

Cutting efficiency of different dental materials utilized in an air abrasion system

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ABSTRACT

Objectives: The aim of the present study was to test cutting efficiency of different materials against conventional alumina in an air abrasion system.

Methods: The powder samples were divided into three groups: Group 1 - alumina (control), Group 2 - 45S5 bioactive glass, and Group 3 - hydroxyapatite. 30 microscope glass slides of 0.5 mm thickness were used as an alternative of human enamel and were also divided randomly into these three groups. The time taken by the abrasive particles to cut a hole through the microscope glass slide was recorded with a stop watch. In addition, morphology of the particles was observed through scanning electron microscopy (SEM). A *t*-test was used to compare the times taken to cut a hole through the microscope glass slides, and the level of significance was set at $P < 0.05$.

Results: The mean time taken to cut a hole through the microscope glass slide was 2.96 s and 23.01s for Groups 1 and 2, respectively, whereas powder of Group 3 did not cut after 120 s. The differences between cutting times of Groups 1 and 2 were statistically significant ($P < 0.05$). The SEM micrographs revealed coarse angular shape for particles of Groups 1 and 2 but Group 3 particles were with round ends and presence of smaller particles was also observed in Groups 2 and 3.

Conclusion: The alumina particles demonstrated excellent cutting efficiency followed by 45S5 particles. The use of bioactive glass particles should be encouraged for cutting purposes whenever a shortage of time for practitioners is not a concern.

Keywords: 45S5, air abrasion, alumina, bioactive glass, dentistry, hydroxyapatite

Introduction

Dental caries is a predominant oral disease, affecting about 40% of children and over 90% of adults in the United States.¹ Dental caries results from bacteria generating lactic and acetic acids by fermenting carbohydrates which initiates dissolution of minerals in the tooth structure. This process is well dependent on various factors such as presence of oral microflora, salivary components, and rates of demineralization and remineralization.²⁻⁴ There is generally an equilibrium present between the processes of remineralization and demineralization but a shift toward demineralization eventually leads to tooth destruction.⁵

The conventional treatment of dental caries is to remove the affected tooth structure and replace it with a restorative material.⁶ According to the minimal invasive dentistry concept, attempt to conserve as much tooth structure as possible should always be made.^{2,7} Techniques that help in the elimination of dental caries, causing no or slight destruction of the adjacent sound dental hard tissue have been studied extensively in the

recent past.^{8,9} Air abrasion is one such technique which has been recognized as a technique which causes minimum tooth structure damage as compared to the traditional methods.¹⁰

Air abrasion is a nonrotatory technique of cutting and eliminating carious dental hard structures. Recent studies have revealed that tooth surfaces prepared with air abrasion illustrate much improved bonding of dental hard tissues as compared to the conventional cavity preparation methods (by carbide burs and high-speed handpiece).²⁻¹³ Air abrasion uses high-speed stream of abrasive particles to remove decayed dental tissues. It produces less heat, sound, and vibration as compared to conventional cavity preparation methods leading to fairly pain free dental procedures. The effectiveness of air abrasion is controlled by various parameters such as air pressure, tip diameter and angle of the nozzle, particle size, and distance between the tip of the hand piece and the cutting object.¹⁴

Alumina particles used in the air abrasion are of irregular shape and are hard enough to cut tooth structure.¹⁵ However, alumina particles are inert in nature, and their long term

inhalation can lead to serious health issues including lung diseases.⁹ In the field of dentistry, bioactive glasses (BG) are being used in the treatment of hypersensitivity and can be used as an alternative to alumina for the conservative cavity preparations.^{16,17} Hydroxyapatite (HAP) is a fundamental component of enamel, dentin, and bone and it comprises calcium and phosphate ions.¹⁸ HAP also has got the ability to remineralize tooth structure and is therefore currently used as an active ingredient in many dentifrices.¹⁹

There is a deficit of studies in literature which are aimed at finding a replacement of alumina used in the air abrasion system. Therefore, the aim of this study was to find an alternative to alumina particles in air abrasion, which is hard enough to cut the cavities and has also got remineralizing capabilities.

Materials and Methods

The ethical approval was obtained before commencing this study. The powder samples (50 g each) for this study were divided into three groups: Group 1 - alumina (control), Group 2 - 45S5 BG, and Group 3 - HAP. 30 microscope glass slides of 0.5 mm thickness were selected for cutting and were randomly allocated to these three groups ($n = 10$ per group).

The powders were sieved to obtain a particle size of $>20 <25 \mu\text{m}$ utilizing mesh analytical sieves (Endecotts Ltd., London, UK). To observe the morphology of the powder particles, scanning electron microscopy (SEM) was used. Powder samples from each of the three groups were mounted on stubs, coated with a thin layer of gold, and were viewed in an SEM (FEI, Inspect F50, The Netherlands) using an electron mode of 20 kV.

Aquacut Quattro air abrasion machine (Velopex, London, UK) was used to perform air abrasion experiments. All the experiments were repeated 5 times and were performed using the maximum air pressure (6-7 bars), maximum feed rate (70 l/min), and maximum speed/velocity (speed: C) available for this particular air abrasion machine. The diameter of the tip of the hand piece used was 0.6 mm, and the distance between the tip and the glass slide (which was held horizontally by a plastic stand) was kept constant at 1 mm (Figure 1) by fixing and locking the hand piece in a burette stand (Figure 2). This was done to avoid alteration of distance between the hand piece and the glass slide. At the start of every cutting experiment for each group, 50 g of the powder sample was placed in the powder tub. To avoid mixing of the particles during air abrasion experiments, an empty tub was placed, and the machine was run for 1 min to remove any residual powder after every group. The time taken to cut a hole through glass slide was noted with a stop watch in such a way that the operator was using the air abrasion machine, whereas the observer was visually watching for the hole to appear in the glass slide, with a stop watch in his hand. As soon as he observed the formation of

a hole and passing of particles from the hole onto the tissue placed beneath the glass slide, the time was noted.

The results of this study were analyzed using the Statistical Package for the Social Sciences software (SPSS version 19.0; Chicago, IL, USA). A *t*-test was used to compare the times taken to cut a hole through the microscope glass slides, and the level of significance was set at $P < 0.05$.

Results

The SEM micrograph for Group 1 shows the presence of particles with coarse and sharp edges (Figure 3). The SEM micrograph for Group 2 reveals presence of sharp edged particles but smaller particles sticking to larger particles are also seen in Figure 4. For Group 3, the SEM micrograph shows presence of rounded particles without sharp edges, and smaller particles are also seen along with the larger particles (Figure 5).

The mean cutting time taken by the powder samples was 2.96 s and 23.01 s for Groups 1 (Figure 6) and 2 (Figure 7),

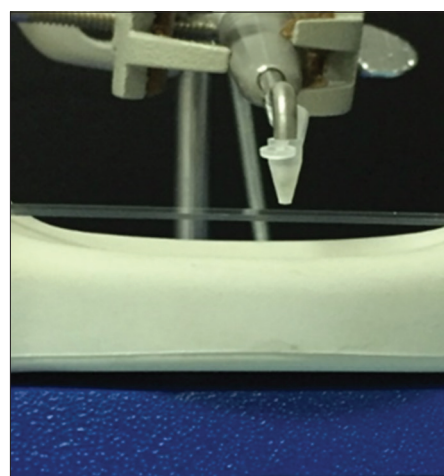


Figure 1: The distance between tip of the hand piece and glass slide

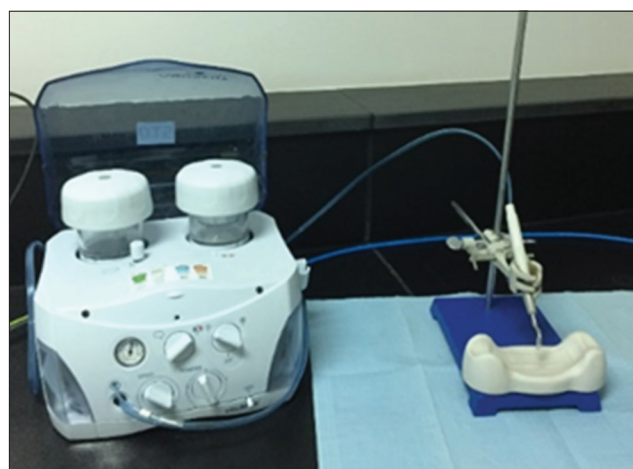


Figure 2: The fixing of the hand piece in a burette stand and placement of glass slide in a plastic holder

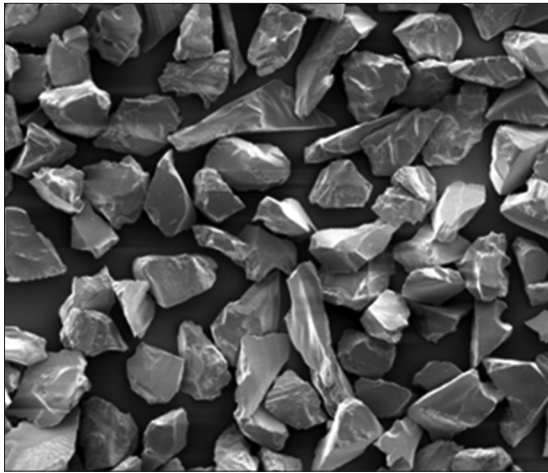


Figure 3: Scanning electron microscopy micrograph of Group 1 (alumina particles) at $\times 500$, scale bar $300\ \mu\text{m}$

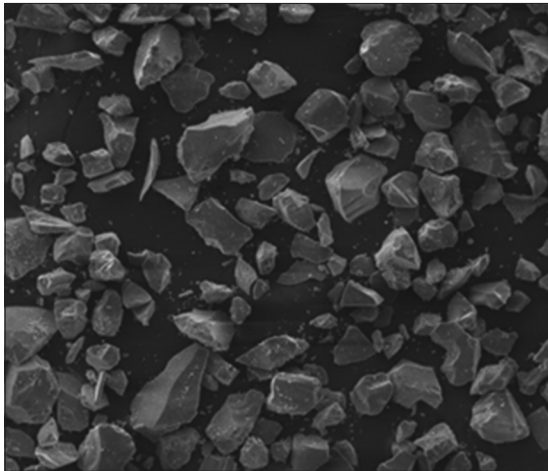


Figure 4: Scanning electron microscopy micrograph of Group 2 (bioactive glass particles) at $\times 300$, scale bar $400\ \mu\text{m}$

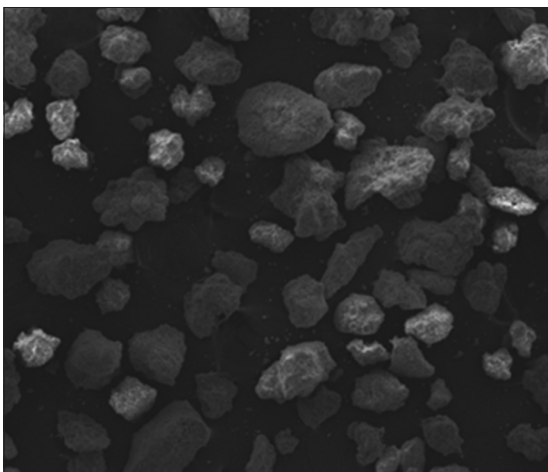


Figure 5: Scanning electron microscopy micrograph of Group 3 (hydroxyapatite particles) at $\times 300$, scale bar $400\ \mu\text{m}$

whereas, the particles of Group 3 were able to flow through the machine but were not able to cut a hole after 120 s (since

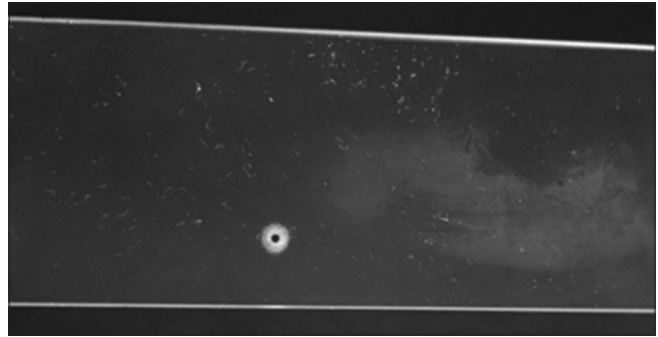


Figure 6: Cutting of a hole in glass slide by alumina particles

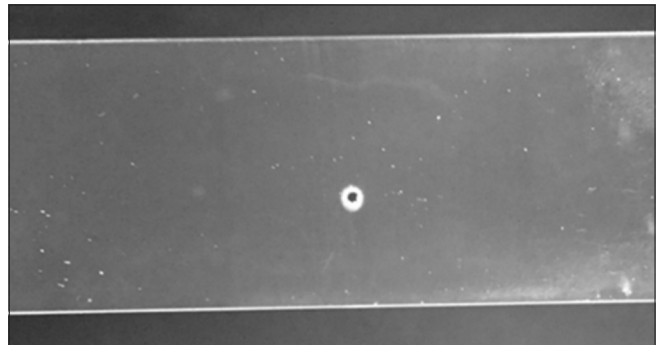


Figure 7: Cutting of a hole in glass slide by bioactive glass particles

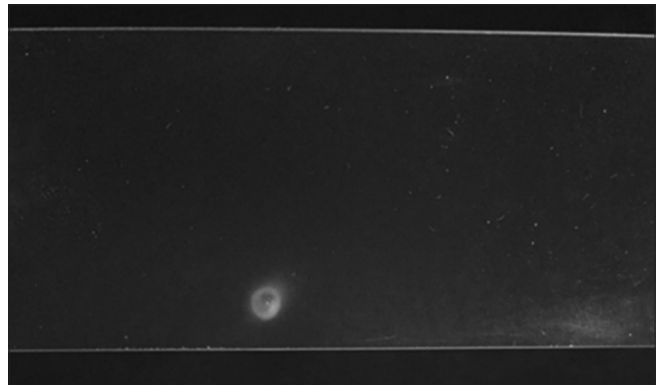


Figure 8: Abrasion (before penetration) in a glass slide made by hydroxyapatite particles

longer cutting times are unsuitable for clinical settings, cutting times >120 sec were not recorded) (Figure 8). A significant difference ($P < 0.05$) was observed between the means of Groups 1 and 2 (Table 1).

Significant difference observed between means of Groups 1 and 2 ($P = 0.008$).

Discussion

The dental air abrasion machine works on the principle of kinetic energy (KE), for which the formula is $KE = \frac{1}{2} mv^2$, where m represents mass and v represents velocity. This implicates that a greater mass and velocity would cause more

Table 1: Mean time (mean±standard deviation) taken by powder samples to cut a hole through microscope glass slide

Group 1 (alumina)	Group 2 (45S5)	Group 3 (hydroxyapatite)
2.96±0.243*	23.01±0.159*	>120 s (did not cut)

The values stated as mean cutting time per second are reported as mean±standard deviation, *t*-test significant at $P<0.05$. *P* value = 0.008

abrasion and *vice versa*.²⁰ In this study, soda lime silicate glass microscope glass slides were used for cutting experiments because of their homogeneity, low cost, and a hardness level which is comparable to that of human enamel. As they have a hardness value of 6.1 GPa,²¹ which is very close to the hardness value of 4 GPa of human enamel.²²

Cutting efficiency in this study could be defined as the ability of the abrasive particles to cut a hole through the microscope glass slides. The results of this study demonstrate that alumina particles showed best cutting efficiency (2.96 s), followed by BG particles (23 s), whereas HAP particles were unable to cut after 120 s. The BG particles are currently being used as a polishing agent in air abrasion machines globally²³ but in our experiment, we used them in the cutting chamber of air abrasion machine and compared their cutting efficiency with alumina particles. Previously, Farooq *et al.* also demonstrated that the inert nature of alumina particles along with coarse angular shape probably makes them most efficient in cutting as compared to the other BG samples in their study.²² The results of our study also demonstrate superior cutting efficiency of alumina particles as compared to the other samples. However, although the BG particles took a little longer, still they were able to cut a hole through the microscope glass slides. It has been established previously that the BG particles undergo dissolution when they are present in an aqueous solution and form HAP.²⁴ The presence of HAP ensures that the tooth structure will be remineralized, unlike alumina which is unable to contribute anything to the tooth remineralization process. Therefore, when a shortage of time is not a concern, BG particles should be used by dental practitioners in air abrasion machine for cutting cavities to restore the teeth.

Another reason for better cutting performance of alumina particles could be attributed to their increased hardness value which is reported to be between 16 and 18 GPa²⁵ whereas, the hardness value of 45S5 BG particles has been reported to be around 5.75 GPa.²⁶ Therefore, new compositions of BG's with increased hardness should be produced so that they can be utilized in air abrasion system.

The presence of rounded shaped particles was probably the reason because of which HAP particles were unable to cut a hole in glass slide through the air abrasion machine. Less coarse angular and rounded shaped particles are unable to abrade the surface effectively as compared to sharp edges particles, even at higher velocities thus decreasing their cutting efficiency.²² The flow of smaller particle size fraction of HAP through

air abrasion shows that it can be used through air abrasion machine. It may take longer to cut, but this also implies that it can be effectively used for polishing or removal of stains from teeth.

Future studies aimed at testing new materials (having remineralizing properties and good cutting efficiency) for use in air abrasion machine should be conducted to find a replacement for alumina particles. Furthermore, further studies on extracted human teeth should be conducted to make comparisons with realistic *in vivo* conditions.

Conclusion

The alumina particles showed superior cutting efficiency as compared to all the other tested materials, however, the use of BG particles via cutting chamber of air abrasion machine has also revealed good cutting efficiency. Therefore, the use of BG particles should be encouraged for cutting purposes whenever a shortage of time is not of concern.

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