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Investigating weaning using dental microwear analysis: A review

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ABSTRACT

This paper provides a theoretical review and a framework of methods for using dental microwear analysis on deciduous teeth to investigate weaning processes from archaeological remains, and provides an approach to assess changes in food consumption during weaning. We review the process of weaning, which can be informative of subsistence transitions, maternal labour, demographic factors including birth spacing and infant health, and highlight the relationships between weaning, immune status, and exposure to pathogens. Prior microwear research has largely focused on adults necessitating consideration of the methods concerning deciduous teeth. Microwear can be used to discern between the consistency and fracture properties of food as enamel is removed during mastication, and is influenced by how food is prepared (for example premasticated, raw, cooked). As such, microwear provides a direct way to explore the introduction of complementary foods during weaning. A conceptual model of the potential confounders of assessing microwear in deciduous teeth including tooth biology, bite force, and the development of oral mechanics is presented. These are pertinent to understanding infant feeding, which changes in tandem with physical development and the sequence of dental eruption. This is relevant to future research for the interpretation of the microwear signatures of infants compared with adults. Understanding weaning practices and early life diet is crucial to expand and develop what we know about cultural systems, population health, nutrition, and subsistence practices in the past.

Contents

1. Introduction

Weaning and the introduction of complementary foods have important implications for anthropological research. Over the course of human history, subsistence has changed with technological development and innovation, domestication, environmental and climatic changes, mobility, and dietary preferences (Gilbert and Mielke, 1985). Understanding the move from foraging and hunting, to pastoralism, and agriculture is critical as the type of foods consumed by a population directly impacts the essential proteins and micronutrients in their diet. Moreover, weaning foods can influence the duration of weaning and therefore has effects on fertility. Without sufficient nutrients infants

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and children can suffer from undernutrition. Adequate nutrition early in life is one key factor underpinning growth and later adult health, and the period of weaning with the introduction of food other than breast milk is the first pivotal stage of this synergy between diet and health. Furthermore, access to different foods within populations can be culturally determined with unequal distribution occurring between sex, biological age, or social age categories. These distinctions can often begin from infancy and childhood.

In bioarchaeological research, the process and timing of weaning have been investigated using stable isotopes from skeletal and dental remains to detect changes in diet from the introduction of complementary foods while breastfeeding (for example Dupras and Tocheri, 2007; Richards et al., 2002; Schmidt et al., 2016b; Tessone et al., 2015). However, the destructive process of stable isotope analysis means that some institutions decline research applications, especially of infant and child remains as these can be under represented in collections acquired by archaeological excavation (Guy et al., 1997; c.f. Halcrow and Tayles, 2008; Lewis, 2007).

In adults, non-destructive techniques for analysing dental microwear have been used successfully to detect different types and consistency of foods in the diet, and the introduction of abrasives into the chewing cycle during mastication (El Zaatari and Hublin, 2014; Hillson, 2005; Schmidt et al., 2016a,b). This has rarely been used on infant and children's dentition even though it provides valuable information on the dietary practices of this under-studied group. Dental microwear analysis has the potential to identify subtle changes to the enamel surface of deciduous teeth from the introduction of complementary foods.

This review highlights the importance of the weaning process for the mortality and morbidity of children and as adults, which has implications for fecundity and population demography. It looks at the ability of dental microwear analysis to detect weaning in infants from archaeological contexts by providing a review of the methods used in this growing field. Deciduous enamel and oral kinetics associated with feeding differ to adults. These aspects are discussed in terms of how they may impact dental microwear signatures on infant and children's teeth (Section 3). This review can act as a guide to the progression of infant jaw movements and how these might impact microwear signatures thereby enabling more accurate interpretations of results in the future. Future research avenues, guiding methods to use at the onset of research, and the potential for combined complementary research with other areas of bioarchaeological studies such as dental macrowear and stable isotope analyses are presented (Section 4). We hope this review will encourage archaeologists and bioarchaeologists to incorporate dental microwear analysis in their reconstruction of weaning processes in the past. Excluding isotope analysis, there are few ways in which this process can be directly explored in the skeletal record.

2. The weaning process

One of the first crucial stages in an infant's life is the weaning process, defined here to commence when food other than breast milk is introduced into the diet. At the end of this process when breastfeeding ceases the child enters a new life stage (e.g. Bogin and Smith, 1996) that in many societies coincides with increased independence and physical development (Gowland, 2015:532). The period of complementary feeding comprises part of the first "1000 days" from conception to 24 months old, which is believed to be the most crucial period for infant growth and development, and much of which is mediated by the nutritional value of the mother and infant's diet (Dewey, 2013; Neville et al., 2012; Victoria et al., 2010). This can have long-term or even generational effects on health. These life stages are part of the life course of an individual, moderated by biological and social changes within a larger shared community (Prowse, 2011).

While complementary foods are required to fulfill the nutritional requirements of an infant from approximately 6 months of age, they often provide an unfortunate gateway for infectious agents and pathogens causing diarrhoeal disease (McDade and Worthman, 1998; Mølbak et al., 1994; Meehan and Roulette, 2013; Stinson, 2002). Identifying the age weaning foods were introduced, or identifying the types of foods introduced over the period of weaning, is therefore important for understanding patterns of health and disease within and between populations. Dental microwear analysis of deciduous teeth has the potential to identify these patterns. To understand why it is important to determine from microwear analysis when complementary foods were introduced into the diet of infants in the past we must first look at the benefits that are provided by breast milk, and the health risks and benefits associated with the weaning process.

2.1. Breast milk, complementary foods, and weaning severance

Breast milk provides vital nutrients that buffer infants from ill health and disease in the first few months of life (Ballard and Morrow, 2013; Filteau, 2000; Neville et al., 2012; Walker, 2010). The first substance produced, colostrum, has high concentrations of multifunctional proteins (Ballard and Morrow, 2013) that promote cell growth, and contains leukocytes, which help fight infection and disease (Walker, 2010). From ≥4 months postpartum breast milk development is complete and no further changes to breast milk composition occur (Ballard and Morrow, 2013). Breast milk is composed of essential macro and micronutrients such as proteins, fats, carbohydrates, and vitamins with anti-inflammatory properties (Ballard and Morrow, 2013; Filteau, 2000; Walker, 2010:S5) that are linked to the mother's nutritional status and diet (Ballard and Morrow, 2013). The nutrients within milk aid in maturation of the immature gut and provide protection against infectious diarrhoea (Neville et al., 2012; Walker, 2010). This is extremely important as, after pneumonia, diarrhoeal disease is the second leading cause of infant mortality in developing countries (Filteau, 2000; Stinson, 2002; UNICEF/WHO, 2009).

Clinical literature suggests that breastfeeding until 6 months of age followed by the introduction of nutritious complementary foods during the weaning process is optimal for good health (Ballard and Morrow, 2013; Breastfeeding, 2016; Dennis, 2002; Sellen, 2001; Valentine and Wagner, 2013; Von Berg, 2006). The World Health Organization recommends exclusive breastfeeding until the age of 6 months (UNICEF/WHO, 2009). Ethnographies and demographic reports show that in some non-industrial populations infants are exclusively breastfed until the age of 4 to 6 months (Plank and Milanesi, 1973; Sellen, 2001; Yáñez, 1980), with additional liquids such as water, tea, or broth occasionally introduced earlier (Dettwyler, 1987; Imong et al., 1995; Mølbak et al., 1994; Sellen, 2001). This may have negative implications for future morbidity as the introduction of complementary foods puts infants at greater risk of diarrhoeal disease, gastroenteritis, and death (Meehan and Roulette, 2013; UNICEF/WHO, 2009:13). Conversely, exclusive breastfeeding for longer periods (>8 months) without providing complementary foods is also detrimental to physiological health because breast milk alone cannot provide the essential nutrients needed for optimum growth and development from this age (Delaney and Arvedson, 2008; Dewey, 2013; Jay, 2009; Lutter and Lutter, 2012; McDade and Worthman, 1998). Complementary foods also need to have adequate nutritional value to provide the best opportunity for good health. The protection from pathogens provided by breast milk can be negated by feeding complementary foods that are insufficient in essential nutrients and through contaminants on or within the food (Imong et al., 1995; Filteau, 2000). When complementary foods are an insufficient source of protein and vitamins, malnutrition and nutrient deficiencies can occur (Dewey, 2013; Filteau, 2000). From this contemporary evidence it is anticipated that complex dental microwear signatures on the first erupted teeth (incisors ±6 months of age) in archaeological populations could aid in explaining morbidity patterns of infants as the early or late introduction of complementary foods have been shown to have detrimental effects on physiological health.