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Comparative Study in Dentinal Tubuli Occlusion Using Bioglass and Copper-Bromide Laser

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***Abstract*—**Cervical dentinal hypersensitivity (CDH) affects 8-30% of adults and nearly 85% of perio-treated patients. Various treatment schemes have been applied for treating CDH, among them being fluoride application, laser irradiation, and, recently, bioglass. The purpose of this study was to investigate the influence of bioglass, copper-bromide (Cu-Br) laser irradiation and their combination on dentinal tubule occlusion as a potential dentinal hypersensitivity treatment for CDH. 45 human dentin surfaces were organized into three equal groups: group A received Cu-Br laser only; group B received bioglass only; group C received bioglass followed by Cu-Br laser irradiation. Specimens were evaluated with regard to dentinal tubule occlusion under environmental scanning electron microscope. Treatment modality significantly affected dentinal tubule occlusion ($p<0.001$). Groups B and C scored higher dentinal tubule occlusion than group A. Binary logistic regression showed that bioglass application significantly ($p<0.001$) contributed to dentinal tubule occlusion, compared with other variables. Under the conditions used herein and within the limitations of this study, bioglass application, alone or combined with Cu-Br laser irradiation, is a superior method for producing dentinal tubule occlusion, and may lead to an effective treatment modality for CDH.

***Keywords*—**Bioglass, Cu-Br laser, cervical dentinal hypersensitivity, dentinal tubule occlusion.

I. Introduction

DENTIN hypersensitivity is a painful clinical condition which may affect 8-35% of the population, and these dentin hypersensitivities, caused by the exposure and patency of dentinal tubules, can affect the patients' life quality [1], [2]. Gingival scaling and root-planing can induce the occurrence of root dentin hypersensitivity, and this gingival scaling might cause a more or less transient occurrence of dentine hypersensitivity [3], [4]. Patients who complain of having sensitive teeth from exposed dentin secondary to gingival recession can be conservatively treated with a diverse procedure, but many dentist-applied treatments for dentine hypersensitivity meet the requirements of an ideal desensitizing agent [5], [6].

According to a former research, the Er:YAG laser desensitization treatment can effectively reduce hypersensitivity of cervically exposed hypersensitive dentin, and the CO_2 laser can be recommended as an ideal tool for desensitization of dental necks [7], [8]. Also, the 660 nm red diode laser was more effective than the 830 nm infrared laser, and a higher level of desensitization was observed at the 30 minute post-irradiation examinations with Er:YAG and diode laser, whereas Nd:YAG laser is more effective than Er:YAG laser in reduction of patients' pain in dentin hypersensitivity [9]-[11]. Low-power laser irradiation suppressed the impulse conduction of unmyelinated A-δ afferents in peripheral sensory nerve, which caused a pain sensation [12]. Moreover, the diffusion of heat induced by the Nd:YAG laser into the pulp within the limit of the desensitization parameters causes no irreversible damages in the dental pulp [13], and the desensitizing effect of Nd-YAG Laser irradiation is effective in preparing occlusal seats for the removable partial denture prosthesis [14].

Conventional desensitizing agents such as professional pastes, toothpastes, mouthwashes aim to obliterate the exposed dentinal tubules and different toothpastes with strontium chloride or potassium nitrate as active ingredients have been commonly used as very effective desensitizing agents. Also, a significant effect of combined desensitizer toothpastes and diode laser therapy occurs in the treatment of desensitization of teeth with gingival recession [9], [10].

The copper bromide laser was an effective tool in the treatment of certain cutaneous vascular lesions, and it's a safe, effective modality for the treatment of the majority of facial telangiectasia [15]-[17]. Especially the 578 nm copper bromide (CuBr) yellow light laser produces excellent results in eradicating red telangiectases of the lower extremities that are less than 2 mm in diameter [18].

Bioglass paste is a highly biocompatible material [19], [20] with the incorporation for treatment of dentin hypersensitivity. Additionally, the inclusion of bioactive glass particles in a suitably formulated vehicle may be an effective agent for the treatment of dentine sensitivity [21]. This application of bioglass paste to dentin was able to occlude the patent dentinal tubule orifices with a formation layer of calcium-phosphate crystals [22].

Laser irradiation alone and combined with bioglass proved superior to bioglass alone on dentinal tubuli orifice occlusion [23]. And the melting point of a composition-modified bioglass could be reduced and its use plus laser have the potential in clinical use to treat dentin hypersensitivity [24]. Therefore, the purpose of this study was to study about the effect of bioactiveglass and laser therapy to dentinal hypersensitivity.

II. Material and Methods

A. Synthesis of Sol-Gel Bioglass Paste

The sol-gel-prepared bioglass was based on a CaO-P_2O_5-TiO_2-Na_2O system (CaO 45%, P_2O_5 45%, TiO_2 3%, Na_2O 7%

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in mole %), and added 20 ml of 95% ethanol. The mixture was fiercely stirred at room temperature for two hours and subsequently placed in an oven at 60 °C for seven to 10 days to form a bioglass gel. Bioglass synthesis needs a slow temperature rising to their ionization. In this study scanning temperature was from room temperature up to 1500 °C with a heating rate of 20 °C /min and N_2 flow rate of 90 ml/min. Total weight of the specimen was 20 mg.

Bioglass gel specimens were pulverized by an alumina ball and then placed in a platinum crucible ball mill and then placed in a platinum crucible for heating in a furnace up to 220 °C for 20 hours. Dried bioglass was pulverized again and heated in the furnace up to 1550 °C for one hour. After quenching, the glasses were coarsely crushed with mortar and pestle and subsequently ball-milled with zirconia beads for eight hours in an ethanol solution. The resulting powders were dried at 37 °C and sieved to less than 35 µm.

In order to verify the bioactivity of these powders, samples were immersed in 200 ml of simulated body fluid for up to 14 days to confirm the formation of crystallization. Finally, the bioglass powder was mixed with α-terpineol and ethyl cellulose in a powder/liquid ratio of 75:25 in wt.% to form a bioglass paste.

B. Copper Bromide Laser

Although an existing laser treatment system with Nd:YAG and CO_2 laser were widely used for dentin hypersensitivity procedure a copper bromide laser system was developed by Bison medical Co., Ltd (Seoul, Republic of Korea) for this purpose. This copper bromide laser equipment consists of optical fiber delivery system and air cooling system and laser tube with 1,100 mm size, which has two wavelengths of 511 nm and 578 nm with maximum output power of 12 W (Fig. 1). This copper bromide laser system consists of laser tube, high power supplier, main control board, handpiece, fiber, foot switch, LCD module, filter wheel, motor wheel (ON/OFF wheel) and other components as shown in Fig. 2. Additionally, there are control part and sensor part which modulate the irradiate laser, also filter part use the two different wave length of copper bromide laser selectively.

Fig. 1 Copper bromide laser equipment

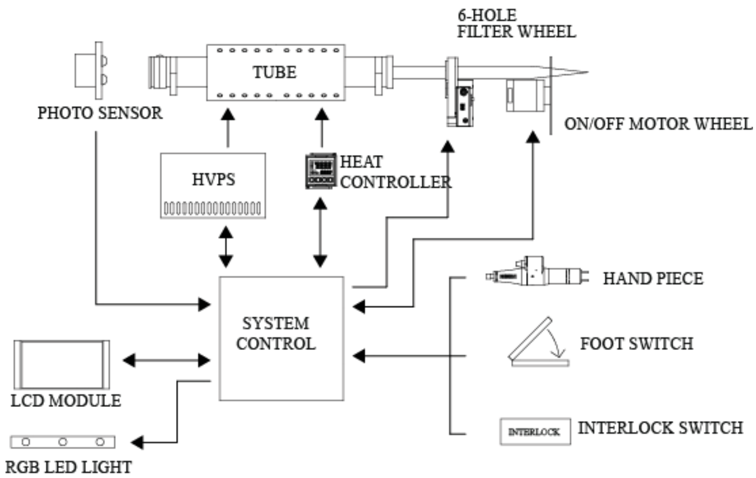

Fig. 2 Copper bromide laser configuration

C. Experiment

45 extracted human molars from 16 to 40-year-old individuals with informed consent at the National Korean University Dental Hospital were used for this study. Crowns with caries, restoration, or fracture were discarded. Any remaining soft tissue was thoroughly removed from the tooth surface with a dental scaler. All teeth were then stored in 4 °C distilled water containing 0.2% thymol to inhibit microbial growth until use.

While hydrated, crown dentin discs of 2-mm thickness were cut perpendicular to the long axis of the tooth by means of low-speed diamond wafering blade. Each cut specimen was immersed in 17% EDTA followed by two minutes of ultrasonic vibration to remove the smear layer, then rinsed with copious distilled water and dried with clean air. These dentin discs were divided into three groups (A to C) with 15 in each group. Group A was designated for Cu-Br laser Group B were designated bioglass paste treatment, while Groups C received bioglass paste treatment followed Cu-Br laser irradiation.

This study utilized Cu-Br laser power of 1 W and 6 W with an optic fiber of 300 micromillimeter diameter. And these both electric powers were used for this study to find the relevant factors to affects the results. The distance between the fiber laser tip and dentin surface was adjusted to 2 mm and an orthodontic wire was connected to the end of laser handpiece to maintain the distance.

Bioglass paste was applied to the specimens for 10 minutes and rinsed with an air-water spray for 20 seconds. All specimens were subsequently placed in 37 °C, 100% humidity environment for three days and then examined by a scanning electron microscope (SEM). The specimens of each group were evaluated for occlusive percentage calculation of the tested material on the orifices of dentinal tubules. A groove was prepared using tapered fissure bur on each specimen to facilitate the sectioning of each specimen with a chisel. Initially, the surface area of each specimen was equally divided into three portions and the specimens were observed at X 50 magnification. Subsequently, one site from each portion was randomly selected. Each selected site was then examined at X1000 magnification to measure the occlusive percentage.

Occlusive percentage was defined as the number of the orifices of dentinal tubules occluded by tested treatment divided by the total number of the orifices of dentinal tubules at X1000 magnification. Three values of occlusive percentage were obtained from each specimen and the mean value calculated. Ten mean values of 15 specimens in each group were calculated again to obtain the final mean value and standard deviation of occlusive percentage.

D. Statistical Analysis

Data obtained were subjective to one-way ANOVA and Tukey's post hoc test with the level of significance set at 5%. Binary logistic regression was used to find the relevant factors associated with dentinal orifice occlusion. Statistical analyses were performed using commercially-available software packages (SPSS Statistics, release 20.0.; Chicago, IL, USA). A P-value less than or equal to 0.05 was considered as statistically significant.

III. Results

A. SEM Observation of Dentinal Tubule Occlusion by Treatment

SEM observation of the persistence of dentinal tubule occlusion effects of treatments.

The SEM observations of the molar dentine discs after treatment were shown in Fig. 3. The majority of the dentinal tubules were blocked by materials in the bioglass treatment group, while some dentinal tubules were empty in the Cu-Br laser irradiation group. Similar SEM observations were obtained for the molar dentine discs treated with bioglass followed Cu-Br laser irradiation group and bioglass group as those for the molar dentine discs.

B. Dentinal Tubule Plugging Rates

The dentinal tubule plugging rates of the molar dentine discs treated with bioglass and Cu-Br laser irradiation were shown in Table I. The rate of the Cu-Br laser irradiation group was significantly lower than that of the bioglass group and bioglass followed Cu-Br laser irradiation group (P<0.05). Although the dentinal tubule plugging rates for one group were slightly increased after Cu-Br laser irradiation, the rate of bioglass group and bioglass followed Cu-Br laser irradiation groups were still higher than the only Cu-Br laser irradiation group (P<0.05).

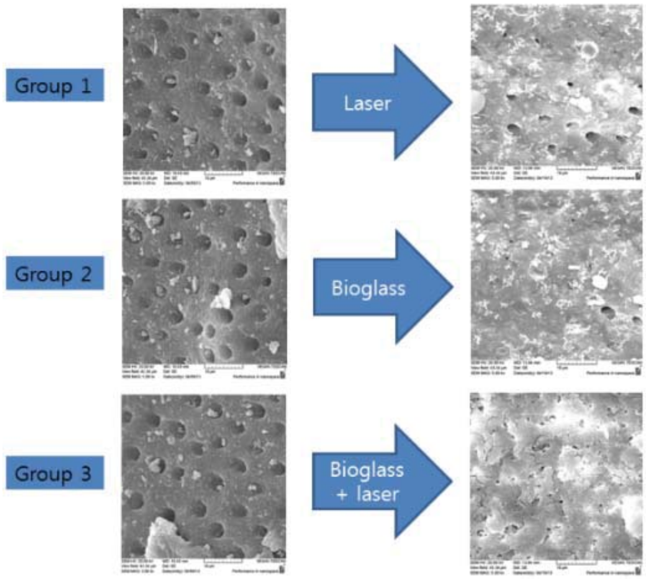

Fig. 3 Dentinal tubule occlusion by treatment, Group 1: Laser 1W, Group 2: Bioglass only, Group 3: Bioglass + laser 6W

TABLE I
One Way ANOVA of Dentin Occlusion Rate (Mean ± SD)

Source	Sum of squares	F probab. (sig.)	Mean	Post hoc (Tukey HSD)
Between groups	7721.6	<0.001	Laser: 71.4	Laser < Bioglass, Laser < Laser + Bioglass
Within groups	2172.4		Bioglass: 97.6	
Total	9894.0		Laser + Bioglass: 99.6	

C. Multivariate Analysis of Dentinal Tubule Occlusion

The mean dentinal tubule occlusion rate of bioglass treatment was 97.5%, and we used this value for the dentin tubule occlusion rate in binary logistic regression analysis [25]. Using this mean dentinal tubule occlusion rate, we divided the sample into low occlusion and high occlusion groups. Dentinal tubule occlusion rate was defined as the dependent variable, and independent variables were treatment, laser power.

Variables included in the logistic regression model were tested by significance of score statistics, and variables excluded from the logistic regression model were tested as probability of likehood-ratio statistics by the maximum partial likelihood estimates. There were two significant variables in the final logistic regression model after all variables were tested. Regarding the multivariate model, treatment and laser power were identified as significant relevant factors for dentinal tubule occlusion rate and their odds ratios were 1.339 (1.135-1.580) and 1.113 (1.012-1.225), respectively as Table II.

TABLE II
MULTIVARIATE ANALYSIS OF DENTIN OCCLUSION RATE

Variables	Regression coefficient (β)	Odds Ratio (e^{β})	95% CI	P value
Treatment	0.292	1.339	1.135-1.580	0.001
Laser power	0.107	1.113	1.012-1.225	0.028

IV. DISCUSSION

Calcium phosphate crystals form on the dentin surface and in the dentin tubules immediately upon sequential application of bioglass. The size of the crystals, their degree of coverage and the thickness of the precipitate depended on the method of application of the concentration of the solutions. The higher the concentration of the solutions, the denser and heavier the precipitates were and the thicker the layer of precipitate occluding tubular orifices became [26].

Mesoporous material exhibited a significant reduction in dentin permeability, even under simulated pulpal pressure, as compared with a commercial desensitizing material [27]. Especially, the hypersensitivity after subgingival scaling could be relieved while the bio-glass powder and the bio-glass paste could reduce the prevalence and the severity of it [28]. And treatment with nanobioglass resulted in particle deposition within tubules and formation of apatite rods which were tightly adherent to tubule walls [29]. Some sealing performance of tubular occlusion was rendered by bioglass catalyzed with HNO3 [30]. But laser irradiation with bioglass is a superior method for producing dentinal orifice occlusion, and may lead to an effective treatment modality for CDH [31].

The methodology used in this study to evaluate the desensitizing agents was different from other studies. A previous study evaluated only the SEM images which categorized the number of closing or patent dentinal tubules. However, the new methodology of this study used to SEM for a precise quantitative assessment of the dentinal tubule occluding effects. This study attempted to quantify the opening tubules area based on every SEM image of samples by using the counting method.

The different point was the main focus on the short-term effects of the desensitizing agents. A previous study only evaluated the long-term effects of desensitizing agents [32].

According to the clinical relevance, an evaluation of the short-term effect of desensitizing agents will be more meaningful. Therefore, this study examined the effects of the short-term use from a treatment. In particular, the tubule closing effect by the desensitizing agents will reflect the immediate self-recognition of pain relief for patients.

In terms of this result, the bioglass followed Cu-Br laser irradiation group showed the most effective occlusion of dentinal tubules. This group showed an occlusion rate of the dentinal tubules of 99.6%.

Consequently, bioglass could occlude the dentinal tubule orifices with calcium-phosphate crystals, and laser potentially improved the mechanical integration of these crystals.

V.CONCLUSION

According to this research, there might be a combination effects about the dentinal tubule occlusion by bioactive glass and copper-bromide laser therapy.

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