2. An evaluation of changes in strontium/calcium ratios across the neonatal line in human deciduous teeth

L.T. HUMPHREY
Department of Palaeontology
The Natural History Museum
Cromwell Road
London SW7 5BD, UK
l.humphrey@nhm.ac.uk

M.C. DEAN
Evolutionary Anatomy Unit
Department of Anatomy and Developmental Biology
University College London
London WC1E 6BT, UK
Chris.dean@ucl.ac.uk

T.E. JEFFRIES
Department of Mineralogy
The Natural History Museum
Cromwell Road
London SW7 5BD, UK
t.jeffries@nhm.ac.uk

Keywords: enamel, trace element, intra-tooth analysis, strontium, calcium, neonatal line, birth, dietary reconstruction

Abstract

Analysis of human tooth enamel using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) provides a basis for systematic evaluation of variation in the chemical composition of enamel in relation to tooth crown geometry. Analysis of thin sections allows a sampling strategy that can be cross-referenced to incremental growth structures in tooth enamel. Strontium and calcium are incorporated into developing teeth in a manner that reflects changing physiological concentrations in the body. Strontium/calcium (Sr/Ca) ratios are expected to decease at birth in breastfed infants, because the mammary gland exerts a greater activating effect on calcium transfer than the placenta. However, Sr/Ca ratios should increase at birth in infants fed on a formula derived from cow's milk. Changes in Sr/Ca ratios across the neonatal line in five out of six deciduous teeth from children of known mode of feeding within the first few months after birth conform to the predicted direction of change, indicating that changes in physiological concentrations of strontium and calcium resulting from a dietary shift during the secretory stage of enamel formation may not be completely overwhelmed during enamel maturation. Implications for the reconstruction of longitudinal records of infant diet from tooth enamel are discussed.

S.E. Bailey and J.-J. Hublin (Eds.), Dental Perspectives on Human Evolution, 303–319.

Introduction

Over the last decade a number of studies have sought to overcome the limitations of traditional studies of paleodiet, seasonal mobility and migration by undertaking discrete analysis of tissues that form at different stages of an individual's development (e.g., Sealy et al., 1995; Wright and Schwarcz, 1998; Balasse et al., 2001; Fuller et al., 2003). This study will focus on the potential of tooth enamel for the reconstruction of individual profiles of dietary change during the first few years of life. Tooth enamel offers many advantages for this type of study. First, the age of onset and duration of enamel formation varies between teeth, such that different teeth preserve a record of different periods of development (Hillson, 1996). Second, since tooth enamel is not remodeled, it retains a durable record of dietary intake during the period of enamel formation. Finally, enamel is an ideal matrix for chemical analysis because it is more resistant to diagenetic change than other biological tissues (Lee-Thorpe and van der Merwe, 1991; Koch et al., 1997; Budd et al., 2000).

Traditional studies of intra-tooth variation use a sampling strategy that involves drilling enamel from an intact tooth in an ordered series of horizontal bands, running from the tip to the cervix of the crown. Sampling procedures such as this will result in a set of samples that is, broadly speaking, chronologically ordered, but which does not respect either the direction of enamel secretion or subsequent mineralization (Balasse, 2003). Techniques now exist for analysing the chemical composition of very small quantities of enamel, providing a basis for discrete multiple sampling investigations of variation in trace element and isotope composition through the tooth crown (Wurster et al., 1999; Kang et al., 2004; Webb et al., 2005; Zazzo et al., 2005). Incremental growth features in the tooth are laid down during the secretory (matrix formation) stage of enamel formation, and preserve a permanent record of the timing of the onset of enamel crystal growth at a given point (Dean, 1987; Boyde, 1989). The pattern and timing of subsequent mineralization will determine whether these incremental growth features are relevant to the development of micro-sampling strategies and their interpretation within a detailed chronological framework. An area of particular interest for life history reconstructions is whether it is possible to use incremental growth structures as a basis for inferring the chronology of changes in diet during infancy and childhood.

Ideas concerning the pattern and process of progressive mineralization of developing enamel have changed considerably over the last 150 years (early work is summarized by Crabb and Darling, 1962). There is now a consensus that enamel formation proceeds via a series of distinct stages, which can be defined on the basis of changes in the structure and function of ameloblasts and their affect on enamel composition (Robinson et al., 1997; Smith 1998). The secretory stage of enamel formation involves the formation of an organic matrix, which starts in the region of the dentine horn and continues outwards through the thickness of the cuspal enamel and simultaneously along the enamel dentine junction to the cervix (Boyde, 1989). Enamel crystals seed within the organic matrix almost immediately after it is laid down and quickly elongate in the wake of retreating ameloblasts to produce thin enamel ribbons extending the full thickness of the enamel (Fincham and Simmer, 1997; Robinson et al., 1997). Following completion of enamel matrix secretion – which may take more than a year in some human molar cusps – ameloblasts undergo a morphological and functional transition and enter the maturation phase (Smith, 1998). This stage involves selective removal of water and organic materials together with addition of more mineral ions. As a result, there is a