Comparative Evaluation of Diode LASER and NovaMin Technology for Dentinal Tubule Occlusion: An In-Vitro Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Analysis (EDX) Study.

Abstract:

Background: Dentinal hypersensitivity is a brief and painful oral condition that is characterized by an abrupt shooting sensation. Stimulation occurs when hot, cold, sweet, or sour food comes into contact with exposed dentinal tubules. The present study used a scanning electron microscope (SEM) and energy dispersive X-ray analysis (EDX) to investigate the efficacy of 810 nm diode LASER and NovaMin Technology in obstructing dentinal tubules.

Material and Methods: We extracted the outer layers of 20 human teeth to expose the tubules and then treated the surfaces with 17% ethylenediaminetetraacetic acid (EDTA) to create an etched effect. Two cohorts were created from the portions. Group A was subjected to 810nm diode LASER with a power output 1W in continuous mode for 30 seconds. Group B was subjected to the application of NovaMin paste, which contains 927-ppm fluoride content. Following the therapy, occluded dentinal tubules were analyzed using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) for quantitative and qualitative examination. The data analysis was conducted using a one-way analysis of variance (ANOVA) and Tukey's test, with a significance threshold of 0.05.

Result: The average percentages of complete blockage of dentinal tubules in Groups A & B were evaluated using the number of entirely unobstructed dentinal tubules at magnifications of 2X ($F = 3.05$, $p = 0.064$), 5X ($F = 5.33$, $p = 0.011$), and 10X ($F = 8.63$, $p = 0.001$). The count of partially open dentinal tubules seen at magnifications of 2000X, 5000X, and 10000X was $F = 10.15$ ($P < 0.001$), $F = 5.97$ ($p = 0.007$), and $F = 2.12$ ($p = 0.140$) accordingly.

Conclusion: NovaMin technology has demonstrated more effectiveness in blocking dentinal tubules than 810nm diode LASER.

Key-words: Dentine hypersensitivity, Laser, Novamin, SEM, EDX

Introduction:

The term dentinal hypersensitivity (DH) refers to pain that originates from exposed dentine and is caused by many stimuli, such as thermal, evaporative, tactile, osmotic, or chemical, and cannot be associated with any other dental defect or condition[1]. 4-74% of people experience this type of pain, which is transient and characterized by its brief and shooting nature, with an instantaneous response felt[2-4]. DH has been caused by the frequent consumption of food and acidic drinks and in patients with eating disorders, such as anorexia and bulimia. Various theories of hypersensitivity have been suggested such as Direct innervation theory, Odontoblast receptor theory, and hydrodynamic theory.

The hydrodynamic theory, given by Brannstrom and his co-workers (1963), was solidified as the primary understanding of Dentin Hypersensitivity[1,5,6]. Initial Treatment modalities were desensitizing toothpaste, dentifrices with potassium salts, and topical desensitizing agents.

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An alternative treatment plan, such as laser treatment, adhesive resin bonding, primers, sealants, varnishes, conventional glass ionomer cement, and resin-reinforced glass ionomer, may be provided by additional professional care. These treatments have demonstrated varying degrees of effectiveness in treating dentine hypersensitivity, with some studies recommending their use and others indicating that they are ineffective[7-9] Recently, the diode LASER demonstrated its potential for treating DH by successfully occluding the exposed dentinal tubules[10,11]. On the other hand, desensitizing agent NovaMin creates crystals resembling hydroxyapatite that blocks exposed dentinal tubules.

The present study aimed to evaluate and compare the efficacy of Diode LASER, and NovaMin in the occlusion of dentinal tubules (both partially and completely occluded tubules) under a scanning electron microscope (SEM) and the presence of inorganic components under Energy Dispersive X-ray Analysis (EDX), providing the information about the elemental composition of the sample[13,14].

Ethical Consideration:

The ethical approval for the study was obtained from the Sardar Patel Post Graduate Institute of Dental and Medical Sciences with institutional review board number (IRB) PG/222374/IEC/SPPGIDMS

Materials and Methods:

Twenty freshly extracted teeth with intact crowns and root surfaces, non-restored, and non-carious teeth with no enamel anomalies were included in the study. The extracted teeth must be free of resorbed and ankylosed roots or with signs of fracture and discoloration. The extracted teeth were divided into two treatment modalities, ie; diode LASER† (†Picasso AMD lasers, USA) at 810nm (Group A), and NovaMin paste‡ (‡SENSODYNE REPAIR & PROTECT®) (Group B) (Figure 1).

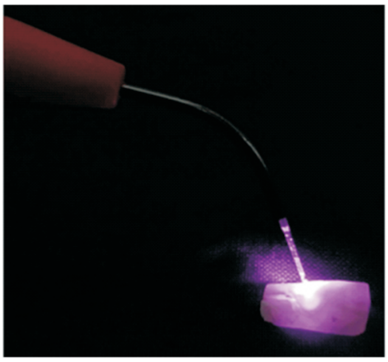


FIGURE 1: Group A specimen treated with Diode LASER

The extracted teeth were cleaned with distilled water followed by scaling and root planning with ultrasonic scalers and Gracey curettes. The teeth were decoronated, and the buccal/facial surface was sliced using carborundum disc bur, and the surface was polished with Arkansas stone, maintaining the thickness of the dentine at 2mm. Etching was done with 17% EDTA for 4 minutes and washed in distilled water for 2 minutes to completely open dentinal tubules[15].

In Group A, 10 buccal/facial surfaces were treated with diode LASER† (810nm wavelength) at 1W in continuous mode for 15sec, spot size 1cm^2 with an energy density of 15J/ cm^2, and in Group B, the 10 buccal/facial surfaces were treated using NovaMin paste‡ (927ppm fluoride content) in a cotton pellet for 3 min. (Figure 2).

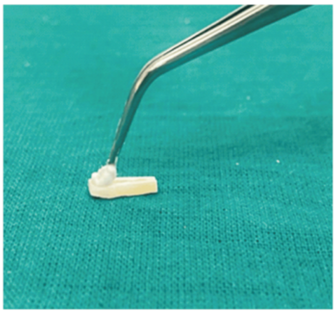
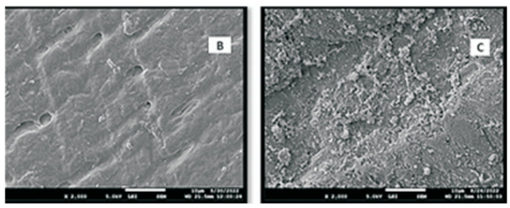


FIGURE 2: Group B specimen is treated with NovaMin paste

Preparation of Samples for Sem analysis:

For scanning electron microscope analysis, the specimens were placed in 2.5% glutaraldehyde in 0.1M HBSS for a minimum of 24 hours[3], followed by washing and dehydration through a graded alcohol series (25%, 50%, 70%, 90%, and 100%) for 10 minutes each, after which specimens were mounted on SEM stubs of 1 cm^2. These mounted specimens were air dried for 48 hours and sputter coated with 30-40 nm of gold using an ion sputtering device§ (§ JEOL, JEC-3000FC). These specimens were examined under SEMk (kJEOL 7610F) by operating at an accelerating voltage of 40 kV. The parameters chosen were tubular diameter and occlusion. Under SEM, each specimen was scanned at variable magnifications (2000X, 5000X, and 10000X) to identify the dentinal tubules, both partially and completely occluded, and was obtained in a longitudinal section[16] (Figure 3).



Energy Dispersive X-ray (edx) Analysis:

In energy dispersive X-ray (EDX), all of the specimens were examined at 20 kV with a spot size of 5nm and a counting time of 300 s to qualitatively determine the presence of chemical elements such as carbon (C), calcium (Ca), phosphorus (P), sodium (Na), potassium (K), and oxygen (O). Statistical analysis One-factor analysis of variance (ANOVA) was used to compare the groups, and Tukey's HSD (honestly significant difference) post hoc test was used to determine the significance of the mean difference between the groups after Shapiro-Wilk's test and Levene's test had determined the homogeneity of variance between the groups.

Results:

Scanning electron microscopic examination provided photomicrographs that were obtained at 2000,5000, and 10000 magnifications at 40 kV voltage. The mean number of fully open dentinal tubules decreases with an increase in magnification (10000X < 5000X < 20000X). ANOVA showed a similar mean number of fully open dentinal tubules among the groups ($F = 3.05$, $P = 0.064$) at magnification 2000X. However, fully open dentinal tubules at both 5000X ($F = 5.33$, $P = 0.011$) and 10000X ($F = 8.63$, $P = 0.001$) magnifications differed significantly among the groups (Table 1).

Group	n	Magnification 2000CX	Magnification 5000X	Magnification 10000X
Group A	10	2.50 ± 0.76	1.00 ± 0.30	0.80 ± 0.13
Group B	10	1.40 ± 0.52	0.90 ± 0.23	0.50 ± 0.17
p-value		0.064	0.011	0.001

TABLE 1: Number of full-open dentinal tubules of two groups at two different magnifications. The number of dentinal tubules full open in two groups at each of the three magnifications was summarized in Mean ± SE and compared by ANOVA (F value). A p-value was considered significant if it was <0.05.

On inter-group comparison, the Tukey test showed a similar ($P > 0.05$) mean number of fully open dentinal tubules between the three groups at magnification 2000X (Table 2).

Magnification	Comparison	Mean diff	q-value	q-value	95% CI of diff.
2000X	Group A vs Group B	1.10	0.08	1.75	-1.112 to 3.312
5000X	Group A vs. Group B	0.10	0.32	4.23	0.154 to 1.646
p-value		0.064	1.41	0.011	0.001

TABLE 2: For each magnification, comparison (p-value) of the difference in mean number of dentinal tubules full open between groups by the Tukey test diff: difference, CI: confidence interval, q value: Tukey test value A p-value was considered significant if it was

EDX is used to analyse the presence of chemical elements like carbon (C), calcium (Ca), phosphorus (P), sodium (Na), potassium (K), and oxygen (O). In all two groups, the weight (%) of element OK was the maximum, and NaK was the minimum (Table 3)

Element	Group A	Group B
CK	15.6	35.81
OK	52.17	43.74
PK	12.40	8.10
CaK	19.67	12.36
NaK	0.00	0.00

TABLE 3: Distribution of presence of element weight (%) among three groups CK: carbon potassium, OK: oxygen potassium, PK: phosphorus potassium, CaK: calcium potassium, and NaK: sodium potassium

Discussion:

The present study was designed to evaluate the efficacy of dental LASERs and the bioactive properties of desensitizing toothpaste with the ability to occlude the dentinal tubules. The diagnosis of DH is crucial for confirming its accuracy and ensuring successful treatment while also eliminating other potential causes of pain. Treatment includes removing etiologic factors causing Dentine Hypersensitivity based on the severity of periodontium health, poor oral hygiene, erosive agents, occlusion correction, and improper brushing techniques[17-19]. The present study determined the efficacy of dental LASERs such as Diode LASER (810nm), and NovaMin technology on the odontoblastic process in the dentinal tubules and was done at fully open and partially open dentinal tubules at three different magnifications.

At 2000X ($p = 0.064$) magnification, the diode group showed fewer occluded dentinal tubules as compared to NovaMin. Fully open dentinal tubules in the group treated with NovaMin at 2000X magnification showed increased tubule occlusion compared to Diode LASER groups.

At 5000X magnification, Group B treated with NovaMin, showed the maximum number of dentinal tubules occlusion. While comparing the fully open dentinal tubules of the NovaMin technology group at 5000X magnification, it showed significant occlusion of dentinal tubules.

At 10000X ($p = 0.001$), fully open dentinal tubules showed decreased dentinal tubules because of increased magnification.However, fully open dentinal tubules were less seen in the NovaMin-treated group. A greater number of partially occluded dentinal tubules were seen when the NovaMin-treated group, showing the effectiveness of NovaMin technology as a desensitizing agent.

At a magnification of 5000X, the diode laser even produced superior results. Due to its low absorption in hard tissues, an in-vitro scanning electron microscopy study revealed that the specimens treated with an 810nm diode laser exhibited the least morphologic changes[24-28]. Hydroxyapatite crystals have a low absorption of light at 810 nm, which permits laser energy to be transmitted, scattered, and propagated through the dentin. This causes the dentin to heat up and melt, obstructing the dentinal tubules[27]. Diode lasers performed better, according to George VT et al. (2016)[29], in terms of treatment longevity and cost-benefit ratios. Diode LASER (810 nm) provided a decrease in cervical dentine hypersensitivity. Gojkov-Vukelic M et al., 2016[30], Asnaashari M et al., 2013[31], and Suri I et al., 2016[32] concluded in their research that diode LASER with wavelengths between 780 and 810 nm has an effect on nerve endings that eliminates cervical dentinal sensitivity.

NovaMin technology showed better occlusion of dentinal tubules against diode laser. The aforementioned outcomes can be linked to its dentine's remineralization characteristics and increased hardness as a result of fluoride's synergistic action. Hydrogen ions are exchanged for sodium in NovaMin. Moreover, phosphate and calcium are released into the environment. The calcium and phosphate ions that are released create a Ca-P layer on the tooth's surface, which crystallizes into hydroxycarbonate apatite when the pH briefly rises.

In accordance with our study, Shivaprasad BM et al. (2016) concluded that NovaMin has the added advantage of chair-side application[26]. Burwell et al. (2010)[33] showed that one time brushing with NovaMin-based dentifrice significantly decreased the visible open tubules adhered to the exposed dentin surface layer. This layer is resistant to acid challenges and is mechanically strong due to the continuous release of calcium. However, the present study results were similar when compared with the group treated with diode LASER.

The primary elements present in the treated samples were analysed using EDX to look for differences in their distribution. Calcium (Ca), potassium (K), phosphorus (P), oxygen (O), and carbon (C) were the main elements found. Table 3 provides a summary of the Ca, K, P, O, and C weight percentages found in the samples. According to EDX analysis, NaK% presence was negligible in the diode laser and NovaMin-treated groups. OK% elements were discovered to be more prevalent in Diode LASER irradiation. By damaging the peritubular dentin, it causes the dentinal tubules to break down irregularly[34]. However, EDX involves only the presence of entrapped molecular elements and is unable to show molecular characteristics.

The limitations of the study were relatively small sample size of 20 healthy human teeth that may not fully capture the variability present in the general population, potentially limiting the generalized findings. Moreover, the short-term evaluation immediately after treatment may not reflect the long-term durability and efficacy of the interventions, necessitating further longitudinal studies. Being a single-centre study, the results might not be broadly applicable to diverse clinical settings and populations, warranting validation through multicentre trials.

Conclusion:

The results of this study indicate that, in the long run, sustained alleviation for dentin hypersensitivity (DH) has been demonstrated by SEM analysis, with NovaMin toothpaste emerging as the best option. Therefore, using a diode laser (810 nm) also produced superior results, and this should be taken into account while creating a treatment plan for DH that offers instant relief. Compared to higher-powered lasers, low-power lasers have the advantage of having a lesser potential to cause heat damage to tooth tissue. Future research would greatly benefit from EDX chemical mapping of these crystals to verify the components present in the cross-sectional SEM pictures.

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