Efficacy of silver diamine fluoride and combination with CO₂ laser in reducing dentin hypersensitivity

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Abstract. Silver diamine fluoride application and CO₂ laser exposure are new alternative treatments for dentin hypersensitivity. The purpose of this study was to evaluate the efficacy of silver diamine fluoride and CO₂ laser in reducing the dentin hypersensitivity score. The study consisted of a single-blind, split-mouth design, and a randomized controlled trial involving 16 subjects with symptoms of sensitive teeth, with at least two hypersensitive teeth that were positive in evaporative or thermal tests. Silver diamine fluoride and CO₂ laser were applied to the surfaces of the subjects’ teeth. This clinical study demonstrated that the application of silver diamine fluoride and CO₂ laser reduced dentin hypersensitivity significantly (p = 0.000 for evaporative and thermal stimuli).

1. Introduction

Dentin hypersensitivity, also known as sensitive teeth, is a common complaint. Dentin hypersensitivity is defined as a brief pain arising from the affected dentin in response to heat, cold, touch, or chemical stimulation and cannot be classified as a form of congenital anomaly or tooth disease [1]. Pain is the normal pulp response to exposed dentin. Dentinal hypersensitivity may be caused by several conditions such as a result of periodontal pathologies, trauma, dental bleaching, professional oral hygiene, acid foods and beverages, bad oral hygiene habits or incorrect brushing techniques with consequent gingival recessions, etc [2]. Dentin hypersensitivity affects eating, drinking, and even breathing. However, despite the pain, patients often do not take preventive action. Some studies have found that dentin hypersensitivity occurs in 25% to 40% of individuals, most often in men [3].

The pain mechanism underlying sensitive teeth has not yet been fully explained, but the most accepted theory is the hydrodynamic theory [4]. According to this theory, the ideal solution is to reduce the flow of fluid in the dentin tubules, block the pulp response, or both [5].

Desensitizing agents can ease teeth hypersensitivity. One of the common desensitizing agents is silver diamine fluoride, a fluoride topical solution containing fluor and silver ions [6]. Previous studies
have shown that topical application of silver diamine fluoride effectively reduces teeth pain for 24 hours to 7 days after treatment [7]. However, this is the same as other desensitizing agents.

Another method to reduce teeth hypersensitivity is the use of laser therapy. In recent years, lasers have been used for the treatment of many endodontic and periodontal diseases. Currently, there are four types of lasers used in the field of dentistry: Er:YAG, CO2, GaALAS, and Nd:YAG lasers. These four lasers are commonly used to treat sensitive teeth and are 52%–100% effective, depending on the type of laser and the parameters used [5]. Research on laser efficacy has been conducted in vitro and in vivo, but the results showed no significant differences between control (placebo) and treatment groups in sensitive teeth management [5].

Laser treatment applied simultaneously with fluors is a recent technique. The heat produced by the laser can facilitate the incorporation of fluoride such as through hydroxyapatite on the surface of the enamel serving as a fluoride reservoir to prevent demineralization. The wavelength of the CO2 laser has the highest capability to aid absorption through hydroxyapatite [8]. However, the efficacy of simultaneous application of silver diamine fluoride and CO2 laser exposure has yet to be investigated.

2. Methods
This was a clinical experimental study. The research was conducted with a single-blind, split-mouth, and randomized controlled design. The subjects of the study were patients with dentin hypersensitivity aged 20 years or older who had at least two teeth on the maxilla with symptoms of dentin hypersensitivity and positivity in evaporative or thermal tests (Visual Analog Scale, VAS). To be included, a participant must have vital cuspid or premolar with a buccal cervical defect and clinical hypersensitivity in response to compressed air with a score ≥ 5 on a visual analogue scale (VAS) for pain. The individual will have had generally healthy gum tissue surrounding this tooth and no ulceration and no leukoplakia in this gingival tissue. Candidates were excluded if they were using any type of tooth desensitizer, had received a fluoride varnish treatment within the preceding month, or were taking prescription medications, aspirin, or non-steroidal anti-inflammatory drugs; women who were pregnant were also excluded. Individuals using smokeless tobacco or chewing coca leaves were excluded. Individuals with known sensitivity to silver or other heavy-metal ions were excluded. The subjects agreed to complete the research and provided informed consent before participating in the study. This study protocol has been approved by the Dental Research Ethics Committee, Faculty of Dentistry, Universitas Indonesia. The selected subjects were divided into two groups. Group 1 received silver diamine fluoride treatment followed by a material application test, whereas Group 2 received silver diamine fluoride followed by CO2 laser treatment.

Measurement of the dentin hypersensitivity was performed with VAS for two types of stimuli (evaporative and thermal), and DIAGNOdent was used as an objective measurement tool to assess the level of hypersensitivity. Measurement was performed four times: before treatment, immediately after material application on the teeth surface, 7 days after material application without reapplication, and 14 days after material application without reapplication.

Data analysis was performed using parametric univariate methods (descriptive analysis) and a bivariate nonparametric method. To measure the change in the VAS score before treatment, after application, after 7 days, and after 14 days, the data were analyzed using the Wilcoxon test for paired groups. To determine the relationship between the measurement results for the teeth used as the control and the sensitive teeth used for the test, the data were analyzed using the Mann–Whitney test for unpaired groups.

3. Results
This study was conducted from September to October 2016. The data was collected from 16 subjects in the clinic, yielding 93 teeth positive for dentin hypersensitivity. The subjects were 20 to 31 years of age.
**Table 1.** Distribution of teeth and regions of positive dentin hypersensitivity based on gender; SDF: silver diamine fluoride

| Gender | Region 1 (SDF) | Region 2 (SDF) | Region 1 (SDF + Laser) | Region 2 (SDF + Laser) | Total Teeth |
|-------|----------------|----------------|------------------------|------------------------|-------------|
| Men   | 12             | 10             | 11                     | 16                     | 49          |
| Women | 8              | 12             | 19                     | 5                      | 44          |

Table 1 shows the frequency of teeth positive for dentin hypersensitivity and the treatment distribution based on gender. Table 2 shows that the male subjects had more hypersensitive teeth (49 teeth) than the female subjects (44 teeth).

Table 3 shows the average VAS scores for dentin hypersensitivity against evaporative stimulus after application of the test materials (baseline) were 7.83 for silver diamine fluoride and 7.33 for silver diamine fluoride and CO2 laser.

**Table 2.** Average VAS score for evaporative stimulus before treatment, immediately after treatment, and 7 and 14 days after treatment; SDF: silver diamine fluoride

| Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|----------------|----------------|-----------------|
| **Baseline**   |                |                 |
| Mean           | 2.45           | 2.41            |
| Range          | 0–9            | 0–9             |
| Median         | 1.5            | 2               |
| **Immediate**  |                | 0.27            |
| Mean           | 0.83           | 0.67            |
| Range          | 0–9            | 0–5             |
| Median         | 0              | 0               |
| **7 Days**     |                | 0.95            |
| Mean           | 1.02           | 0.59            |
| Range          | 0–8            | 0–4             |
| Median         | 0              | 0               |
| **14 days**    |                | 0.74            |
| Mean           | 1.00           | 0.47            |
| Range          | 0–10           | 0–4             |
| Median         | 0              | 0               |

*Using Mann–Whitney Test; p<0.05 (significant difference)

**Table 3.** Average VAS score for evaporative stimulus with baseline score ≥ 5 before treatment, immediately after treatment, and 7 and 14 days after treatment; SDF: silver diamine fluoride

| Group 1 (n:6) | Group 2 (n:6) | The value of p* |
|---------------|---------------|-----------------|
| **Baseline**  |               |                 |
| Mean          | 7.83          | 7.33            |
| Range         | 5–9           | 5–9             |
| Median        | 9             | 7.5             |
Immediate

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 4.50           | 0.67           | 0.10           |
| Range | 0–9            | 0–3            |                |
| Median| 4.5            | 0              |                |

7 Days

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | By 5.50        | 0.83           | 0.03*          |
| Range | 0–8            | 0–2            |                |
| Median| 6              | 0.5            |                |

14 days

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 5.67           | 1.83           | 0.04*          |
| Range | 0–10           | 0–4            |                |
| Median| 5              | 2              |                |

Group 1: SDF
Group 2: SDF Laser and CO2
*Mann–Whitney Test; p<0.05 (significant difference)

Table 4. Average VAS scores for thermal stimulus before treatment, immediately after treatment, and 7 and 14 days after treatment; SDF: silver diamine fluoride

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 3.45           | 3.20           | 0.59           |
| Range | 0–9            | 0–8            |                |
| Median| 3              | 3              |                |

Immediate

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 1.36           | 1.04           | 0.36           |
| Range | 0–8            | 0–8            |                |
| Median| 1              | 0              |                |

7 Days

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 1.05           | 0.59           | 0.10           |
| Range | 0–7 is        | 0–5           |                |
| Median| 0              | 0              |                |

14 days

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 0.95           | 0.71           | 0.31           |
| Range | 0–9            | 0–6            |                |
| Median| 0              | 0              |                |

Group 1: SDF
Group 2: SDF Laser and CO2
*Mann–Whitney Test; p<0.05 (significant difference)

Table 5. Average DIAGNOdent scores before treatment, immediately after treatment, and 7 and 14 days after treatment; SDF: silver diamine fluoride

|       | Group 1 (n:42) | Group 2 (n:51) | The value of p* |
|-------|----------------|----------------|----------------|
| Mean  | 10.31          | 8.73           | 0.53           |
| Range | 0–48           | 1–41           |                |
| Median| 7.5            | 7              |                |
4. Discussion

This study was conducted with a single-blind, split-mouth, and randomized controlled design with the goal of analyzing the efficacy of silver diamine fluoride and CO2 laser in reducing dentin hypersensitivity. This design was selected to minimize variability in the response between comparison groups [9]. Randomization was performed to determine the type of treatment applied to two maxillary regions and the two groups were compared. The stimuli used to measure the degree of dentin hypersensitivity consisted of evaporative and thermal stimuli. Two types of stimuli were used because pain with cold stimuli is the most common complaint for patients with dentin hypersensitivity [10,11]. Additionally, two stimuli were used to assess the degree of hypersensitivity because the response of each individual varies according to the stimulus.

Measurement was conducted four times, specifically for initial data recording (baseline), immediately after the treatment, 7 days after treatment without reapplication, and 14 days after treatment without reapplication. The initial data recording or baseline was necessary to confirm the initial condition of the teeth before treatment. The measurements obtained 7 and 14 days after treatment without reapplication were used to confirm the test material was still working. All measurements were made on teeth positive for hypersensitivity.

Two types of measurements were used: VAS and DIAGNOdent. VAS was used for the two types of stimuli (evaporative and thermal) during subject examination and baseline data collection, immediately after application of the test materials, and 7 and 14 days after treatment without reapplication. VAS was used because it allows the subject to assess stimuli obtained specifically. DIAGNOdent was also used to measure the baseline condition, the sensitivity immediately after application of the test materials, as well as 7 and 14 days after treatment without reapplication. DIAGNOdent was used as an objective tool to assess the level of teeth hypersensitivity because VAS is a subjective assessment tool whereas the pain experienced by the subject is relative. DIAGNOdent was used to assess the demineralization that occurred on the teeth due to dentin hypersensitivity. Even though there is no proof that DIAGNOdent is a valid measuring instrument for clinical tests on sensitive teeth, it is often used to measure the surface demineralization of teeth [12,13]. This tool was used because one of the etiologies of dentin hypersensitivity is exposed dentin resulting from decreased enamel surface area.

The results in Tables 2 and 4 show the decline in the VAS score for evaporative stimulus (51%) and thermal stimulus (51%) against the baseline data after silver diamine fluoride application. After silver diamine fluoride application and CO2 laser treatment, the VAS score decreased for evaporative stimulus (45%) and thermal stimulus (61%) compared with the baseline data.

The same table also shows a decrease in the score for evaporative (50% and 50%) and thermal (59% and 64%) stimuli against the baseline data on the 7th and 14th days after silver diamine fluoride
application without reapplication. On the 7th and 14th days after the application of silver diamine fluoride with CO2 laser exposure, there was a decline in the scores for evaporative (54% and 55%) and thermal (73% and 74%) stimuli compared with baseline data.

Table 5 also shows a decrease in the DIAGNOdent score (34%) after silver diamine fluoride application. The scores on the 7th (39%) and 14th (36%) days were lower than the baseline data. The DIAGNOdent score also decreased (37%) after the simultaneous application of silver diamine fluoride and CO2 laser. The scores on the 7th (31%) and 14th days (34%) were also lower than the baseline data.

The results of this study demonstrate that the application of silver diamine fluoride alone and silver diamine fluoride followed by CO2 laser exposure can significantly reduce dentin hypersensitivity (measured with VAS) to evaporative and thermal stimuli on the teeth surface compared with baseline data (p = 0.000). Dentin hypersensitivity to the same stimulus on the 7th and 14th days after application was significantly lower compared with the baseline data.

Measurement with DIAGNOdent also showed that the application of silver diamine fluoride alone and with the CO2 laser significantly increased the amount of teeth remineralization on the teeth surface compared with baseline data (p = 0.000). On the 7th and 14th days after application, teeth remineralization was also significant compared with the baseline data.

There was a significant decrease in VAS and DIAGNOdent scores following the silver diamine fluoride and CO2 laser application on the teeth surface. Silver diamine fluoride and CO2 laser application on teeth surface is believed to stimulate the process of enamel and dentin surface remineralization, which closes the dentin tubules and inhibits the stimulation of pain in the teeth, preventing hypersensitivity.

Silver diamine fluoride is used to stop caries lesions through the formation of a hard and insulated layer [6]. The fluoride in this material improves remineralization on the surface of the teeth. The utilization of silver diamine fluoride for the prevention of dentin hypersensitivity is supported by research by Castillo et al. (2011), which demonstrated the clinical efficacy of silver diamine fluoride as a desensitization agent. The effect lasts for 24 hours to 7 days after application to the surface of the teeth. However, clinical tests over a longer period and comparison with other techniques are still needed to measure the effectiveness of silver diamine fluoride [7].

The use of CO2 lasers to reduce hypersensitivity in dentin has been tested in several clinical studies. CO2 lasers can improve remineralization by changing the structure of the teeth, making it harder to dissolve in acid because the laser thermal trace minerals on the surface change the nature of the protein, prevent the evaporation of water, and remove carbonate [14]. This mineral redeposition will also ablate the dentin. These results are in accordance with findings by Moritz et al. (2006) that the CO2 laser was clinically effective for reducing dentin hypersensitivity. Therefore, the CO2 laser has been proven to reduce dentin hypersensitivity [15].

There was no significant difference in the reduction of the VAS score for evaporative and thermal stimuli and the DIAGNOdent score between the two types of treatment. The score was significantly decreased between the two types of treatment only could be seen when the teeth have a greater baseline score than evaporative stimulus in the test. After categorization, a reduction in VAS average scores for evaporative stimulus was observed on the 7th (p = 0.01) and 14th (p = 0.01) days after application. The results showed that the decrease of VAS scores was greater on the teeth treated with silver diamine fluoride and CO2 laser than on teeth treated with silver diamine fluoride only. This confirms that the simultaneous use of silver diamine fluoride and CO2 laser is more effective.

Silver diamine fluoride and CO2 laser treatment performed simultaneously appear to be more effective in reducing the dentin hypersensitivity response. This is likely because the laser improves the fluoride retention power on tooth microstructures by increasing adhesion [16]. The CO2 laser was selected because it has the best wavelength for absorbing fluoride [8]. Therefore, there will be more fluoride on the teeth surface, facilitating easier remineralization and closure of the dentin tubules. The results of research by Tepper et al. (2004) and Bahrololoomi et al. (2015) support this theory by showing that the use of the laser after application of Fluoride reduces the disintegration of the enamel structure and increases the absorption of fluoride as well as resistance to acid [8,16]. However,
because of the lack of evidence showing the clinical effectiveness of the simultaneous application of silver diamine fluoride and CO2 laser, future research is needed in vivo.

A significant reduction also occurred in the DIAGNOdent score immediately after (p = 0.04) the two types of treatment. There was a greater reduction in the DIAGNOdent score on teeth treated with silver diamine fluoride only than on teeth treated with silver diamine fluoride and CO2 laser. This result was the opposite of the results for the VAS score and indicated a lower validity for DIAGNOdent when used to measure the level of hypersensitivity. DIAGNOdent was only used to measure the level of remineralization in previous studies. The combination of silver diamine fluoride and CO2 laser was not intended to remineralize the entire surface of the teeth, only to close the dentin tubules.

Treatment with the CO2 laser alone was not performed in this study because previous studies conducted in vitro showed the existence of a crack on the surface of teeth after treatment with the laser. We feared that this could have a negative effect after treatment.

The weakness of this study is the amount of research time, which was relatively short (three weeks). We could not assess the long-term effects, and there was a potential bias due to the order of execution for the systematic VAS and DIAGNOdent measurements in each region. Use of the split-mouth technique as a research design has the side effect that the results obtained from evaporative and thermal tests affect each other. The subjectivity of VAS must also be reassessed in studies using the split-mouth design.

5. Conclusion

The use of silver diamine fluoride alone or in combination with CO2 laser treatment can reduce dentin hypersensitivity.

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