



The use of a Novel Bioactive Glass in Air Polishing for Subgingival Root Debridement



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Submission: October 25, 2019; **Published:** November 13, 2019

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Abstract

Aims: To determine the abrasiveness of using a novel bioactive glass (BioMinF®) in air polishing for subgingival root debridement by measuring dentine loss and compare this value to the reference powders. Furthermore, to confirm the tubular occlusion effect of air polishing with the bioactive glass using Scanning Electron Microscopy techniques.

Material and Methods: Ivory derived from an elephant's tusk was used as the study sample. A balled milled BioMinF® powder (D90 = 87.9 µm), was used as the test powder; This choice was based on a previously performed pilot study [1]. This powder was compared to two reference powders, sodium bicarbonate and glycine. Each powder group constituted of six samples of ivory. The dentine lost was measured in µm using white light profilometry. Scanning electron microscopy was performed for all the tested powders, to evaluate particle shape, and to the study samples to assess the effect of the air abrasive/polishing procedure on dentinal tubules.

Results: The depth of dentine removed (mean ± standard deviation) of the test group, air polishing with the bioactive glass, was 11.0 ± 1.05 µm, control group 1, air polishing with sodium bicarbonate, was 44.1 ± 0.77 µm, and control group 2, air polishing with glycine, was 28.1 ± 1.87 µm. The differences between the three groups were statistically significant. SEM images showed a partial tubular occlusion effect in the test group, and this was absent in both control groups.

Conclusion: The novel bioactive glass, BioMinF®, with ball milled particles 90% sized less than 87.9 µm, was significantly more conservative than sodium bicarbonate powder and glycine powder. There was evidence of partial tubular occlusion following bioactive glass air polishing; however, no tubular occlusion was evident in the samples treated with either sodium bicarbonate or glycine air polishing.

Keywords: Novel Bioactive Glass; Air Polishing; Subgingival Root Debridement

Introduction

Periodontal diseases are strongly associated with the presence of bacterial biofilms on root surfaces [2]. Control and removal of bacterial biofilm from all dental surfaces is essential in the treatment and prevention of these diseases [3,4]. It is necessary for periodontal patients to receive frequently performed subgingival debridement in pockets >3 mm probing depth in order to maintain periodontal health since a pre-treatment composition of subgingival microflora can be re-established after several months [5]. The traditional modalities for plaque and calculus removal involve the use of hand instruments or ultrasonic devices or a combination of both. These are both uncomfortable, technically demanding, as well as being clinically time consuming. It may, also lead to severe, substantial, and irreversible root damage [6], and gingival recession over time if applied repeatedly [7,8]. For treatments that need to be repeated, time efficiency, high patient acceptance, and minimal tissue damage are essential requirements [4]. The use of

other treatment modalities which are effective in removing plaque with minimal abrasion to root surfaces is preferable [9].

Subgingival air polishing (AP) has been suggested as a simplified alternative approach for root debridement [10]. AP has demonstrated to be a valid, highly efficient, and convenient treatment approach to subgingival debridement [10,11]. It is preferable to conventional treatment with respect to patient comfort, safety, and time efficiency and, therefore, may offer more patient compliance and economic benefits [4,10-14]. Bioactive glasses are biocompatible, non-toxic, non-inflammatory, non-immunogenic bioactive agents having the ability to interact directly with living tissues and form chemical bonds. Once the bioactive glass dissolves, it forms a hydroxyapatite or fluorapatite like phase which, chemically is similar to the natural tooth mineral. AP with hydroxyapatite has been demonstrated to be effective in removing plaque, tartar (calculus), and stains from enamel and cementum

surfaces [15]. The treated enamel and cementum surfaces were covered with a layer rich in hydroxyapatite that was not removed by a water spray [15]. This high saturation of superficial enamel and cementum layers with calcium and phosphate supports remineralization of tooth hard tissues and may also reduce dentine permeability by occluding dentinal tubules and thus reduce dentine/root hypersensitivity [15,16]. The primary aim of this study was to determine the abrasiveness of using a novel bioactive glass (BioMinF®) in air polishing for subgingival root debridement by measuring dentine loss and compare this value to the reference powders. A secondary aim was to confirm the tubular occlusion effect of air polishing with the bioactive glass using Scanning Electron Microscopy (SEM) techniques.

Materials & Methods

Sample Preparation

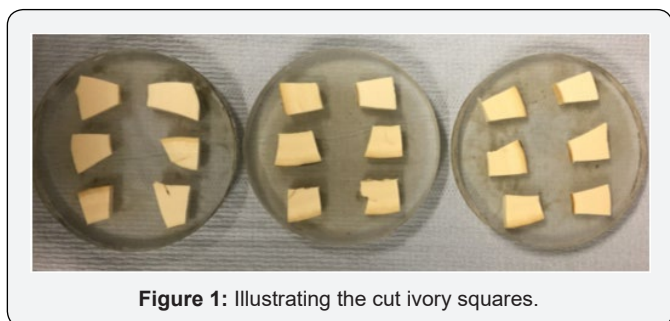


Figure 1: Illustrating the cut ivory squares.

A flat surface pristine ivory dentine (elephant’s tusk) was used as the study sample. An elephant tusk had been previously seized by UK airport customs (illegal smuggling of ivory) and subsequently given to Queen Mary University of London for research use. The tusk was cut manually with a hacksaw in order to obtain a 15 mm thick section of flat surfaces ivory dentine. This was further divided into 18 (10×10 mm) squares. The samples were then mounted in a resin using Claro Cit® (Struers ApS, Denmark), which is a cold mounting acrylic resin (Figure 1). The plastic disc was first painted with a thin coat of Vaseline and then the material was used according to the manufacturer’s instructions. After the resin had cured, the sample was polished to an optical finish using a Kemet 3000 LVAC (Kemet International Ltd, Maidstone, Kent, UK) polishing machine using several polishing discs in this order; 360 Grit, 400 Grit, 500 Grit, 800 Grit, 1000 Grit, and lastly 4000 Grit.

Powder Preparation

BioMinF® bioactive glass was obtained from CDL Ltd Stoke, UK in the form of glass frit (a water-quenched granular glass). The glass was Milled first with a Gyro Mill (Glen Creston, London, UK) then ball milled and sieved to give BioMinF® powder with D90 of 87.9 µm; This was the test powder which was compared to the reference powders, sodium bicarbonate powder (Medivance Ltd, London, UK) and glycine powder (Clinpro™ Glycine Prophy Powder, was obtained from 3M™). Particle size analysis was undertaken for all three powders using a Malvern MASTERSIZER 3000

(Malvern Panalytical, Malvern, UK). SEM images were also taken for each powder.

Experimental Method

An Aqua Care Air Abrasion & Polishing System from Velopex International, Medivance Instruments, Ltd was used in the experiment. The procedure was performed according to manufacturer’s recommendations, a distance of 4 mm, feed rate 1 and air pressure of 80 psi (551.5 kPa). A handpiece with a 0.8 mm tip was used together with disposable plastic tips, both were obtained from Velopex International, Medivance Instruments, Ltd. Plastic tips were changed after each application in order to standardize the experiment. Each sample was air abraded at a 90° angle to the surface for 5 and 10 seconds with the test powders. The amount of powder present in the Powder chamber was checked and always filled to the same level before each application to ensure reproducible and standardized conditions. After the experiment, the substance loss/cutting depth of each sample was evaluated using White Light Profilometry. A Proscan 2000 by Scantron Industrial Products Ltd was used to scan each sample individually. SEM images of each sample were taken to confirm any tubular occlusion effect on the dentine surface. The samples were coated with a layer of silver (Agar Scientific Ltd, UK) to prepare it for SEM.

Results

White Light Profilometry Analysis

Table 1: Cut depth values in µm of the test and control samples following 5 seconds air polishing.

	Test group (BioMinF®) cut depth values in µm	Control group 1 (sodium bicarbonate) cut depth values in µm	Control group 2 (glycine) cut depth values in µm
Sample 1	10.7	44	28.7
Sample 2	12.5	43.5	25.9
Sample 3	11.3	44.9	27
Sample 4	10.2	44.6	26.9
Sample 5	11.9	43.1	29
Sample 6	9.7	45	31.1

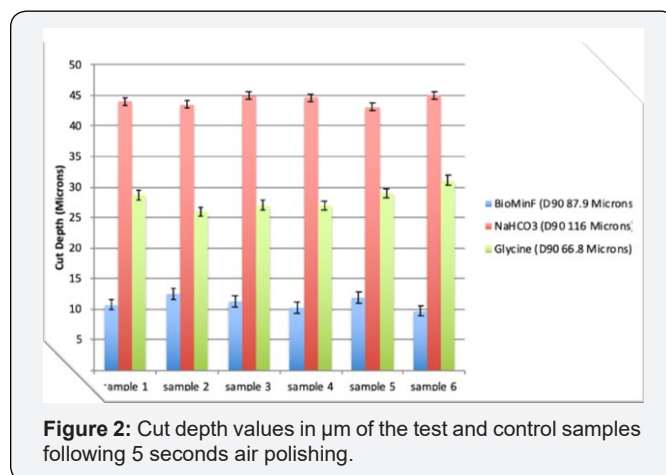


Figure 2: Cut depth values in µm of the test and control samples following 5 seconds air polishing.

Statistical analysis was based on the comparison between the three treatment groups. Differences in cut depth or dentine loss were tested by the use of the Independent Samples t-test. A P-value <0.05 was considered statistically significant. Data handling and statistical testing were performed with the use of the Microsoft Excel software. The individual cut depth values, in μm , of the test and control samples, following 5 seconds of air polishing, are shown in Table 1 & Figure 2. The mean \pm standard deviation of the cut depth of the test group was $11.0 \pm 1.05 \mu\text{m}$; this was significantly less than the mean \pm standard deviation cut depth of the control group 1 (sodium bicarbonate) which was $44.1 \pm 0.77 \mu\text{m}$, and control group 2 (glycine) which was $28.1 \pm 1.87 \mu\text{m}$.

Furthermore, the difference in the cut depth values between the two control groups were statistically significant. Air polishing with the novel bioactive glass, BioMinF®, resulted in statistically significant less cut depth and dentine loss compared to air polishing with sodium bicarbonate or glycine for the same duration ($P < 0.05$). Thus, the null hypothesis, which stated that there was no significant difference in the cut depths between the three powders, was rejected. The small value of the standard error of the mean of all groups, 0.43 for the test group, 0.31 for the control group 1, and 0.76 for control group 2, can indicate the reliability of the means and that these means are more accurate reflection of the actual true mean. The 95% confidence interval values of all groups are shown in Table 2 and indicates that we are 95% confident that the true actual mean of each group lies within this range.

Table 2: Results from the main study.

	Test group (bioactive glass powder)	Control group 1 (sodium bicarbonate powder)	Control group 2 (glycine powder)
Mean (μm)	11.0	44.1	28.1
Standard deviation	1.05	0.77	1.87
Standard error of mean	0.43	0.31	0.76
95% Confidence interval	10.1 - 11.9	43.5 - 44.8	26.5-29.6
P-value	0.00 0.00 ↑-----0.00-----↑		

Scanning Electron Microscopy Images Evaluating Dental Tubules

The surface characteristics of ivory samples of each group were assessed under the scanning electron microscope at a magnification of x10000 at two different points of the experiment:

- a) Before air polishing.
- b) After 5 seconds of air polishing application with the test or control powders.

Extra images at a reduced magnification of x1000 were further used to view each ivory sample at the same points of the experiment. The rationale behind this was to complement the result

seen at the higher magnification and to allow for observation of any tubule occlusion at a wider landscape of view. Also, at this reduced magnification, the dentine tubules appear smaller, thereby increasing the effective field of view which enabled better observation of the spread of the surface deposition. All observations were assessed using the naked eye of the author without any adjunctive aids. For ease of data analysis, the results will be presented individually, for each group before they are compared with each other.

Control Group 1 & 2 (Air Polishing with Sodium Bicarbonate and Glycine)

Figures 3 & 4 represent the surface of ivory dentine before the air polishing procedure, i.e. the normal state of ivory dentine. These figures show a clear surface with zero tubule occlusion, featuring opened dentine tubules. Figure 5 was taken following 5 seconds of air polishing with sodium bicarbonate; the dentine surface showed no sign of tubule occlusion and appeared almost similar to the previous image (Figure 6). A similar finding was observed following 5 seconds of glycine air polishing (Figure 7). At a lower magnification, x1000, the post-operative images, Figures 6 & 8, show the development of cracks or microfractures connecting the dentinal tubules. These were not present or were only minimally present in the pre-operative image, Figure 4.

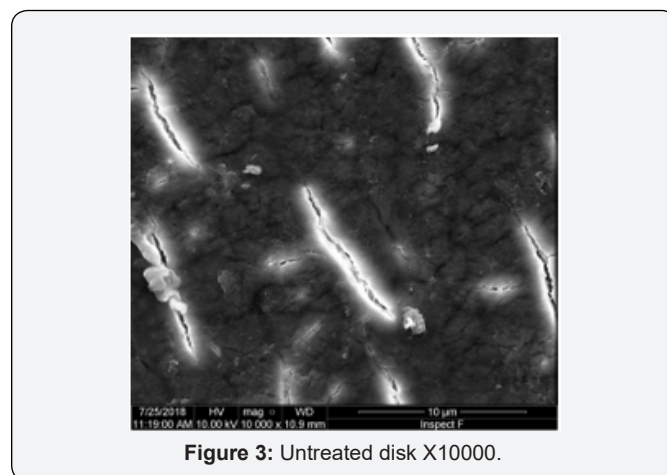


Figure 3: Untreated disk X10000.

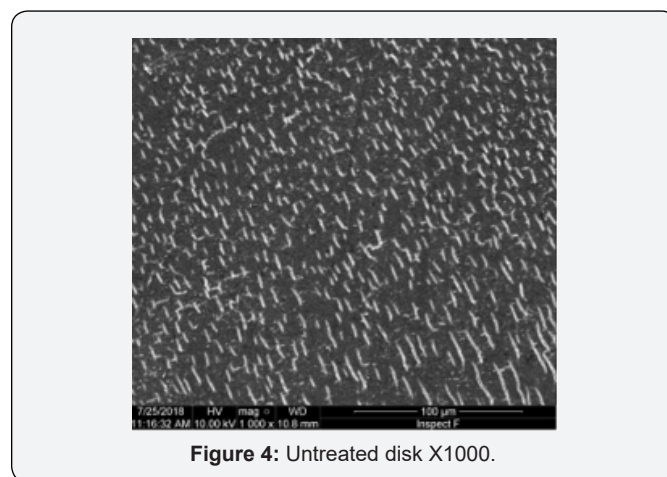


Figure 4: Untreated disk X1000.

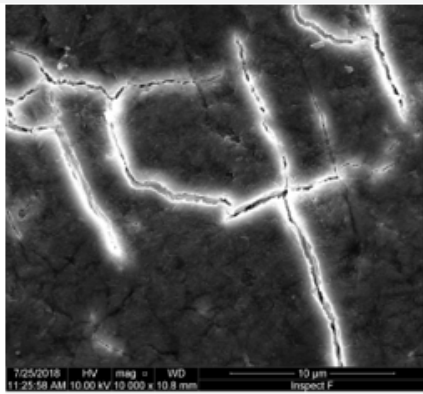


Figure 5: Following air polishing with sodium bicarbonate X10000.

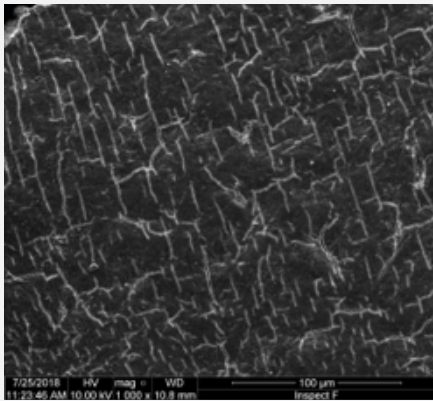


Figure 6: Following air polishing with sodium bicarbonate X1000.

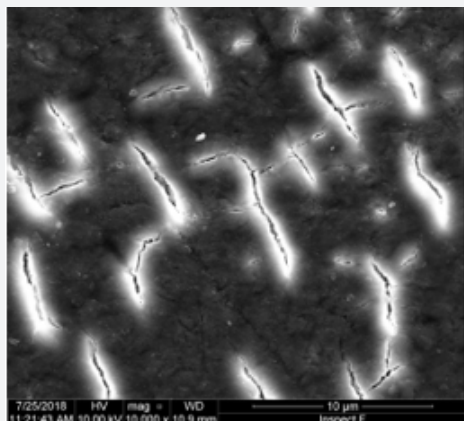


Figure 7: Following air polishing with glycine X10000.

Test Group (Air Polishing with Bioactive Glass)

Figure 9 shows the untreated ivory dentine surface with clear, well-defined, and open dentine tubule margins (Figure 10). SEM analysis of the treated dentine surface with the novel bioactive glass air polishing showed surface structural changes most probably caused by apatite deposition (Figure 11). A narrowing of the dentinal tubules and some tubular occlusion were observed together with scattered deposits on the surface, indicating the for-

mation of an apatite rich smear layer. At the lower magnification, a similar observation to that observed in the control group was also evident in the test group. Cracks and microfractures between the dentinal tubules developed following the application of air polishing (Figure 12); these were not present in the pre-operative image and were probably due to shrinkage effects within the SEM following water loss (Figure 10).

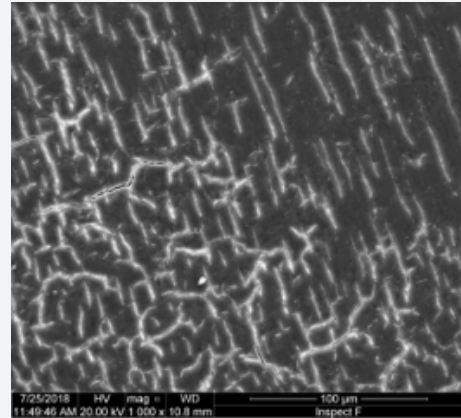


Figure 8: Following air polishing with glycine X1000.

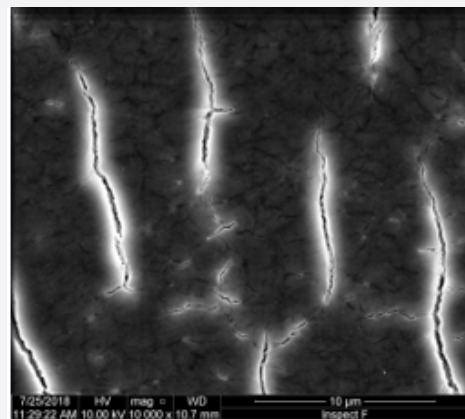


Figure 9: Untreated disc X10000.

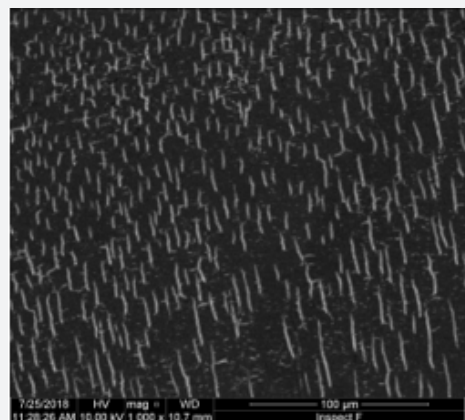


Figure 10: Untreated disc X1000.

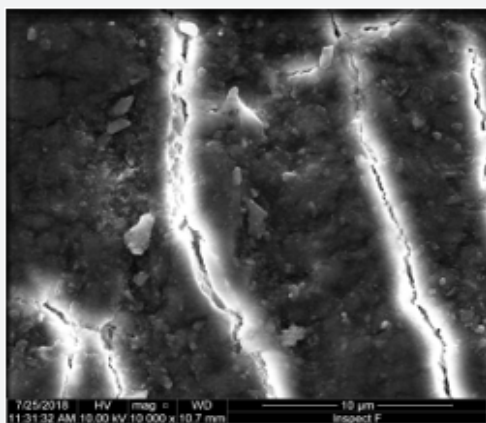


Figure 11: Following air polishing with bioactive glass X10000.

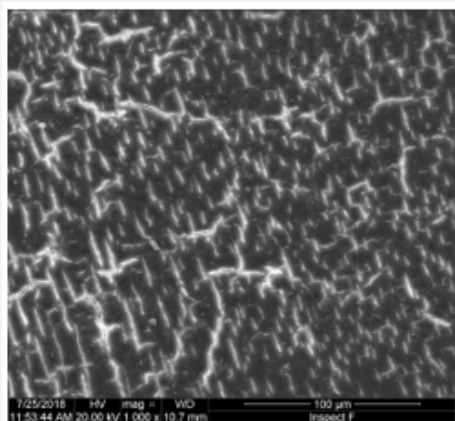


Figure 12: Following air polishing with bioactive glass X1000.

Discussion

The rationale for using pristine ivory dentine (elephant's tusk) in this study may be justified by references to several studies where it was demonstrated that calcium and phosphate ratios were comparable to other animal models [17] as well as the human tooth [18]. The impact of solid particles on the treated surface is the basic event leading to substance removal using air polishing with a water slurry cutting element [19]. This abrasive process is affected by many factors, such as the properties of the applied powder [1], time of exposure, and some parameters of the air polishing device itself (Pressure and Feed Rate) are also influential, such as water pressure and powder emission rate [19-22]. To the best of our knowledge, there are no previous published studies on the abrasive effect of bioactive glass air polishing, used for debridement, on the root or dentine surfaces. Also, there are no published investigations that directly compare the cut depth following bioactive glass air polishing with either sodium bicarbonate or glycine air polishing used for tooth surface debridement. Two previous studies had investigated the effect of bioactive glass air abrasion, used for cavity preparation and caries removal, on the dentine surface [23,24]. The air abrasion unit, bioactive glass powder characteristics, and experimental settings such as appli-

cation time, distance pressure were, however, completely different from our study. Therefore, direct comparison between the present study results and previous results are not valid.

The tubular occlusion effect due to the deposition of apatite minerals in the dentinal tubules with the formation of a surface smear layer was observed in our study following bioactive glass air polishing in agreement with other studies that examined the tested surface following bioactive glass application. Litkowski et al. [25] evaluated the dentine surface after treatment with bioactive glass compounds and reported an increase in tubular occlusion compared with non-bioactive glass containing controls [25]. Furthermore, Wang et al. [26] demonstrated that dentine remineralization and complete occlusion of dentinal tubules was evident after bioactive glass treatment [26]. In addition, Sauro et al. [16] concluded that air polishing with bioactive glass powder reduced dentine permeability and created a dentine surface resistant to citric acid attack, thereby indicating that the procedure was suitable for the treatment of dentinal hypersensitivity [16]. This was further confirmed in *in vivo* studies where patients reported decreased dental sensitivity immediately following bioactive glass air polishing and up to 10 days following the procedure. On the other hand, patients reported increased sensitivity immediately following air polishing with sodium bicarbonate and up to 10 days following the procedure [27]. Also, the bioactive glass appeared to offer a more effective tooth whitening effect when compared to sodium bicarbonate and patients reported increase in comfort of procedure with the bioactive glass over that when using sodium bicarbonate [27].

Studies had also demonstrated that the use of bioactive glass was more beneficial to the tooth surface compared to sodium bicarbonate. *In vitro* studies confirmed the formation of apatite rich smear layer on enamel, dentine and cementum surfaces following bioactive glass application; thus, it supports regeneration and remineralization of dental tissues [26,28-31]. Taha et al reported the remineralization of enamel white spot lesions following air polishing with a fluoride containing bioactive glass [30]. Another group confirmed that pre-conditioning enamel white spot lesion surfaces using bioactive glass air abrasion enhanced the subsequent remineralization therapy [32]. Coupled to this remineralising effect, bioactive glasses have been shown to have an antibacterial effect on oral flora [33,34]. The microfractures and cracks that developed within the ivory samples following air polishing with the tested powders in the present study can be attributed to the dry nature of the tusk as the tusk was stored in dry air.

The mean cut depth following 5 seconds of glycine air polishing in the present study was $28.1 \pm 1.87 \mu\text{m}$, which was comparable to the abrasion data obtained by Buhler et al. [21], who reported on a defect depth of $27.56 \pm 3.01 \mu\text{m}$ following a 5 second application of glycine powder but at a 45° angle [35]. The results from the present study are also comparable to the results of Herr et al, who reported a defect depth of $31 \pm 28 \mu\text{m}$ following 5 seconds of glycine air polishing at a 45° angle [36]. Several studies

have compared the effect of glycine air polishing to sodium bicarbonate air polishing. There is a general agreement that sodium bicarbonate was more abrasive on dental tissues than glycine. The resultant defect depth was significantly greater following sodium bicarbonate air polishing compared to glycine air polishing for the same duration [35,37,38].

Therefore, the present study is comparable to previous investigations. The mean defect depth following 5 seconds of sodium bicarbonate air polishing was $44.1 \pm 0.77 \mu\text{m}$, which agrees with previous reports [39], and, similarly, the difference in the resultant defect depths following glycine and sodium bicarbonate air polishing was statistically significant. The softer effect of glycine air polishing was also evident on the gingival tissues. Glycine air polishing has been reported to cause less gingival erosion compared to sodium bicarbonate air polishing and hand instrumentation [40]. This can partially explain the increased patient comfort reported following glycine air polishing compared to the other procedures [37]. The present study showed that air polishing with the smallest ball milled BioMinF® particles, D90 of $87.9 \mu\text{m}$, was significantly less abrasive than the reference powders, sodium bicarbonate and glycine. However, the efficacy of this novel bioactive glass powder in removing plaque from dental surfaces has yet to be confirmed. An *In vivo* study will be required in order to confirm this de-plaquing effect and determine the clinical effectiveness of using a BioMinF® powder in an air polishing procedure.

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DOI: [10.19080/ADOH.2019.11.555819](https://doi.org/10.19080/ADOH.2019.11.555819)

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