ESRF	**Experiment title:** Texture Mapping Mature and Immature Dental Enamel	**Experiment number**: EC 745
Beamline: BM28	**Date of experiment**: From: 08 Dec 2010 to: 14 Dec 2010	**Date of report**: 02/04/2012
Shifts: 18	**Local contact(s)**: Miss Gemma Newby	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Al-Jawad M[1]*, Montgomery J*[2], Beaumont J*[3], Simmons L[1].

1. Dental Physical Sciences Unit, Barts and the London School of Medicine and Dentistry, Queen Mary University of London.
2. Department of Archaeological, Durham University
3. Archaeological Sciences, University of Bradford

Report:

The aim of this project was to use a powerful and novel suite of techniques to study the temporal and spatial progression during the biomineralisation process in dental enamel. Synchrotron x-ray diffraction measurements of 2D crystallographic texture mapping combined with x-ray microtomography were performed on three human tooth samples at different stages of enamel maturation. For dental and skeletal tissue research, mapping the temporal and spatial progression of enamel maturation will provide unique understanding into biomineralisation events and provide useful insights for developing successful reparative or regenerative medical technologies.

Background, Experimental Procedure, and Highlighted Results

The process of amelogenesis begins *in-utero* (primary dentition) or between birth and 3 years (secondary dentition) and for certain teeth takes up to 4 years to complete. During this process the biological formation of enamel has resulted in a highly anisotropic and heterogeneous distribution of hydroxyapatite crystallites (HA). Currently there is much contradiction in the literature regarding the precise mechanisms and timings of enamel maturation, for example, Hilson states the each ameloblast spends ~300 days in the secretory stage before beginning the maturation stage without drawing conclusions on the time maturation takes [1].

Archaeological skeletal samples obtained from children who died whilst their teeth were still developing provide a resource for the study of the precise timings of the maturation of enamel. Performing synchrotron x-ray diffraction on such samples has afforded the opportunity to compare variations in lattice parameter, texture distribution of HA crystallites, and crystallite size in developing enamel at different points during maturation.

Our previous work showed for the first time how synchrotron x-ray diffraction can be used to determine the basic crystallographic parameters of the HA phase across a whole intact tooth section [2-4]. For this project, we present synchrotron x-ray diffraction measurements of enamel at three stages of development (unerupted crown-half, unerupted crown complete, and erupted fully mature) which were performed on the XMaS beamline at the European Radiation Synchrotron Facility (ESRF) with 150μm resolution. In-house x-ray microtomography (XMT) at 15μm resolution was performed on tooth halves retained after sectioning.

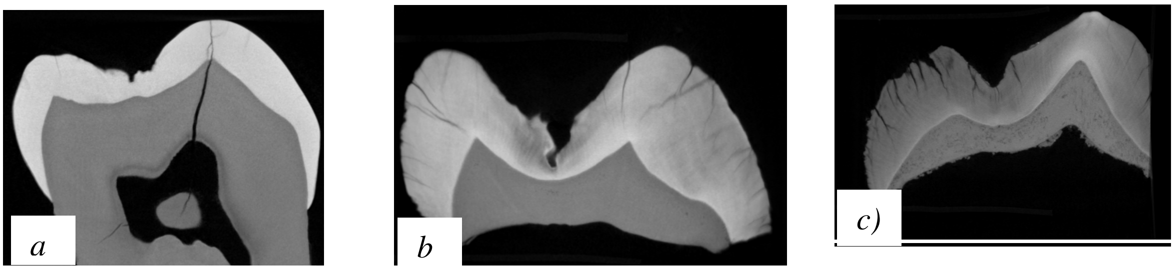

Fig. 1 XMT images of a) erupted fully mature 1st molar, b) unerupted crown complete 1st molar, and c) unerupted crown ½ 1st molar

Figure 1 shows the XMT micrographs. There is an anisotropic distribution of mineral content and a variation in the mineral density within and between each specimen when comparing enamel along the cervical edge, within a fissure and across a cusp. The most homogenous distribution is noted in Figure 1a with the amount of mineral content in the fully mature enamel being close to the accepted value for hydroxyapatite, 3.16 gcm^{-3}. In contrast, mineral content from enamel in the partially formed enamel lower and much more varied across the crown. Fig. 2 shows the contour maps showing the change in magnitude of the preferred orientation of the HA crystallites generated from Rietveld refinements of synchrotron x-ray diffraction data. In all three samples the lowest degree of texture is seen along the EDJ. It is interesting to note the mineral density distribution does not correlate with the texture distribution, in that where we see the most homogeneous density distribution (mature enamel), we see the most variation in the crystallite organisation.

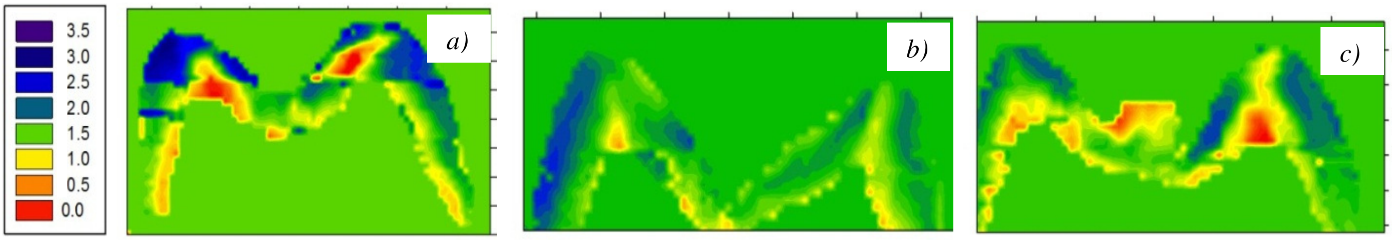

Fig. 2 Contour maps displaying the degree of preferred orientation of HA crystallites in a) erupted fully mature 1st molar, b) unerupted crown complete 1st molar, and c) unerupted crown ½ 1st molar

Main Outcomes

This study has revealed that the growth of hydroxyapatite crystallites during enamel formation is a highly heterogeneous process with complex spatial and temporal variations. For mineral content, crystallite orientation, lattice parameters, and crystallite size, the early and complete stages of maturation show the most heterogeneity spatially across the tooth sections whilst it is interesting to note that the intermediate point in maturation exhibits the most homogeneous relationship of all three samples. The mineral content of the enamel appears to be correlated to the crystallite orientation, whereby as the enamel matures, the mineral content increases and simultaneously the crystallite orientation increases.

References

[1] S Hilson, *Teeth*, 2. Cambridge: Cambridge University Press. 1986,

[2] M Al-Jawad, A Steuwer, S H. Kilcoyne, R C. Shore, R Cywinski, D J Wood. '2D mapping of Texture and Lattice Parameters of Dental Enamel', Biomaterials 28 (2007) 2908

[3] M Al-Jawad, LM Simmons, A Steuwer et al. 'Three dimensional mapping of texture in dental enamel', Key Engineering Materials 361-363 (2008) 877

[4] LM Simmons, M Al-Jawad, SH Kilcoyne, DJ Wood. 'Distribution of enamel crystallite orientation through an entire tooth crown studied using synchrotron x-ray diffraction', European Journal of Oral Sciences, Accepted for publication October 2011