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Comparing Diode Laser (660 nm) & 8% Arginine Toothpaste vs. Laser Alone for Dentin Hypersensitivity: A Randomized Clinical Trial

Simran Genescia[1], **Neetha J Shetty**[1*]

[1]Department of Periodontology, Manipal College of Dental Sciences Mangalore, Manipal Academy of Higher Education, Manipal, Karnataka, India

***Correspondence to**
Neetha J Shetty,
Email: neetha.rajesh@manipal.edu

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Abstract

Introduction: This study aimed to evaluate the effectiveness of a 660 nm diode laser in combination with 8% arginine-based toothpaste compared to the laser used independently for managing dentinal hypersensitivity (DH).

Methods: A total of 12 patients with severe hypersensitivity were included in the study. Selected teeth were randomly assigned to a Test site (diode laser 660 nm + 8% arginine toothpaste) and a control site (660 nm diode laser alone). The selected teeth were irradiated using a 660-nm diode laser at 25 mW power for 60 seconds at a 1 cm^2 area (1.66×10^{-6} J/m^3) in continuous mode using multi-tip low-level laser therapy (LLLT) (8 mm). DH scores were assessed using the VAS and the SCASS at baseline, 15 minutes post-application, and on days 15 and 30.

Results: Clinical parameters such as the visual analogue scale (VAS) and Schiff Cold Air Sensitivity Scale (SCASS) were expressed as mean ± SD or median with IQR. The 660-nm diode laser with 8% arginine-containing toothpaste showed a notable and sustained reduction in mean VAS scores and SCASS scores 15 minutes post-application and on days 15 and 30, compared to the diode laser (660 nm) alone. A *P* value less than 0.05 was regarded as statistically significant.

Conclusion: The adjunctive use of a diode laser (660 nm) with 8% arginine-containing toothpaste shows promise as a treatment alternative for alleviating DH. Unlike conventional desensitizing agents, which predominantly obstruct dentinal tubules or interfere with nerve response, this combination therapy reduces sensitivity immediately and sustainably via two mechanisms: laser-induced nerve modulation and arginine-mediated tubule occlusion. These findings imply that it could serve as a more effective alternative to standard desensitizing toothpaste or laser therapy when used alone.

Keywords: Dentin hypersensitivity; Tubule occlusion; Laser; Desensitizing toothpaste; Arginine-containing toothpaste.

Introduction

Dentinal hypersensitivity (DH), also known as cervical dentinal sensitivity, is a major clinical problem. It appears as pain that is brought on by heat, chemicals, touch, or variations in osmotic pressure, which is frequently caused by exposed dentin and is not related to any other dental disorders.[1] Gingival recession and enamel loss are primary causes of DH, as they expose the underlying dentin.[2] While the treatment of periodontal disease or excessive tooth brushing can cause gingival recession, tooth wear from abrasion, erosion, or attrition can cause enamel loss.[2] Many theories have been put forward to explain the relationship between pulpal nociceptive transduction and DH. The hydrodynamic theory proposed by Brännström has gained wide acceptance as the principal mechanism behind DH.[3] This idea states that a variety of environmental conditions, including physical, temperature-related, and chemical alterations, trigger fluid movement within dentinal tubules. This fluid movement stimulates the terminal nerve fibers at the tubular walls, which in turn produce sudden pain responses.[3] Consequently, the key principles for treating DH involve either restricting fluid flow within dentin tubules or inhibiting stimulation of pulpal nerves.

Since being first applied for DH management in 1985, as reported by Matsumoto et al, lasers have become widely accepted.[4] Various wavelengths, such as low- and medium-intensity lasers, have been utilized with differing levels of effectiveness in DH treatment.[5] He-Ne and GaAlAs low-level lasers (LLLs), which produce red light within the visible range at wavelengths of 630, 780, 830, or 900 nm, are considered to enhance neuronal action potentials, thereby reducing pain conduction.[6] In contrast to moderate-level lasers such as Nd-YAG, which emit infrared light at 1064 nm and stimulate secondary dentin formation while occluding tubules which are open,

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low-level lasers (LLLs) do not change the dentinal tubule structure.[6] Nevertheless, LLL provides rapid analgesic effects by acting on nerve cells.

According to Mantzourani and Sharma,[7] topical desensitizing agents commonly used for managing dentin hypersensitivity include potassium salts, calcium phosphate, soluble oxalates, adhesive resins, and bioactive glasses, and they can complement laser desensitization. However, when used alone, occlusive materials may be susceptible to being washed out of the tubule or may degrade in acidic environments, leading to limited effectiveness or short-term relief. Despite their advantages, including affordability, ease of application, and accessibility, many therapies fall short of providing lasting results. Recent studies indicate that certain naturally occurring constituents of saliva possess desensitizing effects that can help manage DH. Building on this understanding, a novel topical formulation was developed containing 8% arginine in a bicarbonate buffer combined with calcium carbonate, reflecting the chemical profile of saliva.[8] When applied, this preparation deposits a barrier of arginine, calcium, phosphate, and carbonate within exposed dentinal tubules, reducing DH by limiting fluid movement within the tubules.[8]

When used together, laser therapy and topical desensitizing agents have been reported to provide additive or even synergistic effects in managing dentin hypersensitivity, exceeding the benefits observed when each is applied separately. It is common practice to use topical agents alongside laser therapy, a technique proven to block dentinal tubules.[9,10] Previous research has highlighted the efficacy of desensitizing paste formulated with 8% arginine, surpassing other local agents in DH treatment. However, it has not been directly compared to or employed alongside diode laser therapy using the 660-nm wavelength.

Pre-treating with laser irradiation is believed to enhance the efficacy of desensitizing paste formulated with 8% arginine. Hence, the aim of this study was to assess the effectiveness of utilizing a diode laser (660 nm) in conjunction with 8% arginine-containing toothpaste (Colgate Sensitive Plus, Colgate® India) versus using a diode laser (660 nm) alone for managing DH.

Materials and Methods

Study Design

This prospective, interventional, single-blinded, split-mouth, randomized clinical trial was conducted in the Periodontics Department of Manipal College of Dental Sciences, Mangalore. Participants presenting with hypersensitivity as their primary complaint were recruited from individuals visiting the department. The study followed the ethical principles described in the Declaration of Helsinki and received approval from the Institutional Ethics Committee. The study was also registered in the CTRI registry under the protocol ID REF/2023/10/074252 on ClinicalTrials.gov on 09/10/2023. Informed consent was obtained in written format from every participant before data collection.

Patient Selection

Patients presenting to the department with a primary complaint of hypersensitivity were enrolled in the study. Systemically healthy individuals aged between 20-55 years, irrespective of gender, having two or more teeth showing hypersensitivity to air blast or tactile stimulation in at least two quadrants and a Full Mouth plaque Score – less than 25% were included in the study. The criteria for exclusion encompassed several factors: the presence of chronic illnesses, benign or malignant oral lesions, presence of dental caries in the targeted teeth or their neighbouring teeth, orthodontic appliances, cracks in enamel, congenital enamel or dentin deformities, existing dental restorations, previously undergone vital tooth bleaching, periodontal disease, recent periodontal surgeries, treatments for hypersensitivity in the past six months or nonsurgical periodontal procedures in the preceding three months, usage of desensitizing dental agents like toothpaste or mouthwash, ongoing medication regimes, pregnancy or breastfeeding, antidepressant or analgesic use, and any known allergies to the treatment components.

Sample Size Estimation

Based on data from a prior study by Srivastava et al,[11] the sample size was estimated as follows:

With a 1% alpha error, 99% study power, and a clinically significant difference of 0.2 units, the calculated sample size was 12 patients (based on equation 1).

$$N = \frac{(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta})^2 s^2}{d^2} \tag{1}$$

N represents the number of samples.

s = 0.141 is the standard deviation

d = 0.2 denotes the minimum value difference considered clinically significant.

Z(1-α/2) indicates the Z score corresponding to the selected alpha error.

Z(1-β) refers to the Z score associated with the chosen study power.

Randomization

Selected sites were assigned to two different treatment modalities by tossing a coin immediately before each appointment (1:1). The procedures for applying both treatments were standardized as much as possible. Participants were informed about the study structure without revealing which side was receiving which treatment. Opaque envelopes were used to conceal the allocation. Two envelopes were prepared, one for each outcome of the coin toss (e.g., heads for the diode laser group, tails for the 8% arginine toothpaste and diode laser group). Before each surgical appointment, the envelope was opened to reveal the patient's treatment assignment.

- Test site: treated with 8% arginine containing desensitizing paste in combination with a 660-nm diode laser
- Control site: treated with a 660-nm diode laser

Blinding

All clinical assessments were conducted by a single examiner, independent of the principal investigator, to reduce observer bias. Before study initiation, the examiner underwent calibration training for the visual analogue scale (VAS) and Schiff Cold Air Sensitivity Scale (SCASS). Intra-examiner reliability was evaluated using 10 randomly selected patients at baseline, with assessments repeated after one week. The results were analysed using the intraclass correlation coefficient (ICC), which demonstrated an ICC value greater than 0.85, indicating strong agreement and confirming the examiner's scoring consistency and reliability throughout the study.

Evaluation

Tactile Hypersensitivity Measurement Using the Visual Analogue Scale

Tactile hypersensitivity was evaluated by applying gentle manual pressure with a sharp dental explorer at the cementoenamel junction of designated teeth in a mesiodistal direction (Figure 1a). Afterwards, patients were asked to record their pain intensity using the VAS from 0, representing no pain, to 10, representing the maximum intolerable pain, reflecting their subjective perception of DH. Patients with a baseline VAS score of 5 or above were eligible for inclusion in the study.

Sensitivity Assessment by Air Blast Using the Schiff Cold Air Sensitivity Scale

Sensitivity assessment involved directing the air stream from a dental air/water syringe, connected to an air compressor, perpendicular to the tooth surface from a distance of 3 mm. This was conducted at a temperature ranging between 20 °C and 25 °C, with the air stream applied for 5 seconds (Figure 1b). The inclusion criteria incorporated an SCASS score of 2 or above.

Treatment Protocol

Because the study employed a split-mouth design, the selected sites in each patient were randomly assigned to one of the two treatment groups. Prior to the procedure, Phase I therapy was administered, and oral hygiene instructions were provided to all patients.

Control site (Diode Laser group)

The selected teeth were irradiated with a 660-nm diode laser at 25 mW power for 60 seconds at a 1 cm^2 area (1.66×10^{-6} J/m^3) in continuous mode using a multi-tip (8 mm). The laser was directed at the tooth surface perpendicularly, maintained in a fixed position, operated in non-contact mode, and applied with continuous emission for 60 seconds on each tooth.

Test Site (8% Arginine Toothpaste and Diode Laser Group)

8% arginine-containing toothpaste was applied to the selected tooth surface using a micro-applicator tip for at least 1 minute, after which the teeth were irradiated with a diode laser. The procedure followed was the same as that used for the control site (Figures 1c and 1d).

Post-treatment Evaluation

The evaluation of DH scores was conducted with the help of the VAS and the SCASS, both at baseline (pre-treatment) and after treatment at various intervals: 15 minutes post-treatment, on the 15th day, and on the 30th day. Participants were instructed not to use any other mouthwash or desensitizing toothpaste throughout the trial. They were advised to maintain their regular oral hygiene routine, brushing twice daily with their usual toothpaste.

Statistical Analysis

Data entry was performed in Microsoft Excel, and the statistical analysis was carried out using SPSS software, version 29 (IBM, Armonk). Clinical parameters, including tactile hypersensitivity assessed with the VAS and air-blast sensitivity measured using the SCASS, were expressed as mean ± standard deviation or as median with interquartile range (IQR). The Kolmogorov–Smirnov test was applied to verify the normality of data distribution across different time intervals. As this test produced a

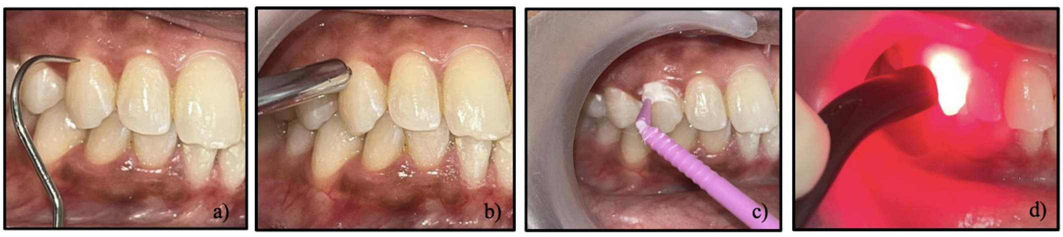

Figure 1. a) Tactile hypersensitivity measurement b) Sensitivity assessment by air blast c) Application of 8% arginine-containing toothpaste d) Diode laser irradiation (660 nm)

significance value below 0.05, non-parametric methods were chosen for intergroup comparisons. Differences between the control site (diode laser group) and the test site (8% arginine toothpaste combined with diode laser group) were analysed using the Mann–Whitney U test. VAS and SCASS outcomes were compared from baseline to 15 minutes post-therapy, and subsequently on the 15th and 30th days. Follow-up assessments were conducted with the Wilcoxon signed-rank test, and a P value < 0.05 was considered statistically significant.

Results

Twelve participants were enrolled in the study. The baseline median scores of VAS and SCASS did not show any statistically significant variation between the two intervention sites. Both the test site and the control site exhibited a reduction in DH when comparing the median and IQR values of baseline VAS, VAS at 15 minutes post-treatment, VAS on the 15th day, and VAS on the 30th day (Table 1). On intragroup comparisons, both the test site and the control site showed statistically significant differences between the median values of baseline and 30th-day VAS scores. The test site demonstrated a statistically significant difference of 5.46 ± 0.88, while the control site showed a statistically significant difference of 4.38 ± 0.92 (Figure 2). When comparing the median differences between the test sites and the control sites, the test site showed higher median values, with a statistically significant difference of 1.083 with a P value of < 0.05.

The analysis of the median and IQR values for the SCASS at baseline, 15 minutes after intervention, on day 15, and on day 30 indicated that both the test group and the control group experienced reductions in dentin hypersensitivity (Table 2). Within each group, a significant difference was detected when baseline SCASS scores were compared with those recorded on the 30th day. The magnitude of change was greater at the test site (1.96 ± 0.62) compared to the control site (1.13 ± 0.74) (Figure 3). When differences between the two groups were compared, the Test site exhibited higher median improvement, with a mean difference of 0.833 and a P value < 0.05. No treatment-related adverse effects were reported.

Discussion

The aim of this study was to evaluate the efficacy of combining a diode laser (660 nm) with 8% arginine-containing toothpaste to reduce DH. The outcomes demonstrated a noteworthy decrease in DH in comparison to the diode laser (660 nm) and 8% arginine-containing toothpaste alone over a period of 30 days post-application.

A relatively simple clinical approach to diagnosing dental hypersensitivity involves running an explorer on the exposed dentin for tactile stimulation or using an evaporative or air blast method to examine each tooth surface where the patient complains of pain and hypersensitivity.[12] In addition, measures of patient-related outcomes such as the VAS and the SCASS can provide valuable insights into the degree of DH and its impact on patients and their quality of life.[13]

The main goal of treating DH is to alleviate hypersensitivity by inhibiting pulpal nerve response or occluding dentinal tubules, which reduces their reactivity to external stimuli. One useful treatment for DH symptoms is over-the-counter desensitizing toothpaste that has compounds like strontium chloride, potassium nitrate or arginine. For more severe cases or when conservative treatments are insufficient, professional therapies such as fluoride varnishes, dental sealants, or in-office desensitizing agents may be advised.[14]

A range of topical agents, including potassium oxalate, strontium chloride, fluorides, and silver nitrate, have demonstrated varying degrees of potency and duration of effect in alleviating DH. Some naturally occurring salivary components have been shown in recent studies to have desensitizing qualities that help relieve DH.[15] A new topical agent formulated with 8% arginine in a bicarbonate buffer and calcium carbonate was developed based on the saliva composition. Upon application to exposed dentin, the formulation creates an occluding deposit in dentin tubules that contain arginine, calcium, phosphate, and carbonate, which reduces DH by obstructing fluid

Table 1. Visual Analogue Scale (VAS) Score During the Study for Each Treatment Site

	Base VAS	15 Mins VAS	15th Day VAS	30th Day VAS
Control site				
N	12	12	12	12
Median	5.00	2.00	1.00	1.00
IQR	1.00	0.00	1.00	1.00
Test site				
N	12	12	12	12
Median	2.00	1.00	0.00	0.00
IQR	0.750	0.00	0.00	0.00

Table 2. Schiff Cold Air Sensitivity Scale (SCASS) Score During the Study for Each Treatment Site

	Base SCASS	15 Mins SCASS	15th Day SCASS	30th Day SCASS
Control site				
N	12	12	12	12
Median	2.00	1.00	1.00	1.00
IQR	0.750	0.750	0.00	0.0
Test site				
N	12	12	12	12
Median	2.00	1.00	0.00	0.00
IQR	1.00	1.00	0.00	0.00

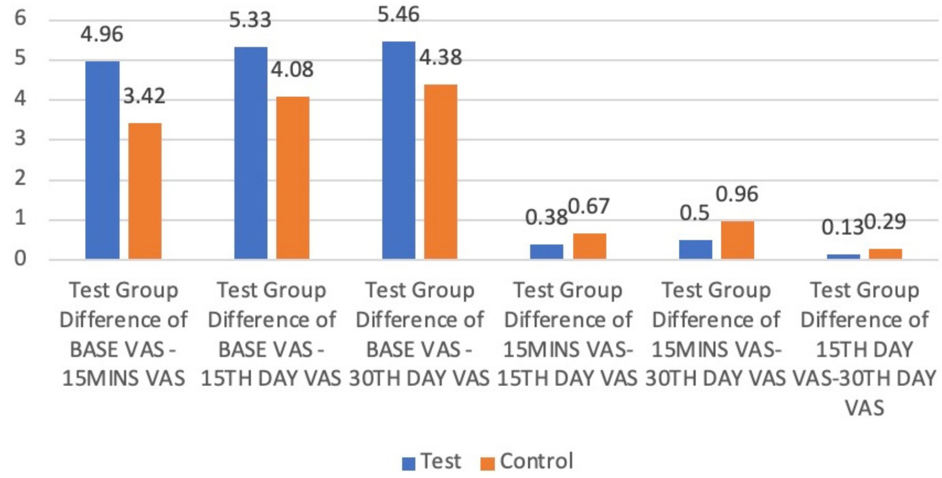

Figure 2. Comparison of VAS Score at Each Interval Between the 8% Arginine Toothpaste and Diode Laser Group

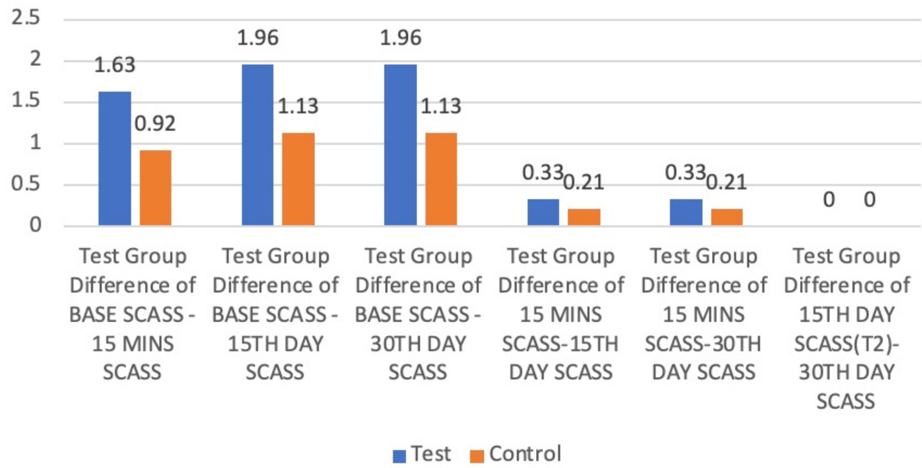

Figure 3. Comparison of SCASS Score at Each Interval Between the 8% Arginine Toothpaste and Diode Laser group

movement within tubules.[15,16]

Several randomized controlled trials have assessed the chairside application of arginine–calcium carbonate paste. Evidence from earlier studies indicates that when the paste is applied after scaling and prophylaxis, patients experience rapid relief from dentin hypersensitivity, with the effect persisting for up to 28 days.[15,17] Similarly, using the paste prior to professional cleaning has been shown to markedly reduce sensitivity to tactile and evaporative stimuli immediately after the procedure.[18]

Photobiomodulation therapy, also known as low-level laser therapy (LLLT), involves delivering low-output laser light to specific tissues. According to a theory, it works by inducing biological responses, reducing inflammation, and controlling pain perception. In the context of DH, LLLT aims to reduce pain and discomfort by encouraging dentin tubule occlusion and reducing nerve sensitivity.[19,20] In addition to dentinal tubule obstruction and nerve desensitization, probable biological factors contribute to the analgesic benefits of diode laser therapy. One such mechanism is the laser-induced release of nitric oxide (NO), a vasodilator that is essential for cellular signalling. NO can alter nociceptive transmission by increasing blood flow, decreasing inflammation, and lowering neuronal excitability, resulting in acute and long-term pain alleviation.[21] Another important process is the activation of ATP-sensitive potassium channels in nerve cell membranes. LLLT may activate these channels, causing neuronal membrane hyperpolarization and inhibiting action potential propagation. This lowers the sensitivity of nociceptors to external stimuli.[22] These biological effects of LLLT demonstrate its ability to control pain at the molecular level, in addition to occluding dentinal tubules. Several studies have investigated the efficacy of LLLT in reducing the symptoms associated with DH, with largely positive results. These studies have demonstrated improvements in pain evaluations, reduced hypersensitivity, and increased patient satisfaction after LLLT treatments. Moreover, LLLT has demonstrated a rather rapid onset of efficacy; many patients report feeling better following a few treatment sessions.[23]

Several low-intensity and mid-intensity lasers have been utilized to treat dentin hypersensitivity. Many distinct types and wavelengths of lasers, ranging from HeNe lasers at 630 nm to GaAlAs lasers at 900 nm, were employed. The trials that used lasers in the visible red spectrum were the most relevant to the current study because the laser effect depends on the wavelength of the light emitted.[24]

Prior research utilizing diode lasers with a wavelength between 660 and 685 nm showed a marked decrease in sensitivity in comparison to baseline data. Nevertheless, these results were considerably weakened by the absence of a meaningful difference when compared to a placebo or the absence of a placebo control. Evidence from clinical trials indicates that DH improved to a similar extent from baseline in both treatment groups when a 660 nm diode laser was compared with sodium fluoride and with an 830 nm diode laser.[25,5] Furthermore, both groups considerably improved in a study comparing Nd:YAG with 685 nm diode lasers, with the Nd:YAG group showing a significantly higher reduction in sensitivity after 60 days.[26]

In an in vitro experiment, Tunar et al[27] employed scanning electron microscopy to evaluate the effects of desensitizing paste (DP), Er:YAG laser, and their combined application on dentinal tubules. Forty freshly extracted teeth were allocated into four groups: Group I (control), group II (Er:YAG laser), group III (DP containing 8% arginine and calcium carbonate), and group IV (DP + Er:YAG laser). The combined approach produced a statistically significant level of tubule occlusion. While the difference between the DP group and the combination group was significant, no meaningful differences were noted between the Er:YAG laser alone and DP, or between the Er:YAG laser alone and the combination.

Rezazadeh et al[28] reported that an 810 nm diode laser is effective in the management of dentin hypersensitivity, particularly due to its rapid onset of pain relief. The laser stimulates a photobiomodulatory response within the pulp tissue, promoting dentinal tubule occlusion and enhancing tertiary dentin formation. It also maintains pulp vitality and increases the metabolic activity of odontoblasts. The laser reduces pain by obstructing nerve signals that are transmitted to the central nervous system.[28] The present study utilized a diode laser of 660 nm in treating DH, which not only occludes dentinal tubules but also provides long-term pain relief.

Srivastava et al[11] in a recent clinical trial confirmed these findings by evaluating the combined use of an 810-nm diode laser with calcium carbonate and 8% arginine for the management of dentin hypersensitivity. According to their randomized controlled trial, which involved 66 patients, the combination therapy produced the most significant and long-lasting reduction in DH when compared to either modality used alone. Despite employing a different laser wavelength, their findings are consistent with ours, demonstrating that combination therapy has higher clinical efficacy in managing DH.

Both the test site and the control site displayed greater immediate pain reduction, particularly in response to air stimulation, in the test site compared to the control site. A statistically significant decrease in DH was noted in the test site when comparing VAS and SCASS scores between the two sites. The test site exhibited the most substantial reduction, particularly in SCASS scores. This could be attributed to diminished nerve transmission resulting from the closure of dentinal tubules, offering immediate relief. Hence, it can be inferred that the combination of the diode laser (660 nm) with the desensitizing agent (8% arginine-containing toothpaste) demonstrated superior efficacy in alleviating DH, likely due to enhanced dentinal tubule occlusion.

Our research primarily focused on short-term follow-up to evaluate which treatments could effectively address patients' acute DH complaints with a single application. However, further research with expanded cohorts and extended follow-up durations is warranted to determine treatments that offer sustained relief from DH over time. The inclusion of an additional control group treated with 8% arginine alone would have strengthened the interpretation of the results. We recognize that the absence of this group restricts our capacity to fully understand the potential synergistic interaction between arginine and diode laser treatment. In the absence of this group, the nature of the interaction can only be hypothesized, which constitutes a limitation of the present study. Furthermore, given that laser therapy is a relatively newer treatment approach compared to the widespread availability of 8% arginine-containing toothpaste, additional randomized controlled trials are needed to ascertain the role of laser therapy in DH management. Despite the limitations of our study, we can conclude that the combined use of the 660-nm diode laser and 8% arginine-containing toothpaste led to statistically significant improvement and immediate relief from acute DH.

Conclusion

The concurrent use of laser therapy and desensitizing toothpaste provides immediate relief, presenting a cost-effective and minimally invasive solution for alleviating DH. Desensitizing toothpaste containing 8% arginine has demonstrated notable effectiveness in occluding dentinal tubules. However, its efficacy is further enhanced when combined with a diode laser (660 nm), making this combination the most efficient approach.

Further investigations are needed to clarify the long-term outcomes and resilience of the combination therapy, as well as its effects on different types of dentin exposure and patient-reported outcomes. Comparative research involving various laser wavelengths, power settings, and alternative desensitizing agents may contribute to the optimization of treatment techniques. To corroborate these findings and determine clinical application, *in vivo* studies with expanded participant numbers and extended follow-up are warranted.

Authors' Contribution

Conceptualization: Simran Genescia, Neetha J Shetty.
Data curation: Simran Genescia, Neetha J Shetty.
Formal analysis: Simran Genescia.
Investigation: Simran Genescia, Neetha J Shetty
Methodology: Simran Genescia.
Project administration: Simran Genescia, Neetha J Shetty
Resources: Neetha J Shetty.
Software: Neetha J Shetty.
Supervision: Neetha J Shetty.
Validation: Neetha J Shetty.
Visualization: Simran Genescia, Neetha J Shetty.
Writing–original draft: Simran Genescia.
Writing–review & editing: Simran Genescia, Neetha J Shetty.

Competing Interests

None to declare.

Data Availability Statement

No new datasets were created or analysed during this study.

Ethical Approval

Ethical clearance was obtained from the Institutional Ethics Committee (Protocol Ref. No. 23097) prior to participant recruitment. The study adhered to the ethical principles outlined in the Declaration of Helsinki. Additionally, the trial was registered with the Clinical Trials Registry of India (CTRI) under protocol ID REF/2023/10/074252 on 09/10/2023. Written informed consent was obtained from all participants before the collection of data.

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