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ORIGINAL ARTICLE

The effect of plasma treatment and bioglass paste on enamel white spot lesions

Noha A. El-Wassefy [1,*]

Faculty of Dentistry, Mansoura University, Egypt

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Abstract *Objective:* Bioglass can be used as a non-invasive remineralizing treatment for enamel white spot lesions (WSLs). Cold plasma application can boost enamel surface properties by increasing its surface energy and wettability without disturbing the bulk structure or raising up pulp temperature. It is thought that the remineralizing ability of bioglass, might be enhanced if proceeded by plasma application. This study investigated the combined effect of cold plasma and bioglass on demineralized enamel.
Methods: Forty bovine incisors were sectioned to obtain flat enamel specimens and challenged by demineralization solution of pH 4.47 for 72 h. The enamel specimens were randomly divided into four groups: (I) control, demineralized enamel with no treatment (C); (II) demineralized enamel primarily treated with cold plasma, then bioglass paste protected with adhesive, afterward additional application of cold plasma (PBP); (III) demineralized enamel treated with cold plasma, then bioglass paste protected with light cured adhesive (PB); and (IV) bioglass paste applied to demineralized enamel and protected with light cured adhesive (B). All groups were stored in remineralizing solution for 24 h, subsequently cross-sectional micro-hardness measurements were done and then a scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscope (EDS) were used to examine specimen's surface morphology and chemical analysis.
Results: Group II (PBP) showed a significant higher cross sectional micro-hardness value than bioglass group at 30 μm depth. SEM revealed numerous surface deposits of spheroidal and prismatic shape, EDS showed that the elements are mainly calcium, phosphorus with trace amount of silica and sodium.
Conclusion: Combined plasma/bioglass/plasma treatment could improve the remineralization of enamel white spot lesions.

* Address: 35516 El-Gomhoria Street, Mansoura University, Egypt.
E-mail addresses: nohahmed@mans.edu.eg, nohaelwassefy@gmail.com.
[1] Former Visitor at Minnesota Dental Research Center for Biomaterials and Biomechanics, United States.
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1. Introduction

White spot lesions (WSLs) are one of the predominant side effects of fixed orthodontic treatments, affecting about 50% of patients. Fixed orthodontic appliances impair oral hygiene and decrease salivary flow that cause formation of biofilm.[1]

Mature tooth enamel is a crystalline structure, containing up to 96% hydroxyapatite (HA, $Ca_{10}(PO_4)6(OH)_2$) by weight, the rest is made up of water and organic matter.[2] At pH < 5.5, HA dissolves in a process known as demineralization. The amount and rate of dissolution depends on the pH and the concentration of calcium and phosphate ions in oral saliva.[3] If good oral hygiene was not maintained, the acid produced from biofilms can cause enamel demineralization which will be manifested clinically as WSLs.[4]

Enamel demineralization causes increased porosity within the lesion body, which changes light reflection by enamel. Since the light is scattered, an active WSL has a chalky white, opaque appearance.[5,6]

The lesion surface is clinically intact when lightly probed in early stages. It is suggested that the management of tooth demineralization should focus on early detection and inhibition, such as tooth remineralization, before applying a restorative approach.[7,8] Remineralization of the enamel surfaces may increase mechanical properties of these regions and their resistance to any further cariogenic or erosive challenges.[9] However, cavitation may occur if the cariogenic challenge is ongoing, which might lead to the necessity of invasive restorative treatments.[10]

Bioactive bioglass materials show a promising potential for repairing enamel and is an interesting area of research.[11] Currently, a procedure of applying bioglass paste, that could release calcium and phosphate ions, was introduced and proved capable of remineralizing the enamel exposed to erosion.[12] The bioglass paste formed a calcium phosphate-rich "interaction layer" on eroded enamel surfaces within 24 h.[13]

Plasma is a gaseous medium which can penetrate into irregular cavities and fissures. Plasma can kill pathogens in bacterial plaque and dental caries, without damaging the normal tissue. Plasma does not cause discomfort to patients, as it does not prompt thermal damage.[14,15]

In dentistry, cold plasmas have been studied for surface modifications of dental implants, adhesion, caries treatment, endodontic treatment and tooth bleaching.[16] It was also confirmed that non-thermal atmospheric plasmas could improve adhesive penetration in the interface region.[17] Cold plasma can interact with subjects physically, chemically and biologically without causing damage.

This study aimed to investigate the combined effect of cold plasma treatment to demineralized enamel together with bioglass paste application. The hypothesis of this study is that the cold plasma application to demineralized enamel before bioglass application could improve enamel remineralization, while extra plasma application to the adhesive, will cure it and improve its performance as a bioglass protective shield.

Cross-sectional micro-hardness was inspected. The morphology and chemical analysis of treated surfaces were examined by scanning electron microscope (SEM) coupled with energy dispersive X-ray spectroscope (EDS).

2. Materials and methods

2.1. Specimen preparation

Forty non-carious bovine incisors were obtained from a slaughter house and used in this study following guidelines approved by Minnesota Dental Research Center for Biomaterials and Biomechanics. The teeth were sectioned to remove their buccal surfaces using water-cooled diamond saw (Isomet low speed saw, BUEHLER, Lake Bluff, IL, USA) then ground flat with water-cooled silicon carbide disks (600-, 1200- 2400-grade papers; Buehler) to obtain flat enamel surfaces; this help in the creation of a more consistent, reproducible artificial enamel lesions. Specimens were then flushed with distilled water in ultrasonic cleaner (Cole-Parmer, Model 08849-00, Vermont Hills, IL, USA) for 30 min to remove all surface deposits. Two layers of protective nail varnish (Revlon Miami, Florida, USA Lot TV14078) were applied to protect the enamel area leaving a treatment window of 4×4 mm (Fig. 1). Each enamel specimen was challenged by a 15 ml demineralization solution composed of 2.0-mM calcium, 2.0-mM phosphate, 4.73 ml acetic acid, and 6.0 mM $C_2H_3NaO_2$ with PH adjusted to 4.47 at 37 °C.[18]

2.2. Specimen grouping

Specimens were randomly assigned to four groups (n = 10): group I; control group with no treatment (C); group II; cold plasma application prior to bioglass paste, then adhesive application then another plasma application (PBP); group III; cold plasma application prior to bioglass paste, then adhesive application, that is cured with visible light curing unit (PB); and group IV; solely bioglass paste application and light cured adhesive (B) as shown in Table 1. After treatment, specimens were immersed in a remineralizing solution for 24 h.

2.3. Cold plasma application

The plasma cleaner (Harrick Plasma, PDC-32G, Ithaca, NY, USA) was used in the study. Oxygen was used as a gas source, plasma Cleaners require a vacuum pump with a minimum pump speed of 1.4 m^3/h and an ultimate total pressure of 200 mTorr. Plasma treatment time was set for 5 min. In group II; (PBP) the plasma jet is used first to treat the enamel surface, then additional application after bioglass paste and adhesive coat; to strengthen and cure the adhesive. In group III; (PB) the plasma jet is only used to treat the enamel surface before bioglass paste application.

2.4. Bioglass application

45S5 bioglass powder[19] with an average particle size 44 μm was prepared and used in the study (composition mentioned in Table 2). A glass slap and a spatula were used to mix 0.1 g of bioglass with 0.2 ml of 50 wt% phosphoric acid that was prepared from 85 wt% phosphoric acid (Fisher Scientific Company, Fairlawn, New Jersey, USA) by distilled water for 1 min to form a paste.[13] The paste was applied to demineralized specimen surface of groups II-IV using micro-brush