# 2D Mapping of Texture in Human Dental Enamel

M. Al-Jawad,[1] R. Cywinski,[1] S.H. Kilcoyne,[2] D. J. Wood,[3] R.C. Shore,[3] L. Bouchenoire, [4]A Steuwer[5]

[1]*School of Physics and Astronomy, University of Leeds, Leeds, UK*
[2] *Institute for Materials Research, University of Salford, Salford, UK*
[3] *Leeds Dental Institute, Leeds, UK*
[4] *XMaS, ESRF, 6 rue J Horowitz, 38043 Grenoble, France*
[5] *FaME38, ILL-ESRF, 6 rue J Horowitz, 38042 Grenoble, France*

## Introduction

Dental enamel is the most highly mineralised and strongest biological hard tissue. It comprises 95% hydroxyapatite (HA) mineral, 5% water, and 1% organic matter (non-collegenous protein). The hydroxyapatite crystal structure of dental enamel has been determined previously by several workers. It has space group $P6_3/m$ with lattice parameters a=9.513Å and c=6.943Å [1,2]. However the measurements were made on powdered enamel collected from many teeth, therefore any texture information regarding the growth of the HA crystallites was lost. Information on texture is extremely valuable both for understanding the formation of dental enamel, and also to be able to increase the longevity of restorations by improving their clinical placement. We have used the beamlines ID11, BM28 at the European Synchrotron Radiation Facility in Grenoble, France to carry out the first position-sensitive x-ray diffraction experiments to map the texture distribution as a function of position within intact enamel. Here we present the preliminary results.

## Methods and Materials

High-resolution synchrotron x-ray diffraction was used to collect 2D diffraction images at 150μm spatial resolution over the entire tooth crown. A 2D Mar CCD detector was used so that the change in texture around full diffraction rings could be observed. Basic texture contour maps were generated by performing Rietveld refinement analysis, using an inhouse batch processing program and the GSAS software [3], and extracting the intensity (texture) coefficients.

## Results

A composite map of CCD images of an adult second premolar is shown in Fig. 1 where diffraction patterns were collected every 150μm. Each point on the image is one 2D diffraction pattern, and these images have been arranged to form the whole image for illustration. The shape of the tooth can clearly be seen from this composite image. The lighter patterns around the edge are formed by the strongly textured enamel, and the darker patterns in the middle are the dentine. Below this image are four individual diffraction patterns from different parts of the tooth. Scans a), c) and d) illustrate the change in texture direction at difference positions within the enamel. Scan b) shows that dentine is nanocrystalline (broader peaks) and less textured.

## Discussion

The strongest degree of preferred orientation was found in the 002 reflection, and areas of high crystallite alignment on the tooth cusps are found on the expected biting surfaces of the teeth. The texutre direction of enamel is perpendicular to and follows the shape of the enamel-dentine junction. Additionally, it can be seen that below the groove between the two cusps (the fissure), there is a circular region of enamel which is less textured than the surrounding structure. We believe this to be caused by a fissure lesion in the enamel which has demineralised the enamel and possibly affected it's crystalline structure. Our results bring novel insight on the texture distribution and crystallinity within teeth and have the potential to optimise the clinical placement of dental composite materials in restorations.

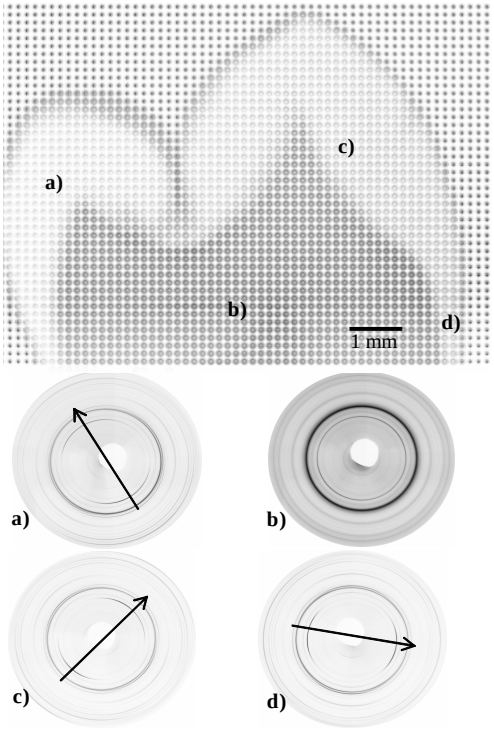


Fig. 1 2D images of whole tooth section with different regions highlighted. a),c), d) enamel ; b) dentine,

## Acknowledgments

This work was performed on the EPSRC-funded XMaS beam line (BM28) at the ESRF. We are grateful to J. Wright for his invaluable assistance, and to S. Beaufoy for additional administrative support.

## References

[1] R.A. Young, P.E. Mackie, Materials Research Bulletin 15, 17 (1980).
[2] R.M. Wilson, J.C. Elliott, S.E.P. Dowker, American Mineralogist 84, 1406 (1999).
[3] A.C. Larson, R.B. Von Dreele, General Structure Analysis System (GSAS) Los Alamos National Laboratory Report, LAUR 86-748 (2004).