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Original Research Article

Evaluation of dentinal permeability reduction provided by different desensitizing treatments

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Abstract

Introduction: Dentinal hypersensitivity consists in an increasing problem at dental offices and new approaches may be developed. **Objectives:** The authors studied different desensitizing treatments and their efficacy in reducing dentinal permeability and dentinal tubules opening. **Material and methods:** One hundred bovine incisors roots had their buccal surface flattened and treated by 3 applications of each desensitizing agent, following the respective groups (n = 10). After treated, 7 specimens of each group were prepared for a 0.5% basic fuchsin permeability test and the other 3 specimens were prepared to SEM qualitative analysis. The permeability test specimens were sectioned with a diamond saw in order to evaluate the stained and unstained areas. Kruskall Wallis statistical analysis was performed ($p < 0.05$). **Results:** Colgate Pró-Alívio paste and toothpaste, diode and Nd:YAG Lasers, GHF, Sensi Active, Oxagel and 2% Desensibilize promoted a significant permeability reduction when compared with the respective control groups ($p < 0.05$). Comparing the mean permeability differences between the different groups after the treatments, Oxagel and Nd:YAG were better than 0.2% Desensibilize group. **Conclusion:** None of the treatments may be considered 100% effective in treating dentinal hypersensitivity since a partial reduction of the permeability was observed.

Introduction

In recent decades, a significant reduction in the incidence of teeth decay was observed [27, 33]. Thus, the teeth have remained longer in the mouth, which makes them more susceptible to other types of non-carious lesions such as gingival recession and tooth wear which may, in some cases, cause dentin hypersensitivity [1, 2, 35, 36]. The prevalence of hypersensitivity varies widely (from 8% to 57%) depending on the population, methodology and resources used for diagnostic [3, 36, 42].

Dentin hypersensitivity has a multifactorial etiology and can be described clinically as an acute pain that occurs in response to thermal (hot or cold), chemical (acid fruits, spicy foods, sugar and salt), mechanical (brushing) and evaporative stimuli (air jets) applied to the exposed dentin due to the presence of opened dentinal tubules. The exposure of dentin to the oral environment may occur due to processes as gingival recession and root erosion, abrasion or attrition, as well as surgical and non-surgical periodontal treatments [3, 5, 8, 22, 32, 42].

The most widely accepted theory to explain dentinal hypersensitivity is the "Hydrodynamic Theory" from Brännström [7] that provides a plausible explanation for the hypersensitivity manifestation in which the motion of dentinal tubules internal fluids are able to stimulate nervous cells present in the pulp tissue, leading to a painful sensation [8, 30].

The treatment of dentinal hypersensitivity has as goal pain remission, often by topic application of desensitizing agents, anti-inflammatory agents, agents that block the neuronal response, root coverage procedures through periodontal plastic surgery and, most currently, high and low input laser irradiation [5, 11, 43].

Although there are different therapies for the treatment of dentin hypersensitivity, the main challenge is to find a substance or treatment that effectively eliminates the pain and does not relapse, which unfortunately is still not available [28].

So, it is fundamental to have comparative studies of different treatments and products, considering their dentinal tubules physical obliteration efficiency and the associated dentin permeability reduction.

Material and methods

Experimental design

The experimental design presented one variation factor (treatment), divided in ten levels. The quantitative response variable was percentage of infiltrated area, measured by imaging software. The sample size was 100 bovine incisors, divided into ten groups (n = 10).

Specimen preparation

One hundred bovine incisors had their roots separated from the respective crowns. The root lingual surfaces were flattened with 320 grit SiC sandpaper (Extec. Corp., Enfield, USA) and after achieving a flat surface, the specimens were fixed in acrylic discs using viscous wax, with the buccal surface upwards. This surface was also flattened and polished using 320, 600 and 1200 grit SiC sandpaper, at low speed (Figure 1). Specimens were stored in 0.1% thymol solution after extraction for a maximum time period of 3 months. All specimens were prepared at the same time and stored at 4°C deionized water until used (treatment applications).

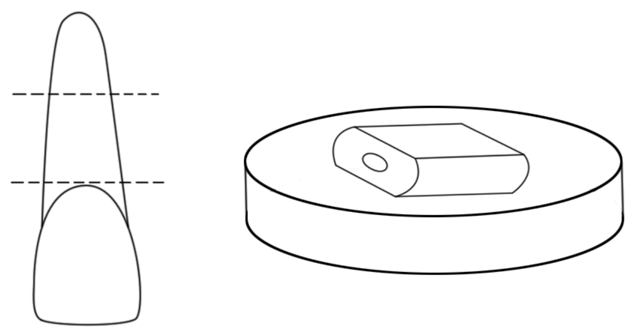


Figure 1 – Schematic aspect of buccal surface after specimen flattening

The specimens were randomly divided into 10 groups (n = 10), with 3 applications of different desensitizing treatments. Seven specimens of each group were used for dye infiltration test and the others were used for visual analysis in scanning electron microscopy (SEM).

Each flattened surface was marked in the center with a ¼ steel drill at low speed in order to delimit the test and control areas. EDTA pH 7.5 was applied (1 minute) over the flattened surface, with a KG microbrush (Kg Sorensen, Cotia, SP, Brazil), in order to remove debris allowing a wide-open dentinal tubules aperture. Half of the surface was protected with a light-cured gingival barrier (Top-Dam, FGM, Joinvile, SC, Brazil), based on the previously center mark. On the other half (non-protected) the treatment was performed according to the guidelines of the respective manufacturer (Table I and Figure 2).

Figure 2 – Desensitizing agent application over the test surface (non-protected)

Considering the laser groups, a 30 mm² area (5.0 X 6.0 mm) was delimited using the gingival barrier, half of this area (15 mm² – 2.5 X 6.0 mm) was protect with gingival barrier (control area) and the unprotected test area was irradiated as follows:
- Nd:YAG laser: 1064nm wave-length, 300 μm fiber diameter, 0.5W power output, 10 Hz frequency, long pulse and entire area scanning (30s) in contact mode;
- Diode laser: 970nm wave-length, 300 μm fiber diameter, 0.5W power output, 10 Hz frequency, long pulse and entire area scanning (30s) in contact mode.

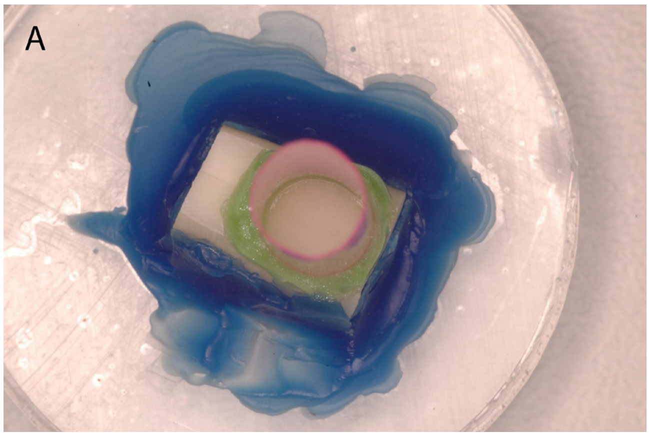
After the treatments, the gingival barrier was removed of the specimens' surface.

Table I – Different desensitizing products and treatments and their respective manufacturer and active ingredients

Group	Product	Manufacturer	Active ingredients	Application
1	Paste Colgate Pró-Alívio	(COLGATE, São Bernardo do Campo, SP, Brazil	8% Arginine and calcium carbonate	Prophy brush for 1 minute
2	Toothpaste Colgate Pró-Alívio	COLGATE, São Bernardo do Campo, SP, Brazil	8% Arginine, calcium carbonate and 1.10% sodium monofluorophosphate (1450ppm F)	Prophy brush for 1 minute
3	0.2% Desensibilize	FGM, Joinville, SC, Brazil	5% Potassium nitrate, 0.2% sodium fluoride	Microbrush for 10 minutes
4	2% Desensibilize	FGM, Joinville, SC, Brazil	5% Potassium nitrate, 0.2% sodium fluoride	Microbrush for 10 minutes
5	Oxa-gel	Art-Dent, Araraquara, SP, Brazil	3% Potassium oxalate	Microbrush for 2 minutes
6	Sensiactive	Ativus Farmaceutica Ltda, Valinhos, SP, Brazil	3% Potassium oxalate	Active microbrush for 4 minutes
7	GHF	Biodinâmica, Ibiporã, PR, Brazil	5.1% Glutaraldehyde, 36.1% HEMA, sodium fluoride	Microbrush for 30 seconds
8	Gluma Desensitizer	Heraeus-kulzer, Hanau, Hesse, Germany	5% Glutaraldehyde, 36%HEMA	Microbrush for 60 seconds
9	1064nm Nd:YAG Laser - Smart File	Deka M.E.L.A. Calenzano, Italy	----	Scanning in contact mode
10	970nm Diode Laser - SIRO Laser	Sirona Dental Systems GmbH - Bensheim-Germany	----	Scanning in contact mode

Permeability tests

In order to realize the permeability test, 0.1mL of 0.5 % basic fuchsin was placed in contact with the buccal surface for 4 hours, using a 5mm diameter plastic tube centered over the guide hole, hold steady with use of the gingival barrier (Figures 3A and 3B).



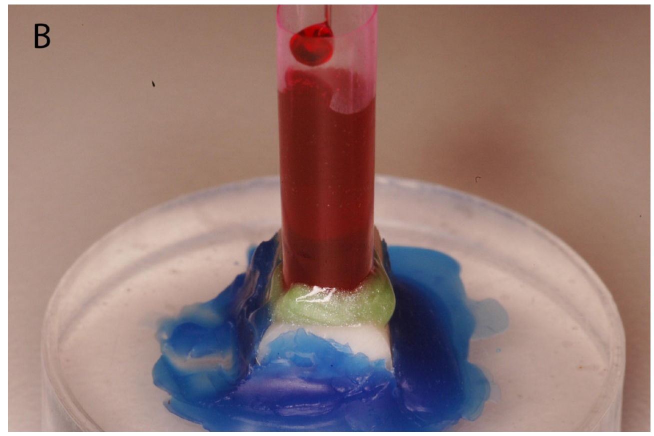


Figure 3 – (A) plastic tube fixed with gingival barrier centered over the guide hole; (B) dye application on buccal surface

After the dye infiltration time, the plastic tube and gingival barrier were removed and the surface was washed with air-water spray for 2 minutes.

The stained specimens were taken to the cut machine in order to perform a mesiodistal section, also based on the guide hole. In sectioned specimens was possible to visualize the test and control surfaces (Figure 4).

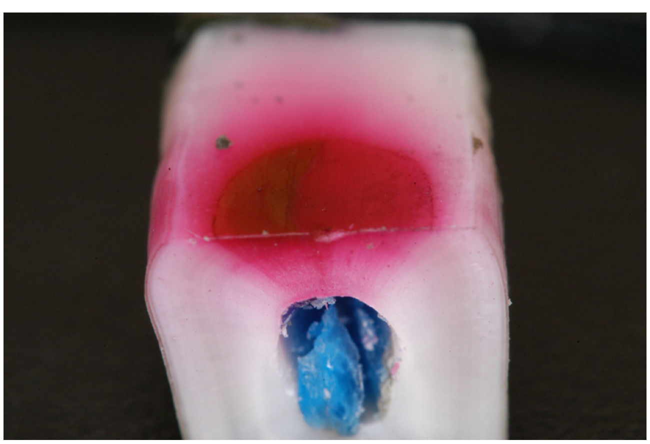


Figure 4 – Sectioned specimen aspect in order to make the dye infiltration analysis (left side control and right side test)

The image of each half was captured with a professional digital camera (Nikon D100, Japan). The digital images were transferred to UTHSCSA Image Tools version 3.0 software, where the total area (from flattened surface to root canal as vertical length) and the dye leakage area (test and control sides) were quantified, allowing to calculate the percentage of dye penetration in each specimen.

Scanning Electron Microscopy

Three randomly selected specimens of each group were processed for qualitative analysis. The specimens were fixed on a metallic stub with their treated surfaces facing up. After dried in an desiccator and metallized, the samples were analyzed in a scanning electron microscope JSM-T220a (Jeol, Tokyo, Japan) with 15 kV and 1000X magnifying. Digital photomicrographs, from both test and control sides, were analyzed qualitatively illustrating the behavior of each treatment.

Statistical analysis

The results of each group were obtained from the percentage of infiltrated (stained) area versus the total area. Since the means did not reach the normality test, a non-parametric Kruskal-Wallis test was applied ($p < 0.05$).

Results

Permeability

The infiltration observed (% ± SD) in all groups after 3 applications of the desensitizing treatment is shown in table II (test and control areas values) and table III (test and control mean differences).

Table II – Dye infiltration mean (% ± SD) at control and test areas after different treatments

Product	Test area	Control area
Colgate Pró-Alívio Toothpaste	59.18 ± 8.621[a]	63.93 ± 6.363[b]
Colgate Pró-Alívio Paste	51.30 ± 8.355[a]	59,52 ± 5.647[b]
0.2% Desensibilize	68.69 ± 13.12[a]	71.14 ± 14.46[a]
2% Desensibilize	54.74 ± 18.35[a]	61.80 ± 15.93[b]
Oxagel	35.26± 16.79[a]	51.11 ± 17.35[b]
Sensi Active	49.35 ± 10.98[a]	60.67 ± 10.33[b]
GHF	51.61 ± 11.76[a]	62.90 ± 11.36[b]
Gluma Desensitizer	56.05 ± 5.871[a]	60.65 ± 6.345[a]
0.5W Nd:YAG laser	42.90 ± 8.998[a]	57.63 ± 6.881[b]
0.5W Diode laser	58.17 ± 6.820[a]	64.71 ± 7.896[b]

Different letters indicate difference in the same group/line ($p < 0.05$)

Table III – Test and control mean differences (% ± SD) considering different treatments

Product	3 Applications
Toothpaste Colgate Pró-Alívio	4.752 ± 3.511[ab]
0.2% Desensibilize	2.443 ± 5.741[a]
2% Desensibilize	7.056 ± 3.525[ab]
Oxagel	15.84 ± 10.98[b]
Sensi Active	11.32 ± 6.705[ab]
GHF	11.29 ± 8.440[ab]
Gluma Desensitizer	4.604 ± 5.672[ab]
0.5W Nd:YAG laser	14.73 ± 5.066[b]
0.5W Diode laser	6.534 ± 2.542[ab]
Paste Colgate Pró-Alívio	8.215 ± 5.073[ab]

Different letters indicate statistical difference ($p < 0.05$)

Colgate Pró-Alívio paste (in office) and toothpaste, diode and Nd:YAG Lasers, GHF, Sensi Active, Oxagel and 2% Desensibilize promoted a significant permeability reduction than the respective control groups ($p < 0.05$). Comparing the mean permeability differences between the different groups after the treatments, Oxagel and Nd:YAG were better than 0.2% Desensibilize group.

Scanning Electronic Microscopy

In general, a superficial deposit and consequently reduction in diameter and obliteration of the dentinal tubules could be observed, at varying degrees, but with the presence of some open dentinal tubules. Considering the desensitizing agents and the lasers, different levels of superficial deposit were observed; when considering the Nd:YAG laser group, an irregular surface with mosaic-like structures was observed, compared with the wide open tubules observed in the control groups (Figures 5A, 5B, 5C and 5D).

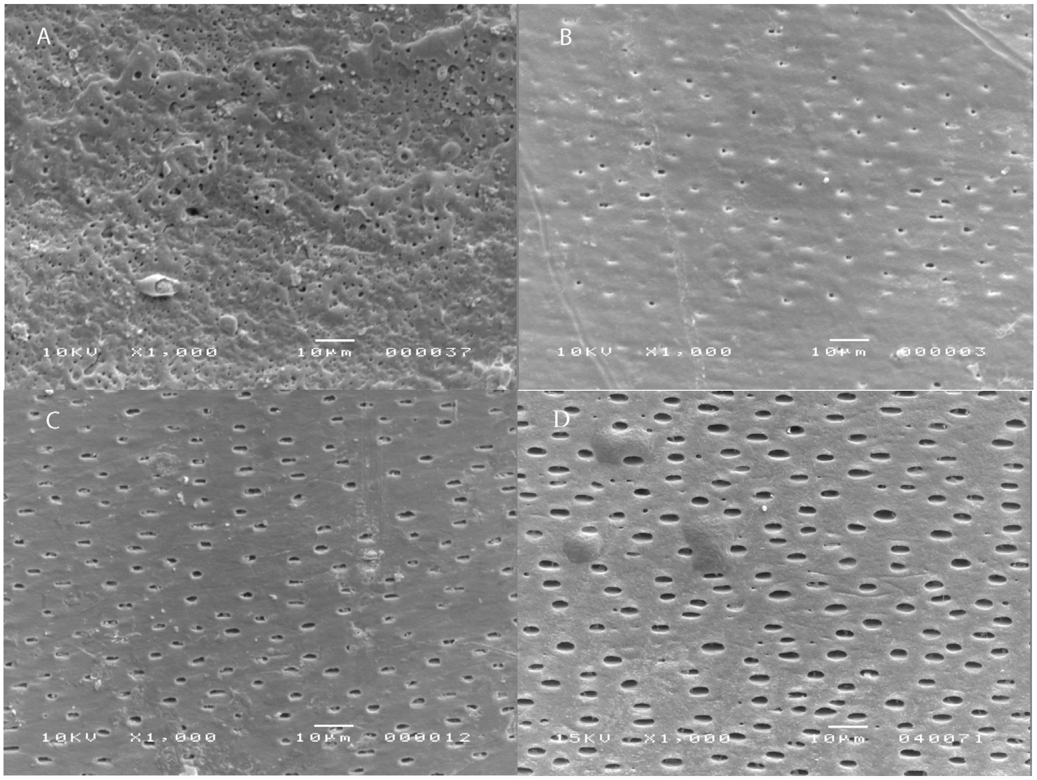


Figure 5 – (A) Dentinal surface after 3 applications of Nd:YAG laser, (B) Sensi Active, (C) Pró-Alívio paste and (D) Control

Discussion

Dentin hypersensitivity has been the subject of many studies that have evaluated different strategies and products for its treatment [5, 11, 43] and the use of bovine dentin near to the cementum-enamel junction consists in a suitable substitute of the human dentin considering the permeability and SEM analysis [38]. Among the tested products in this study, it is worth mentioning the different action mechanisms. The GHF and Desensibilize are NaF based products and act through the formation of a CaF_2 layer on the surface promoting a dentinal permeability reduction through the obliteration of exposed dentinal tubules [12, 13, 25]. It is important to say that GHF also has glutaraldehyde in its composition, which may act as an active component in desensitizing. In the present study, a significant reduction in dentin permeability could be observed after 3 applications of these products.

The Oxagel and Sensi Active are potassium oxalate based products that also act by depositing crystal-like structures within the lumen of the tubules [5]. These crystals are formed after active substance penetration within the tubules resulting in insoluble calcium oxalate crystals formation [6, 15, 17, 19, 31]. The precipitates occur within the dentinal tubules, forming crystals that extend 15 μm depth and with various dimensions that allow different degrees of tubules occlusion [10]. This fact can explain the results of the present study in which, even with a superficial deposit not as great as in some treatments, the permeability test showed an statistically significant reduction in dentin permeability.

The Gluma Desensitizer is an aqueous solution containing 5% glutaraldehyde and 35% HEMA. It has been suggested that its action mechanism is based on the dentinal tubules occlusion through reaction with plasmatic dentinal fluid, which would lead to the formation of a thin resin layer of about 1 μm thickness (due to the HEMA polymerization) that can obliterate the dentinal tubules [24, 40]. In the present study, Gluma showed no significant reduction in dentin permeability and these results are consistent with a clinical study where no reduction in dentin hypersensitivity was observed before one week after agent application [24].

Pastes and toothpastes containing desensitizing agents has also been widely researched and produced. In the products tested in this study, these agents differ by the presence of 1.10% sodium monofluorophosphate, present in the toothpastes. The arginine and calcium carbonate work together in order to accelerate the dentinal tubules natural obliteration mechanisms by "dentin-like" mineral deposits containing calcium phosphate within dentinal tubules [34]. In the present study, a significant reduction of dentin permeability was observed after three applications of both products, but in photomicrographs a great number of opened dentinal tubules could still be observed.

Another treatment used to relief dentin hypersensitivity by physical obstruction of the tubules is high-intensity laser irradiation on hypersensitive dentine. According to some authors, the laser consists in an easy application method and also painless, with a fast action [9, 14, 18, 20]. According with Dilsiz et al. 2009 [10] there are two types of lasers: the high (e.g. Nd: YAG) and low level (e.g. diode laser) that can in some models, operate at high intensity.

The Nd: YAG laser has been used for the reduction of dentin hypersensitivity as it induces an occlusion or narrowing of the dentinal tubules, leading to a pain relief [14, 21, 23]. Dentin is fused after a brief laser exposure (melting), whereas it re-solidifies in the form of a glazed and non-porous surface [4]. In the present study, all irradiated samples showed the same surface changes with irregular mosaic-like structures with a significant reduction in dentin permeability. Similar results also were observed by other authors [16, 23, 37, 39].

In the present study, the diode laser also promoted a significant decrease in dentin permeability. In photomicrographs a reduction in the number and diameter of dentinal tubules could be observed. Umberto *et al*. 2012 [41], also observed a significant reduction in dentin hypersensitivity after 980nm diode laser irradiation.

It is also unclear whether permeability must be completely stopped before sensitivity can be treated, considering this, it is important to say that some substances may also have a desensitizing effect observed only "in vivo", such as Desensibilize that has also potassium nitrate in its formula, which acts as a neural depolarizer; Sensi Active and Oxagel, based on potassium oxalate, which can inhibit the transmission of nerve impulses [26]. Besides these, the low-level lasers can also interact with the pulp tissue inducing a biomodulatory effect that increases odontoblastic metabolic activity enhancing the production of tertiary dentin and can also interfere in the sodium pump reducing intra dental nervous response [29, 44].

Even with the limitations of this study it has been concluded that none of the treatments may be considered 100% effective in treating dentinal hypersensitivity since a partial reduction of the permeability was observed.

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