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Bio-active glass air-abrasion has the potential to remove resin composite restorative material selectively

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ABSTRACT

The aims of this study were to assess: (a) the chemistry, morphology and bioactivity of bio-active glass (BAG) air-abrasive powder, (b) the effect of three air-abrasion operating parameters: air pressure, powder flow rate (PFR) and the abrasive powder itself, on the selective removal of resin composite and (c) the required "time taken". BAG abrasive particles were characterised using scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDX) and Fourier-transform infrared spectroscopy (FTIR). Standardised resin composite restorations created within an enamel analogue block (Macor™) in vitro, were removed using air-abrasion undersimulated clinical conditions. 90 standardised cavities were scanned before and after resin composite removal using laser profilometry and the volume of the resulting 3D images calculated. Multilevel linear model was used to identify the significant factors affecting Macor™ removal. BAG powder removed resin composite more selectively than conventional air-abrasion alumina powder using the same operating parameters ($p < 0.001$) and the effect of altering the unit's operating parameters was significant ($p < 0.001$). In conclusion, BAG powder is more efficient than alumina in the selective removal of resin composite particularly under specific operating parameters, and therefore may be recommended clinically as a method of preserving sound enamel structure when repairing and removing defective resin composite restorations.

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1. Introduction

Using rotary instruments to remove or repair aesthetically and biologically unsatisfactory resin composite restorations or resin luting cement remnants on tooth surfaces after de-bonding fixed orthodontic appliances, alters tooth surface topography resulting in enamel cracks, scarring and scratches [1,2]. Air-abrasion tooth cutting technology may be a useful alternative, utilising the abrasive particulate kinetic energy to produce small, rounded cavity margins, ideal internal line angle contours and a surface finish optimised for the adhesion of contemporary dental materials [3,4].

Bio-active glass (BAG) was discovered by Hench and colleagues in 1969 with numerous applications in the repair and reconstruction of damaged tissues [5]. BAG 45S5 powder contains 45 wt% SiO_2, 24.5 wt% NaO, 24.4 wt% CaO and 6 wt% P_2O_5 [5]. This powder has been used as a clinical abrasive powder benefitting from its remineralisation ability and its potential to remove selectively more softened, diseased or weakened tooth structure [6–8]. A previous study showed that using BAG air-abrasion for orthodontic adhesive cement remnant removal in vitro caused significantly less enamel surface damage/loss compared to that caused by using conventional 27 μm alumina air-abrasion [9].

In the light of results from a previous study evaluating BAG air-abrasion cutting efficiency/patterns [10], it would seem logical to expect that altering the air-abrasion operating parameters may affect its capacity to remove selectively resin composite and consequently preserve more sound, intact enamel. Therefore, the objectives of this study were to assess: (a) the chemistry, morphology and bioactivity of BAG powder, (b) the effect of three clinically adjustable air-abrasion operating parameters: air pressure, powder flow rate (PFR) and the abrasive powder itself, on the selective removal of resin composite and (c) the required clinical time taken to carry out the procedures.

The characteristics of BAG powder were determined using scanning electron microscopy-energy dispersive X-ray spectrometry (SEM-EDX) and laser diffraction particle analysis, whilst

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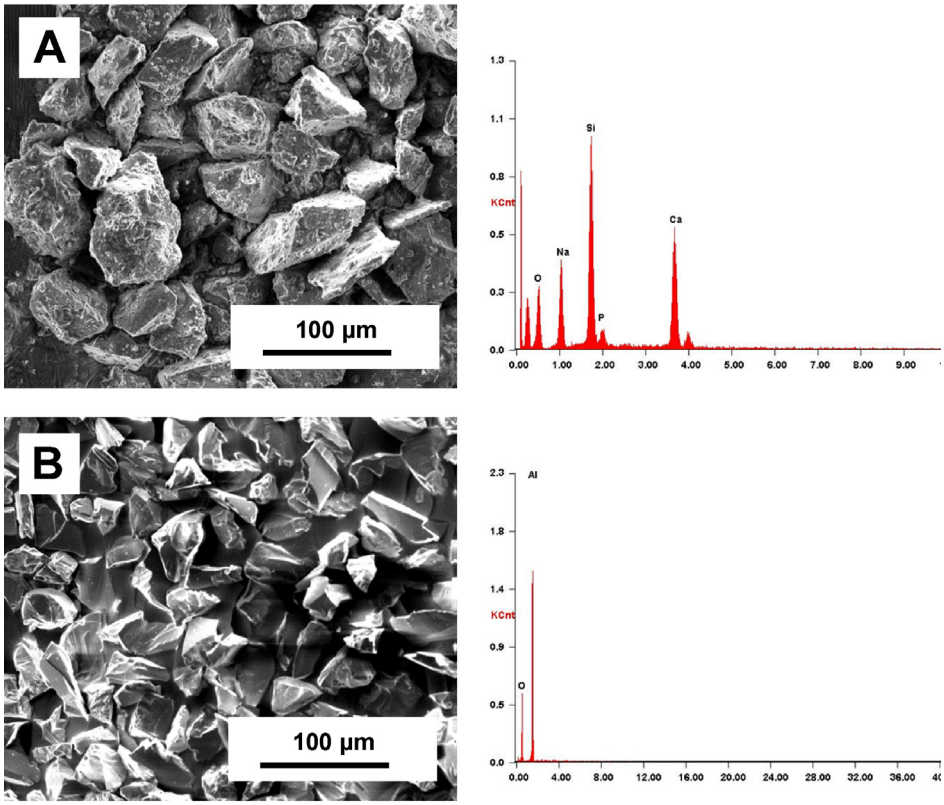

Fig. 1. SEM-EDX (accelerating voltage: 10 kV, working distance: 10 mm) for BAG (A) reveals the particles' aspect ratio of 1:1, with angular edges and surrounded by a submicron dust. They contained calcium, phosphorus, sodium and oxygen. The particles within the alumina powder (B) exhibit an angular shape and consist of aluminium and oxygen.

the powder bioactivity was inspected using Fourier-transform infrared spectroscopy (FTIR). The selective removal measurement was accomplished by comparing the volume of standardised cavities created within an enamel analogue (Macor^{TM}) permitting an experimental standardisation of hardness and thermal properties, both similar to those of human dental enamel [11]. The three null hypotheses investigated in this study were: (a) using BAG as an alternative to conventional 27 μm alumina powder shows no difference in resin composite removal selectivity; (b) there is no effect of air pressure and PFR setting on resin composite removal selectivity within both abrasive powder groups, and (c) the required clinical time taken is no different between alumina and BAG powders.

2. Materials and methods

2.1. Characterisation of abrasive powders

BAG 45S5 abrasive powder (Sylc, OSspray, London, UK) and alumina powder (Aquacut, Velopex, Horesham, UK) particles' surface topography and elemental composition were determined using SEM-EDX (FEI Co. Ltd., Cambridge, UK) (accelerating voltage: 10 kV, working distance: 10 mm). Particle size analysis was carried out using a laser diffraction particle analyser (1180, CILAS, Orleans, France).

The bioactivity of BAG powder was validated by adding 0.3 g of BAG powder to 200 ml Tris (tris-hydroxymethyl amino methane) buffer solution adjusted to pH 7.25 with hydrochloride acid. The bioactivity test was conducted dynamically, permitting a uniform exposure of the particles to the buffer solution in a water bath at 175 rpm and 37 °C for 20 h. The powder was then filtered, acetone-washed, air-dried and scanned using a FTIR Spectrometer (Perkin-Elmer, Beaconsfield, UK). The FTIR spectrum was collated by averaging 8 scans with a 4 cm^{-1} resolution and 400–1400 cm^{-1} spectral range. The bioactivity test procedures using Tris buffer was repeated three times.

2.2. Resin composite removal assessment

An Aquacut^{TM} air-abrasion unit (Velopex, Harlesden, UK) with a circular cross-section nozzle (internal diameter 600 μm) was used throughout the study. This unit utilises a mechanical vibration mechanism to admix the abrasive powder with the propellant air stream and thus enables the operator to control both air pressure and PFR independently using pre-set dials on the unit's fascia [10].

Rounded cavities with standard dimensions (diameter; 3 mm, depth; 0.7 mm) were prepared within a Macor^{TM} sheet using a standardised drill bit. The reference Macor^{TM} area around each cavity was protected by placing tape with a standard 7 mm round hole, onto the Macor^{TM} surface over the cavity. Thus, each cavity was surrounded by a peripheral ring of flat Macor^{TM} exposed to the air-abrasion stream and a taped, covered area which acted as a reference level from which to analyse the scanning outputs. All cavities were filled with Filtek^{TM} Supreme Ultra (3 M ESPE, St. Paul, MN, USA) resin composite restorative material, and light cured (Optilux 501, Kerr, Orange, CA, USA) for 40 s according to the manufacturer's instructions. For each clinically adjustable air pressure value (40, 60 and 80 psi) three PFR dial settings (1, 3 and 5 representing the lowest, the middle and the highest values respectively on the unit) were tested, establishing nine experimental groups for each abrasive powder. The resin composite was removed according to the conditions of each group ($n = 5$). The powder reservoir was refilled to a pre-determined line consistently throughout the experiment. Complete resin composite removal was confirmed after rinsing and drying the cavity, by visual inspection using 2.5× magnification

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