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In situ Mechanical Measurements to Access the Effects of Bioglass on Dentin and Enamel Surfaces.

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1/10/12

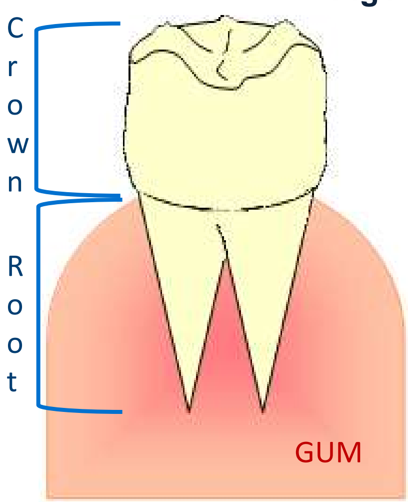
Sector of Biological and Soft Systems

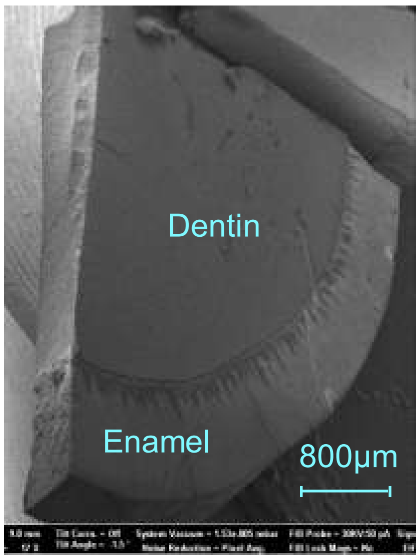
GlaxoSmithKline

The Hierarchical Structure of Teeth

Macro-Structure

Fig1.





Enamel:
90-98% mineral:
Impure Calcium
Hydroxy-apatite (HA)

Dentin:
A matrix of mineralised collagen fibrils. ~65% HA, ~25% Collagen & 10% Water

Dentin Micro-Structure

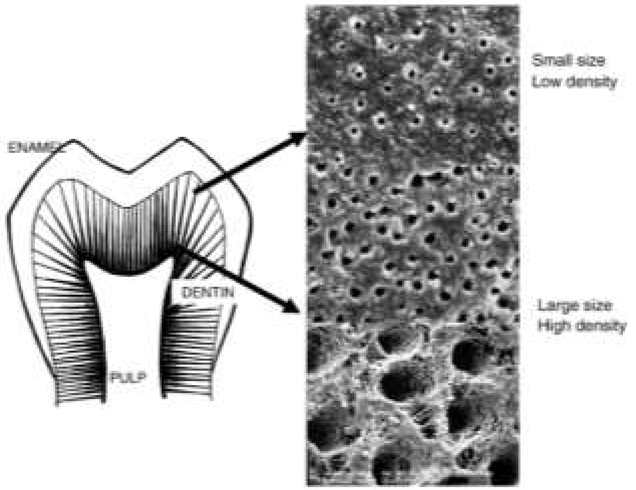


Fig2. Cross-sectional images show change in dentin tubule diameter and density with increasing distance from DEJ. [1]

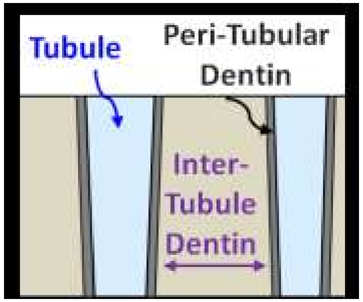


Fig3. Sub-Micro-structure

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Motivation for Bio-active Toothpastes:

Dental Caries (*Tooth decay*)

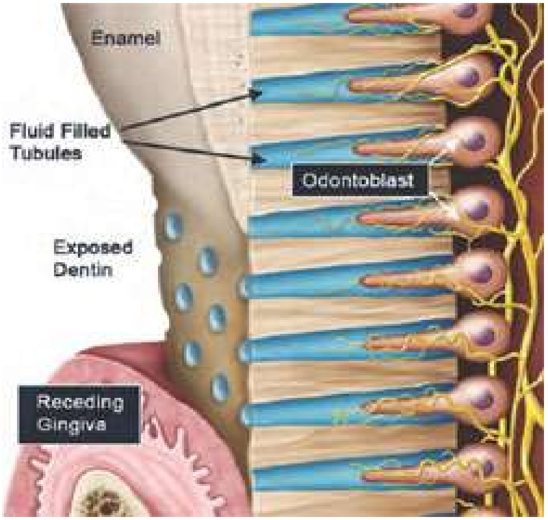
- Root Caries is an increasing problem in dental health. [2]
- Nominally caused by bacterial infection: e.g. *Streptococcus mutans* and *Lactobacillus*.
- Leads to demineralisation of Dentin and Enamel
- Fluoride treatments not substantially effective on Root Caries.

Fig 4: *[Wiki-commens]*

Dentinal hypersensitivity

- Pain associated with sensitive teeth.
- Caused by fluid flow in exposed dentin tubules. [Bransstrom's (1966) hydrodynamic theory [3]]

Fig 5: *Diagram of Tooth Neck-region[4].*



Bioglass in Action:

By occluding tubules and remineralising below the surface of dentin Bioglasses looks to be a promising treatment solution.

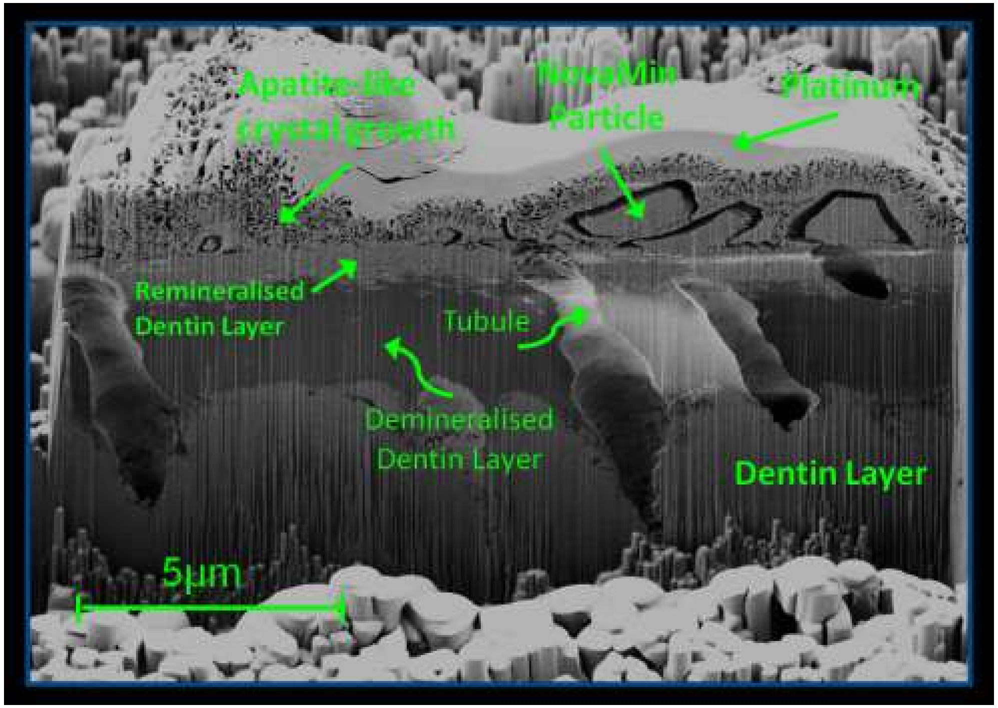


Fig.6: *SEM image [R. Langford] - Cross-section of Bioglass treated Dentin: shows remineralisation layer and porous-honeycomb structure of HA layer.*

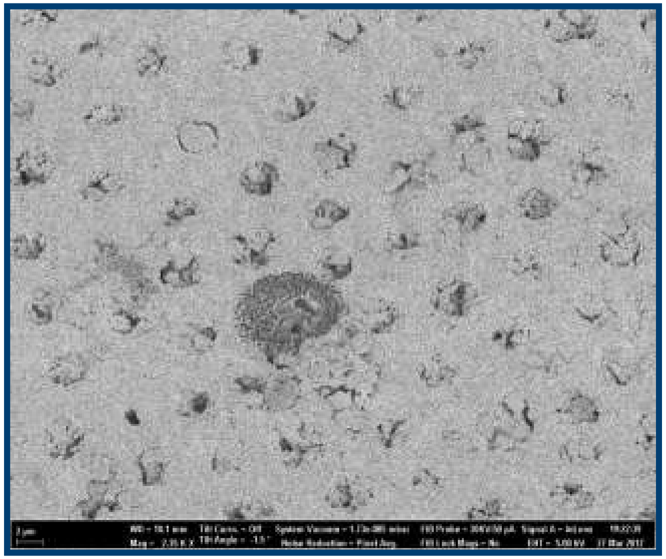


Fig.7: *SEM image - Toothpaste treated Dentin: the formed Hydroxy-Apatite-like layer occludes tubules.*

Objectives

Quantify the effectiveness of Bioglass enriched toothpaste treatment:

- To determine the Strength and Adhesion of the formed HA-layer
- To determine the efficiency of the remineralisation

By establishing relative differences in mechanical properties of the micro-structure of dentin & enamel subjected to different treatment regimes.

Problem – Traditional ex-situ testing methods result in a large range of values for the mechanical properties of dentin.

In-situ Mechanical Testing

The use of in-situ techniques offers advantages over traditional methods.

In-situ Nanoindenter

Fig.9: *SEM image showing in-situ nanoindenter tip. [EMPA, Switzerland]*

Kleindiek micromanipulator with FMS attachment

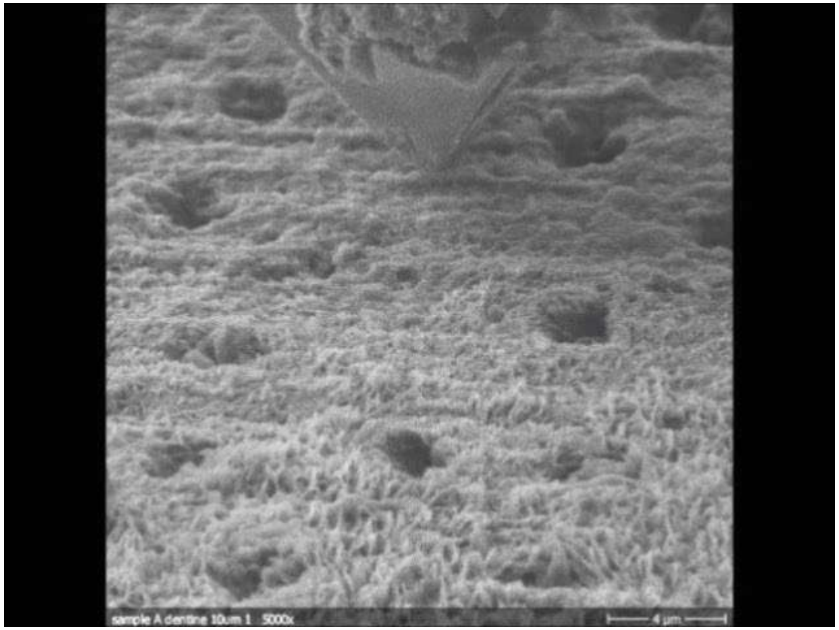
Fig.10:

Fine piezoelectric motor control with four-degrees of freedom provides high spatial precision for indentation.

The ability to correlate mechanical testing with high-resolution real-time imaging allows site specific loading and a greater wealth of information alongside mechanical data.

Alemnis In-situ Nanoindenter

10µm indentation on NovaMin treated Dentin



10µm indentation on NovaMin treated Enamel

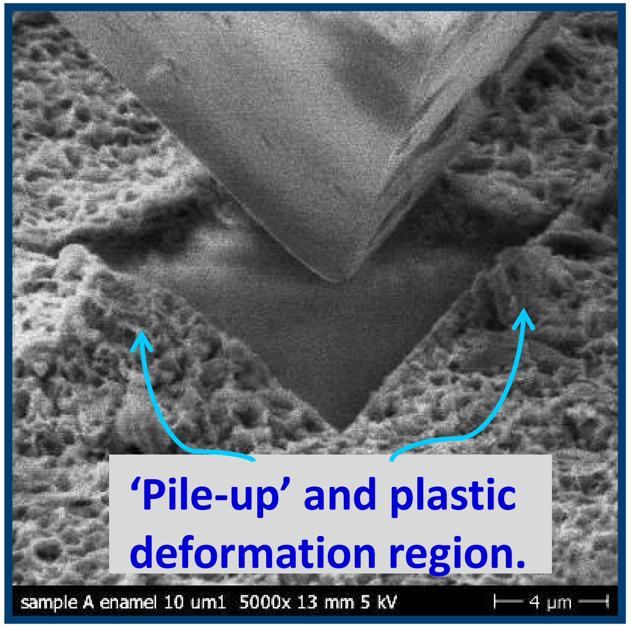


Fig.11:

The Differing Effects of Indentation:

6μm indentation on untreated Dentin

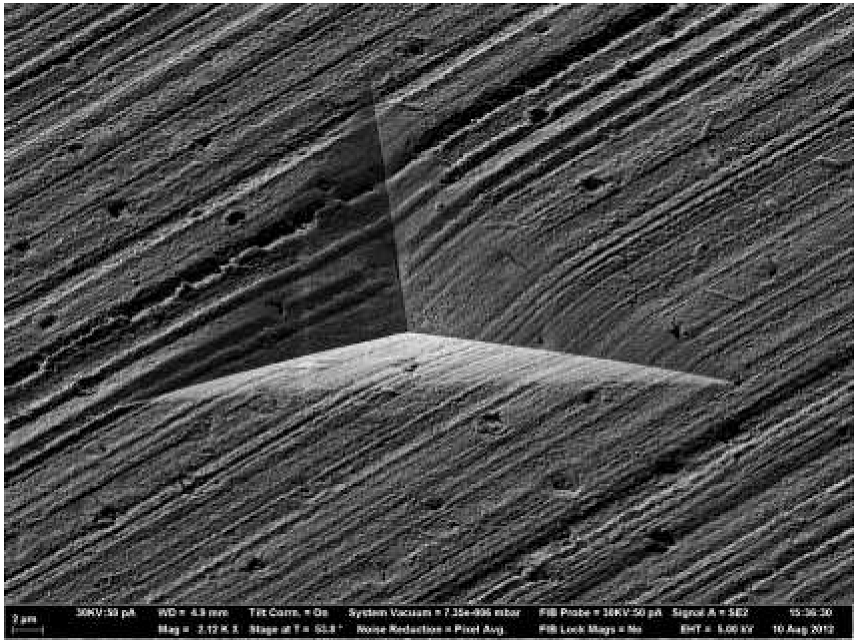


Fig.12:

6μm indentation on Acid-treated Dentin

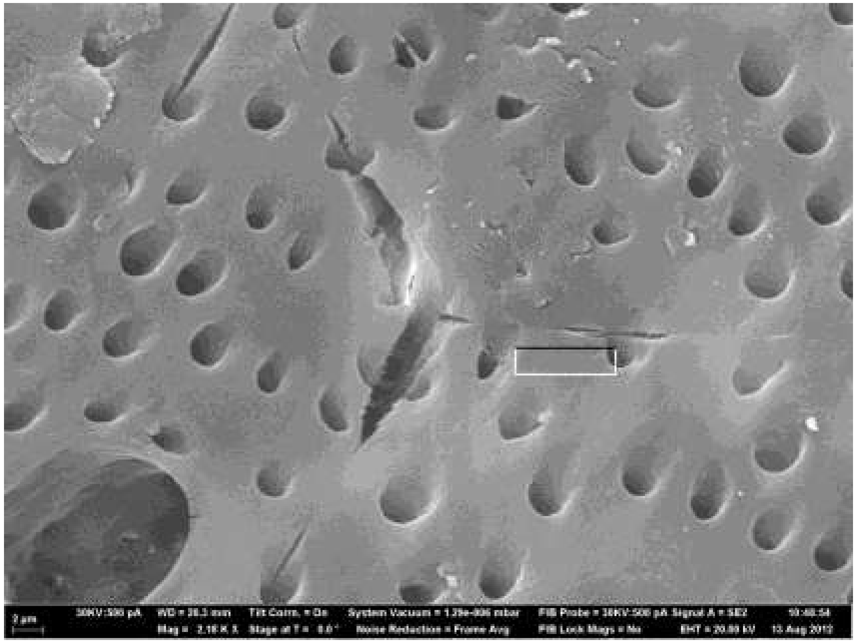
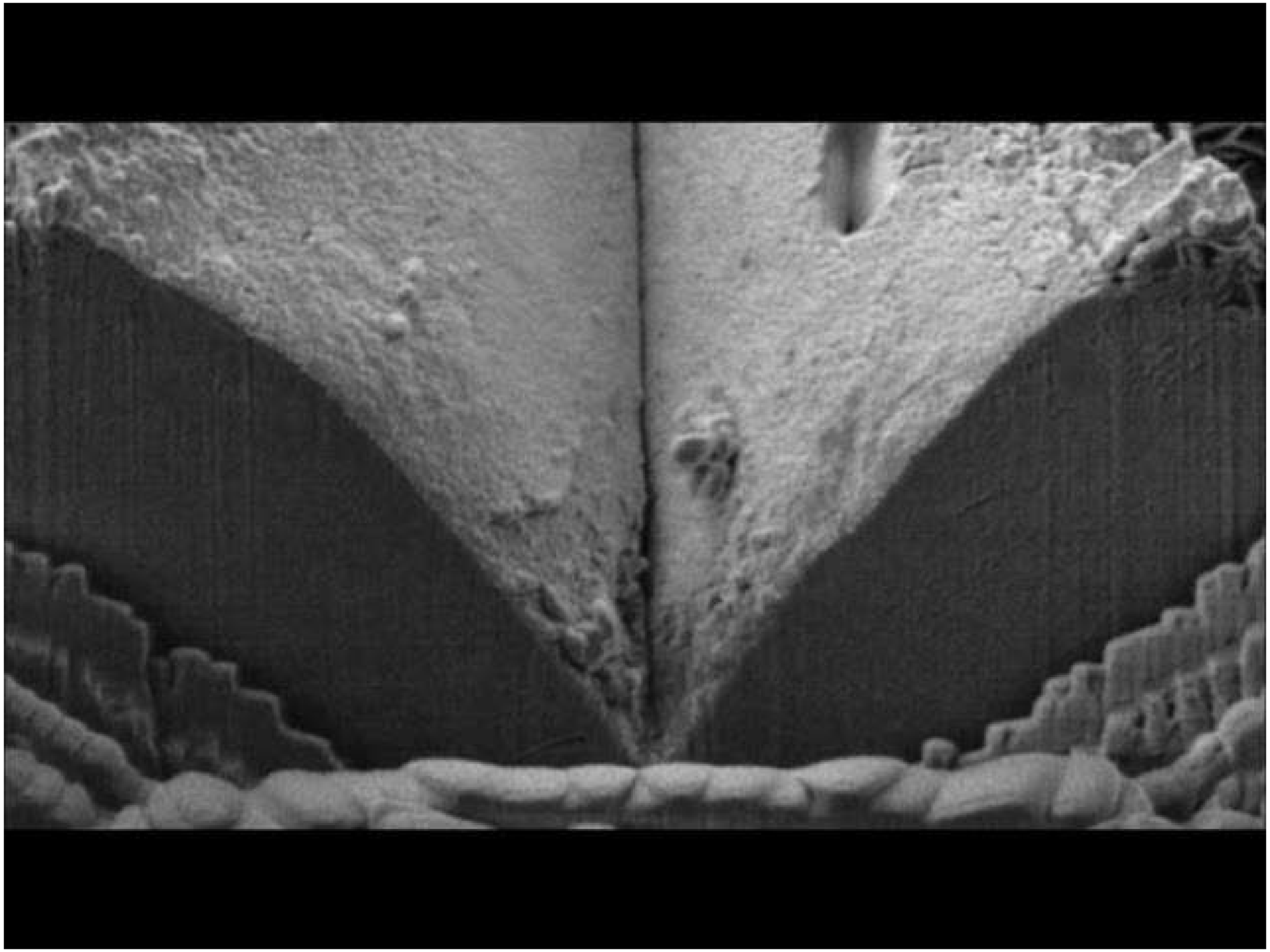


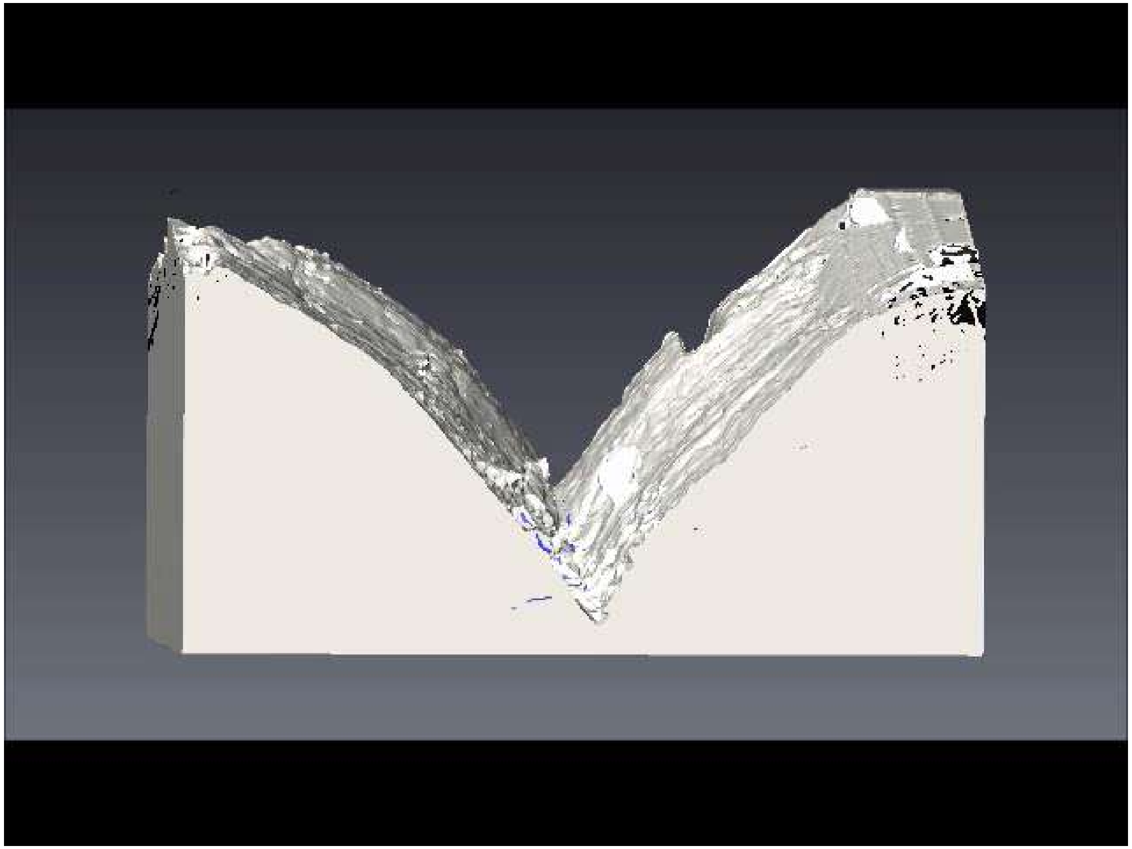
Fig.13:

With additional processing more information can be gathered about the mechanical properties of a material after indentation.

FIB 'slice and view' of Indentation on treated Dentin

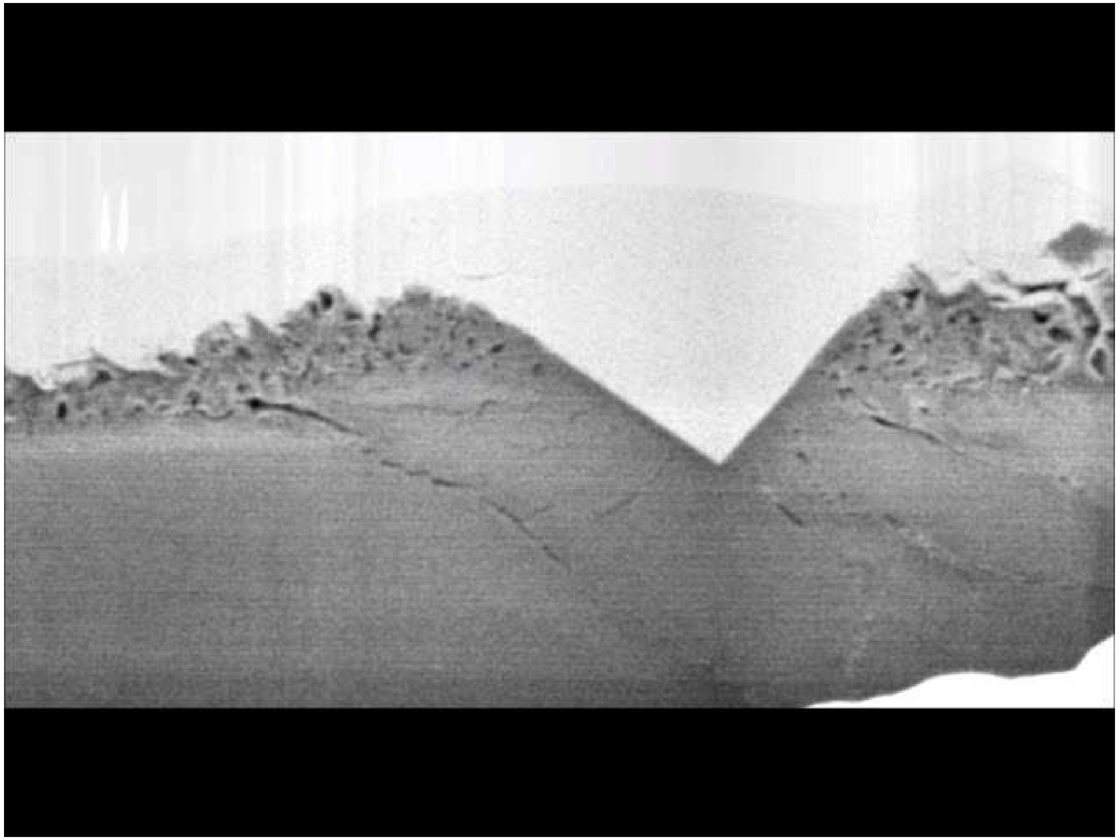


3D AVISO reconstruction: Crack Propagation



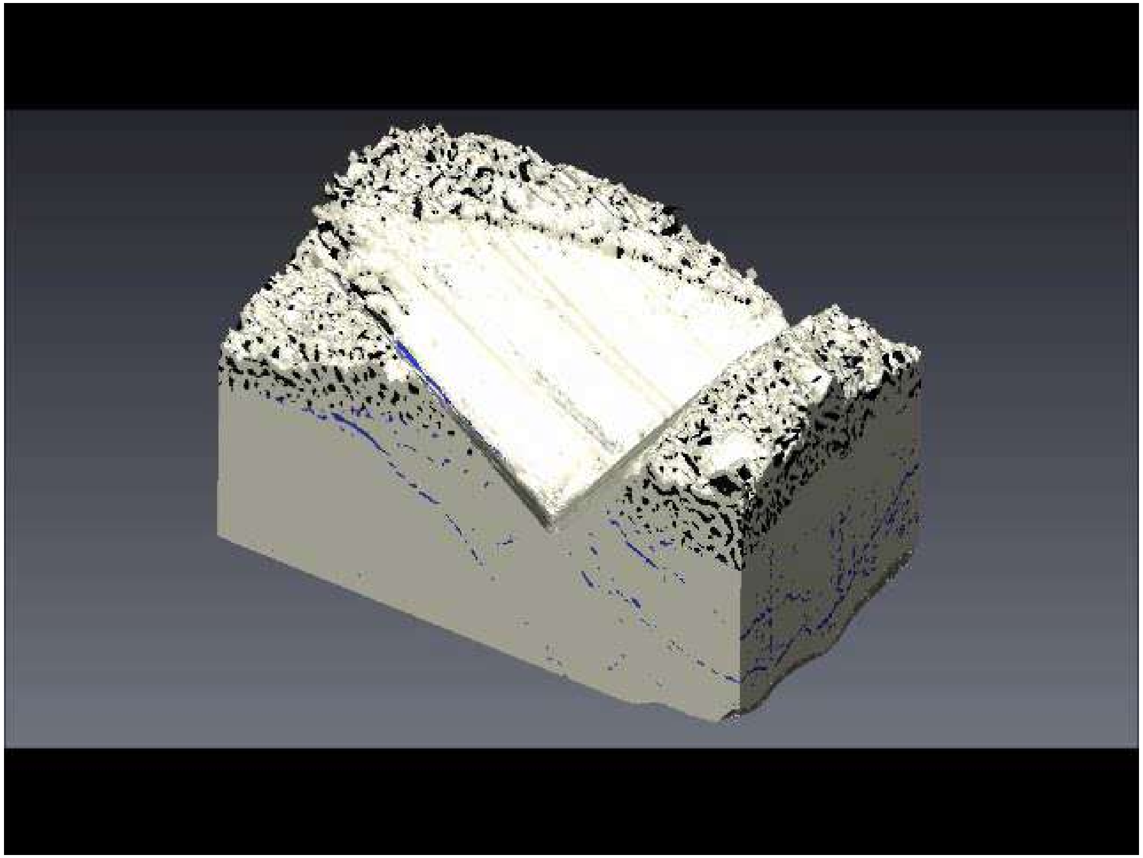
The 3D reconstruction allows clear tracking of the crack propagation due to indentation through the dentin material .

FIB 'slice and view' of Indentation on treated Enamel



The cracks appear to propagate mostly through the Bulk enamel and not the newly formed HA on the surface.

3D reconstruction of Crack Propagation in Enamel



The 3D reconstruction helps emphasis the differences between Enamel and Dentin crack propagation profiles. Highlighting their differing mechanical properties.

Conclusions

- In order to quantify the effectiveness of the Bioglass treatments. Care must be taken in how the relative diffrences in mechanical properties are arrived at via mechanical testing and analysis.
- We've shown that both material type (Dentin and Enamel) and treatment type will have not only different mechanical properties but different crack propagation behaviour
- Thus if we find bioglass restores the properties of demineralised dentin and enamel we must ensure that this restoration is mirrored in its crack propagation profile.
- FIB 'Slice and View' and 3D reconstruction of this data is ideal in aiding the gathering of such information.
- It is hoped that the combination of in-situ mechanical testing and 3D reconstruction of FIB 'slice and view' data will elucidate the mechanical properties of structurally complex biomaterials.

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GlaxoSmithKline

References

[1] J. Lawrence Katz et. al., *'Multiscale mechanics of hierarchical structure/property relationships in calcified tissues and tissue/material interfaces'*, Mat. Sci. & Eng. **C 27**, pp.450-468 (2007)

[2] Burwell, a K., Litkowski, L.J. & Greenspan, D.C. Calcium sodium phosphosilicate (NovaMin): remineralization potential. *Advances in dental research* **21**, 35-9 (2009).

[3] M.Brännström, *'Sensitivity of dentine'*, Endodontics (1966)

[4] H.E.Strassler, *'Inter-Relationship to Ginigval Recession and Acid Erosion'*, C.C. Edu. Dent. **29**, 1-9 (2008)