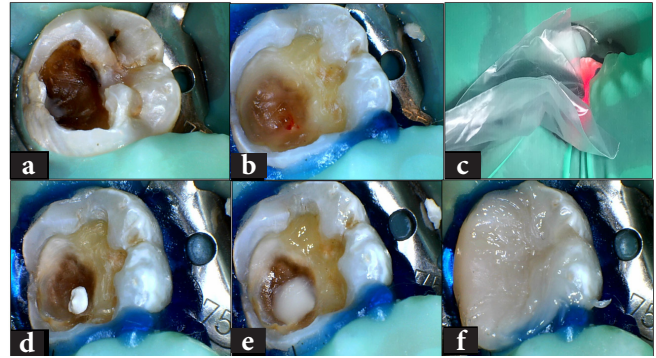


Figure 1: (a) Pre-operative clinical picture showing cariously exposed pulp in tooth 37. (b) Pinpoint pulp exposure. (c) Photobiomodulation of the exposed pulp. (d) Nanohydroxyapatite was placed over the exposed pulp. (e) Resin-based GIC placement. (f) Final restoration with composite resin. GIC: Glass Ionomer Cement

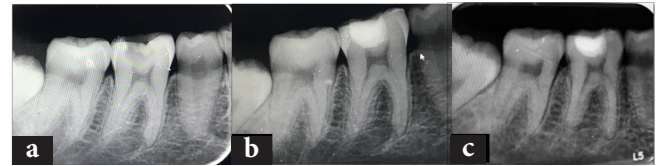


Figure 2: (a) Pre-operative IOPA X-ray showing a deep carious lesion in tooth 37. (b) Immediate post-operative IOPA of pulp capped with Nanohydroxyapatite powder & restored with composite. (c) One-year follow-up X-ray. IOPA: Intraoral Periapical

Case 2

A 25-year-old female reported pain in the lower right first molar (#46). Pain was intermittent, provoked by sweet and cold stimuli, and resolved within a few seconds of removal of stimuli, and there was no history of unprovoked pain. Examination revealed a deep occlusal caries extending close to the pulp. Radiographs showed caries approximating the pulp, without periapical involvement. A clinical diagnosis of reversible pulpitis was made for tooth 46.

After anesthesia and isolation, caries excavation resulted in pulp exposure (~1 mm). Hemostasis was achieved in 5 minutes using a cold 2.5% Hypochlorite-moistened cotton pellets. A diode laser with a Wavelength of 660 nm, 100 mW power for 120 seconds, in a contactless continuous wave mode, was applied over the exposed pulp. Mineral trioxide aggregate putty (Safendo Dental India Pvt.Ltd) was applied

directly over the pulp exposure, followed by placement of a resin-modified glass ionomer liner. The tooth was definitively restored with composite resin. At 3, 6, and 12 months, the patient remained asymptomatic, and vitality tests were positive. Radiographs revealed no periapical changes, and the tooth remains under active follow-up [Figure 3]. Both cases were reported in accordance with the PRICE 2020 guidelines and the workflow is depicted in Figure 4.

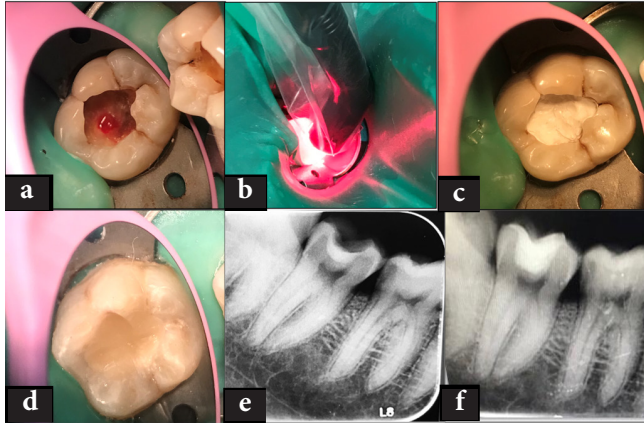


Figure 3: (a) Pre-operative clinical picture showing pulp exposure. (b) Photobiomodulation of the exposed pulp. (c) Placement of MTA. (d) Restoration with composite resin. (e) Post-operative IOPA showing pulp capping with MTA & restored with composite. (f) One-year follow-up IOPA X-ray. MTA: Mineral trioxide aggregate IOPA: Intraoral periapical

Post-operative instructions to the patients

Patient compliance with oral hygiene is crucial for maintaining the tooth's vitality and preventing infection or damage to the temporary or permanent restoration. For this, written instructions were provided to the patient, informing him about post-operative home care, pain management, and regular follow-up. They were informed that they might experience mild sensitivity to hot and cold temperatures or slight discomfort and were prescribed anti-inflammatory analgesics as needed. They were to contact the dental office immediately if they experienced severe pain, swelling, or if the temporary/permanent filling became loose or had dislodged. Additionally, they were informed that if the symptoms persisted, the tooth might require endodontic treatment.

DISCUSSION

These two clinical cases demonstrate the favorable outcomes of direct pulp capping (DPC) using bioactive capping agents, nHA and MTA, in conjunction with photobiomodulation therapy. Both cases maintained pulp vitality and no untoward radiographic or clinical signs/symptoms, consistent with the biologic rationale of combining regenerative materials with biostimulatory laser therapy.

MTA has been extensively validated in vital pulp therapies and is considered the benchmark material owing to its high biocompatibility, superior sealing ability, and ability to release bioactive ions that stimulate dentin bridge formation.^[12,13] MTA promotes odontoblastic differentiation, induces expression of dentin sialoprotein, and generates a tight seal against bacterial microleakage.^[14] A recent systematic review by Pinto *et al.* on long-term clinical trials reports success rates exceeding 90% when MTA is used for pulp capping in permanent teeth.^[15]

nHA is an emerging biomimetic material that closely resembles the inorganic component of dentin and enamel. Its nanostructure provides a large surface area for protein adsorption, cell adhesion, and nucleation of apatite crystals.^[16] In vitro studies have shown that nHA enhances odontoblastic marker expression, promotes remineralization of demineralized dentin, and supports pulp cell viability.^[17] Animal models confirm the ability of nHA to stimulate reparative dentinogenesis, accompanied by reduced pulpal inflammation.^[18] It also stimulates the differentiation of stem cells into fibroblast and odontoblast-like cells to promote tissue mineralization and reparative dentin. In a recent histological animal study conducted on rabbits comparing MTA, nHA, and Hydroxyfluorapatite (HFA), it was observed that the nHA group showed dentin bridge formation at the operating site at 6 weeks.^[18] It has also been seen that the proliferative effect of nHA can be increased by using bioactive scaffolds, such as poly- ϵ -caprolactone.^[19] While MTA enjoys a more established evidence base, nHA demonstrates promise as a biologically active alternative that could integrate seamlessly with dentin and potentially provide a more natural regenerative environment.

The adjunctive use of PBMT provided an additional advantage in these cases. PBMT, delivered through low-level laser therapy, exerts its effects at the cellular level by stimulating cytochrome c oxidase in the mitochondrial respiratory chain, leading to increased ATP production and modulation of reactive oxygen species.^[20] As per a systematic review by Karkehabadi *et al.*^[21] These biochemical changes lead to increased fibroblast proliferation, angiogenesis, and the differentiation of pulp stem cells into odontoblast-like cells.

Animal studies consistently demonstrate that PBMT enhances dentin bridge thickness and reduces inflammatory infiltrate following pulp exposures.^[22] Additionally, PBMT promotes angiogenesis and collagen synthesis, which may accelerate the reparative process.^[23] Recent clinical trials have also reported improved outcomes when PBMT is combined with vital pulp therapies. For instance, Jasararia *et al.*^[24] found higher clinical and radiographic success rates for Er:YAG laser-assisted vital pulp therapy compared to conventional capping techniques at 12 months. A single-

CASE 1 A 22-year-old male	CASE 2 A 25-year-old female
Both patients were systemically healthy, with no previous history of any dental treatment	
Mild pain in the lower left first molar (#37). provoked by cold stimuli, subsided in a few seconds no spontaneous pain	Mild pain in the lower right first molar (#46), provoked by cold stimuli, resolved within a few seconds, no history of unprovoked pain.
A clinical diagnosis of reversible pulpitis was made for the affected tooth in both cases.	
The treatment plan: excavating the carious tooth structure and conducting a laser-assisted direct pulp capping of the tooth with bioactive materials in case the pulp was exposed during or after pulpal exposure	
A written informed consent document was signed by the patients	
Exposed pulp (size 0.5-1mm) was irradiated with photobiomodulation using a 660 nm diode laser in both cases.	
DPC with MTA	DPC with nHA
The patient was recalled for follow-up at 3, 6 and 12 months for a evaluation for any symptoms of pain, signs of tenderness on percussion, sinus formation, or any changes in periapical area radiographically	
Follow-up at 6 and 12 months for an evaluation for any symptoms of pain, signs of tenderness on percussion, sinus formation, or any changes in periapical area radiographically	
Both patients reported on all the follow-ups. The treated teeth for both cases had no inadvertent clinical or radiographic signs/symptoms till the last follow-up	

Figure 4: PRICE 2020 FLOWCHART for reporting of case reports

session PBM therapy could be done in these cases, as it is difficult to recall a patient with an exposed pulp for multiple sessions. This was planned based on a few previous studies that followed a similar protocol.^[25] In a recent study by Hamdy Ismail *et al.*^[26] PBM therapy was used in a single session for post-endodontic healing, and the results were comparable to the conventional non-laser group.

The combination of bioactive pulp capping agents with PBMT likely creates a synergistic healing environment. While materials such as MTA and nHA provide a physical barrier, ion release, and scaffolding for reparative dentinogenesis, PBMT enhances the biological responsiveness of pulp cells and microcirculation at the exposure site. This dual approach may be particularly beneficial in young permanent teeth, where the reparative potential is high and preserving vitality is crucial for a long-term prognosis.

CONCLUSION

From a clinical standpoint, these cases highlight several important considerations. The choice of material plays a crucial role, as both MTA and nano-hydroxyapatite nHA demonstrated favorable outcomes. This finding suggests that nHA, although relatively new, may serve as a promising and viable alternative to established capping agents, such as MTA. In addition, the use of photobiomodulation therapy as an adjunctive modality enhances clinical success by reducing inflammation and accelerating dentin bridge formation, which is particularly beneficial in cases of carious pulp exposures. These observations align with the growing emphasis on conservative endodontics, where biologically based therapies such as PBMT-assisted DPC offer the potential to preserve pulp vitality and, in many cases, delay or even avoid the need for root canal therapy.

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Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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