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ORIGINAL ARTICLE

Low-power laser and potassium oxalate gel in the treatment of cervical dentin hypersensitivity—a randomized clinical trial

Paula Cesar Sgreccia[1] · Rodrigo Edson Santos Barbosa[2] · Nailê Damé-Teixeira[3] · Fernanda Cristina Pimentel Garcia[3,4]

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Abstract

Objective To evaluate the effectiveness of different protocols for the treatment of cervical dentin hypersensitivity (CDH) in non-carious cervical lesions (NCCLs).

Materials and methods The CONSORT checklist was used to design this study. The sample with $n = 74$ participants (389 NCCLs) was randomly allocated into three groups: G1, potassium oxalate (Oxa-Gel BF); G2, GaAlAs (gallium-aluminum-arsenate) low-power laser (100 mW, 808nn, 60 J/cm^2); and G3, potassium oxalate (Oxa-Gel BF) associated with the GaAlAs low-power laser. The CDH was triggered by the evaporative stimulus test (EST) and by the tactile stimulus test (TST). The visual analog scale (VAS) was used to quantify the degree of CDH. Changes in sensitivity were assessed from baseline over 3 weeks. Data were analyzed for NCCLs using mixed-effects models with unstructured direct product covariance structure ($\alpha = 0.05$).

Results After the first application, participants from G1 and G3 had a reduction in CDH ($p < 0.05$) compared with group G2 for TST. After the second application, G3 participants had a reduction in CDH ($p < 0.05$) in relation to G2 for both stimuli. Reduction in CDH ($p < 0.05$) occurred over 3 weeks for EST and TST for all groups; however, there was no difference between groups at the end of the therapies.

Conclusion Potassium oxalate was more effective in reducing immediate CDH. After four applications, all groups showed similar results for the reduction of CDH.

Clinical relevance GaAlAS laser irradiation and oxalate potassium gel could reduce the symptoms of CDH; thus, they are viable alternatives for the treatment of this condition. Chemical occlusion of dental tubules showed effective results after a shorter time interval.

Trial registration Brazilian Clinical Trials Registration Platform under protocol number RBR-4ybjmt. http://www.braziliantrials.com/?keywords=RBR-4ybjmt&order=%7Eensaios.patrocinador_primario

Keywords Non-carious cervical lesion · Cervical dentin hypersensitivity · Potassium oxalate · Low-power laser · Clinical study

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✉ Fernanda Cristina Pimentel Garcia
garciafcp@unb.br

[1] Faculty of Health Sciences, University of Brasilia, Brasília, Federal District, Brazil

[2] Dental Prosthesis, Catholic University of Brasília, Brasília, Federal District, Brazil

[3] Department of Dentistry and Pos Graduate Program in Dentistry, Health Sciences School, University of Brasília, Campus Asa Norte, Brasilia, Federal District 70904-970, Brazil

[4] Department of Dentistry and Pos Graduate Program in Dentistry, Health Sciences School for Faculty of Health Sciences, University of Brasília, Campus Asa Norte, Brasilia, Federal District 70904-970, Brazil

Introduction

Non-carious cervical lesions (NCCLs) have an increasing prevalence [1]. These lesions are defined as the loss of dental structure at the cemento-enamel junction (CEJ), unrelated to bacterial activity [2]. The NCCLs associated with cervical dentin hypersensitivity (CDH) are conditions commonly encountered in clinical practice [3], most often in the cervical region of teeth [4].

Dentin hypersensitivity (DH) is an abnormal response of the tooth to mechanical, thermal, chemical, and osmotic stimuli, characterized by specific acute short-term pain [1, 5, 6]. Different theories have been researched in an attempt to explain the mechanism of DH, including transducer theory, gate and vibration control theory, and hydrodynamic theory [7],

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but a consensus on the mechanism that generates DH is lacking. However, the most accepted theory is hydrodynamics by Brännström et al., in which an external stimulus causes fluid displacement within the dentinal tubules, leading to compression or stretching from the periphery of the odontoblasts to the pulp, thereby stimulating nerve termination and causing pain [5, 6, 8–10].

Difficulties in treating CDH have led to a variety of therapeutic techniques and procedures for pain relief [1]. Two approaches have been the most commonly used: (a) dentinal tubule occlusion and (b) nerve stabilization or desensitization 11 ,7]]. Based on the hydrodynamic principle, any treatment that blocks or reduces fluid movement will reduce CDH [3, 8, 9]. Partial or complete occlusion of dentinal tubules is the basis of a wide variety of treatments, including the use of ions, salts, and proteins (oxalates, calcium phosphate, fluoride and hydroxyapatite, aldehydes such as formaldehyde and glutaraldehyde) to buffer the tubules; the application of restorative materials (dentin sealants) designed to physically block stimuli; the use of periodontal soft tissue graft for complete root coverage; and the use of high-power lasers to ablate the dentin surface and tubule sealing through dentin fusion and recrystallization [7].

In contrast with therapies that aim to occlude the dentinal tubules, the action of the widely studied low-power laser is based on analgesic, biostimulation, and anti-inflammatory actions, as well as the regulation of cellular metabolism [8]. Low-intensity laser radiation has been successfully used because it induces changes in the neural transmission network within the dental pulp, rather than causing changes in the surface of the exposed dentin, as with most treatments. In addition, the bio stimulatory effect induces the production of secondary dentin, allowing the physiological occlusion of the dentinal tubules and the stimulation of endorphin release from the nerve terminal synapses located in the dentinal tubules [13–15].

The aim of this randomized clinical trial was to compare the efficacy of desensitizing therapy protocols in NCCLs that use the following approaches: chemical occlusion of the dentinal tubules (Oxagel) and photo biomodulation (GaAlAS) and its association. Clinical follow-up was performed at the end of four sessions.

Methods

This randomized clinical trial followed the CONSORT guidelines [16]. The research protocol was approved by the Ethics Committee of the Health Sciences of the University of Brasilia (number 2.740.067) and registered in the Brazilian Clinical Trials Registration Platform under protocol number RBR-4ybjmt. Participation was voluntary, and the study was conducted in accordance with the principles of the Declaration of Helsinki (World Medical Association Declaration of Helsinki, 2008). The free and informed consent form was obtained from all participants. All participants were instructed about the purpose and design of the investigation, signed an informed consent form, and received routine dental treatment.

Participant selection

Participants enrolled in this study were military employees, dependents, or pensioners recruited at the Dental Clinic of the Federal District Military Fire Department who had complained of NCCL-associated CDH. A detailed medical and dental history was recorded. Individuals were considered suitable for the study if they had at least one sensitive tooth (CDH) showing tooth wear with exposure of cervical dentin (NCCL).

Sample size

The sample size was determined using OpenEpi.com website, based on previous clinical studies. Mean values obtained from studies by Gojkov-Vukelic et al. [1] and Mehta et al. [17] were used as references. The access was made on December 13, 2017 at 2:32 PM. The calculation was performed with an expected mean difference in CDH reduction of 1.64 points per group after 2 weeks. The selected test details were significance $(\alpha) = 0.05$; test power $(1-\beta) = 0.80$; dropout = 0.10. The final sample size was $n = 25$ participants per group, totaling to $N = 75$ research participants.

Eligibility criteria

Inclusion criteria were age, ranging from 18 to 60 years old; not having used home remedies in the previous month with desensitizing toothpaste or mouthwash containing potassium nitrate, oxalates, strontium, arginine bicarbonate, or 5000 ppm/F; not having received an in-office treatment with desensitizing agents such as applying varnishes, gels, or laser therapy in the last month; and willing to avoid anti-inflammatory or analgesics during treatment. Exclusion criteria were teeth with NCCL, but without CDH; continuous use of anti-inflammatory or analgesic medications; orthodontic appliances; presence of periodontitis, pulpitis, active carious lesions, or unsatisfactory restorations; pregnant or lactating women; and teeth with very deep NCCLs, where it was possible to see the outline of the pulp chamber and immediate restorative treatment was indicated.

Intraoral examination was performed to identify oral health problems such as periodontal diseases, mucosal lesions, carious lesions, pulpitis, or the presence of unsatisfactory restorations that could interfere with the outcome of the data collected. Differential diagnosis was performed to exclude the possibility of other pathologies. Radiographs and the cold spray

test were used to test the vitality of the teeth with CDH and NCCLs before the treatment. The CONSORT flowchart showing the sampling of this study is presented in Fig. 1.

The degree of CDH was determined by the visual analog scale (VAS) [6], a one-dimensional instrument for pain intensity assessment numbered 0–10 anchored by "no pain" and the "worst pain imaginable." The participant was then asked to indicate on the scale the degree of CDH felt after stimulus application [6]. The stimuli adopted to trigger CDH was the evaporative stimulus (ES) and the tactile stimulus (TS).

The ES consisted of the application of an air blast from a dental air-water syringe, applied perpendicularly and at a distance of 10 mm from the surface of the lesion. Distance standardization was performed with a fragment from a millimeter probe attached to the air-water syringe tip.(Fig. 2). The stimulus had a maximum duration of 3 s or until the participant raised his or her hand. Immediately, adjacent teeth were isolated by a cotton roll so that there was no interference in the measurement. Immediately after the evaporative stimulus test (EST), the patient indicated in the VAS the level of sensitivity experienced, and the recording was made in the clinical record as the baseline.

The TS was performed by moving an explorer across the lesion in the mesiodistal direction under light pressure. Care was taken to ensure that the explorer did not pass through gingival tissue . After the tactile stimulus test (TST), the patient indicated in the VAS the level of sensitivity experienced, and the recording was made in the clinical record as the baseline.

Only dental elements with a CDH level greater than zero in at least one of the tests were selected. After baseline CDH registration, therapy with the selected desensitizing agent was started. At the end of each session, the operator recorded the pain rate (VAS) after applying the selected therapy. There were four applications at 7-day intervals totaling a 3-week follow-up.

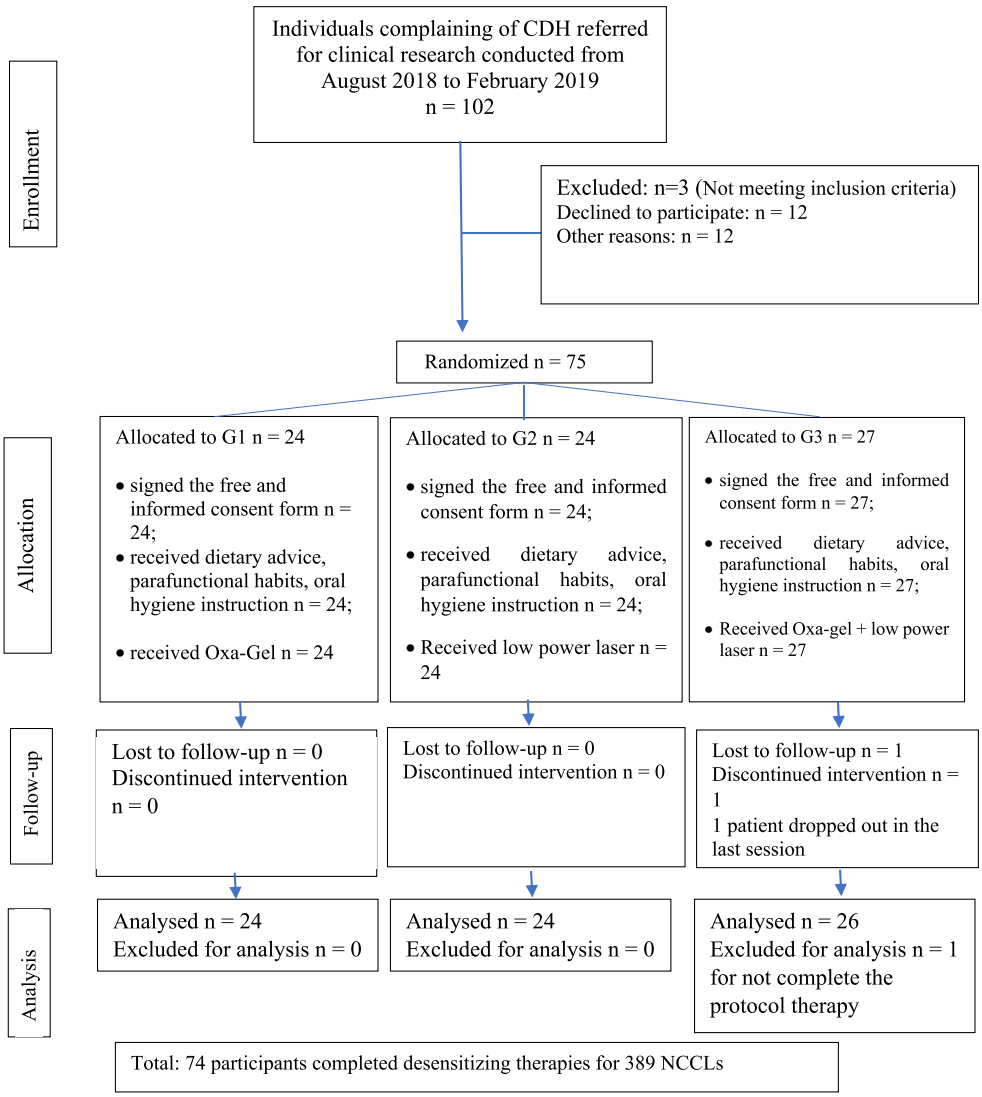

Fig. 1 Patient selection flowchart

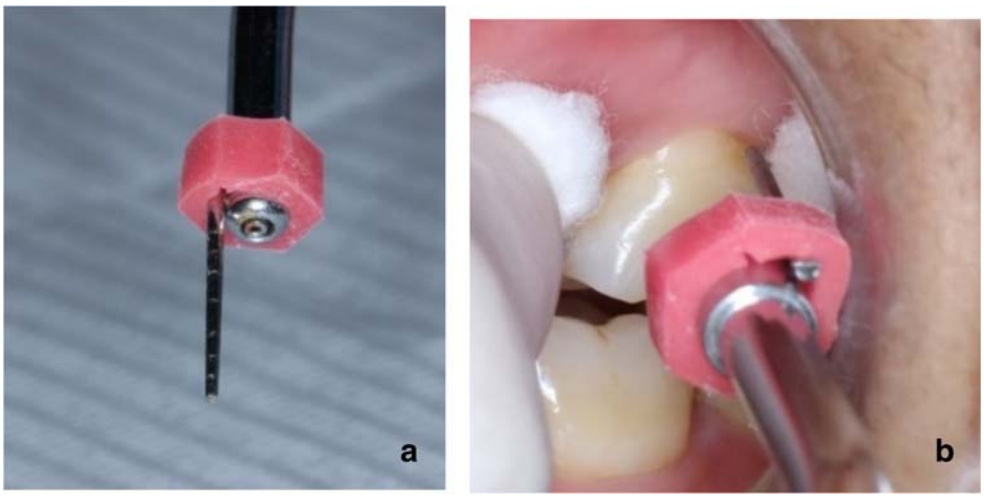

Fig. 2 Evaporative Stimulation Test (EST). **A** Standardized at 10 mm distance with the tip of a millimeter probe. **B** Adjacent teeth isolated with cotton balls

Clinical examinations were performed by two trained and calibrated operators. Both underwent CDH diagnostic tests, application of therapies, and their respective post-therapy sensitivity tests. Calibration tests to observe the agreement between both operators was performed using the simple kappa coefficient and the intraclass correlation coefficient, model ICC (2,1), with a 95% confidence interval calculated for a two-factor analysis of variance (ANOVA) based on absolute agreement. The values obtained were Kappa = 0.80 and ICC = 0.97. The procedures were performed with the participant seated in the same dental chair, with the same equipment yielding similar air pressure and explorer pressure.

Randomization: sequence generation and allocation

After the screening process, selected participants were randomly assigned to the three treatment groups: G1: Oxa-Gel BF® Kota; G2: GaAlAs low power laser, and G3: Oxa-Gel BF associated with GaAlAs low-power laser. A list of the three interventions was randomly sorted with a table of random numbers generated by the OpenEpi.com website on August 3, 2018 at 4:39 pm. These numbers were distributed in envelopes by a researcher who did not participate in the clinical stage and sequentially selected by the two researchers responsible for the clinical research at the first appointment of each participant. The randomization resulted in 24 participants in (G1), 24 participants in (G2) and 27 participants in (G3).

Anamnesis and physical examination

All medical information and clinical findings were recorded. Medical history was obtained in detail to define the patient's general condition, and a second intraoral examination was performed to verify the intensity and distribution of the occlusal contacts in the maximal habitual intercuspation position and in excursive movements (right, left, and protrusion movements). The analysis was visually performed after recording the contacts generated by articulating film (Parkell, Inc. USA Red/Black Accu Film II, 0.02 mm). Occlusal adjustments were performed to modify the axial distribution of the occlusal forces. The adjustment was performed by selective grinding, restricted to enamel at high or low rotation for better load distribution. Small increments of composite resin were also added to cusp tips when no occlusion guidance was observed. The distribution of occlusal forces avoids stress concentration in the cervical region and promotes greater stability.

The risks of appearance and progression of NCCLs and CDH were assessed through an interview. Data about parafunctions, bruxism, tension, friction, and erosion were collected to profile the population studied. The interview consisted of five question blocks to identify the habits involved in the etiology of NCCLs (Supplementary material). The presence of the etiological factor was considered when the answer was positive for at least one question in the respective block.

The participants received printed guidelines about eating habits, oral hygiene, and parafunctional habits (Additional Information). Individualized oral hygiene instruction was conducted with guidance on the most appropriate techniques, brush type, and toothpaste. The objective was to reduce or eliminate factors that could contribute to the progression or appearance of NCCLs and CDH.

Blinding of participants

The participants were not told to which group they would be allocated. The participants were blinded by simulating some steps for certain groups. All sessions were started by placing laser-safe eyewear and initiating the NCCL preparation step.

Preparation phase

First, prophylaxis of the NCCLs was performed with a rubber cup and pumice. Then, the area was washed with air/water spray, dried with a cotton ball soaked in 2% chlorhexidine solution (DentalVillele do Brasil LTDA), and dried with a cotton ball. Sequentially, relative isolation was performed, and the therapy was performed according to groups.

Treatments

Table 1 summarizes the protocol for preparing NCCLs and applying the desensitizing therapies used in the three groups. CDH was recorded for EST and TST and measured by VAS for each NCCL. The tests and records occurred before the beginning of the therapies and at the end of each session.

G1—potassium oxalate

The Oxa-Gel BF (Kota Industria e Comercio EIRELI São Paulo, Brazil) was applied with a microbrush using a rubbing motion for 2 min. Subsequently, laser therapy was simulated by adjusting the whitening function of the Whitening Laser II equipment (DMC, São Carlos São Paulo, Brazil). The laser tip was positioned 1 mm from the lesion but not triggered. An acoustic signal was emitted by the DMC equipment, using the whitening tip, simulating the activity of the device.

G2—GaAlAs low power laser

Irradiation was performed with the Whitening Laser II equipment (GaAlAs) (DMC Equipment LTDA) in the assisted mode (preprogrammed protocol). The emitter power was fixed at 100 mW, the wavelength was 808 nm, and the energy density standardized at 60 J/cm^2. Considering the tip size of 0.028 cm^2, the dose applied per point was 1.68 J. The tip was positioned perpendicularly along the tooth axis at a distance of 1 mm from the NCCL. The duration of application was 16 s per point in three regions of the NCCLs: mesial, central, and distal. An application of gel desensitizing agent was simulated before the laser application. A microbrush was applied in continuous motion over the length of the NCCLs for 30 s.

G3—potassium oxalate + GaAlAs low-power laser

The G1 therapy protocol was performed in the first two sessions, and the G2 therapy protocol was performed for the last two sessions. Thus, the Oxa-Gel BF acted in the first and second sessions and the irradiation low-power laser acted in the third and fourth sessions.

Statistical analysis

Initially, the sample characteristics and clinical characteristics at baseline were compared with the ANOVA test. When $p < 0.05$, the Bonferroni correction was used for multiple comparisons or the Pearson chi-square test ($\alpha = 0.05$).

The NCCLs were used as a unit of analysis to verify the behavior of CDH throughout the four applications and to adjust the estimates for clustered data, mixed-effects models with unstructured direct product covariance structure (UN @ UN) [18] were used, adjusted for baseline measurements.

The changes in CDH stimulated by the EST and TST over the follow-up period in relation to the baseline were performed separately for air and explorer stimuli in the three groups. When the overall p value of group-time interaction was less than 0.05, the Bonferroni correction was used to adjust comparisons among the three groups ($\alpha = 0.05$). The statistical software SAS version 9.4 was used for data analysis.

Results

Table 2 represents the mean distribution and correlation among groups of the sample variables (age, sex, number of NCCLs) and clinical characteristics of the sample (sensitivity of the tests and mean baseline CDH). Data were presented with their respective standard deviation or frequency. Among the participants who completed the treatment, $n = 38$ were men and $n = 36$ women. The age range was 22 to 54 years. No complications such as irreversible pulpal effects or allergic reactions were observed or reported during or after the treatments. Treatment was completed for 389 NCCLs as shown in Fig. 1. Table 3 shows the distribution of the factors involved in the etiology of NCCLs and CDH according to groups.

Table 1 Protocol for the application of desensitizing therapies according to groups

Groups	First session	Second session	Third session	Fouth session
G1	Oxa-Gel BF + Laser simulation	Oxa-Gel BF + Laser simulation	Oxa-Gel BF + Laser simulation	Oxa-Gel BF + Laser simulation
G2	Gel simulation + Laser	Gel simulation + Laser	Gel simulation + Laser	Gel simulation + Laser
G3	Oxa-Gel BF + Laser simulation	Oxa-Gel BF + Laser simulation	Gel simulation + Laser	Gel simulation + Laser

G1 Group 1, *G2* Group 2, *G3* Group 3

Table 2 Sample variables and clinical characteristics at baseline by groups

Variables[a]	Groups			
	G1	G2	G3	*p* value #
Age	40.92 ± 7.28	40.04 ± 7.38	41.08 ± 6.30	0.8559
Sex				0.2120
Male	15 (62.50)	9 (37.50)	14 (53.85)	
Female	9 (37.50)	15 (62.50)	12 (46.15)	
NCCLs[b]	6.54 ± 3.22	4.54 ± 2.62	4.73 ± 2.39	0.0249
EST				0.6486
0	1 (4.17)	0 (0.00)	0 (0.00)	
> 0	23 (95.83)	24 (100.00)	26 (100.00)	
TST				1.0000
0	3 (12.50)	2 (8.33)	3 (11.54)	
> 0	21 (87.50)	22 (91.67)	23 (88.46)	
EST	4.46 ± 2.24	4.89 ± 2.27	5.93 ± 2.44	0.0758
TST	2.72 ± 2.24	3.68 ± 2.77	3.64 ± 3.24	0.4026

[a] Values expressed as mean ± standard deviation or frequency (%)

[b] Result of multiple comparisons for NCCLs: ($p = 0.0694$) between G1 and G2; ($p = 0.0426$) between G1 and G3; ($p = 1.0000$) between G2 and G3

p value # ANOVA or chi square test

NCCLs = non-carious cervical lesions, EST = evaporative stimulus test, TST = tactile stimulus test

The mean variations in CDH were recorded for both stimuli, TS and ES, over 3 weeks, and their changes by groups and comparison among groups are shown in Table 4. According to the analysis of the collected data, the longitudinal changes for the ES were significantly different among the groups over the evaluation period ($p = 0.0005$). For ES, in the second week, participants in the G3 group had significantly lower pain sensitivity when compared with those in the G2 group (53% reduction in CDH for G3, 42% for G2, $p = 0.0303$).

Table 3 Distribution by groups of the possible etiological factors involved in the etiology of non-carious cervical lesions and cervical dentin hypersensitivity

Variables[a]	Groups			
	G1 Oxa-Gel BF	G2 Low power laser	G3 Oxa-Gel BF+low power laser	*p* value[#]
Parafunction				0.3349
Absence	3 (12.50)	5 (20.83)	8 (30.77)	
Presence	21 (87.50)	19 (79.17)	18 (69.23)	
Bruxism				0.6882
Absence	3 (12.50)	1 (4.17)	3 (11.54)	
Presence	21 (87.50)	23 (95.83)	23 (88.46)	
Tension				0.2662
Absence	9 (37.50)	4 (16.67)	6 (23.08)	
Presence	15 (62.50)	20 (83.33)	20 (76.92)	
Friction				0.0999
Absence	4 (16.67)	10 (41.67)	5 (19.23)	
Presence	20 (83.33)	14 (58.33)	21 (80.77)	
Corrosion				0.2044
Absence	0 (0.00)	2 (8.33)	0 (0.00)	
Presence	24 (100.00)	22 (91.67)	26 (100.00)	

[a] Values expressed as frequency (%)

[#] *p* value chi square test

Table 4 Comparison of longitudinal changes in cervical dentin hypersensitivity for evaporative stimulus test and tactile stimulus test by groups and between groups

	Groups[a]			*p* value[†]	*p* value[#]		
Variables	G1	G2	G3	Interaction between group and time	G1 × G2	G1 × G3	G2 × G3
EST				0.0005			
Baseline	4.45 ± 0.21	5.25 ± 0.29	5.60 ± 0.26		–	–	–
After first application	− 2.35 ± 0.19	− 1.66 ± 0.22	− 1.72 ± 0.21		0.0639	0.0840	1.0000
After second application	− 2.53 ± 0.19	− 2.21 ± 0.22	− 2.98 ± 0.20		0.8151	0.3063	0.0303
After third application	− 3.07 ± 0.18	− 2.84 ± 0.21	− 3.39 ± 0.19		1.0000	0.6759	0.1596
After fourth application	− 3.35 ± 0.17	− 3.92 ± 0.18	− 3.74 ± 0.20		0.4176	0.0783	1.0000
TST				0.0063			
Baseline	2.69 ± 0.24	3.98 ± 0.35	3.06 ± 0.32		–	–	–
After first application	− 1.42 ± 0.18	− 0.52 ± 0.21	− 1.71 ± 0.20		0.0048	0.9036	< 0.0001
After second application	− 1.85 ± 0.16	− 1.27 ± 0.19	− 1.97 ± 0.18		0.0711	1.0000	0.0237
After third application	− 2.03 ± 0.17	− 1.68 ± 0.19	− 1.85 ± 0.18		0.5340	1.0000	1.0000
After fourth application	− 2.13 ± 0.15	− 2.07 ± 0.18	− 2.05 ± 0.17		1.0000	1.0000	1.0000

[a] Values expressed as mean ± standard error

[†] *p* value obtained by fitting mixed-effects models with unstructured direct product covariance structure, adjusted by baseline measurements

[#] *p* value adjusted by Bonferroni correction

EST = evaporative stimulus test, TST = tactile stimulus test

G1 = Oxagel BF group, G2 = low power laser group, G3 = Oxagel BF + low power laser group

Data analysis for the TS showed that longitudinal changes were also significant among groups over the evaluation period ($p = 0.0063$). After the first application, participants in groups G1 and G3 had significantly lower pain sensitivity (reductions of 53% and 56%, respectively). The equivalent reduction for participants in group G2 was 13%. The comparison between groups G1 vs G2 and G2 vs G3 were significantly different ($p = 0.0048$ and $p < 0.0001$, respectively) for the same period. For TS, after the second application, participants in group G3 had significantly lower pain sensitivity than those in group G2 (a reduction in CDH of 64% for G3 and a reduction of 32% for G2, $p = 0.0237$). For the other weeks, the longitudinal changes did not show significant differences among the groups.

TST and EST were performed immediately after the first, second, third, and fourth therapeutic application for each group. The evolution of CDH was measured by VAS, and its mean by group is represented in Fig. 3.

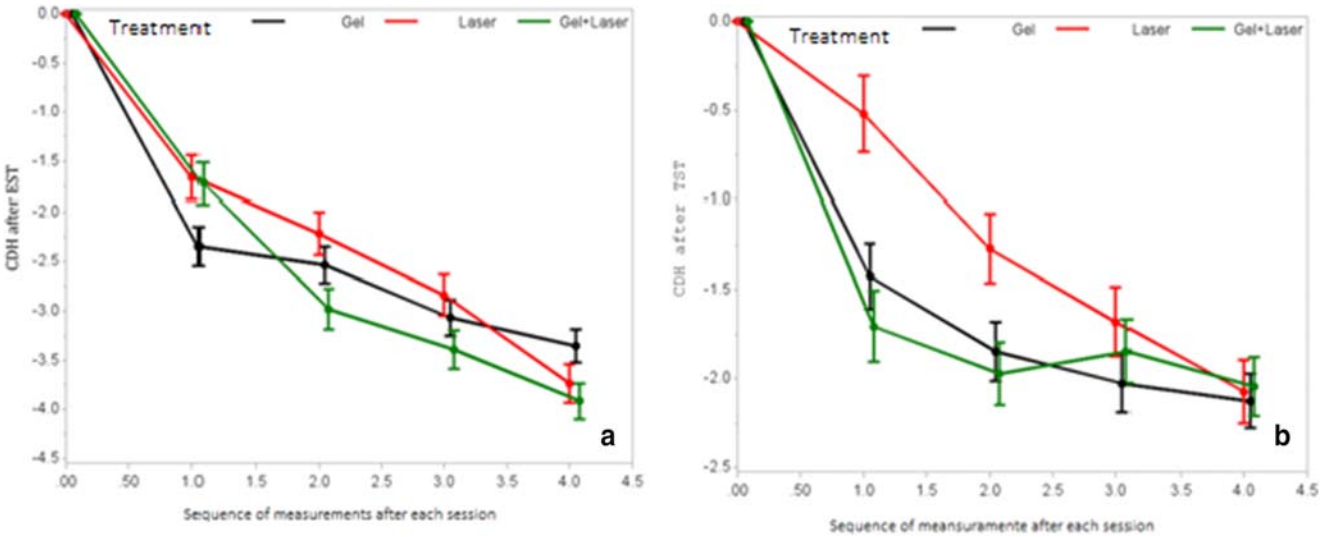

Fig. 3 Mean reductions in cervical dentin hypersensitivity (CDH) for evaporative (**A**) and tactile (**B**) stimuli immediately after first, second, third, and fourth applications

Discussion

NCCLs and CDH may be inherently linked. Several authors [19–21] have suggested conditions that cause erosion, abrasion, and attrition as possible causes and risk factors for NCCLs and CDH. In a few patients, a specific causative factor for the development of NCCLs can be identified. Increased life expectancy has also led to behavioral changes that result in a higher incidence and prevalence of these conditions [22]. Bartlett et al. (2011) concluded that there is rarely a single causative factor for the development of NCCLs and that typically an association with erosion, attrition, and abrasion factors is seen [23]. These characteristics were also identified by other studies, where factors of parafunction, bruxism, tension, friction, and corrosion were present for most participants [24–26]. The present study analyzed the distribution of lesions in the specific population and evaluated the evolution of CDH after the application of three desensitizing protocols.

The distribution of NCCLs associated with CDH among the 74 participants evaluated was 198 teeth in the maxilla (50.9%) and 191 teeth (49.1%) in the mandible. Kehua at al. (2012), in a cross-sectional study, estimated that the maxilla teeth were the most affected and the presence of both conditions was most commonly found in premolars, followed by first molars and finally by second molars [27]. The present study enrolled participants with 59.6% of lesions in the premolars, 27.2% in the molars, 8.5% in the canines, and 4.6% in the incisors. Borcic et al. (2004) [28], in a study of 1002 patients, reported a greater distribution of premolars and molars, with incisors being the least affected teeth. Teeth with the highest prevalence of NCCLs and CDH were the mandibular premolars at 56.9% followed by the maxillary premolars at 43.1%. This finding was similar to that of the study by Lee et al. [29], who stated that mandibular premolars are affected by NCCLs more frequently and more severely than maxillary premolars.

Two triggers of CDH were initiated to ensure the correct diagnosis of DH, similar to other clinical studies [6, 8, 15, 30–32]. The ES was responsible for triggering the pretreatment CDH response in 96.9% of the total teeth studied, while TS was able to trigger the response in 63.7% of the lesions. The greater number of air-sensitive teeth may be related to the fact that only a small area is typically sensitive. Thus, if the explorer did not touch this area, sensitivity would not be reported [33].

The null hypothesis that no statistically significant reductions in immediate CDH would occur was rejected, and the null hypothesis that there would be no statistically significant difference between treatments at the end of the 3-week follow-up was accepted. The distribution by age group (in years) of participants with the two associated conditions was 9.5% for the (21–30) group, 27.0% for the (31–40) group, 60.8% for the (41–50) group, and 2.7% for the (51–60) group. These results are consistent with those of previous studies, which suggested that the progression of NCCLs is correlated with time [3, 21, 22, 25]. In contrast, decreased DH with increasing age may be explained by continuous dentin deposition and subsequent pulp atrophy [26].

Desensitizing protocols were performed in four sessions. Monohydrogenated monopotassium oxalate (Oxa-gel BF® from Kota) was used for the G1 group in the four sessions and for the G3 group in the first and second sessions. This product is a gel developed for in-office topical application. According to the manufacturer's information (KOTA Industria e Comércio EIRELI, São Paulo-SP), the product combines with ionized calcium on the dentin surface to form an insoluble calcium oxalate complex. This complex adheres to the dentin surface and to the openings of the dentinal tubules, blocks the circulation of pulpodentinal fluid, preventing pulp pressure variations, and consequently inhibits sensitivity.

Potassium oxalate fulfills various requisites of a desensitizing agent and is typically described as having an occlusive effect on dentin, although some authors have suggested the possibility of a neural effect [3].

Oxalate salts have been known to occlude tubules by reacting with naturally occurring calcium ions in the oral fluids to precipitate as insoluble calcium oxalate crystals. This precipitate blocks fluid flow in the dentinal tubules, leading to decreased hypersensitivity [11, 34, 35]. Furthermore, precipitates of oxalates are relatively resistant to dissolution in acidic environments, increasing their durability [11]. Using in vitro hydraulic conductance models, several researchers have demonstrated a decrease in fluid flow across dentine samples with exposed tubules treated with oxalates [3, 34, 36].

The second theory suggests that the high levels of potassium in the topically applied oxalate solutions could increase extracellular potassium concentration around the nerves deep in dentin causing their depolarization, and thus making them less excitable. This phenomenon could explain the immediate short-term desensitizing effect of potassium oxalate [35].

After the first application of Oxa-gel BF, for TS, a reduction in CDH of 53% for the G1 group and 56% for the G3 group was detected. After the first application of the laser, the reduction of CDH was 13%. Therefore, it appears that potassium oxalate is an effective short-term desensitizing agent and may be an agent of choice for patients who need to reduce sensitivity at a faster rate. When analyzed by the ES, after the first application, there was a noticeable reduction of CDH for all groups; however, it was not possible to observe significant changes among groups.

For the EST, after the second application of therapies, there was a statistically significant difference between the G3 and G2 groups ($p = 0.0303$). The G3 group had a reduction in CDH of 53%, while the G2 group had a reduction of 42%, demonstrating a higher potassium oxalate efficiency over the laser for the evaporative stimulus for this time interval. The

groups using the low-power laser (G2 and G3) demonstrated a slower relief of CDH for ES and TS, but was equally effective at the end of 3 weeks. Importantly, when analyzing the TS in group G3, the level of sensitivity was increased when replacing potassium oxalate with the laser treatment.

After four potassium oxalate applications, the G1 protocol, a reduction of 79.2% for the TS and 75.3% for the ES was observed. Potassium oxalate has been reported to occlude dentinal tubules effectively. Clinical studies have reported CDH reductions ranging from 42 to 87% [12, 37, 38] after 30-day follow-ups. In vitro studies have also shown reductions in dentinal permeability of between 88.7 and 98.4%, after potassium oxalate application [3, 39–41].

After four applications of the low-power laser, the G2 protocol, a reduction of 52.0% for the TS and 74.7% for the ES was observed. Low-level laser therapy has been explored widely in treating DH. Unlike high-power lasers, low-power lasers do not emit heat and stimulate the normality of cell functions. This is because they lead to the occurrence of change in the electrical potential of the cell membrane, activating the Na+/K+ ATPase pumps, providing an increase in adenosine triphosphate (ATP) synthesis, and bringing about analgesic, potential anti-inflammatory, and biomodulation benefits to the cells [22].

It is postulated that this type of low-output-power lasers mediates an analgesic effect related to depressed nerve transmission. According to physiological experiments using the GaAlAs laser at 830 nm, analgesic effect is caused by blocking the depolarization of C-fiber afferents [22, 42].

Other studies still report its anti-inflammatory and biostimulative effects. The laser interaction with the dental pulp causes a photobiomodulating effect, increasing the cellular metabolic activity of the odontoblasts and obliterating the dentinal tubules with the intensification of tertiary dentine production [6, 22, 43].

Low-power laser has been previously studied as a desensitizing agent, and clinical studies have reported reductions in CDH ranging from 45.9 to 94.2% [6, 12, 15, 32] for different stimuli after 30-day evaluations. Yuri et al. (2003), cited by Dantas et al. (2016), evaluated the efficacy of GaAlAs laser application on teeth with CDH and reported that the percentage of teeth without pain was reduced from 2 to 62% as assessed by the evaporation test and from 46 to 86% by the tactile test, demonstrating that GaAlAs laser therapy was effective in reducing CDH [15].

After four applications in the G3 protocol, in which the objective was to verify whether the association of dentinal tubule occlusion strategies with the photobiomodulatory effect would result in greater CDH reductions, a 67.0% reduction was observed for the TS and 66.8% for the ES. G1 showed a statistically higher number of NCCLs ($p = 0.04$) than G3. However, the G1 group showed similar results to those of G3 after the first and second application when Oxagel BF was used exclusively for both. Between the last two applications, there were no statistically significant results among the three groups; therefore, it appears that the results were not influenced by the difference in the number of lesions.

The measurement of pain is a subjective criterion and is subject to psychological interference. The VAS is an instrument that is easily understood by the patient and widely used in studies that analyze CDH. Long-term follow-up is needed to better evaluate the outcome of the therapies. If predisposing factors are not removed or modified, desensitizing treatment may provide only short-term relief, which may partially contribute to the limited effectiveness of currently available desensitization therapies [44]. To date, no desensitizing therapy has been established as a gold standard capable of meeting all therapeutic requirements.

Conclusions

Based on the findings from this clinical study, the following conclusions were drawn: All treatments were effective in reducing CDH associated with NCCLs; all groups showed CDH reductions similar to TS and ES at the end of the treatment; and potassium oxalate was more effective in reducing immediate CDH.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed were in accordance with the ethical standards of the Ethics Committee of the Health Sciences of the University of Brasilia (number 2.740.067) and registered in the Brazilian Clinical Trials Registration Platform under protocol number RBR-4ybjmt and with the 1964 Helsinki declaration and its later amendments.

Informed consent All subjects signed an informed consent form prior to the initiation of the study.

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