

<b>Institution: Queen Mary University of London</b>		
<b>Unit of Assessment: UoA 12</b>		
<b>Title of case study: BioMin toothpastes for mitigating tooth sensitivity made using bioactive glasses</b>		
<b>Period when the underpinning research was undertaken: 2009-31 Dec 2020</b>		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Prof Andy Bushby	Professor of Materials Science	Pre 2000-present
Dr Karin Hing	Reader in Biomaterials	Oct 1995-present
<b>Period when the claimed impact occurred: August 2013-31 Jul 2020</b>		
<b>Is this case study continued from a case study submitted in 2014? N</b>		
<p><b>1. Summary of the impact</b></p> <p>Dental biomaterials research at Queen Mary led to the formation of BioMin Technologies Ltd in 2014. Their toothpastes, BioMinC® and BioMinF® are based on Queen Mary's patented bioactive glasses, which release fluoride over 10-12 hours (vs 10 minutes for most toothpastes) and form fluorapatite minerals that protect the tooth from decay and reduce the effects of hypersensitivity. BioMinF is the first toothpaste to be accredited by the Oral Health Foundation, UK for dentine hypersensitivity and tooth remineralisation. In clinical trials, BioMinF has proved twice as effective in relieving pain as other sensitivity toothpastes. 90% of users surveyed had reduced tooth sensitivity after using the product, and professionals are now recommending it. BioMinF toothpastes, launched in 2016, are now on sale in over 20 countries globally with up to 100,000 tubes being produced every month. BioMin Technologies Ltd receives revenues of approximately GBP500,000 per year.</p>		
<p><b>2. Underpinning research</b></p> <p>Fluoride in toothpaste plays a key role in preventing tooth decay and promoting re-mineralisation of teeth, helping them to resist decay. However, most of the fluoride from conventional toothpastes is lost in the first few minutes after brushing and the formation of chemically stable fluoroapatite, a component of tooth enamel, takes at least four hours. For improved health benefits, a formulation was needed that 'sticks' to the teeth and enables fluoride to be released slowly, over a relatively long period of time. Furthermore, the development of fluoroapatite minerals in situ provides an opportunity to re-mineralise tissue and block exposed dentinal tubules, which are associated with dentinal hypersensitivity.</p> <p>Queen Mary has a long history of research in dental materials and biomineralisation dating from the Interdisciplinary Research Centre, inaugurated in 1991. Today, Queen Mary's School of Engineering and Materials Science (SEMS) and Dental Institute have a world-leading structural understanding of bioactive glasses (Prof. Hill, Dental Institute), apatite chemistry (Hing) and biomaterials characterisation (Bushby). The research underpinning the development of the BioMin toothpastes initiated from a research project by Mo Mneimne in 2009, which arose from Prof Bushby from SEMS (submitted to UoA 12) collaborating with Prof Hill from the Dental Institute (submitted to UoA 3). The Queen Mary team went on to develop the bioactive glass formulations based on a detailed understanding of their structure and chemistry [3-1-3.3].</p> <p>Bioactive glasses dissolve in body fluids, such as saliva, releasing calcium, phosphate and fluoride ions that can form fluoroapatite minerals. The balance of minerals to form beneficial fluorapatites is delicate. In a key development, the team showed that there is a critical concentration of fluoride in solutions of 12 ppm, above which undesirable calcium fluoride forms on enamel but below which the beneficial fluorapatite mineral crystallises [3.1]. This was confirmed with the use of accurate and reproducible solid-state nuclear magnetic resonance spectra of fluorine 19, which is the only method capable of distinguishing the formation of fluorapatites from other calcium apatite phases. The release of calcium, phosphate and fluoride ions into solution in the right proportions is essential to the formation of fluorapatites and is facilitated when the level of fluorine in the glass is less than 5 mole% [3.3]. These new fluoride-containing bioactive glasses release fluoride over 10-12 hours, the average time interval between tooth brushing [3.1-3.2].</p>		

Further studies by Dr Hing and coworkers showed that rapid formation of fluorapatite also occurred in clinically relevant conditions [3.4] and that neutral pH was necessary to drive enamel remineralisation. While the presence of proteins delayed apatite precipitation, it did not prevent it [3.5]. Queen Mary researchers have also investigated the ability of the glasses to reduce fluid flow through dentinal tubules [3.6], which is the cause of tooth pain associated with hot, cold or mechanical stimulation. Occlusion of tubules with apatite minerals, as seen in Figure 1, may prevent bacteria entering the dentine, impeding tooth decay.

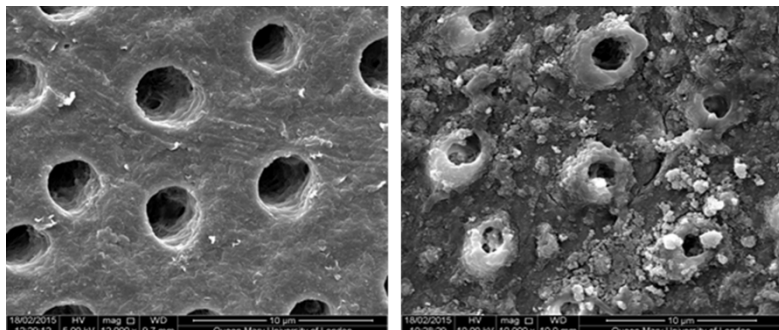


Figure 1: Scanning Electron Micrographs of Dentinal Tubules. Left before treatment with the glasses, showing exposed tubules and Right after treatment with BioMinF and immersion in Saliva.

### 3. References to the research

[3.1] Mneimne M, Hill RG, Bushby AJ, Brauer DS (2011). High phosphate content significantly increases apatite formation of fluoride-containing bioactive glasses. *Acta Biomaterialia*, 7, 1827-34. <https://doi.org/10.1016/j.actbio.2010.11.037>

[3.2] Brauer DS, Mneimne M and Hill RG (2011). Fluoride-containing bioactive glasses: Fluoride loss during melting and ion release into tris buffer solution. *Journal of Non-Crystalline Solids*, 357, 3328–3333. <https://doi.org/10.1016/j.jnoncrysol.2011.05.031>

[3.3] Brauer DS, Anjum MN, Mneimne M, Wilson RM, Doweidar H, Hill RG (2012). Fluoride-containing bioactive glass-ceramics. *Journal of Non-Crystalline Solids*, 358, 1438–1442. <https://doi.org/10.1016/j.jnoncrysol.2012.03.014>

[3.4] Shah FA, Brauer DS, Wilson RM, Hill RG, Hing KA (2014). Influence of cell culture medium composition on in vitro dissolution behavior of a fluoride-containing bioactive glass. *Journal of Biomedical Materials Research - Part A*, 102(3), 647-654. <https://doi.org/10.1002/jbm.a.34724>

[3.5] Shah FA, Brauer DS, Hill RG, Hing KA (2015). Apatite formation of bioactive glasses is enhanced by low additions of fluoride but delayed in the presence of serum proteins. *Materials Letters*, 153, 143-147. <https://doi.org/10.1016/j.matlet.2015.04.013>

[3.6] da Cruz LPD, Hill RG, Chen XJ and Gillam DG (2018). Dentine Tubule Occlusion by Novel Bioactive Glass-Based Toothpastes. *International Journal of Dentistry*. <https://doi.org/10.1155/2018/5701638>

### Evidence of quality of research:

[EQR. 1]: BioMinF (2013). Venture Prize. The novelty and commercial potential of the new bioactive glass toothpastes was recognised. *Armourers and Brasiers, a Guild of the City of London*. The award was judged by three Fellows of the Royal Society and three business experts and is based on the scientific innovation and commercial potential of the product and the business plan. GBP25,000. <https://www.armourershall.co.uk/venture-prize/previous-venture-prize-winners>

[EQR. 2]: BioMinF (2017). Finalist, Innovation of the Year. *Dental Industry Awards*. The scheme recognises excellence among the companies that support dentistry. The awards are a celebration of the high-quality work done by the dental industry, rewarding excellence in innovation and customer service and marketing. <https://www.dentistry.co.uk/2017/10/27/finalists-announced-dental-industry-awards/>

#### 4. Details of the impact

In July 2014, Queen Mary set up the company BioMin Technologies Ltd (BTL), which launched the remineralising sensitivity toothpaste BioMinF® in April 2016. The Queen Mary team developed the toothpaste based on special patented glasses (WO2011/000866 and WO2011/161422) that dissolve in saliva, slowly releasing calcium, phosphate and fluoride ions over a 10-12h period (typical time interval between tooth brushing). In November 2017, BioMin Technologies Ltd launched the fluorine free chloride version BioMinC® (Patent: WO2014/154874).

#### Commercial success of BioMin Technologies Ltd

Initial licensing option agreements on the fluoride bioactive glass patent generated sufficient income (approximately GBP50,000) to cover the costs of patent filing. In July 2014, the GBP25,000 from the Venture Prize was used to produce the prototype BioMinF toothpaste, which was launched in April 2016. Following this, BioMin Technologies Ltd raised over GBP410,000 from investors. BioMin Technologies Ltd now receives revenues of over GBP500,000 per year and forecasted to develop at over 50% compound annual growth from three sources [5.1]:

- Sales of toothpaste to global distributors (95% of sales are exported, as the UK holds only 3-4% of the international toothpaste market)
- Sale of bioactive glass to toothpaste manufacturers
- Licensing fees for bioglass manufacture

In April 2020, the BioMin toothpastes were featured in a [BBC4 documentary](#) that was viewed by over 300,000 people [5.2]. The documentary generated significant new interest in the toothpastes with over 2,000 new visitors visiting the BTL website within 2 hours of the end of the documentary and proceeding to buy toothpaste online.

#### *Structure of commercial activities at BioMin Technologies Ltd [5.1]*

BioMin Technologies Ltd licences the manufacture of its bioglasses to Ceradynamics Ltd (CDL), buys back the glass powder and then sells it to Group Pharmaceuticals (GP), based in Bangalore, India, which manufactures the toothpaste, as well as selling it directly within the sub-continent. CDL employs 5 people as a result of the BTL work. CDL generates GBP200-250,000 sales per year through the sale of the bioglass material to GP. The manufacture of BTL's glass represents approximately 10% of CDL's dental materials business.

At GP, BioMin related activities account for ~5-10% of their activities as a business. BTL has a dedicated Product Manager, and employees involved in manufacturing and packaging, totalling 5 employees. GP makes approximately 90,000 tubes per month, selling 30,000 back to BTL and the remainder in the Indian market where it costs about GBP2 per tube. Thus, GP makes approx. GBP120,000 per month from toothpaste sales in India. In India, GP does not advertise the BioMin toothpastes directly; they sell to dentists and pharmacists, who then recommend the product to their patients. 80% of sales, therefore, are to consumers with a problem with either sensitivity or demineralisation. Around 30-40% of purchases are repeat purchases.

#### *Current markets and sales for BioMin toothpastes*

A map of the current markets for BioMin toothpastes is shown in Figure 2.

In terms of current sales, approximate annual numbers by country are:

- India up to 1,000,000 tubes
  - Sold by Group Pharma (as Elsenz) and by Abbot Laboratories (as Hydent Pro)
- China 100,000 tubes
  - Sold by Kwang Wang in China as BioMinF
  - Medical Device Approval in China was obtained in 2020
- Europe 150-200,000 tubes
  - In UK and Germany, online through Dental Shop and Amazon and in German, Polish, Baltic and Slovakian pharmacies
  - From the end of April 2020, BioMinF for Kids has been sold in European markets primarily on-line
  - In May 2020, BioMinC and BioMinF received CE mark approval [5.3]

- North America 20,000 tubes
  - FDA 510k Medical Device clearance has been granted for BioMinC in the US [5.3]
  - Licensing/distribution deals have also been signed by Dr Collins in the US and with Healthpulze in Canada for BioMinC
  - BioMinF, marketed by Dr Collins in the US as BioMin Restore Plus was granted FDA approval for Rx (prescription) sales in 2020 [5.3]. It is the first fluoride toothpaste to receive such approval in the US.
- Gulf 3,000 tubes
  - An exclusive distribution agreement signed between BioMin Technologies Ltd and Dubai based Al Multaqa Drugs & Pharmaceutical has enabled BioMin toothpastes to be distributed across the Gulf Arab states of UAE, Saudi Arabia, Oman, Bahrain, Qatar and Kuwait



Year	Countries entered
2016	India, UK
2017	China, Germany, Iceland
2018	Australia, Canada, Czech, Hungary, Lithuania, Poland, Slovakia, Slovenia
2019	Belgium, Finland, Ireland, Netherlands, Spain, Switzerland, UAE, USA
2020	France, Italy, Qatar

Figure 2: Left: Map of the current markets for BioMin toothpastes; Right: Table of countries entered and years. Reprinted from Impact Case Study: Bioactive Glass Based Products - BioMin™, Fresh Perspectiv [2020].

### BioMin toothpastes improve tooth sensitivity

The key benefits of BioMin toothpastes over competitive products (eg Sensodyne Repair and Protect) are:

- Controlled delivery of fluoride over time (the 5µm particles adhere to the tooth surface and are less likely to be rinsed away by saliva)
- Enhanced acid resistance of fluorapatite over hydroxyapatite (another component of tooth enamel)
- More rapid formation of fluorapatite

### User feedback

BTL surveyed 436 users of the toothpaste and found that users found the texture (63%), foaming (86%), flavour (87%) and price (72%) of the toothpaste acceptable. 52% said that it reduced their tooth sensitivity post-brushing and 48% said that it was more effective than other sensitivity toothpastes they had tried [5.4].

### Feedback from dental professionals

Donna Paton, a dental hygienist based in Mullingar, Ireland, and President of the Irish Dental Hygienists' Association said "patients love it, and it is flying out of the doors." She recommends BioMinF to patients with a variety of dental problems, specifically dentine hypersensitivity and routinely applies BioMinF before and after scaling and use of the Airflow. She confirmed that "no other product does what BioMinF does, it has all the elements you would want in a toothpaste and it is our duty as hygienists to get the team on board and recommend it to patients to improve their oral health." Sam Davidson, a hygienist in four practices across the South East said "I am now passionate about BioMin toothpaste. I trialled it on myself first. I found I was sensitive to cold air when I had had whitening treatment, so I used BioMinF for 14 days and the sensitivity was improved enough for me to go on with the treatment. As a trial in the practice, I gave about 30 patients a sample and all gave positive feedback. Many have continued to buy it. A couple of cases have been especially successful: a patient suffering from sensitivity during



whitening was able to resume treatment after using BioMin. Also, one with extreme sensitivity was so improved, that I could carry out scaling” [5.4]. A dentist in India also found that Biomin toothpastes had long lasting beneficial effects. He said ‘With the other toothpastes we found that just a few days after discontinuation of use the discomfort returned. Thus, we had a lot of patients complaining of rebound pain. With Biomin toothpastes the patient is getting more relief in the longer term” [5.1].

#### *Independent evidence of improved sensitivity from clinical trials*

There are currently several key published clinical trials on BioMinF toothpaste that have been carried out independently of BioMin Technologies Ltd [5.5, 5.6]. They demonstrate that the toothpaste is more effective than a potassium nitrate based toothpaste in treating dentine hypersensitivity. BioMinF has been compared with GSK’s NovaMin toothpaste and shown to be much more effective. Finally, BioMinF has been compared against a sodium fluoride toothpaste by Colgate in children aged 3-6 years and found to have higher salivary retention at 1 hour [5.1].

BioMinF was the first toothpaste to be accredited for both dentine hypersensitivity and tooth remineralisation by the Oral Health Foundation, UK after a rigorous review by a panel of dental experts [5.7]. In 2019, BTL was awarded the ‘UK Best Oral Sensitivity Relief Provider’ in the Healthcare and Pharmaceutical Awards [5.8].

#### **5. Sources to corroborate the impact** (indicative maximum of 10 references)

[5.1] Fresh Perspectiv (2020). *Impact Case Study: Bioactive Glass Based Products - BioMin™*

[5.2] BioMin (2020). *Bioglass technology described as ‘magic stuff’*. <https://biomin.co.uk/news/article/bioglass-technology-described-magic-stuff>

[5.3] US Food and Drug Administration (13 June 2019). *Traditional 510(k) Premarket Notification* (K181965– Restore Toothpaste); National Drug Code Directory Package code 77055-100-01 for Rx (Prescription) Sales; The National Standards Authority of Ireland as a duly designated Notified Body for the purposes of the European Communities (Medical Devices) Regulations (13 May 2020). *Quality System Approval* (GMDN Code: 11168 – BioMinC and BioMinF)

[5.4] BioMin. *Professional Testimonials*. <https://www.biomin.co.uk/testimonials>. 29 October 2020  
R Whatley (2016). *Presentation to Trycare*. BioMin.

[5.5] Pradeep AR, Sharma A (2010). Comparison of clinical efficacy of a dentifrice containing calcium sodium phosphosilicate to a dentifrice containing potassium nitrate and to a placebo on dentinal hypersensitivity: a randomized clinical trial. *J Periodontol*, volume 81(8),1167-73. <https://doi.org/10.1902/jop.2010.100056>

[5.6] Ashwini S, Swatika K, Kamala DN (2018). Comparative evaluation of desensitizing efficacy of dentifrice containing 5% fluoro calcium phosphosilicate versus 5% calcium sodium phosphosilicate: A randomized controlled clinical trial. *Contemp Clin Dent*, volume 9, 330-336. [doi.org/10.4103/ccd.ccd\\_735\\_17](https://doi.org/10.4103/ccd.ccd_735_17)

[5.7] Oral Health Foundation (2019). *Accreditation from expert panel for sensitivity and tooth remineralisation*. <https://www.dentalhealth.org/news/oral-health-foundation-approves-biomin-toothpaste#:~:text=The%20Oral%20Health%20Foundation%20is,some%20stage%20in%20their%20life.>

[5.8] BioMin Technologies Ltd (2019). Healthcare and Pharmaceutical Award: Best Oral Sensitivity Relief Providers, UK. *GHP*. <https://www.healthpulze.ca/blogs/news-articles/ghp-healthcare-pharmaceutical-awards-2019>.