ENAMEL HYPOPLASIA RELATED TO HISTORICAL FAMINE STRESS IN THE CONTEMPORARY CHINESE POPULATION

LIMING ZHOU AND ROBERT S. CORRUCCINI
Department of Anthropology, Southern Illinois University. Carbondale. Illinois 62901-4502 U.S.A.

ABSTRACT Linear enamel hypoplasia (LEH), a defect in enamel formation, has been frequently attributed to malnutrition and other physiological stress during periods of enamel development (Sarnat and Schour, 1941; Kreshover, 1960). LEH has been widely used as an indicator of developmental stress in skeletal studies among historic and prehistoric populations (Goodman et al., 1980; Corruccini et al., 1985; Goodman and Rose, 1990). S study of 3,014 subjects in 26 birth-year cohorts, sampled from urban and rural communities of China, indicated that significant differences in LEH frequencies occurred between persons whose teeth developed during the famine years (1959-1961) and those whose teeth calcified during non-famine years. This result points to a causal link between enamel hypoplasia and childhood nutritional stress at the population level, and casts some light on the magnitude and effects of the little-documented Chinese famine.

INTRODUCTION

Although LEH has great potential as an indicator of population nutritional stress, the relationship has not been completely resolved (Goodman and Rose, 1990; Goodman and Capasso, 1992). Some epidemiological studies, which focused at the individual and small group level, have been conducted to assess this relationship (Goodman et al., 1987, 1991). This study examined the possibility of a direct link between LEH and nutritional stress at the population level during a large-scale famine.

A famine in China between 1959 and 1961 is considered to have been among the most devastating famines in human history (Kane, 1988; Rodzinski, 1988; Newman, 1990). Massive starvation resulted from failed national policies, mainly Mao's Great Leap Forward, which was a utopian production drive in which Mao formed rural communes and attempted to achieve rapid industrialization (Ashton et al., 1984; Kane, 1988; Rodzinski, 1988; Newman, 1990). According to Chinese official statistics released 20 years later, this famine is estimated to have caused more than 30 million deaths plus 30 million lost and postponed births. Famine stress is thought to have been evenly distributed among the entire population of 650 million people due to the socialist system (Ashton et al., 1984; Banister, 1984; Bernstein, 1984; Peng, 1987; Riskin, 1987; Rodzinski, 1988; Kane, 1988; Newman, 1990). In recent years, new information on the famine indicates that at least 40 people million died from the famine, and that "it was more widespread than long believed and could have been avoided" (Southerland, 1994:6-7).

The bioanthropological perspective of this famine remains poorly studied (Kane, 1988; Southerland, 1994). We report here the results of a study of the prevalence of LEH in relation to famine stress among the contemporary Chinese population.

MATERIALS AND METHODS

An eight-month field project was carried out in China in 1993 and 1994 by one of us (LZ). LEH was assessed on the buccal surface of the anterior teeth of individuals born between 1949 and 1974. The sample consisted of 3,014 individuals in 26 birth-year cohorts. Of these 1,544 (806 females, 738 males) were from urban communities in the city of Shanghai and 1,470 (741 females, 729 males) from rural villages near Qingji township, Anhui province, 500 km northwest of Shanghai.

The recording of LEH followed the epidemiological standard for classification of developmental defects of dental enamel (DDE index) of the Federation Dentaire International adapted by Goodman et al. (1987, 1991). The examiner and recorder of LEH were always blind to the subject's age and birth year. Information regarding birth date, birth place, height and body weight and other variables were collected after the dental examinations and recording had been completed. For estimation of the reliability of the field assessment, 600 photos of 2,400 teeth (6.67 % of sample) were taken from randomly selected subjects to serve as permanent record.

The LEH data were analyzed in two ways. The first involved comparisons of frequencies of dentitions with at least one LEH on the 12 anterior teeth (maxillary and mandibular incisors and canines). The second entailed comparisons of percentages of the presence of LEH on one of six developmental zones of the mandibular canines.

The 12 anterior teeth were chosen for the first part of the analysis because they are the easiest to examine, are often studied by other researchers, and have relatively high hypoplastic rates (Goodman & Armelagos, 1985). For this part of the analysis, data for 26 birth-year cohorts were pooled into three birth cohorts: pre-famine (1949-1953), famine (1954-1961), and post-famine (1962-1974) (Table 1). When interpreting the results, the 4.5 to 6.5 postnatal developmental period of anterior teeth is important to consider. Thus, the 1954-1961 cohorts have some anterior teeth which developed during the famine years.

The mandibular canines were studied in the second part of the study because they were the most hypoplastic teeth of the present study. Moreover, the canine has a development period of six years. Each LEH can be accurately attributed to a specific horizontal zone roughly corresponding to a particular one-year period (Goodman et al., 1987). This feature allowed us to estimate the time of formation of a LEH from the distance to the cemento-enamel junction relative to the person's birth year. The results provided an accurate picture of the relationship between LEH and famine stress (Goodman et al., 1987). For this portion of the study, 21 birth-year cohorts were pooled into three birth cohorts: pre-famine (1954-1958), famine (1959-1962), and post-famine (1963-1974) (Table 2).

RESULTS

Out of the 3,014 subjects observed for LEH on the 12 anterior teeth, 1,486 (49.30%) had at least one LEH (Table 1). The differences between the frequency of LEH in the famine (1954-1961) birth cohorts (55.91%) and those in the pre-famine (49.04%) and post-famine cohorts (45.50%) is real ($p<0.05$) in both cases, despite substantial overlap in tooth-forming ages and birth cohort years. These differences can only be explained by the affects of the famine stress.

In the 6,019 mandibular canines analyzed for the second part of the study, 26,997 developmental zones formed between 1954 to 1974 were recorded (Table 2). Of these developmental zones, 3,433 (12.72%) had LEH. The results of statistical tests comparing the percentages of LEH zones between pre-famine (1954-1958) and famine (1959-1962) birth cohorts, between famine and post-famine (1963-1974) birth cohorts, and between pre-famine and post-famine birth cohorts are summarized in Table 2. The null hypothesis that no difference exists in LEH formation between famine years and pre-famine years and between famine years and post-famine years cannot be accepted ($p<0.05$).

This diachronic pattern of LEH frequencies of developmental zones on mandibular canines is compatible with the differential survivorship of birth-year cohorts of the population, another well accepted biological indicator of famine stress. Fewer randomly selected informants were born between 1959 and 1961 (96 per year) than between other years (119 per year), especially rural subjects (38 per year) compared with urban subjects (59 per year). This selective mortality probably removed the most stressed individuals, especially rural individuals, from potential study. The diachronic patterns of LEH frequencies thus provide a unique biological confirmation and record of the great Chinese famine between 1959 and 1961 (Kane, 1988; Ashton et al., 1984; Peng, 1987).

CONCLUSIONS

We conclude that LEH frequencies are significantly higher in teeth developed during the famine years than in the teeth developed during the pre- and post-famine years in the contemporary Chinese population. This result suggests a causal link between the nutritional stress of the famine and increasing LEH frequencies at the population level. Additional details of these results will be reported elsewhere. For example, LEH was significantly elevated in males versus females, and in rural versus urban subjects.

The results are all the more noteworthy in view of two factors. First, a steady rate of hypoplasia persisted during the relatively good times, that is during pre- and post-famine years. However, a lesser peak in LEH was observed in the sample over the years of disruption owing to the Cultural Revolution about 1969. We continue to suspect that

TABLE 1. Contingency table comparing LEH frequencies of birth cohorts of pre-famine (1949-1953), famine (1954-1961), and post-famine (1962-1974) birth cohorts. Data based on the presence of at least one LEH on the 12 anterior teeth.

Birth cohort	n	N	%		Birth cohort	n	N	%	Chi-square	p
Pre-famine	282	575	49.04	vs	Famine	506	905	55.91	6.66	0.0100
Famine	506	905	55.91	vs	Post-famine	698	1,534	45.50	24.67	0.0001
Post-famine	698	1,534	45.50	vs	Pre-famine	282	575	49.04	2.11	0.1465
Total	1,486	3,014	49.30			1,486	3,014	49.30		

n is the number of individuals with at least one LEH. N is the number in the sample. % is the frequency of n/N.

TABLE 2. Contingency table comparing LEH frequencies of developmental zones on teeth of birth cohorts formed in pre-famine (1954-1958), famine (1959-1962), and post-famine (1963-1974) birth cohorts. Data based on the presence LEH in six developmental zones on the mandibular canines.

Birth cohort	n	N	%		Birth cohort	n	N	%	Chi-square	p
Pre-famine	786	6,186	12.71	vs	Famine	641	3,937	16.28	25.40	0.0001
Famine	641	3,937	16.28	vs	Post-famine	2,006	16,874	11.89	55.50	0.0001
Post-famine	2,006	16,874	11.89	vs	Pre-famine	786	6,186	12.71	2.85	0.0916
Total	3,433	26,997	12.72			3,433	26,997	12.72		

Abbreviations are the same as those in Table 1.

many minor hypoplasia lines are trivial. They might not necessarily be related to clear-cut episodes of developmental disruption, while the stress signal may be clear when attention is restricted to the palpably indented major growth arrest lines (Corruccini et al., 1985). Second, the most affected individuals were missing from the sample, as they did not survive the famine. Thus, recovery from LEH-inducing stress ironically may be a sign of increased adaptability during the famine.

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CRYSTALLOGRAPHIC AND COLORIMETRIC ANALYSIS OF DENTAL ENAMEL

LJILJANA TIHAČEK-ŠOJIC, VLADIMIR MILIĆEVIĆ, AND MARIJA ĐURIĆ-SREJIĆ
Belgrade University, Faculty of Stomatology, Clinic for Prosthodontics (LT-S and VM) and Belgrade University, Faculty of Medicine, Institute for Anatomy, Laboratory of Anthropology (MĐ-S), dr Subotica 4/11, 11000 Belgrade, Yugoslavia

ABSTRACT Tooth color and the correlation of the composition of dental enamel with color were investigated in samples of teeth from two medieval Serb cemeteries. Differences in the composition of apatite crystals in the dental enamel of the two samples were found. Color ranges of teeth from the two samples differ in hues and chromas. This result suggests that enamel composition may have an influence on the color of teeth. The prevalence of chlorapatite in enamel causes tooth color to be closer to red and of higher chroma than teeth whose enamel consists of hydroxylapatite. No evidence indicated that soil ingredients were incorporated into the dental enamel of either sample.

INTRODUCTION

In this study we investigated tooth color and the correlation of tooth composition and color. The main inorganic elements of dental enamel are found in the form of apatite crystal, which comprises more than 90 percent of the enamel. Inorganic components significantly determine the color of teeth.

The color of teeth is not, of course, solely dependent on the optical properties of enamel. One of the main optical characteristics of enamel is translucency. Therefore, the layer of dentin situated under the enamel, which has its own optical properties, also influences the color of a tooth. Dentin is characterized by about 40 percent organic component (Arwill et al., 1969). In the case of a skeletal sample, the influence of dentin on tooth color is not important for two reasons. First, skeletal dentin does not have an organic component because the

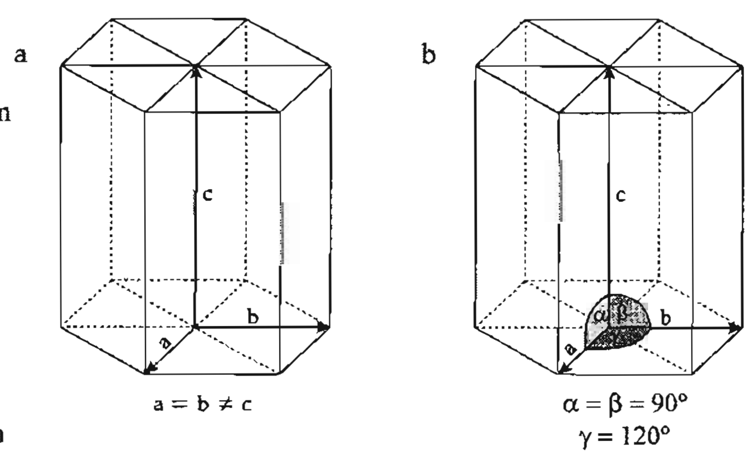

Fig. 1. Hexagonal structure of the apatite crystal.