



Comparison of the efficacy of 940-nm diode laser, Gluma, and 5% sodium fluoride varnish in dentinal tubule occlusion

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Abstract

Background and aim Various treatments have been proposed to reduce dentinal hypersensitivity. This study compares the efficacy of 940-nm diode laser, Gluma, and 5% sodium fluoride (NaF) varnish in dentinal tubule occlusion.

Materials and methods In this experimental study, the enamel of 40 intact human premolars was removed, with an area of 2 × 2 mm and a depth of 2 mm, from the cervical midline of the buccal surface. The samples were divided into four groups: NaF varnish, Gluma, 940-nm diode laser, and control. After the interventions, the samples were examined under a field emission scanning electron microscope (FE-SEM). The total number of dentinal tubules and the number of open, completely occluded, and semi-occluded tubules were counted. The results were analyzed using Kolmogorov–Smirnov test, one-way analysis of variance (ANOVA), and Tamhane’s test.

Results The highest mean rate of dentinal tubule occlusion was 84.01 ± 12.08% in the 940-nm laser group, 74.4% ± 11.62 in the Gluma group, 61.78 ± 15.25% in the NaF varnish group, and 15.03% ± 3.39 in the control group. This rate in the control group was significantly different from that of the Gluma, NaF varnish, and 940-nm laser groups ($P < 0.05$). The Gluma group showed no significant difference with the NaF varnish and 940-nm laser groups ($P > 0.05$). The NaF varnish group exhibited a significant difference with the 940-nm laser group ($P < 0.05$).

Conclusion Based on the results, 940-nm diode laser, Gluma, and 5% NaF varnish are effective in sealing of dentinal tubules. Gluma had the same effect as the other two modalities, but the effect of the 940-nm diode laser was greater than that of NaF varnish.

Keywords Dentin desensitizing agents · Dentin hypersensitivity · Gluma · Fluoride varnish · Diode lasers

Introduction

Dental sensitivity is one of the common problems that dental patients face, which causes discomfort, transient pain, and a burning sensation in the teeth when exposed to heat and

cold, as well as acidic, spicy, and sweet substances. The prevalence of dental sensitivities is more than 40% in the world’s adult population and follows an ascending trend [1]. In 1982, dental sensitivities were considered a puzzle due to a lack of information in this respect [2, 3]. In 1990, Addy defined dental sensitivity as a sharp pain due to dentin exposure in response to osmotic, tactile, thermal, chemical, etc. stimuli that cannot be attributed to another pathology [4]. According to the hydrodynamic theory by Brannstrom in 1962, dentin sensitivity is due to the movement and displacement of the tubular fluid [4]. The treatment of dental sensitivity is based on sealing of dentinal tubules and preventing the movement of the tubular fluid or depolarizing the dental nerves [5].

So far, various treatments, including the use of desensitizing gels, solutions, and pastes containing various compounds, such as fluoride Gluma and potassium nitrate, have been proposed to treat dentin sensitivity [6].

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With the advancement of technology, diode lasers with different wavelengths are also used in the treatment of dentin sensitivity [7]. The use of lasers to treat dental hypersensitivity was introduced in the mid-1980s [8]. Its action is due to its analgesic, biostimulatory, and anti-inflammatory properties which also regulate the cellular metabolism which makes it effective.

Despite the treatment alternatives, dentin sensitivity still exists as a chronic problem with an unknown prognosis [3], and yet no cure has been accepted as the only acceptable way to reduce pain at a satisfactory level in all cases [5].

Numerous studies have examined dental sensitivity, and there have been reports of a positive effect of sodium fluoride (NaF) varnish, Gluma, and lasers, but there is an information gap in the comparison of these three methods [1, 3, 9, 10].

The null hypothesis of the study is that 940-nm diode laser irradiation and NaF varnish or Gluma application do not have any effect on dentinal tubule occlusion.

Materials and methods

In this *in vitro* experimental study, the study samples comprised freshly extracted human premolar teeth without any decay, restoration, root canal treatment, crown or root fractures, abrasions, cracks, or dental anomalies [1, 11].

Number of samples

According to the results of a study by Joshi et al. [6], using one-way analysis of variance (ANOVA) power analysis in PASS II software with $\alpha=0.05$ and $\beta=0.2$, the mean standard deviation (SD) of 0.077, and the effect size of 0.57, the

minimum sample size required in each of the four groups was estimated to be 10 samples. A simple random method was used for sampling.

After the approval of this research by the Ethics Committee of the Faculty of Dentistry of Islamic Azad University of Medical Sciences, Tehran, Iran, 40 premolars were selected from teeth of 12- to 25-year-olds, which were freshly extracted for orthodontic purposes. Soft and hard tissue debris was removed using #5–6 Gracey periodontal curettes (Hu-Friedy, Chicago, IL, USA) [11]. The teeth were cleaned with fluoride-free pumice powder (Maquira Dental Products, Maringa, PR, Brazil) using a rubber cup mounted on a handpiece for 10 s and then washed with distilled water for 15 s and air-dried [8].

The teeth were then kept in a 10% formalin solution at room temperature [6]. The prepared samples were numbered and randomly divided into four groups, including three experimental groups and one control group, each group containing 10 teeth. The enamel of the samples, with an area of 2×2 mm and a depth of 2 mm, was removed from the cervical midline of the buccal surface of the teeth using a 008 fissure diamond bur (Teezkavan, Tehran, Iran) mounted on a handpiece (Fig. 1). The dimensions of the removed area were checked using a Williams periodontal probe (Hu-Friedy, Chicago, IL, USA). Then, a #135 flat-end conical 12-blade carbide bur (Dia Tessin, Vanetti SA, Switzerland) was used to flatten the prepared surfaces [12]. The prepared samples were first placed in a 17% ethylenediaminetetraacetic acid (EDTA) solution (Nik Darman, Tehran, Iran) for 1 min to remove the smear layer and expose the dentinal tubules [1]. Then, the samples were washed with distilled water, soaked in a sodium hypochlorite (NaOCl) solution for 1 min, and washed again with distilled water. The samples were then kept in distilled water until therapeutic interventions [13].

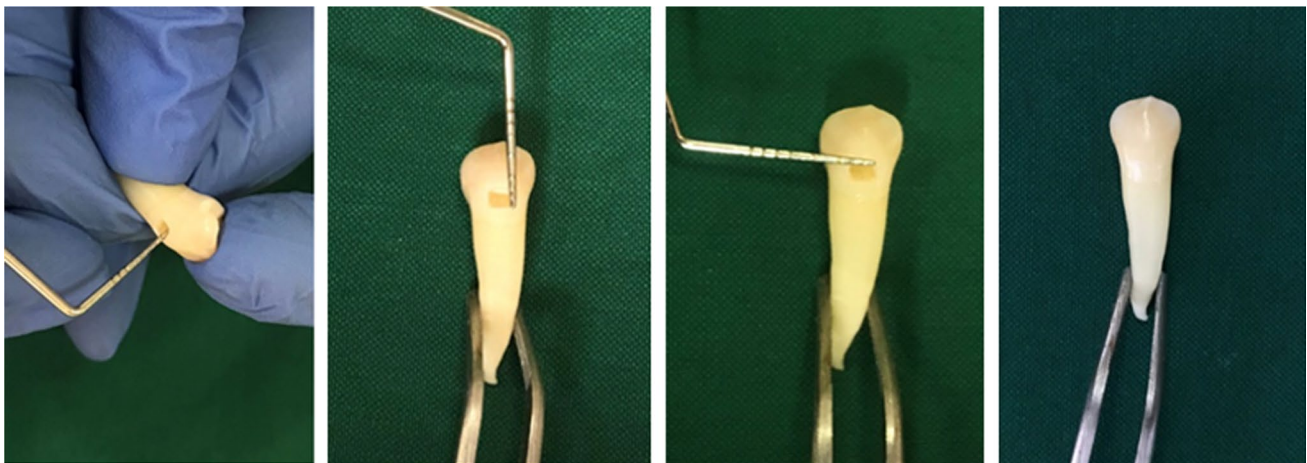


Fig. 1 A Sample of a human premolar tooth before preparation. B 2-mm long preparation in the cervical midline of the buccal surface. C 2-mm wide preparation in the cervical midline of the buccal surface. D 2-mm deep preparation in the cervical midline of the buccal surface

Study groups

Control group

Ten tooth pieces were kept in distilled water after 1 min of immersion in a 17% EDTA solution [1]. These samples did not undergo any intervention [14].

Gluma group

The Gluma desensitizer gel (Heraeus Kulzer, Hanau, Germany) was applied as one drop, using the applicator tip, to the wet dentin surface of the midbuccal part of the cervical area of the prepared teeth for 60 s. The samples were left for 30 s, and then, the Gluma was dried on the surface using an air syringe [8]. The criterion for drying of the Gluma on the surface is that it disappears and leaves a non-shiny surface [6]. The samples were then washed with distilled water for 10 s [14].

Fluoride varnish group

First, the surface of the samples was dried. Then, the special brush in the varnish packaging was impregnated with NaF varnish (Aria Dent, Asia Chemi Teb, Tehran, Iran), and the varnish was applied to the midbuccal surface of the cervical area with the tip of the applicator [15]. According to the manufacturer's instructions, 3 min were considered for the varnish to dry on the tooth surface [16]. Then, the teeth were kept in distilled water [13].

940-nm diode laser group

The samples were continuously irradiated by the 940-nm diode laser (Biolase, CA, USA) with a power of 0.5 W for 15 s, with 2.5 J/cm², once a day for 3 days [5, 17]. The laser was tangential to the midbuccal surface of the cervical area of the samples and was irradiated with rapid apicocoronal and mesiodistal movements [5].

Scanning electron microscopic (SEM) analysis

The samples were analyzed using a field emission scanning electron microscope (FESEM; Nikon, Tokyo, Japan)

to assess dentinal tubule occlusion. Before preparing the samples for the SEM analysis, the crown of all teeth was separated from the root using the 008 fissure diamond bur. Then, the samples were washed and covered with a thin layer of gold of 100-Ångstrom thickness [9]. Next, the teeth were vacuumed in a vacuum device, mounted in the microscope, and examined. The microscope settings were set to 10 kV and 2000 and 5000 magnifications [14, 18].

Finally, photomicrographs with magnifications of 2000 and 5000 were randomly generated from the midbuccal surface of the cervical region. Due to the greater clarity of dentinal tubules in magnification of 5000, the total number of tubules and the total number of open and occluded tubules (both full and half occluded) were counted manually on the photomicrographs with this magnification. The results were determined as a percentage and statistically analyzed in the four groups using Kolmogorov–Smirnov test, one-way ANOVA, and Tamhane's test.

The percentage of occluded tubules (completely occluded and semi-occluded) was obtained by dividing the total number of occluded and semi-occluded tubules by the total number of dentinal tubules seen in the image multiplied by 100 [14, 18]. Tubules that were completely sealed at the opening of the canal were considered fully occluded tubules, whereas tubules that had a reduced opening diameter but were open in the center were considered semi-occluded tubules [6]. According to references 14 and 17 in the article, in this study, all closed and semi-closed dentinal tubules, more than 50%, were considered closed dentinal tubules.

The results obtained from the SEM analysis were statistically analyzed using PASS II software according to Kolmogorov–Smirnov test, one-way ANOVA, and Tamhane's test.

Results

In this study, which was conducted to compare the effect of Gluma gel, NaF varnish, and 940-nm diode laser on dentinal tubule occlusion between three groups of 10 suitable teeth and one group as a control, the results of tubule occlusion percentage were as follows:

According to Table 1, the highest mean dentinal tubule occlusion rate was $84.01 \pm 12.08\%$ in the 940-nm laser group followed by the Gluma group ($74.4 \pm 11.62\%$), the

Table 1 Statistical specifications of dentinal tubule occlusion rate in the studied groups

Groups		Number	Minimum	Maximum	Mean	SD
Control	Percentage	10	8.60	20.00	15.0300	3.4
Gluma	Percentage	10	61.00	100.00	74.4000	11.6
Varnish	Percentage	10	30.00	88.00	61.7840	15.2
940-nm laser	Percentage	10	69.50	100.00	84.0150	12.08

SD standard deviation.

NaF varnish group ($61.78 \pm 15.25\%$), and the control group ($15.03 \pm 3.39\%$).

The data presented in Table 1 were tested with Kolmogorov–Smirnov test, and it was proved that the data distribution was normal ($P > 0.05$). Therefore, the data were tested with one-way ANOVA. This test showed a significant difference between the groups ($P < 0.05$).

Pairwise comparisons of the groups were made using post hoc tests. Due to the different distribution of data in this study, Tamhane's test was performed, rendering the following results (Table 2):

The dentinal tubule occlusion rate in the control group was significantly different from that of the Gluma, NaF varnish, and 940-nm laser groups ($P < 0.05$).

The dentinal tubule occlusion rate in the Gluma group was not significantly different from that of the NaF varnish group. Likewise, the 940-nm laser group did not show any significant difference with the Gluma group ($P > 0.05$).

The dentinal tubule occlusion rate in the NaF varnish group was significantly different from that of the 940-nm laser group ($P < 0.05$).

Diagram 1 shows that the control group differed significantly from the three therapeutic groups in dentinal tubule occlusion rate ($P < 0.05$), indicating that the therapeutic groups were effective in this respect. The Gluma group was also more effective than the varnish group but not significantly ($P > 0.05$). The 940-nm diode laser was the most effective modality. The laser and Gluma groups did not differ significantly in dentinal tubule occlusion rate ($P > 0.05$).

Photomicrographs taken from the samples in the four groups of control, Gluma, NaF varnish, and 940-nm diode laser are shown in Figs. 2.

In general, the results of this research were as follows:

- 1- The amount of dentinal tubules occlusion in the laser group was higher than other groups, and there was a significant difference between the laser group and fluoride varnish and control groups. But there was no significant difference between the laser and Gluma groups.
- 2- The amount of dentinal tubule occlusion in the Gluma group was not statistically significant compared to the laser group and fluoride varnish group, but there was a significant difference compared to the control group.
- 3- The amount of dentinal tubule occlusion in the fluoride varnish group was significantly different from the laser and control group, but there was no significant difference compared to the Gluma group.
- 4- The amount of dentinal tubule occlusion in the control group was less than other groups and was statistically significant.

Discussion

Dental sensitivity is a clinical condition that manifests itself in the form of short, sharp pain caused by tactile, thermal, osmotic, or chemical stimuli [1]. According to the hydrodynamic theory, the movement and displacement of the tubular fluid cause dentinal sensitivity, resulting in a message of pain in the nerves [3].

Dental sensitivity is known as a chronic problem, and the resultant pain can prevent good hygiene maintenance, leading to plaque accumulation and future periodontal disease [7].

Dentinal hypersensitivity is associated with the number of exposed dentinal tubules. The main goal of successful treatment is to reduce the movement of the tubular fluid by

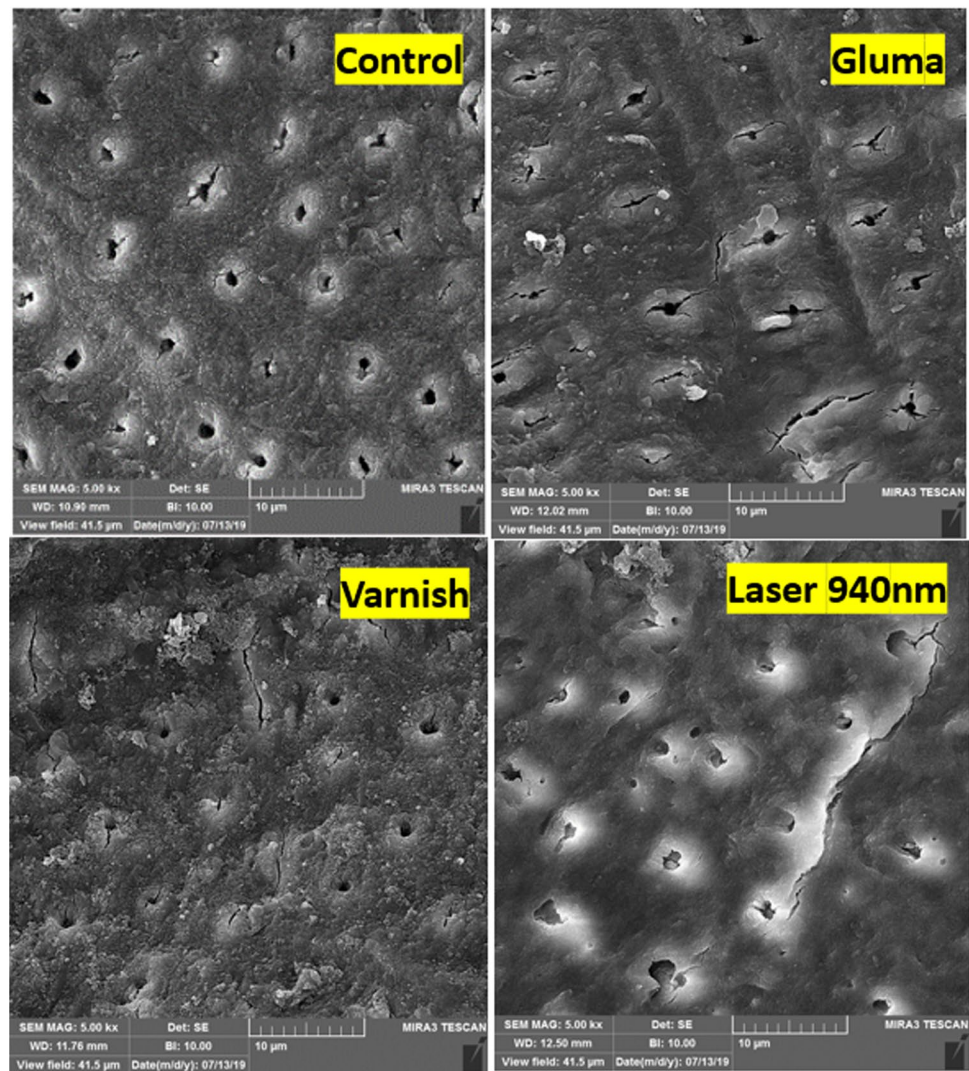
Table 2 The results of Tamhane's test

Groups		Average difference (I-J)	SE	Significance	95% CI	
					Lower bound	Upper bound
Control	Gluma	-59.37000*	3.83029	0.000	-71.7281	-47.0119
	Varnish	-46.75400*	4.94351	0.000	-62.9325	-30.5755
	940-nm laser	-68.98500*	3.96978	0.000	-81.8236	-56.1464
Gluma	Control	59.37000*	3.83029	0.000	47.0119	71.7281
	Varnish	12.61600	6.06616	0.279	-5.4506	30.6826
	940-nm laser	-9.61500	5.30275	0.419	-25.2765	6.0465
Varnish	Control	46.75400*	4.94351	0.000	30.5755	62.9325
	Gluma	-12.61600	6.06616	0.279	-30.6826	5.4506
	940-nm laser	-22.23100*	6.15518	0.013	-40.5227	-3.9393
940-nm laser	Control	68.98500*	3.96978	0.000	56.1464	81.8236
	Gluma	9.61500	5.30275	0.419	-6.0465	25.2765
	Varnish	22.23100*	6.15518	0.013	3.9393	40.5227

SE standard error, CI confidence interval.

*The mean difference at 0.05 is significant.

Fig. 2 Photomicrograph of one of group samples with magnification of 5000 occluded dentinal tubules in control, 940-nm diode laser, varnish and Gluma



sealing these tubules completely or in a semi-occluded fashion or to depolarize the nerves [1].

So far, various treatments, including laser treatment or the use of desensitizing gels, solutions, and pastes containing various compounds, such as fluoride, potassium nitrate, and oxalate, have been proposed to reduce dental sensitivity [6]. Since dental sensitivity is one of the most common conditions in the oral environment and is annoying for patients, there is always a need to develop new treatments and new products to reduce the symptoms [19]. NaF varnish, Gluma gel, and 940-nm diode laser are among the treatment methods for sealing of dentinal tubules, the effectiveness of which in tubule occlusion has been studied in the present research.

Based on the experiments and the obtained statistics, it is concluded that the rate of dentinal tubule occlusion was $84.01\% \pm 12.08$ in the 940-nm diode laser group, $74.4\% \pm 11.62$ in the Gluma group, $61.78\% \pm 15.25$ in the NaF varnish group, and $15.03\% \pm 3.39$ in the control group.

This shows the effectiveness of all treatments compared to the control group, and most of all, the effectiveness of the 940-nm diode laser. In comparison between the treatment groups, the intergroup difference with the control group was significant in dentinal tubule occlusion ($P < 0.05$). The difference between the 940-nm diode laser group and the NaF varnish group was also significant ($P < 0.05$), while the difference between the laser and Gluma groups, as well as between the Gluma and NaF varnish groups, was not significant ($P > 0.05$). This study demonstrates the ability of all three therapies to occlude dentinal tubules.

Kara et al. stated that the increase in dental sensitivity is more noticeable in younger people due to the decrease in the diameter of the tubules in older people [7]. Therefore, in the present study, teeth extracted from 12- to 25-year-olds, due to orthodontic reasons, were used [15], and the samples were matched in terms of dentinal tubule conditions and were morphologically homogeneous.

After a systematic evidence-based search in the databases regarding the methods of dentinal tubule occlusion and treatment of dental sensitivity, articles were obtained that showed different and varied effects of different desensitizing methods and materials [1–3, 5–8, 15, 19, 20].

Al-Khafaji et al. concluded that the 940-nm diode laser with 0.8, 1.6, and 2 W powers is effective in dentinal tubule occlusion, but with the 940-nm diode laser with 3 W power, there was evidence of carbonization, indicating the irreversible destruction of the dentin surface [1].

Diode lasers with a wavelength between 800 and 980 nm have low adsorption in water and hydroxyapatite. This low laser energy adsorption by dentin leads to a thermal accumulation and a gradual increase in dentin surface temperature. This increase in temperature causes denaturation and deformation of the organic dentin matrix to an amorphous form, resulting in tubule occlusion with the use of low-power lasers. The SEM analysis in the study by Al-Khafaji et al. showed that the higher the laser power, the greater are its effects on the dentin surface due to the increase in absorbed energy such that with a 3 W laser, irreversible destruction is observed at the surface of the tubules [1].

High-power lasers setting cause matrix meltdown and recrystallization at the dentin surface, while the mechanism of action of low-power lasers is mostly through the direct effect on the pulpal nerve endings, resulting in changes in neural transmission [1]. Kara and colleagues showed that these lasers act by reducing the neural signals of afferent C-nerve fibers [7]. As a result, the use of low-power lasers setting is likely to have a greater and better effect in *in vivo* studies, given that these lasers use both mechanisms of dentinal tubule occlusion and neural depolarization.

Femiano et al. attribute the effect of high-power lasers setting to a mechanical thermal mechanism associated with the high absorption of their wavelengths by water; the occluding effect of the laser is due to the thermal coagulation of tubular fluid proteins and consequently reduced permeability of tubules [5].

According to a study by Liu et al., the dentin structure changes due to changes in temperature created by laser energy. The crystalline structure and meltdown are the result of the absorption of energy by the mineral part of dentin, which includes carbonates and phosphates [17].

Jain et al. stated that low-power lasers have anti-inflammatory effects on teeth, whereas higher-power lasers setting have destructive effects on the pulp [21].

In a study by Rizzante et al. on the effects of lasers, it has been reported that high-power laser setting melts dentin and that the dentin becomes a non-perforated, shiny surface during the re-hardening process. In the SEM analysis of the laser-irradiated group, a mosaic-like irregular surface was observed compared to open and wide tubules in the

control group [22]; the abovementioned results have also been observed in the present study.

Reddy et al. stated that changes in the morphology of laser-irradiated dentin are detectable by the SEM and depend on parameters such as power and frequency and the way the laser is applied [18].

When the laser beam irradiates the surface of a sample, there are four ways to continue: (1) being reflected, (2) passing through the sample, (3) being absorbed, and (4) disperse. Of these four paths, changes in the dentin surface have been largely related to energy absorption, which is a thermal process. Therefore, the most important issue in laser treatment is to decide on the best parameters to achieve the desired results without heat effects on the pulp or fracture or carbonization [18].

Corona et al. stated that laser therapy with the right parameters could stimulate physiological cellular functions [3]. Lasers can stimulate the production of tertiary dentin by increasing the metabolic activity of odontoblasts, eliminating dentinal tubules; in this way, they improve the internal occlusion of dentinal tubules [3].

For this reason, in the present study, we used a 940-nm diode laser with a power of 0.5 W (low-power), which was successful in sealing dentinal tubules, and its effect in terms of the average percentage of dental tubule occlusion was more prominent than that of the other two desensitizing agents (NaF varnish and Gluma).

In the study by Kara et al., the 940-nm diode laser and Gluma reduced dental sensitivity, and no superiority was observed between the two ($P > 0.05$) [7]. Likewise, in the present study, the laser was insignificantly more effective than the Gluma ($P > 0.05$). They considered the use of diode lasers as an alternative to desensitizers due to sensitivity control by closing dentinal tubules or reducing the patient's pain threshold by depolarizing the nerves [7]. The reduction of the patient's sensitivity through nerve depolarization can only be investigated in clinical trials (*in vivo* studies), whereas in the present study, which was performed *in vitro*, the reduction in sensitivity can only be assessed by the rate of tubule occlusion after laser application.

In SEM images, Kara et al. observed that in the teeth treated by the Gluma, multiple transverse septa formed in dentinal tubules in contact with their walls to a depth of nearly 200 μm ; they concluded that these transverse septa influence tubular fluid movement [7]. In addition, HEMA present in the Gluma increases the penetration of glutaraldehyde into the tubules, which in turn leads to the fixation of serum proteins in the tubular fluid and the closure of the tubules [7].

In general, desensitizing agents seal dentinal tubules and reduce the response to stimuli through two mechanisms: they can create a mechanical seal on the surface of tubules with or without the need for light-curing (Gluma), or they cause

the deposition of proteins and crystals inside and around dentinal tubules by being rubbed on the surface using a microbrush [7].

Femiano et al. also observed the effect of the Gluma gel on tubular sealing [5]. The desensitizing Gluma gel contains 35% HEMA and 5% glutaraldehyde and coagulates the serum albumin in the tubular fluid [5]. The reaction of glutaraldehyde and albumin causes HEMA polymerization. HEMA increases the penetration of glutaraldehyde into dentinal tubules. Glutaraldehyde closes dentinal tubules by denaturing the tubular fluid amino acids [5]. Femiano et al. consider the mechanism of action of the Gluma to be based on the coagulation of tubular fluid proteins and state that the formation of multiple septa results in the formation of an inherent barrier in dentinal tubules [5].

In the present study, the Gluma and NaF varnish were both effective in sealing dentinal tubules compared to the control group, but the difference between the two substances was not significant ($P > 0.05$). Likewise, in the study by Femiano et al., both NaF varnish and the Gluma were effective in sealing dentinal tubules but the difference between the two substances was significant ($P < 0.05$) [5]. The reason for the difference between the results of the present study and the study by Femiano et al. could be the difference in the method of use (time and frequency of use) and the type (brand) of substance used.

The mechanism of action of NaF varnish, which belongs to the family of tubular sealing agents, is through the deposition of calcium fluoride (CaF₂) crystals on the opening of dentinal tubules without chemical bonding, forming a mechanical blockage. The short-term effect of NaF varnish can be due to the loss of the CaF₂ barrier due to dissolution in saliva [5].

Corona et al. stated that NaF varnish is a short-acting desensitizing agent [3]. The varnish has a gradual therapeutic effect that increases over time, and it may eventually be removed by tooth brushing before achieving its full effect [3]. Therefore, the effect of NaF varnish on dental sensitivity should also be evaluated in a long-term manner.

The gradual activity of NaF varnish indicates a reaction between NaF and calcium ions in the tubular fluid, which leads to the formation of CaF₂ crystals that precipitate on the openings of dentinal tubules [3].

Al-Khafaji et al. and Reddy et al. used an SEM with a magnification of 5000 to count dentinal tubules due to the higher clarity of tubules in this magnification [1, 18]; that is why in the present study, we used the 5000 magnification to count half-occluded, occluded, and open tubules.

In the qualitative study of the tubules, in the present study, it was observed that in the control group, most of the tubules were completely open and wide. In the laser group, in most of the samples, completely sealed tubules were observed. In the Gluma and NaF varnish groups, in

most of the samples, dentinal tubules were observed as semi-occluded. In different studies, different techniques and materials have shown different effects on the quality of sealing of dentinal tubules. In the study by Joshi et al., it was concluded that most tubules in the Gluma group were semi-occluded [6]. In a study by Patil et al., it was found that the number of fully sealed tubules was higher in the laser group, whereas in the NaF varnish group, the majority of dentinal tubules were semi-occluded [19].

In the present study, based on the SEM images, the effect of Gluma, NaF varnish, and 940-nm diode laser was different on the morphology and three-dimensional (3D) topography of tubules. The laser caused superficial destruction of tubules but the two other substances only blocked the tubules, leaving a smoother and softer surface not far from the main topography of the tubules compared to the laser group. Laser-induced surface alterations can be justified by its effect on denaturation and deformation of the organic matrix of dentin to an amorphous form [1], whereas Gluma and NaF varnish only cause mechanical blockage of dentinal tubules [5, 23]. If part of the sensitive tooth that has been treated by lasers needs restoration in the future, the presence of open dentinal tubules would be necessary for the penetration of resin and the formation of resin tags. These treatments can be difficult if the dentinal tubules are occluded or superficially destructed.

As a final point, based on the results of this study, it was concluded that Gluma, NaF varnish, and 940-nm diode laser have a greater effect on dentinal tubule sealing than the control group, certainly reducing the dental sensitivities of patients. However, since in general treatment of dentinal sensitivities, the effect of desensitizing substances on nerve depolarization should also be considered, and this is possible only in *in vivo* studies, more research is recommended for clinical evaluation of dental sensitivities.

Conclusion

The results of this study showed that in all three therapeutic methods with 940-nm diode laser, Gluma gel, and 5% NaF varnish, dentinal tubule occlusion rate was significantly higher compared to the control group. The effect of Gluma on dentinal tubule occlusion was similar to that of the other two modalities, but the 904-nm diode laser was more effective than NaF varnish.

Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest The authors declare no competing interests.

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