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A clinical evaluation and comparison of bioactive glass and sodium bicarbonate air-polishing powders

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SUMMARY

Objective: Compare clinical effectiveness of sodium bicarbonate and bioactive glass powders used for dental prophylaxis.
Methods: 25 patients were allocated to either good or poor oral hygiene subgroups ($n = 50$). Using a double-blind, split-mouth model, all patients underwent prophylaxis treatment on mandibular teeth; maxillary teeth were untreated controls. Bioactive glass (Sylc, OSspray Ltd., UK) and sodium bicarbonate (Prophy Jet, Dentsply, UK) were applied randomly to opposite sides of each mouth. Sensitivity to cold air/ethyl chloride, dental shade change and procedural comfort were measured. All parameters were recorded immediately pre- and post-treatment and at 10-day recall.
Results: Bioactive glass air-polishing, in both subgroups, reported a 44% (0.80 ± 0.10, $p < 0.05$) decrease in dental sensitivity, against controls, immediately after application, and a 42% (0.85 ± 0.05, $p < 0.05$) decrease at 10-day recall when stimulated with cold air. Ethyl chloride stimulation showed a 10% (3.05 ± 0.17, $p < 0.05$) and 22% (2.64 ± 0.33, $p < 0.05$) reduction in sensitivity immediately post-op and at 10-day recall. Application of sodium bicarbonate powders increased sensitivity, 17% (1.76 ± 0.3, $p < 0.05$), at 10 days when stimulated with cold air. Both powders showed variation between subgroups in colour change, bioactive glass powder 1 and 4 shades whiter, sodium bicarbonate 1 and 2 shades whiter in good and poor oral hygiene groups, respectively. Patients in both subgroups reported a 46% (7.9 ± 1.4, $p < 0.05$) increase in comfort of procedure with the bioactive glass over that when using sodium bicarbonate.
Conclusions: Bioactive glass air-polishing was more clinically and statistically effective at desensitising both good and poor oral hygiene groups, and removing stain in the poor oral hygiene patient subgroup. Bioactive glass also provided better overall patient comfort during the procedure.

1. Introduction

The air-polishing of teeth has traditionally been achieved with sodium bicarbonate powders in order to remove extrinsic staining on teeth. This operator-sensitive procedure can lead to excessive abrasion on the exposed dentine surfaces, often resulting in patients experiencing increased dental sensitivity post-operatively. Consequently, dental practitioners and hygienists are reluctant to use air-polishing powders on patients who have existing dental hypersensitivity.[1] Dental hypersensitivity is a clinical problem that affects approximately 40 million adults in the United States, 10 million of

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which can be considered chronically affected. It is estimated that some 17% of adults in the U.S. have at least one or more sensitive teeth.[2] It has been reported in a UK study that the prevalence of dentine sensitivity in a large cohort of general practice patient was lower at 4%.[3] The variation in prevalence rates may reflect differing study designs.

The generally accepted basis for the physiological cause of dentine hypersensitivity is Brännström's hydrodynamic theory.[4] This concept states that exposed, open dentinal tubules at the tooth surface permit dentinal fluid movement along the tubules which in turn, excites the nerve endings in the subodontoblastic nerve plexus in the dental pulp, so causing acute discomfort.

There are many approaches to the treatment and prevention of dentinal hypersensitivity. Treatment of the tooth with a chemical agent that penetrates into the dentinal tubules and depolarizes the nerve synapse, so reducing sensitivity by preventing the conduction of pain impulses, is a method used in daily use toothpastes (e.g., potassium nitrate).[5,6] An alternative approach is to treat the tooth with a chemical or physical agent that creates a layer that mechanically occludes the exposed dentinal tubules, thus reducing sensitivity by preventing dentinal fluid flow—a method used by prophylaxis pastes and varnishes (e.g., potassium oxalate, ferric oxalate).[7,8] Although both approaches are effective at reducing or eliminating hypersensitivity, the duration of the relief is variable. Dentine hypersensitivity usually reoccurs due to abrasion from excessive tooth brushing, chemical erosion, or mechanical failure of the coating material.[9] Therefore, there is a need for dental materials that can chemically react with dental tissues, adhering to tooth structure, so significantly reducing the possibility of reopening occluded tubules. Progress has been made towards meeting this need through the development of materials that deposit calcium phosphate onto the tooth surface to mechanically occlude exposed dentinal tubules. Commercially available products such as Tooth Mousse (GC, USA) and NovaMin (NovaMin Technologies, USA) provide such ions for remineralisation.[10–12] A novel cleaning and desensitising prophy-powder, based on bioactive glass technology, has been developed (OSspray Ltd., UK) which aims to occlude open dentine tubules, whilst leaving calcium phosphate ions adhered to the surface in a single application via an air-polishing treatment.

The null hypothesis investigated in this in vivo study was that bioactive glass air-polishing has the same clinical effectiveness of desensitisation of exposed dentine, extrinsic stain removal and procedural comfort when compared to using conventional sodium bicarbonate air-polishing techniques.

2. Materials and methods

Fifty patients were recruited from Kings College London Dental Institute with appropriate ethics approval (Bromley REC: 07/H0805/24). Twenty-five patients were allocated to either a low or high oral hygiene subgroup determined by pre-operative plaque scores and clinical examination. Inclusion/exclusion criteria were as follows:

Inclusion criteria:

1. Male or female patient; 18–64 years old.
2. Patient has relevant teeth present for the study (incisors and first premolars) and these are unrestored and the patient is not wearing dentures.
3. Patient is able to give informed consent.
4. Patient's maxillary teeth to be included in the study will have a shade of C1 or darker, as determined by clinician, using the standard Vita value-ordered shade guide.

Exclusion criteria:

1. Orthodontic appliance treatment within the last three months.
2. Periodontal surgery within the last 3 months.
3. Crowns or abutments on upper right or left central incisors, upper right or left central laterals, or upper right or left canines.
4. Patients receiving radiation or chemotherapy.
5. Patients having undergone dental prophylaxis within the last 3 months.
6. Previous history of dental bleaching procedures.
7. Known allergy to silica.

Using a double-blinded, split-mouth model, all patients underwent a full prophylaxis treatment on the mandibular teeth. Air-polishing therapies were applied until a clinically significant clean was complete or until additional treatment would no longer result in any additional improvement in cleaning judged clinically. All treatments were applied for a minimum of 20 s. All powders were applied using a Dentsply Cavitron Jet air-polishing device (Dentsply, USA). Bioactive glass (Sylc, OSspray Ltd., UK) and sodium bicarbonate (Prophy Jet, Dentsply, UK) were applied randomly to opposite sides of the mandibular dentition. The maxillary dentition was left as the untreated control in each patient. Three parameters were measured:

(1) *Sensitivity to cold air and ethyl chloride*: Prior to any treatment the patient's response to cold air was measured. Cold air via a 3-in-1 hand piece was applied to the tooth surface at a distance of approximately 1 cm for three seconds. Lower left 1, 2, 4, lower right 1, 2, 4 and upper right 1, 2, and 4 were measured using a VAS Scale (Fig. 1). After a delay of 5 min, the same procedure was used but ethyl chloride (''Glacier'' Produits Dentaires, Vevey, Switzerland) was applied via a cotton wool swab to the dried buccal surface of each tooth for 3 s. The order of tooth application was randomised. The two tested, blinded prophylaxis treatments were then applied to randomly assigned sides of the lower dentition in each patient. Sensitivity to cold air and ethyl chloride was then re-measured immediately post-treatment using the same pre-treatment protocols.
(2) *Shade change*: Prior to any treatment, tooth shade was measured using an intra-oral spectrophotometer, Vita Easyshade (Vivadent, USA). The spectrophotometer was calibrated as per manufacturer's instructions and was used to measure the shade of the following teeth: lower left 1, 2, 4, lower right 1, 2, 4 and upper right 1, 2, and 4 (both test

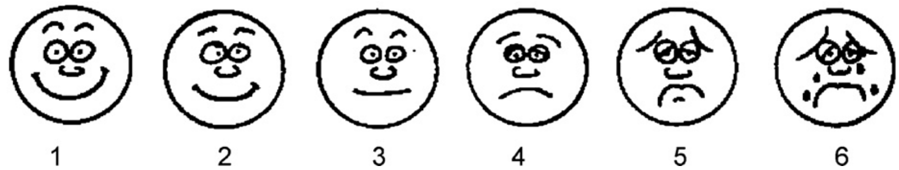

Fig. 1 – Visual analogue scale to measure dental pain. Patients must choose one from the scale of six images to express their level of discomfort.

teeth and controls in each patient). The two tested, double-blinded prophylaxis treatments were then applied to randomly assigned sides of the lower dentition in each patient. Dental surface shade was then re-measured immediately post-treatment using the same pre-treatment protocol.

(3) *Comfort of procedure*: Immediately post-treatment, patients were asked to rate their overall experience of each double-blinded prophy treatment. A 10-point linear scale was used, 1 = bad experience through to 10 = good experience. All 50 patients were recalled to the surgery 10 days post-operatively for a follow up consultation. Sensitivity to cold air and ethyl chloride as well as the tooth shade were re-measured using the methods previously described.

Data was statistically analysed using Students paired *t*-test.

3. Results

3.1. Sensitivity to cold air and ethyl chloride

Analysis of bioactive glass data reported a 44% (±10%) reduction in sensitivity to cold air stimulus immediately post-treatment. The reduction in cold air sensitivity was maintained at the 10-day follow up at 42% (±5%). Both results were statistically significant from the pre-treatment controls ($p < 0.05$). The sodium bicarbonate data showed a small reduction is sensitivity but this was not significant to the pre-treatment controls. The 10-day follow up reported a statistically significant ($p < 0.05$) 17 ± 15% increase in sensitivity to cold air (Fig. 2).

Application of ethyl chloride to the bioactive glass treated surface showed a statistically significant drop in sensitivity, 10% (±5%) ($p < 0.05$). However, at 10-day follow up the sensitivity had dropped to 22% (±12%) ($p < 0.05$). Sodium bicarbonate treated surfaces showed no significant difference in sensitivity when stimulated with ethyl chloride (Fig. 3).

Students paired *t*-test analysis of the cold air and ethyl chloride stimulus data showed no statistical difference in sensitivity between the two test and one control areas in each of the patients' mouths, pre-treatment. Nor was there any statistical change in sensitivity in the control area of the mouth over the duration of the trial.

Analysis also showed no statistical difference in sensitivity for both good and poor oral hygiene groups throughout the trial.

3.2. Shade change

Both test powders showed variation between good and poor oral hygiene subgroups. Tables 1 and 2 show the mean starting shade (good OH group: shade B1 and poor OH group: shade C2), and the relative lighter shade immediately post-treatment and at 10-day follow up. It appeared from the data sets, that the effect of Bioglass air-polishing was to lighten the shade by at least one further tab than the equivalent sodium bicarbonate treatment in the patients with poor oral hygiene.

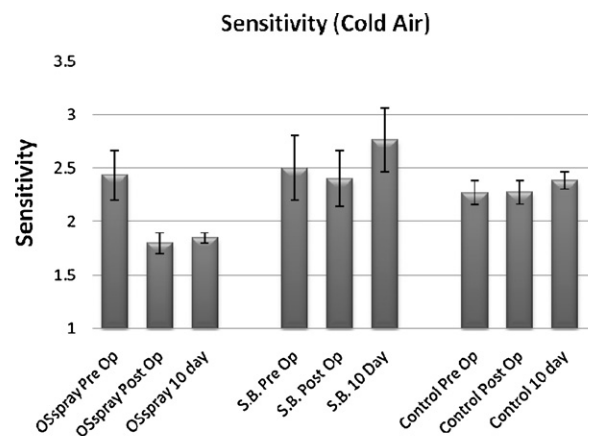

Fig. 2 – Data showing changes in sensitivity to cold air pre- and post-treatment and at the 10-day follow up (measured using VAS). Statistically significant reductions in dentine sensitivity were found in the Bioglass group alone (OSspray) with an increase shown in the 10-day follow up with sodium bicarbonate (SB).

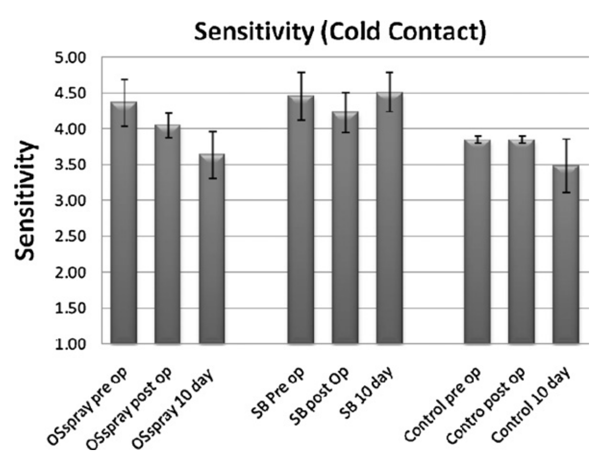

Fig. 3 – Data showing the statistically significant drop in sensitivity (measured using VAS) elicited by ethyl chloride contact in the Bioglass treatment group (OSspray) post-op and after the 10-day follow up. No other statistically significant differences were found.

Table 1 – Good oral hygiene subgroup. Patients started out with shade B1 and after 10-days both groups elicited a lightening effect, measured using the spectrophotometer.

	Pre-op	Immed post-op	10 Days post-op
Bioactive glass (n = 25)	B1	−2	−1
Sodium bicarbonate (n = 25)	B1	−1	−1

Table 2 – Poor oral hygiene subgroup. In this group of patients, it appeared that the Bioglass treatment lightened the dental shade further after 10 days.

	Pre-op	Immed post-op	10 Days post-op
Bioactive glass (n = 25)	C2	−4	−3
Sodium bicarbonate (n = 25)	C2	−2	−2

Table 3 – Data showing patient comfort differences between Bioglass and sodium bicarbonate treatments. There is a statistically significant difference in patient experience between the two procedures (p < 0.01, Students paired t-test).

	Mean	SD	
Bioactive glass	7.9	1.4	n = 50
Sodium bicarbonate	5.4	2.0	n = 50

3.3. *Comfort of procedure*

Patients treated with bioactive glass, in both subgroups reported a 46 ± 18% ($p < 0.05$) increase in comfort of procedure with the bioactive glass over that of sodium bicarbonate (Table 3).

4. Discussion

The marked differences in the dentine sensitivity data indicates the two tested air-polishing powders behave in differently in their interaction with the exposed dentine surface. Initially the sodium bicarbonate occluded some tubules, so reducing immediate post-operative sensitivity, but after 10 days the soluble sodium bicarbonate dissolved in the oral cavity and so the sensitivity increased. However, the bioactive glass composed of elements that occur naturally in the body's hard tissues (calcium sodium phosphosilicate), when exposed to an aqueous environment undergoes a surface reaction over several hours, allowing it to physically adhere to exposed dentine and to physically occlude tubules. Within a short period of time, essentially all of the bioactive glass particles react to form hydroxycarbonate apatite (HCA), which is chemically and structurally similar to natural tooth mineral.[10–12] This leads to a more long-term reduction in dentine hypersensitivity as this material is less easily degraded and removed in the oral cavity. It is also possible that the relative alkalinity of the bioactive glass-dentine interface may help neutralise, to a degree, the surface effect of dietary acids which may contribute to clinical dental hypersensitivity in some patients.

The relative increase in sensitivity associated from cold air and ethyl chloride stimulation was expected. However, the level of desensitisation from the bioactive glass would suggest these particles seal the exposed tubules sufficiently well so that the cold and physical movement of the air cannot penetrate the tubule structure. The increased stimulation from the much colder iced cotton wool swab is still reduced with bioactive glass at post-treatment testing (10%) but the closure of the tubule structure is not complete until the bioactive glass has been able to convert to the HCA structure hence a greater (20%) reduction in sensitivity.

The shade changes differing between poor and good oral hygiene groups were expected. The lower the level of oral hygiene can be associated with greater levels of extrinsic staining. Both air-polishing powders were more effective at improving whiteness on already stained teeth. The bioactive glass powders appeared to be a better stain removal system than the sodium bicarbonate, due to the fact that these particles have greater density and a more spherical aspect ratio than the sodium bicarbonate, so making them more efficient physical stain-removers.

Patient comfort data showed a very clear improvement in the acceptance of the procedure when using bioactive glass powders. The comments regarding sodium bicarbonate's taste and 'stinging of soft tissue' effects are key drivers in the low patient acceptance of air-polishing with conventional sodium bicarbonate as a prophylaxis technology.

Limitations of the present investigation included the relatively low number of patients included within the study suffering from relatively low levels of dentine sensitivity pre-operatively. However, even with this patient number, both clinical and statistical differences were highlighted indicating that adequate numbers had been used to indicate differences between the two systems. The 10-day follow up period was used both as a clinical indicator and for study convenience, but it might be prudent in future to assess the effects further long-term in patients with higher levels of pre-operative dentine sensitivity. It was appreciated that although the clinicians were blinded as to which powder was used, once the procedure was under way, it would be evident which powder dissolved. The powders were blindly randomised to try to reduce operator bias.

5. Conclusions

Within the limits of this study, the null hypothesis was disproved. The bioactive glass powder had a significant longer term desensitising effect, whereas the sodium bicarbonate powders tended towards increasing dentine sensitivity. The bioactive glass appeared to offer a more effective whitening effect when compared to sodium bicarbonate. The bioactive glass system also provided a more acceptable patient experience. Thus the bioactive glass powder may afford a more acceptable clinical experience for professional dental stain removal with a significant added benefit of reducing dental sensitivity.

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