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Enamel hypoplasia in an early medieval population of Prząsław (11-12th century), Jędrzejów municipality, Świętokrzyskie province, Poland

Hipoplazja szkliwa we wczesnośredniowiecznej populacji z Prząsławia (XI- XII w.), gm. Jędrzejów, woj. świętokrzyskie, Polska

Key words: enamel hypoplasia, weaning stress, Middle Ages

INTRODUCTION

Human teeth are a particularly important object of paleoanthropological and bioarchaeological analysis, with great potential in the identification of factors influencing living conditions, as well as in research on different adaptation strategies in prehistoric populations. Therefore, a comprehensive dental and anthropological analysis of teeth may be a method for assessing health and dietary habits, and, indirectly, the living conditions characteristic for prehistoric human populations determined by cultural and social factors.

Macroscopic analysis is usually focused on the quantitative indicators of physiological stress detectable on the surface of tooth crowns in the form of enamel hypoplasia. Such defects most often occur in the form of lines, grooves and pits of varying number and location, and sometimes may be accompanied by discolouration and opalescent spots [5,17,47]. Studies on changes in the morphology of enamel development require a standardized method for the identification of defects. The Commission on Oral Health, Research and Epidemiology, operating under the World Dental Federation (FDI), used the clinical picture of developmental disorders and the hard tissue mineralization process, both for individual and entire groups of teeth, to create the epidemiological index of developmental defects of dental enamel (DDE-Index), which is also applied in paleoanthropological research [2,5,19]. The DDE-Index helps to determine the frequency and severity of disorders, and their location and distribution on the labial/buccal and palatal/lingual surfaces of all teeth in the human oral cavity (fig.1).

Figure 1. Hypoplastic defects (horizontal grooves) on the maxillary incisors of fossilized material (phot. by P. Dąbrowski)

Modified DDE indices proposed by Clarkson and O'Mullane [6], Kaczmarek et al. [20] and other researchers have also gained great popularity, particularly because they are simpler to use and offer uncomplicated interpretation of collected data. When describing the DDE-Index several categories of defects can be distinguished,

of which the most frequently listed are opaque areas and pigmentary changes, and structural defects, i.e. enamel hypoplasia and aplasia [20, 23].

Some features of the enamel, such as high sensitivity of the currently formed part of the dental crown to stress factors, and sequenced and rhythmic forming, allow, by means of appropriate mineralization charts relevant for specific types of dentition, for the retrospective assessment of the biological age at which negative environmental factors affecting enamel growth and mineralization occurred [18, 42]. This is important in studies assessing the adaptability of prehistoric and historic populations to living conditions based on the skeletal indicators of physiological stress [40]. Hypoplastic defects identified in prehistoric populations are usually attributed to a modified diet and gastrointestinal disorders. Thus, studies on enamel hypoplasia in skeletal materials from archaeological sites, due to the exceptional durability of tooth crowns in the conditions of fossilization, can help to reconstruct the diet and, indirectly, the economic status of historic human populations, and to identify the health status of these populations [3, 8, 24, 26, 30, 32, 44, 49].

AIM

To identify the type of negative environmental factors and the time of their activity on skeletal material we set the following research aims:

1) to determine the frequency of enamel hypoplasia,
2) to characterize the types of hypoplastic defects,
3) to estimate the developmental age at formation of the earliest enamel hypoplasia.

MATERIALS

Archaeological work in Jędrzejów municipality, Świętokrzyskie province, Central Eastern Poland, was carried out in late 2011 and early 2012 by the archaeological company ARKADIA from Leszno. Bone material delivered to the Paleoanatomy Laboratory at the Department of Normal Anatomy, Wrocław Medical University, was excavated from 50 graves identified at the archaeological site Prząsław 1 (fig. 2).

Figure 2. Location of the archaeological site Prząsław 1, Central-Eastern Poland

Initially, the cemetery was relatively dated to the 11/12th century, based on the type of grave goods and available records in chronicles. Items found in graves included iron knives, glass beads, temple rings and pendants. The spatial arrangement of graves, the position of skeletal materials inside the graves, and the presence of glass and metal artefacts on the site were characteristic for the majority of medieval early-Christian burials identified in Western, Central and South-Eastern Poland, e.g. Słaboszewo 14th c. [39], Ostrów Lednicki (12-14th c.) [33], Czersk (12th c.) [4], Złota near Pińczów 11th c. [50] and Złota, near Sandomierz (11-12th c.) [12]. The skeletons inside graves were in anatomical arrangement of bones along the E-W axis, with a slight dislocation towards the NW-SE axis (fig.3).

Figure 3. Grave no. 50, bones of the upper extremities positioned on the pelvis, Prząsław 1 site. (phot. by K. Nowaczyk)

During the excavations at the cemetery 41 graves with adult skeletons were identified (22 male and 19 female). In addition, bone materials from individuals classified to the juvenis age group and the remains of 7 infants were identified (tab. 1). Bone and tooth preservation quality was estimated as satisfactory.

Tab. 1. Sex and age structure of skeletons found at the cemetery in Prząsław (11-12th c.).

	Sex			Total
	Male	Female	Unidentified	
Infans I	-	-	5	5
Infans II	-	-	2	2
Juvenis	1	1	-	2
Adultus	17	13	-	30
Maturus	5	6	-	11
Total	23	20	7	50

Further analysis was carried out only for teeth from adult male and female individuals. In total dental assessment was performed for 795 permanent teeth (tab. 2).

Table 2. Number of permanent teeth in the categories of biological age for individuals buried at the cemetery in Prząsław (11-12th c.)

AGE /SEX		Maxilla								Mandible								Total
		M3	M2	M1	P2	P1	C	I2	I1	M3	M2	M1	P2	P1	C	I2	I1	
Juvenis	male	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	31
	female	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	31
	Total	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	62
Adultus	male	13	18	21	24	24	26	10	12	25	30	13	23	25	14	13	10	301
	female	18	15	21	19	20	20	16	14	19	22	10	18	20	15	15	14	276
	Total	31	33	42	43	44	46	26	26	44	52	23	41	45	29	28	24	577
Maturus	male	6	6	4	3	3	5	5	5	8	9	4	7	5	4	3	2	79
	female	4	5	5	4	4	6	5	4	7	8	3	4	6	6	2	2	75
Total		10	11	9	7	7	11	10	9	15	17	7	11	11	10	5	4	154

METHODS

Bone materials were analysed using standard methods for anthropological, paleopathological and odontological aspects, and then catalogued. The anthropological identification of sex (adult individuals) and age-at-death (children) was carried out based on commonly used skeletal and dental sets of diagnostic features. These included morphological diagnostic features of the skull, pelvic bone, long bones, closure of cranial sutures, involutive changes in the pubic symphysis, tooth eruption and wear of permanent teeth [1, 5, 31, 35, 37, 41]. The hypoplastic changes on the tooth crown were assessed using the international scale (DDE-Index) designed by the Commission on Oral Health (Technical Report of the FDI Commission on Oral Health, Research and Epidemiology) [2]. Age at the formation of enamel hypoplasia was estimated using Massler's mineralisation chart modified by Swärdstedt [17], and a simple regression model [18]. The CEJ-EH distance was measured with accuracy +/- 0.01 mm using a digital caliper (Mitutoyo 150 digimatic). Statistical analysis was carried out using a package from STATISTICA-Statsoft, Inc., Tulsa, USA. Qualitative features were analysed using a test for two structural parameters and the chi2 test. Differences in mean values for features scored on an interval scale were analysed using the independent samples t-test. Normality of distribution was analysed using the Kolmogorov-Smirnoff test. The statistical significance in the carried out analyses was set at $p<0.05$ [45].

RESULTS

The analysis of teeth from individuals younger than adultus revealed enamel hypoplasia in 2 individuals from the age group infans II. In each child 2 deciduous medial incisors of the maxilla with defects on the incisal edge were identified. The analysis of all teeth with developmental enamel defects (from adult males and females, both alveolar arches) revealed an almost identical number of permanent tooth crowns with identified enamel hypoplasia in each compared group (tab. 3). In addition, enamel hypoplasia other than linear was observed only in teeth from male individuals. Among 18 teeth obtained from the maxilla enamel developmental defects in the form of pits were found on the crowns of 3 incisors, which accounts for about 5% of all permanent teeth with enamel hypoplasia confirmed by macroscopic analysis.

Tab. 3. Number of teeth with enamel hypoplasia in adult individuals

Teeth with hypoplasia	Males			Females			Total
	Maxilla	Mandible	Total	Maxilla	Mandible	Total	
	18	9	27	17	11	28	55

In further analysis only a dichotomical classification was considered, i.e. absence or presence of a defect in an individual, regardless of a defect type. Thus, the analysis was focused on an individual in which at least one hypoplastic tooth was found, and to obtain a full image of stress episodes all teeth available in each case were

assessed. This approach has been recommended by some researchers, e.g. Skinner and Goodman [46], for the assessment of adaptive success in human populations living under different socio-economic conditions.

Among 41 identified adult individuals hypoplastic enamel defects were found in about 34% of analysed cases. Much higher frequency of enamel hypoplasia was found in females (42%) when compared to males (27.3%) and the differences were statistically significant at $p<0.05$ (tab. 4).

Tab. 4. Enamel hypoplasia in males and females from a medieval population of Prząsław

Hypoplasia	Sex		Total
	Male	Female	
	6/22 (27.3%)	8/19 (42.1%)*	14/41 (34.2%)

p – difference between sexes, * - $p<0.05$

The regularity of the growth process is a feature of enamel with a strong potential for interpretation, and is particularly useful in the retrospective assessment of developmental disorders during enamel formation. Metabolic disorders always strongly affect the area of the tooth crown, which at a given moment demonstrates increased activity of ameloblasts [17, 29]. As recommended by Italian researchers, the reconstruction of timing in disorders of enamel development in our analysis included only data on the time at formation of the earliest hypoplasia in the studied teeth, regardless of the tooth type, to identify the earliest moment when the body responded to stress [7, 36]. We assumed that the occurrence of a stress episode was at the same time the developmental age of the individual.

To reconstruct the chronology of hypoplasia we used standards for enamel development created by Massler and later modified by Swärdstedt [15], and a model of simple regression proposed by Goodman and Song [18]. This enabled us to estimate the age at the occurrence of a stressor causing enamel defects with an accuracy of +/- six months, and to estimate the mean age at which the stressor occurred causing disorder in the activity of ameloblasts. The analysis revealed that the population of Prząsław was most susceptible to the formation of enamel defects at age 2.5 to 3.5 years. These findings were made based on the increased number of individuals with enamel defects in this age group compared to all individuals with identified linear enamel hypoplasia. Interestingly, increased frequency of enamel hypoplasia was found in male individuals six months earlier when compared to the time interval of increased frequency of linear enamel hypoplasia in female individuals. In both cases results indicated that the formation of enamel defects occurred at an age following the weaning period (tab. 5).

Tab. 5. Age at formation of the earliest hypoplastic defect in males and females from Prząsław (11-12th c.)

Age at formation of the earliest hypoplastic defect	Sex	
	Male	Female
2.0 – 2.5	-	1
2.5 – 3.0	4	2
3.0 – 3.5	2	5

Differences between mean values for age at stress episod*e* in male and female individuals were not statistically significant. Therefore, the mean age at formation of enamel hypoplasia calculated for the whole studied group of adult individuals from Prząsław was 3.32 years (tab. 6).

Tab. 6. Mean age at formation of the earliest enamel hypoplasia in males and females from Prząsław (11-12th c.)

Mean age at formation of enamel hypoplasia	Sex		
	Male	Female	Total
	3.15	3.5	3.32

DISCUSSION

Researchers evaluating the status and biological changes in prehistoric and historic populations caused by environmental stressors have classified pathologies of the masticatory organ as quite sensitive indicators of the body's response to adverse living conditions. The most common pathologies include genetically determined defects, infections, and degenerative and developmental defects [13, 15, 19, 29]. Of these developmental defects are recorded in macroscopic analysis in the form of enamel hypoplasia on the tooth crowns. The analysis of skeletal material from the medieval cemetery in Prząsław demonstrated that enamel hypoplasia in permanent teeth occurred in 34% of adult individuals. This rate is slightly lower than that found for several selected series of bone material from medieval Poland, representing rural and urban populations (tab. 7).

Tab. 7. Enamel hypoplasia in medieval populations in Poland

Study site	Number of analysed individuals	Number of individuals with enamel hypoplasia	% of individuals with enamel hypoplasia
1. Sypniewo (12-13th c.)	113	44	38.90
2. Gródek n. Bugiem (13-15th c.)	196	94	47.95
3. Wrocław (12-14th c.)	123	50	40.65
4. Prząsław (11-12th c.)	41	14	34.2

1. Staniowski et al. 2004; 2 and 4. Authors' own data; 3.Kwiatkowska (2005)

The paleoanthropological literature also provides research data on materials excavated in Slovakia (Borovce, 8-12th c.) Croatia (Nova Rača, 14–18th c.) and Serbia (Gracanica and Dici, 14-19th c.) which are comparable to findings from odontological analysis for individuals buried at the cemeteries in Prząsław [25]. It is worth noting that the frequency of enamel defects found for Prząsław, regardless of the size of the analysed sample, may be associated with biological, endogenous and environmental factors, and also with the life style and nutrition of the studied population.

The significantly higher number of teeth with hypoplastic defects in women compared with men may be explained by the ecosensitivity of the male sex, but also by social determinants preferring parental investments focused on ensuring better economic status, health and nutrition (including breastfeeding) and caring behaviour for boys [14, 19, 29, 34]. However, some researchers reported that there is no clear model describing the effects of stressors which would suggest the increased sensitivity of ameloblasts in men or women. This hypothesis was supported by studies on prehistoric and historic bone materials for which either no statistically significant differences in the frequency of enamel hypoplasia were found between sexes, or higher frequency of hypoplastic defects in male individuals was demonstrated, in contrast to the population of Prząsław [9, 22, 30, 48, 49].

When assessing the living conditions and health in the early medieval population of Prząsław it should also be emphasized that the population of the early medieval village of Prząsław belonged to the category of bond servants providing agricultural work for the Jedrzejów church and monastery complex located nearby [38]. People from this population also suffered from skeletal disorders caused by overload, largely resulting from strenuous physical work in which the social class of low economic status was typically involved. Data obtained in previous paleopathological studies on bone material from Prząsław pointed out difficult living, health and occupational conditions in this population with reference to living conditions and health, reconstructed using biological indicators for other rural populations from Poland [10]. These conditions could have had a significant effect on the biological status of people living in Prząsław.

Enamel growth, formation and disorders are processes of a cyclical nature. They are described by the charts of enamel development on tooth crowns [15, 19, 42, 43] and are associated with disorders in ameloblast activity. Therefore, stress factors can be identified by the retrospective determination of their occurrence, which indirectly allows for the assessment of living conditions during childhood in a studied population [21, 25, 49]. The lower incidence of dental enamel hypoplasia found for the population of Prząsław, characterised by socio-economic living conditions comparable to other rural populations, may indicate a slightly different life style, including a higher level of parental care and better health of children, and through this better health and living conditions during childhood, despite the negative environmental factors to which adults from this population were exposed. This hypothesis can be

indirectly supported by the fact that the mean age at formation of the earliest enamel hypoplasia in Prząsław was 3.32 years (tab. 6), and this defect most frequently occurred at age 3.0 to 3.5. years (tab. 8).

Tab. 8. Peak age at stress for enamel hypoplasia in the population of Prząsław versus other medieval populations in Poland

Population	Dating	Peak age at stress
1. Sypniewo	12-13th c.	3.5 - 4.0
2. Milicz	12-14th c.	2.0 - 2.5
3. Gródek n. Bugiem	13-15th c.	3.0 - 3.5
4. Słaboszewo	14-17th c.	3.0 - 4.5
5. Wrocław	12-14th c.	2.5 - 3.0
6. Kołobrzeg	14-18th c.	1.5 - 2.5
7. Prząsław	11-12th c.	3.0 - 3.5

1. Staniowski et al. 2004; 2. Dąbrowski, Gronkiewicz 1996; 3 and 7. Authors' own data; 4. Kozak,. Krenz-Niedbała 2002; 5. Kwiatkowska (2005); 6. Krenz, Piontek 1996

The peak age at stress (3.0- 3.5 years) identified for the population of Prząsław is comparable to that found for several selected rural and urban medieval populations in Poland (tab. 3). It also corresponds with the period of childhood for which the less significant influence of weaning stress has been emphasized, but instead a stronger influence of infectious factors in the formation of linear enamel hypoplasia. Weaning and the emergence of post-weaning factors in prehistoric and historic populations was found usually at the age of 2 to 4 years [25, 42, 49]. Considering the age at which hypoplastic defects were most frequent in the studied population, and the historical background, health and socio-economic status, we can conclude that the weaning stress occurred relatively late, and its influence on enamel development might have been enhanced by synergistic environmental factors such as infectious and parasitic diseases or malnutrition. Other factors are likely, as epidemiology attributes enamel hypoplastic defects to about 100 causes that may emerge during the developmental period. These include mineral deficiencies (calcium, phosphorus, magnesium, fluoride), vitamin deficiencies (A, C, D, K), febrile diseases, childhood diseases, infectious diseases (rubella, measles, varicella, diphtheria, scarlet fever, pertussis), endocrine disorders, local injuries, and the previously mentioned weaning stress [11, 17, 28, 46]. At the same time, because of non-specific response of enamel to stressors, many researchers analysing the defects of tooth crowns in prehistoric or historic populations have suggested that the presence of weaning stress may be one of the most important factors in the postnatal period, influencing enamel development disorders, but mainly until the age of 2 years [13, 28, 46]. However, our

retrospective analysis to estimate the age at which enamel developmental defects occurred in the population of Prząsław indicated a rather limited effect of weaning stress. This suggests, in relation to studies by other authors, that developmental enamel defects might have been caused by the combination of late weaning stress and adaptive processes associated with the switching to the "adult diet" and the accompanying intestinal disorders, leading to increased susceptibility to viral infections [25, 32, 43].

CONCLUSIONS

Despite the limited amount of analysed skeletal material, the pattern of enamel developmental defects established in our study and expressed as the frequency of enamel hypoplasia, and a retrospective assessment of the biological age of the emergence of stress episodes in adult population of medieval Prząsław, suggests that the quality of life in early childhood was strongly affected by factors determining health, physical fitness and living conditions. The peak age at stress, comparable to that found for other rural medieval populations in Poland, shows the positive effect of parental care, but also the combined influence of weaning stress and the post-weaning period in young age groups. All these factors affected the frequency of enamel hypoplasia, which is associated with the low social and economic status of the studied population of farmers. The results, despite of the non-specific nature of factors causing enamel hypoplasia, may indicate, with some generalization, the poor health and living conditions in medieval Prząsław, as confirmed by archaeological data and previous attempts to reconstruct the health status of the early medieval population based on the analysis of vertebral pathologies in bone material.

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ABSTRACT

The aim of the study was to determine the frequency of enamel hypoplasia, and to estimate the developmental age at formation of the earliest hypoplastic defect in the permanent teeth of individuals buried at the early medieval cemetery in Prząsław. Analysis included teeth from 41 adult individuals (22 male and 19 female). In total, assessment was performed for 795 permanent teeth. Bone and tooth preservation quality was estimated as satisfactory. Enamel hypoplasia in permanent teeth was found in 34% of adult individuals, which is slightly lower than the frequency rate found in other studies on historic bone materials. The higher frequency of teeth with hypoplastic defects in women compared with men may be explained by the higher ecosensitivity of the male sex, but also by economic, social and cultural preference factors and parental investments. The retrospective analysis of stress episodes in early childhood revealed the increased frequency of factors disturbing ameloblast metabolism, mainly in the post-weaning period. This indicated that the mean age of enamel hypoplasia occurrence was at over 3 years. Findings from the study, despite the non-specific nature of aetiological factors for enamel hypoplasia, may suggest poor health and living conditions in medieval Prząsław.

STRESZCZENIE

Celem pracy było określenie częstości występowania hipoplazji szkliwa oraz oszacowanie wieku rozwojowego powstania „pierwszej hipoplazji" w uzębieniu stałym wśród mieszkańców pochowanych na wczesnośredniowiecznym cmentarzysku w Prząsławiu Prząsłąwia. Materiał badawczy stanowiło uzębienie 41 osobników dorosłych, w tym 22 płci męskiej i 19 płci żeńskiej. Łącznie badaniem

objęto 795 zębów stałych. Stan zachowania kośćca oraz uzębienia określono jako zadowalający. Uzyskana częstość występowania zmian hipoplastycznych szkliwa zębów stałych wyniosła 34% i była nieznacznie niższa w stosunku do wartości odsetkowych uzyskanych w badaniach innych kostnych materiałów historycznych. Częstsze występowanie zębów z defektami hipoplastycznymi u kobiet w porównaniu z uzębieniem mężczyzn może być wynikiem zarówno większej ekosensytywności osobników płci męskiej w porównaniu do osobników płci żeńskiej jak i uwarunkowań ekonomicznych, społeczno-kulturowych w odniesieniu do preferencji oraz inwestycji rodzicielskich. Ocena retrospektywna epizodów stresowych we wczesnym dzieciństwie ujawniła wzrost natężenia czynników zaburzających metabolizm ameloblastów głównie po okresie weaning. Wskazuje na to średni wiek powstania hipoplazji szkliwa, wynoszącym ponad 3 lata. Uzyskane wyniki, mimo nieswoistego charakteru czynników etiologicznych hipoplazji szkliwa mogą wskazywać na występowanie trudnych warunków zdrowotnych i bytowych w średniowiecznym Prząsławiu.

Artykuł zawiera 34422 znaki ze spacjami