More to it than meets the eye

Moira Crawford explores the technological advances made on glass.

Glass surrounds us every day of our lives; we look through it, we drink out of it, we break it – of course we know what it is. But in recent years developments in glass technology have resulted in a new generation of this material with far reaching applications in many areas of science and medicine. It's very far from the hard, fragile, sharp-edged material that is generally recognised as glass.

The first generation

Bioactive glasses were initially developed as bone substitutes to be used in implants. These materials are designed to carry compounds within their structure, and to dissolve in body fluids to release them. Correctly known as calcium phosphosilicates, they contain calcium and phosphate which, when released, form hydroxycarbonated apatite. Such glass was never originally intended to be used in dental products, but as apatite is required for the re-mineralisation of tooth enamel, research soon focused on incorporating bioactive glass into a toothpaste.

The glass used in the first generation of toothpaste, Novamin, was not specially adapted for oral care, but turned out to be surprisingly effective. However, researchers at Queen Mary University of London, led by Professor Robert Hill, research director at the dental institute and head of dental physical sciences, have carried out extensive research into glass technology, which has resulted in a product specifically designed and optimised for use within toothpaste BioMinF.

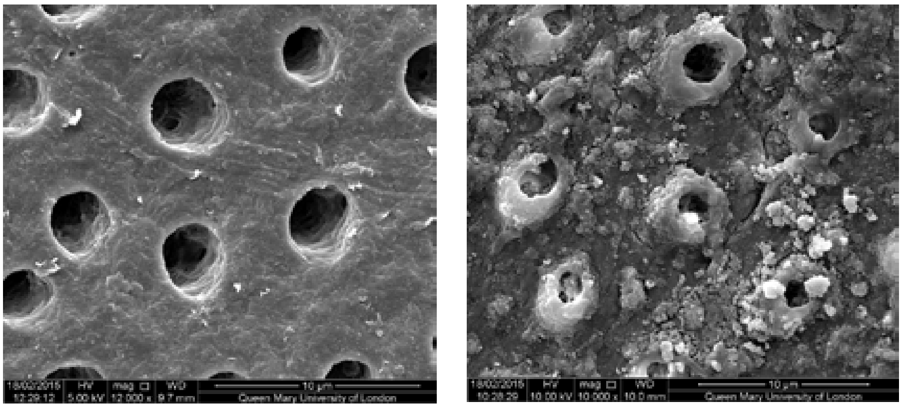

Fig 1: Tubule occlusion – before and after brushing with BioMinF.

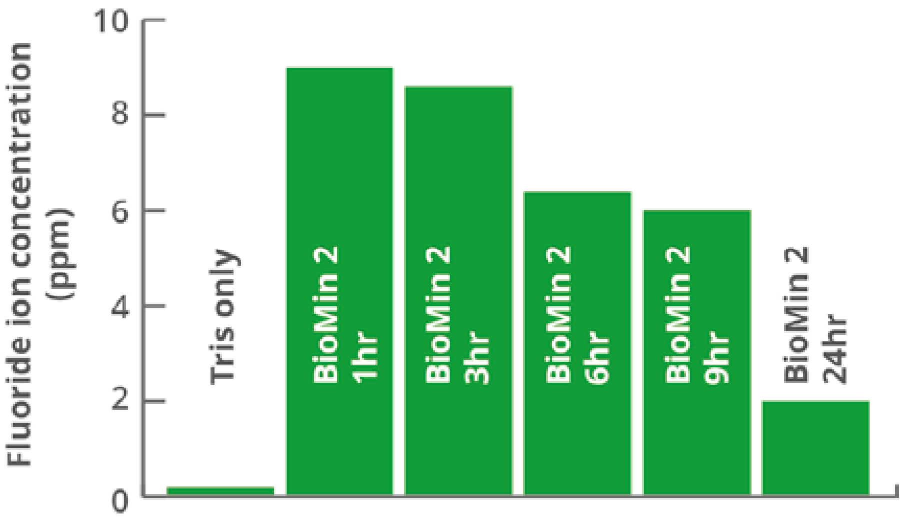

Fig 2: Low levels of fluoride released over several hours.

BioMinF contains fluoride within its structure, with its known benefits to oral health. It also has a significantly higher phosphate content, which aids and speeds the action of re-mineralisation; and thirdly it has a smaller particle size, which allows it to enter and occlude the dentinal tubules, as well as making it less abrasive than Novamin.

How it works

Following brushing with BioMinF, the particles adhere to the tooth structure and enter the dentinal tubules, where they dissolve slowly over around 12 hours, gradually releasing fluoride, phosphate and calcium ions in the optimum proportions to effect acid neutralisation and re-mineralisation. Professor Hill explained, "As it dissolves, the glass structure in BioMinF provides a slow release vehicle for calcium, fluoride and phosphate together, enabling it to form fluorapatite, which aids effective re-mineralisation and is more stable and resistant to acid conditions than hydroxyapatite formed by the previous generation of bioactive glasses." (fig 1)

Trials have demonstrated that as it dissolves, BioMinF continues to release fluoride over several hours, with levels gradually dropping as fluorapatite is formed, leaving little excess fluoride. Some effects are seen to be continuing up to 24 hours after brushing (fig 2). Because it is used more effectively, the quantity of fluoride required in BioMinF is lower than in conventional toothpastes containing simple soluble➲

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fluoride salts.

The glass component of BioMinF has an additional smart effect: in acid conditions in the mouth, for example, after consuming an acid drink, the effect actually kicks in more rapidly.

New applications of bioactive glasses

This, however, is just the first of many possible new uses for bioactive glass in the dental arena.

Filling materials

The search has been on for many years for a filling material that will effectively replace amalgam: one that is easy and quick to use, is not sensitive to moisture or cavity design and, ideally, inhibits the growth of bacteria at the marginal gap and prevents the development of secondary caries. As a result, research is now focusing on the possibilities of a composite based on bioactive glass, to utilise its ability to slowly release fluoride, calcium and phosphates at the site of the restoration.

Currently inert glass is used in filling materials, but using a bioactive glass could make it possible to produce a composite resin capable not only of filling but also of re-mineralising the area around hard carious lesions following minimally invasive removal. Also known as atraumatic restorative therapy (ART), this involves removing the soft, carious dentine but leaving the harder demineralised dentine behind, and using materials to seal the cavity, prevent further decay and encourage re-mineralisation of the carious dentine.

This new generation of filling material consists of 80 per cent bioactive glass with resin, and slowly releases fluoride and calcium and phosphate ions to form fluorapatite. The principle is similar to that in BioMinF toothpaste, but of course the glass composition is different. The bioactive glass here does not dissolve completely – it releases the fluoride, calcium and phosphate ions but leaves the silica in place to fill the cavity. Figure 3 shows a cross section of a bioactive glass restoration which indicates the reacted layer to the right of the dotted line, 30-40 microns thick. Reacted and partially reacted particles can be seen at the surface and a small amount of apatite has been formed on the bioactive glass particles in the reacted surface layer. In the bulk of the restoration to the left of the dotted line, the particles remain unreacted.

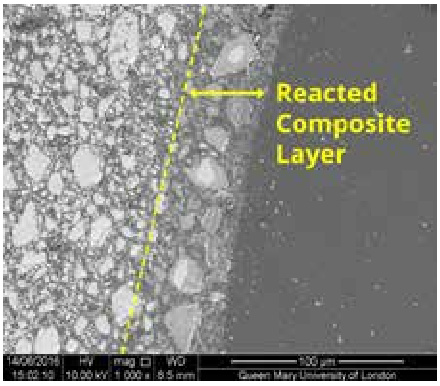

Fig 3: Reacted and partially reacted particles at the surface.

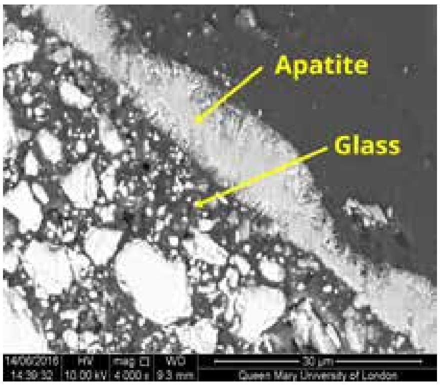

Fig 4: Fluorapatite crystals forming at the surface.

In figure 4, in artificial saliva the needle-like crystals of fluorapatite can be seen forming a thin surface layer (approximately 10 microns thick). The same apatite layer may form in marginal gaps on the surface of carious lesions within cracks and voids. Figure 5 shows apatite as the white material which is infilling the marginal gaps and cracks, potentially preventing bacteria from infiltrating and causing secondary caries.

The ion exchange process at the surface raises the pH in the mouth, neutralising the acids and discouraging further bacterial growth and the development of secondary caries in the area.

Orthodontics

Applications in orthodontics are also being investigated. Following removal of orthodontic appliances there can be an incidence of white spot lesions due to demineralisation around the brackets in between 50 per cent and 90 per cent of cases. Trials using brackets bonded with a composite resin adhesive that contains bioactive glass, releasing fluoride, calcium and phosphate, dramatically reduced demineralisation around the bracket and no visible

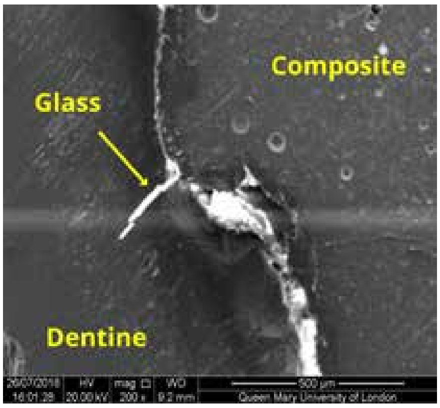

Fig 5: Fluorapatite forming in margins and cracks.


Fig 6a: Demineralisation around bracket bonded with conventional resin.

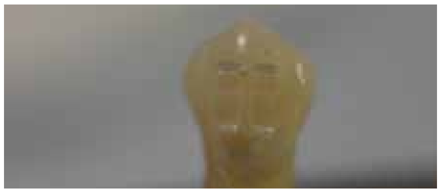
Fig 6b: No demineralisation around bracket bonded with resin containing bioactive glass.

white spots. Figure 6 shows the difference between a bracket bonded with conventional adhesive and one containing a bioactive glass composite. After immersion in artificial saliva for eight hours, the first tooth (6a) is turning white as the enamel is becoming demineralised, while the second, bonded with resin containing bioactive glass (6b) has not become demineralised.

These new bioactive glass-based products will be launched onto the market before long, and other uses for bioactive glass are being considered, including varnishes that release calcium, phosphate and fluoride. Understanding the glass chemistry is central to exploiting its potential, explained Professor Hill. "Dissolution and apatite formation are key to the design and development of new bioactive glass-based products."

This capability means that in the future bioactive glass could have exciting applications in a huge variety of settings. There's more to glass than meets the eye!