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Evaluation and comparison of the efficacy of the diode laser and Biodentine on dentinal tubule occlusion

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ABSTRACT

Background & aim: Dental hypersensitivity (DH) is a common issue characterized by discomfort and pain when cold, hot, or acidic substances are consumed. DH treatment aims to control or eliminate causative factors and utilize desensitizing agents to occlude open dentinal tubules; however, there is no standardized definitive treatment yet. The increasing use of lasers, especially diode lasers, along with innovative materials such as Biodentin has contributed to advancing treatments. This study aimed to evaluate and compare the efficacy of a diode laser and Biodentin in the treatment of dentinal tubule occlusion.

Materials & methods: In this experimental study, 48 extracted human teeth were randomly divided into four groups: a control group (no treatment), a Biodentine-treated group, a diode laser 660 nm-treated group, and a combination group treated with both laser and Biodentine. After treatment, the samples were examined by scanning electron microscopy (SEM), and the percentage of tubule occlusion was categorized into four levels.

Results: A total of 83.3 % of the samples in the combination group (laser and Biodentine) achieved level 3 occlusion (more than 75 % occlusion), whereas 91.7 % of those in the Biodentine-only group were also in level 3. The percentage of patients in the laser-only group was 33.3 % in Level 2 and 66.7 % in Level 1 occlusion.

Conclusion: In conclusion, there was no significant difference in the occlusion measurement between the combination treatment group and the Biodentine-only group, with both being primarily rated as Level 3 occlusions. Therefore, the use of a diode laser at 660 nm in conjunction with Biodentine has effects similar to those of Biodentine alone.

1. Introduction

Dentin hypersensitivity (DH) is one of the most prevalent and distressing clinical conditions encountered in dental practice. It is defined as a short, sharp pain arising from exposed dentin in response to various external stimuli, including thermal, tactile, evaporative, or osmotic changes.[1,2] Among the several proposed mechanisms, Brännström's hydrodynamic theory remains the most widely accepted explanation, suggesting that external stimuli induce fluid movement within the dentinal tubules, which subsequently activates pulpal mechanoreceptors and elicits a pain response.[3]

The reported prevalence of DH varies considerably, ranging from 4 % to 74 %, depending on the studied population, diagnostic criteria, and methods of assessment.[4,5] This wide variability underscores the multifactorial etiology of DH, encompassing factors such as enamel loss due to erosion, abrasion, or attrition, and gingival recession leading to root surface exposure. Despite the availability of numerous desensitizing agents—including fluorides, potassium salts, oxalates, and resin-based sealants—no single treatment has demonstrated consistent or permanent efficacy, and symptom recurrence remains a persistent clinical challenge.[6]

In recent years, laser therapy has emerged as a novel and minimally invasive modality for the management of DH. Among various laser systems, low-level diode lasers (wavelengths between 630 and 810 nm) have shown promising results in reducing dentin sensitivity and promoting structural modification of the dentin surface. Their therapeutic effect is attributed to photobiomodulation, which induces mineral precipitation and microstructural changes without producing thermal damage to the pulpal tissues. Moreover, diode laser irradiation has been reported to modulate cellular metabolism and stimulate reparative

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dentinogenesis, thereby contributing to durable desensitization and improved dentin–pulp complex stability.[7–9]

Concurrently, Biodentine—a calcium silicate–based dentin substitute—has gained substantial attention due to its superior bioactivity, excellent biocompatibility, and favorable mechanical and sealing properties.[10,11] Upon setting, Biodentine releases calcium ions that interact with phosphate ions in tissue fluids to form hydroxyapatite-like crystals, which effectively occlude dentinal tubules and reduce dentin permeability. Additionally, Biodentine has been shown to stimulate tertiary dentin formation and enhance mineral deposition within peritubular dentin, thereby reinforcing long-term sealing and decreasing hypersensitivity.[12,13]

Although multiple studies have independently evaluated the desensitizing effects of diode lasers and Biodentine, comparative and combinatory assessments remain limited. The potential synergistic effect of diode laser irradiation and Biodentine application may further enhance clinical efficacy, as the photobiomodulative action of the laser could potentiate the bioactive sealing and remineralizing capabilities of Biodentine.[14–17] Therefore, the aim of the present study was to evaluate and compare the efficacy of a 660 nm diode laser, Biodentine, and their combination in achieving dentinal tubule occlusion, using scanning electron microscopy (SEM) analysis.

2. Materials and methods

This in vitro experimental study was approved by the Research Ethics Committee of the Faculty of Dentistry, Tehran University of Medical Sciences (Ethical Approval Code: IR. TUMS.DENTISTRY. REC.1403.051). This study is reported as per CRIS guidelines for reporting in vitro studies.

A total of 48 sound human premolars, extracted for orthodontic reasons, were collected for this study. Teeth presenting cracks, carious lesions, restorations, or structural defects were excluded. After extraction, all specimens were cleaned and disinfected in a 0.5 % chloramine-T solution, then stored in distilled water at 4 °C until use (within three months).

Each tooth crown was sectioned 2 mm below the cementoenamel junction, and dentin discs measuring 8 × 8 × 4 mm were prepared for further analysis. To obtain uniform surface conditions and open the dentinal tubules, all samples were etched with 6 % citric acid for 2 min to remove the smear layer.

The specimens were randomly assigned to four groups (n = 12 per group) as follows:

1. Group I – Control: No treatment; specimens stored in distilled water.
2. Group II – Biodentine: Biodentine (Septodont, France) was prepared according to the manufacturer's instructions and applied to the dentin surface. Samples were stored in distilled water for 14 days before SEM analysis (11, 12).
3. Group III – Diode Laser: Samples were irradiated daily for 14 days using a 660 nm diode laser (power = 30 mW, exposure = 20 s, distance = 0.5 mm, continuous, non-contact mode) with a sweeping motion (17).
4. Group IV – Laser + Biodentine: The dentin surfaces were first coated with Biodentine, and after 24 h, the specimens were irradiated using the same diode laser parameters daily for 14 days (12, 8).

Dice were rolled to randomly assign the samples. If numbers 1 to 4 appeared, the samples remained in their respective groups; if 5 or 6 appeared, the dice were rolled again. The laser irradiation parameters for the diode laser groups are summarized in Table 1.

The specimens underwent a series of procedures that involved dehydration, mounting, gold sputter coating, and finally, studying under scanning electron microscopy (SEM, Philips XL-30). The captured images were at a 2000 times magnification, and the staining of the dentin tubules was assessed separately by two evaluators who were unaware of the treatment using standardized criteria.[18] The judges classified the occlusions as follows:

Table 1
Laser irradiation parameters used in the diode laser groups.

Parameter	Specification
Wavelength	660 nm
Power output	30 mW
Fluence	15 J/cm^2
Exposure time	20 s
Spot diameter	400 μm
Distance from surface	0.5 mm
Mode	Continuous, non-contact
Application technique	Forward–backward sweeping motion
Laser device brand	*Thor Photomedicine Ltd., London, UK*

- Score 0: No occlusion (open tubules)
- Score 1: <25 % occluded
- Score 2: 25–75 % occluded
- Score 3: >75 % occluded (11)

Consensus was the method used to settle discrepancies between the two reviewers.

Data were analyzed using SPSS version 24 (IBM, USA).

Descriptive statistics were calculated, and group comparisons were performed using chi-square, Fisher's exact, and Kruskal–Wallis tests. Sample size was determined using G*Power 3.1.9.7 with $\alpha = 0.05$, power = 0.8, and effect size = 0.4, based on previous studies.[18,19] Significance was set at $p < 0.05$.

3. Results

Table 2 demonstrates Frequency of tubule obstruction at different levels based on the groups evaluated in the study.

Representative SEM micrographs revealed distinct morphological differences among the groups.

- The **Control group** showed numerous open tubules (Score 0).
- The **Diode laser group** exhibited partial occlusion (Scores 1–2), indicating superficial mineralization.
- The **Biodentine group** achieved the highest percentage of complete occlusion (Score 3, >75 %).
- The **Laser + Biodentine group** showed similar results to Biodentine alone (Score 3 = 83.3 %) (Table 3.).

Statistical comparison indicated significant differences among the groups ($p < 0.05$), except between Groups II and IV ($p = 1.00$). (Fig. 1).

4. Discussion

This study investigated and compared the effects of a 660 nm diode laser, Biodentine, and their combination on dentinal tubule occlusion. The results showed that both Biodentine and the laser–Biodentine combination produced significantly higher occlusion scores than the diode laser alone. These findings highlight the superior sealing potential of Biodentine and its capacity to provide more stable tubule occlusion compared to laser application by itself.

The enhanced occluding performance of Biodentine observed in this study is consistent with previous research reporting its ability to release calcium ions, promote hydroxyapatite-like crystal formation, and induce intratubular mineralization.[8,10,20] Nevertheless, not all studies have confirmed these outcomes. Some investigations have reported less pronounced calcium ion release or weaker mineralization when compared with other calcium silicate–based materials such as ProRoot MTA.[21,22] Such inconsistencies are likely attributable to methodological differences among studies, including variations in the material's physical

Table 2
Frequency of tubule obstruction at different levels based on the groups evaluated in the study.

groups * tubules Crosstabulation

			Tubules				Total
			level0	Level1	Level2	Level3	
Groups	control	Count	12	0	0	0	12
		% within group	100.0 %	0.0 %	0.0 %	0.0 %	100.0 %
	laser	Count	0	8	4	0	12
		% within group	0.0 %	66.7 %	33.3 %	0.0 %	100.0 %
	biodentin	Count	0	0	1	11	12
		% within group	0.0 %	0.0 %	8.3 %	91.7 %	100.0 %
	laser + biodentin	Count	0	0	2	10	12
		% within group	0.0 %	0.0 %	16.7 %	83.3 %	100.0 %
Total		Count	12	8	7	21	48
		% within group	25.0 %	16.7 %	14.6 %	43.8 %	100.0 %

Table 3
Comparative study of the values of the different groups studied relative to each other.

Sample1-sample 2	Test static	S.E	S.T	Sig.	Adj. sig.
Control/Laser	−12.500	5.402	−2.314	0.21	0.124
Control/Biodentine	−30.333	5.402	−5.615	0.000	0.000
Control/Laser + Biodentine	−29.167	5.402	−5.399	0.000	0.000
Laser/Biodentine	−17.833	5.402	−3.301	0.001	0.006
Laser/Laser + Biodentine	−16.667	5.402	−3.085	0.002	0.012
Biodentine/Laser + Biodentine	1.167	5.402	0.216	0.829	1.000

form (powder, set disc, or paste), the immersion medium, incubation duration, and analytical techniques. Moreover, it has been suggested that in vitro conditions may not accurately reproduce the dynamic physiological environment of dentinal fluid and pulp tissues, which could explain why mineral deposition observed in laboratory studies is not always replicated in vivo.[23–26]

Although many reports have demonstrated Biodentine's ability to form mineral tags and occlude dentinal tubules, some authors have presented conflicting observations. Kouzmanova and Dimitrova,[27] for instance, found tubule penetration only in the Harvard MTA group and not in Biodentine specimens. Similarly, Özdemir and Oncu[28] reported that NeoPUTTY showed greater dentinal infiltration than Biodentine in a confocal microscopy analysis of primary teeth. Shokry et al.[29] also

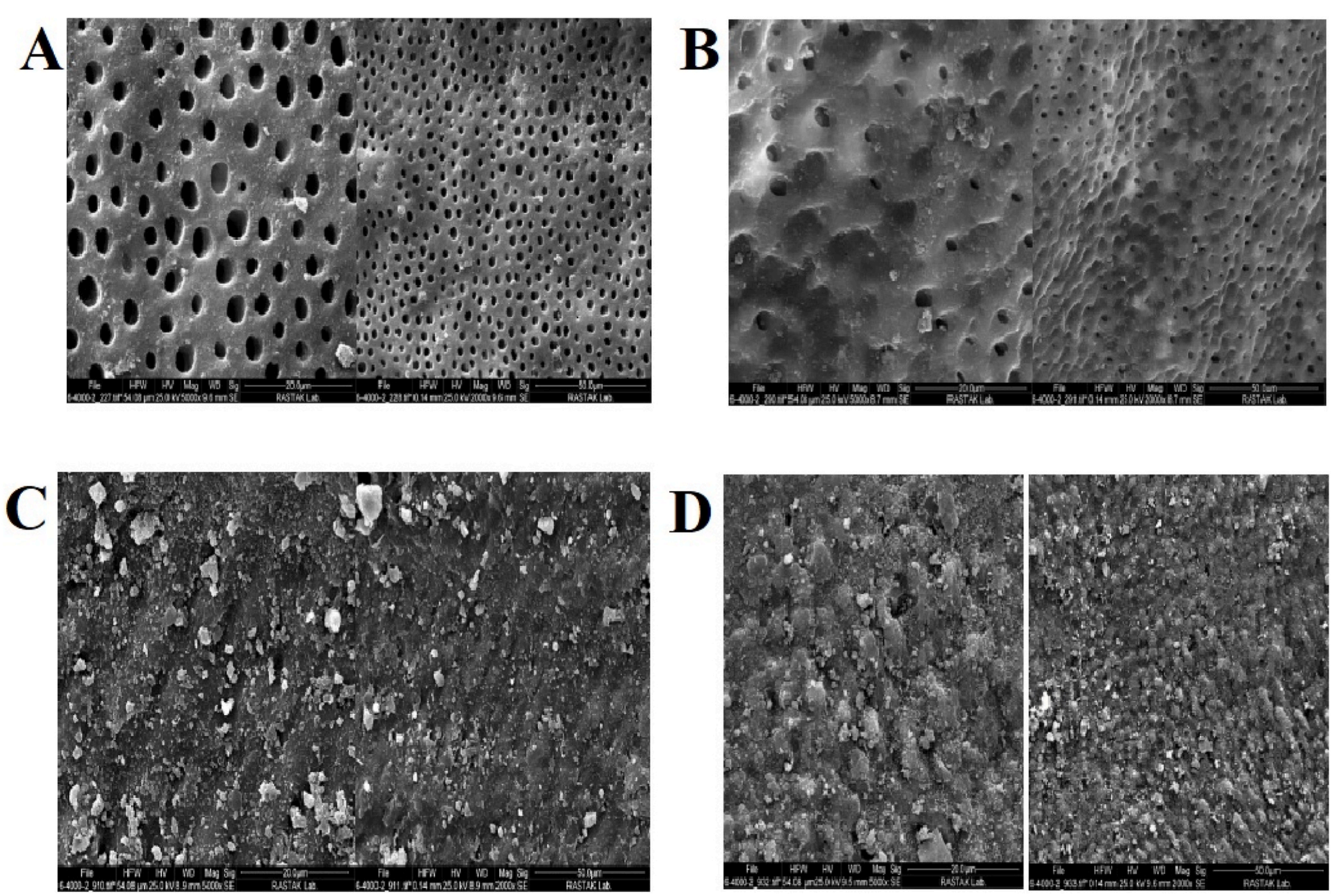

Fig. 1. Comparative examination of teeth of three groups using scanning electron microscopy (SEM). (A): Control group, (B): Laser group (660 nm Diode laser), (C): Biodentin group with magnification, (D): Laser and Biodentin combination group (Zoom 2×10^{3}X and 5×10^{3}X).

documented shallower material penetration and more extensive bacterial invasion in Biodentine compared with MTA or IRM retrofills. Additionally, Sameera et al.[30] noted that diode laser contact could thermally alter the Biodentine surface, resulting in a melted morphology that may hinder intratubular tag formation. Taken together, these findings suggest that the degree of tubule occlusion produced by Biodentine is sensitive to multiple variables, including experimental setup, material composition, and adjunctive treatment parameters.

The 660 nm diode laser used in the present study demonstrated a moderate ability to reduce dentin hypersensitivity, which can be attributed primarily to its photobiomodulatory effects. Previous studies have shown that diode lasers in this wavelength range enhance cellular metabolism, stimulate odontoblastic activity, and promote tertiary dentin formation.[7,9,21] However, due to their limited physical capacity to seal tubules, diode lasers alone typically result in partial occlusion. Several investigations have shown that higher-wavelength diode lasers (810–980 nm) can induce melting and re-solidification of the superficial dentin layer, creating a smooth, glazed surface that effectively reduces dentinal permeability without harmful temperature rise in the pulp.[31,32] Comparable occlusive effects have been achieved using Er:YAG and CO_2 lasers through microstructural recrystallization and surface melting, leading to significant reductions in the number of open tubules.[33,34] Furthermore, combining laser irradiation with chemical desensitizing or fluoride agents has been reported to yield synergistic effects, providing smoother surfaces and more durable tubule sealing.[35]

In the present study, although the combination of diode laser and Biodentine did not significantly outperform Biodentine alone, the observed trend suggests that the laser may enhance the setting reaction or facilitate deeper mineral penetration. Nonetheless, the absence of statistical significance implies that Biodentine itself remains the dominant factor responsible for the observed tubule closure.

Recent literature supports these conclusions. Kaur et al.[16] and Singh et al.[18] found that Biodentine achieved superior dentinal occlusion compared to calcium hydroxide and other desensitizing materials. Maheswari et al.[13] and Orsini et al.,[14] through systematic reviews, confirmed that diode lasers—especially those in the 630–810 nm range—are effective in reducing dentin hypersensitivity symptoms, particularly when combined with topical agents. Similarly, the meta-analysis by Tengrungsun et al.[15] emphasized the consistent but modest effects of photobiomodulation lasers when used alone.

Overall, the findings of this study reinforce the growing evidence that Biodentine is a highly effective material for dentinal tubule occlusion due to its bioactive properties and ability to promote mineral deposition. While diode lasers can contribute to surface modification and stimulate biological repair, their role appears to be complementary rather than decisive. Future in vivo and long-term clinical investigations are recommended to explore the optimal laser parameters and application protocols that could maximize the synergistic effects of combined The strengths of this study include its standardized methodology, validated scoring system, and direct SEM-based evaluation of occlusion. Inclusion of a combination treatment group adds comparative value rarely addressed in previous in vitro models. However, as an in vitro study, it lacks the biological complexity of the oral environment, where saliva, occlusal stress, and pH variations may influence long-term outcomes.

Future in vivo and clinical trials are warranted to evaluate the durability and patient-reported outcomes of laser–Biodentine treatments. Biodentine–laser treatment in the management of dentin hypersensitivity.

5. Conclusion

Within the inherent limitations of this in vitro investigation, both Biodentine and 660 nm diode laser treatments effectively promoted dentinal tubule occlusion. The combined application of Biodentine and diode laser yielded outcomes comparable to those achieved with Biodentine alone, suggesting that Biodentine exerts the predominant sealing effect. Nonetheless, diode laser therapy may serve as a valuable adjunctive modality, offering a minimally invasive and clinically applicable approach for the management of dentin hypersensitivity.

Consent for publication

As this is an in vitro laboratory study using extracted human teeth, no identifiable data or images (such as names, dates of birth, or clinical photographs linked to individuals) are included in this manuscript. The study includes scanning electron microscopy (SEM) images of dentinal tubules post-treatment with a 660 nm diode laser, Biodentine, or a combination of both, presented in (with magnifications of 2×10^3 and 5×10^3). Additionally, anonymized data on the percentage of dentinal tubule occlusion are summarized in Tables 1 and 2 Consequently, no written consent for publication was required.

Description of material

The manuscript includes scanning electron microscopy (SEM) images of dentinal tubules following treatment with a 660 nm diode laser, Biodentine, or a combination of both, presented in (magnifications of 2×10^3 and 5×10^3). Anonymized data regarding the degree of dentinal tubule occlusion are summarized in Tables 1 and 2 No identifiable information, such as clinical photographs, videos, or personal data, was used in this study.

Author contributions

All authors contributed to the study design, data collection, analysis, and manuscript preparation.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Faculty of Dentistry, Tehran University of Medical Sciences (Approval Reference: IR. TUMS.DENTISTRY.REC.1403.051) and conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki. This laboratory-based study utilized 48 extracted human premolar teeth collected for orthodontic purposes. The teeth were obtained from anonymous donors, and no identifiable information related to the donors was used in this study. Therefore, informed consent for participation was not required.

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Declaration of competing interest

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

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Data availability

The data generated or analyzed during this study are included in the tables and figures of the manuscript. Raw data are available upon request, subject to compliance with ethical requirements.

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