Aspects of teeth from archaeologic sites in Sweden and Denmark

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The purpose of this study was to examine ground sections of primary second molars and permanent first molars from the same jaws. Teeth from 11 individuals were collected from archaeologic sites in Sweden and Denmark. Longitudinal buccolingual sections were examined in a polarization light microscope and in a Philips scanning electron microscope (SEM). The seven teeth from Sweden appeared to have been subjected to environmental influences at their burial site, which had affected both the dentin and the enamel. The teeth from the Danish sites had a normal color, and no disintegration of the dentin was seen. The general morphologic appearance was normal in all primary and permanent teeth. The position of the neonatal line indicated a normal full-term gestational age. The observed accentuated incremental lines in both the primary and permanent enamel suggested periods of dietary changes, possibly related to periods of illness. SEM images of the surface area of the Swedish teeth showed an extremely porous enamel surface with severe changes in the prism structure as an effect of acid penetration. The Danish teeth did not show any marked changes in the enamel. □ *Archaeology; dentin; enamel; polarized light microscopy; scanning electron microscopy*

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Macroscopic and microscopic investigations of dental hard tissues have the potential of being a valuable tool in archaeologic research. Since disturbances to dental enamel during its formation will remain as aberrations in the tissue, enamel may serve as an indicator of stress caused by the hazards and insufficiencies of society, such as malnutrition, diseases, and insanitary conditions (for an overview see Ref. 1).

The primary teeth start to mineralize in the 19th week of fetal life and continue up to 3 years of age. This provides a possibility to study mineralization disturbances even during the period before birth. The neonatal line, an incremental line in the dental hard tissues that is formed at birth, thus makes it possible to distinguish the prenatal from the postnatal enamel.

Linear enamel hypoplasia (LEH) is a common finding on teeth from prehistoric populations (1). Environmental stressors like malnutrition and diseases are held responsible for the hypoplasias, but maternal stress could also have been a factor in populations with a high infant mortality. LEH has been used extensively in attempts to reconstruct prehistoric lifestyles, especially during transitional periods such as the transition from hunter-gatherer to agriculturist. Linear enamel defects are 'chronologic hypoplasias'. The estimated age of occurrence in many prehistoric populations has a peak frequency in the 2- to 4-year interval (indicating postweaning stress), whereas the frequency is low in the first year of life (1). It also means that LEH is more rarely found on primary teeth and permanent first molars than on canines and premolars, which are formed later in childhood.

Different types of hypoplasia have been described (2). Besides the types visible on the enamel surfaces, microscopic alterations are seen on ground sections of teeth. Accentuated or abnormal striae of Retzius may or may not be associated with the macroscopic types of enamel hypoplasia (3). Microscopic changes are also to be expected in populations with a high frequency of enamel hypoplasia in the permanent dentition (LEH and/or pit patches). Previous studies have shown that the neonatal line is almost always present (4–8). Prenatal abnormal striae of Retzius are rare, whereas postnatal accentuated striae of Retzius occur quite often, and they are commoner in children with a history of systemic diseases than in healthy children (9).

The purpose of this study was to examine ground sections of primary second molars and permanent first molars from the same jaws from skulls found in five burial sites, one in Sweden and four in Denmark. It was intended to study the microscopic alterations of the enamel structure that might occur in the teeth with no macroscopic defects and to study any effects of the burial sites on the teeth.

Materials and methods

Teeth from 11 individuals were collected from five archaeologic sites, one in Sweden and four in Denmark (10–12). Radiographs were taken, and dental stone models of the teeth were made before the teeth were dissected from the jaws. From all but one case, both a permanent

Table 1. Dental number of the examined teeth, estimated age in years, estimated period of the skulls, and location of the archaeologic findings (DK = Denmark; SW = Sweden) (Refs. 10, 11, 23, 24)

No.	Permanent tooth	Primary tooth	Estimated age, years	Period	Site
1	46	85	9	3000–1800 B.C.	(DK, Zealand)
2	16	64	3	3000–1800 B.C.	(DK, Zealand)
3		74	5	A.D. 200	(DK, Simonsborg)
4	36	74	4	A.D. 1000	(DK, Trelleborg)
5	16	55	4	2300–1800 B.C.	(SW, Enköping)
6	16	55	5	2300–1800 B.C.	(SW, Enköping)
7	46	85	8	2300–1800 B.C.	(SW, Enköping)
8	36	75	4.5	2300–1800 B.C.	(SW, Enköping)
9	36	75	5.5	2300–1800 B.C.	(SW, Enköping)
10	16	85	10	2300–1800 B.C.	(SW, Enköping)
11	36	85	4	2300–1800 B.C.	(SW, Enköping)

and a primary tooth were obtained. The details of the collected material are given in Table 1.

In the late Neolithic period a small village existed near the gallery grave at Annelund/Enköping (12). The site was situated by the sea at the inner parts of lagoon-like surroundings. People utilized several resources. They were primarily farmers, but they also had domestic livestock (cattle, swine, and goats/sheep). It is likely that maritime hunting and fishing also took place, although no bones of wild animals or fishbones have been found (12).

Radiographs were taken from each jaw. An age estimation for each individual was made from the radiographs, on the basis of the age determination method described by Gustafson & Koch (13).

Each tooth was carefully dissected from the upper or lower jaw, respectively. After it had been embedded in Epofix, longitudinal buccolingual ground sections with a thickness of 100 μm were prepared in a Leitz low-speed saw microtome (14). The sections were examined dry in air and after alcohol imbibition in a polarization light microscope, using strain-free objectives.

Scanning electron microscopy

The sections were etched with 30% phosphoric acid for 1 min, carefully rinsed with distilled water, and dried. After being mounted on sample holders the specimens were sputtered with gold and investigated in a Philips scanning electron microscope (SEM), 515 at 15 kV.

Results

The mean age of the individuals according to the age estimation was 5.6 years, with a range of 3–10 years (Table 1).

Primary teeth

The results of the polarized light examination are given in Table 2. The general morphologic appearance was normal in all teeth, and a neonatal line could be discerned, thus enabling the discrimination of the prenatal enamel from the postnatal. In one case the neonatal line was wider than normal. The neonatal line was found in all sectioned primary teeth. The position of the neonatal line indicated a normal full-term gestational age. In one case thin prenatal incremental lines were seen. In 9 of the 11 samples, postnatally located incremental lines were found corresponding to an age range of 1–2 years. In two cases incremental bands were found close to the neonatal lines.

The prenatal enamel appeared to have a microporous zone, a zone with less well-mineralized enamel, extending

Table 2. Morphologic findings in the enamel of the primary teeth examined

No.	Tooth	Appearance of incremental lines
1	85	Two thin prenatal incremental lines. One wide and three thin incremental lines in the postnatal enamel
2	64	
3	74	One postnatal incremental line shortly after birth
4	74	Wide neonatal line. Six postnatal incremental lines
5	55	Thin postnatal incremental lines
6	55	One incremental line shortly after birth, two postnatal incremental lines
7	85	Three distinct postnatal incremental lines in outer half of the enamel thickness
8	75	
9	75	One postnatal incremental line shortly after birth, three postnatal incremental lines in the middle of the enamel thickness
10	85	Four incremental lines in the inner third of the postnatal enamel
11	85	Three postnatal incremental lines in the outer half of the enamel

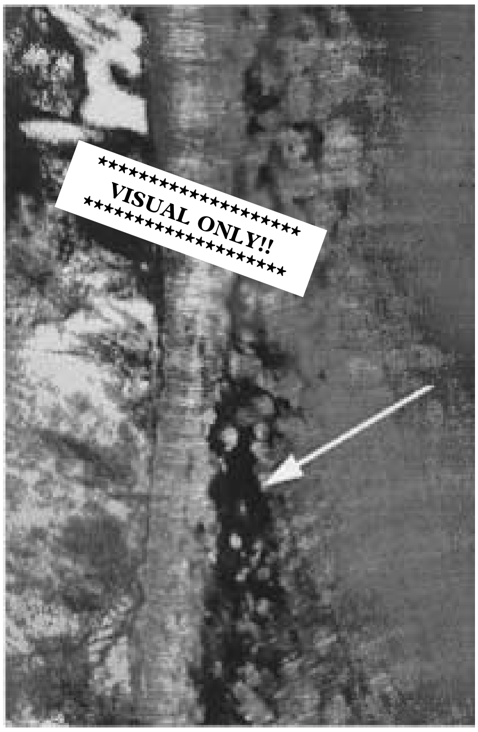

Fig. 1. Ground section seen in polarized light showing interglobular dentin in a primary molar (arrow).

Fig. 2. Ground section of a permanent tooth from the Enköping material showing changes in the enamel due to environmental effects at the burial site. Note the destruction of the dentin and the fan-shaped dark areas in the enamel due to a probable acid influence from the burial site.

over the neonatal line. The remaining part of the enamel had a normal degree of mineralization.

When the dentin could be analyzed in the polarized light microscope, interglobular dentin was noted in connection with the mantel dentin. This was particularly evident in the Danish material (Fig. 1).

The occlusal surface of the primary molars was abraded to a flat surface.

Permanent teeth

The results are summarized in Table 3. The overall morphology of the enamel, as seen in polarized light, appeared to have a normal structure. However, in the case of a heavy environmental influence, as with the sample from Enköping, changes in the enamel were observed (Fig. 2). Incremental lines were found in all teeth, sometimes visible as wide hypomineralized bands (Fig. 3). The lines correspond to a range of 2–4 years of age.

The dentin of the permanent molars also showed areas of interglobular dentin, which confirms the findings in the primary molars from the same individuals.

Postmortem changes

The seven teeth from Enköping appeared to have been subjected to environmental influence at their burial site, which had affected both the dentin and the enamel. The

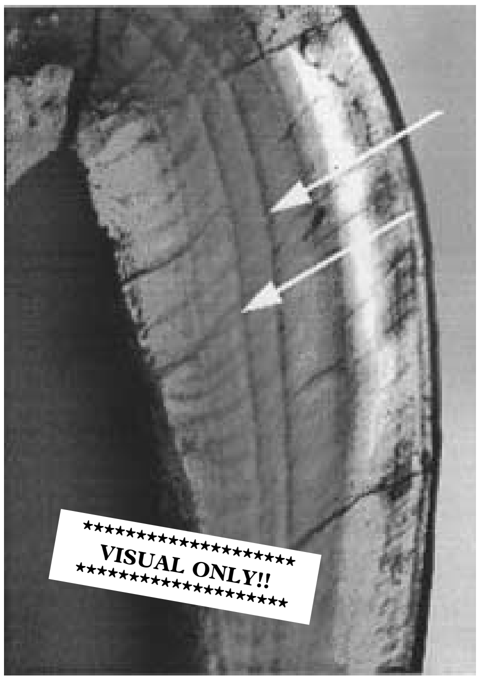

Fig. 3. Hypomineralized lines and bands seen in the enamel of a permanent tooth (arrows pointing at wide incremental bands). The ground section was examined in polarized light.

Table 3. Morphologic findings in the enamel of the permanent teeth examined

No.	Tooth	Appearance of incremental lines
1	46	Nine incremental lines
2	16	Two wide hypomineralized bands, a large number of distinct incremental bands
4	36	Two incremental lines shortly after birth
5	16	One wide incremental line in the middle of the enamel thickness
6	16	Four incremental lines in the middle of the enamel thickness
7	46	Three incremental lines in the inner third of the enamel thickness
8	36	Three incremental lines in the inner half of the enamel, two incremental bands in the middle of the enamel thickness
9	36	Two distinct incremental lines in the middle of the enamel thickness
10	16	Two incremental lines in the middle of the enamel thickness
11	36	Three incremental lines in the outer half of the enamel thickness

changes were seen in both primary and permanent teeth (Fig. 2). The dentin had disintegrated and had to a large extent fallen apart. The enamel was affected both from the outside and from the inside owing to the loss of dentin. Both the intact teeth and the sections had a brownish discoloration. However, imbibition in alcohol made it possible to examine the morphology of the enamel. The teeth from the Danish sites appeared to have a normal color, and no disintegration of the dentin was seen, as in the Swedish material. However, the dentin appeared to have a homogeneous structure, showing no or few dentinal tubules.

Scanning electron microscopic findings

In polarized light the two specimens from the Swedish material appeared to have a brown discoloration in the enamel and a collapse of the dentin. In incident light the brown color of the hard tissues remained.

In the SEM analysis the Hunter–Schreger bands were readily seen. The bands appear as an effect of changes in the prism directions. No relation was seen between the main structures of the prisms and the morphologic changes seen in the polarized light microscope.

Images from the surface areas show an extremely porous enamel surface with prisms that were severely changed. Deeper into the enamel the porous appearance and the changes in the prisms become less pronounced. The crystallites are readily seen in the deeper part of the enamel, whereas in the outer parts of the enamel the crystallites are less distinct (Fig. 4). It is evident from the SEM examination of the enamel that a slowly progressing penetration by acids from the outside had taken place, resulting in destruction of the prisms and the crystallites. The appearance in the polarized light microscope thus corresponds not only to an optical phenomenon but also to a breakdown of the enamel.

The other tooth in the Swedish material had a similar appearance but also showed some other structural and chemical changes in the enamel. In the middle part of the enamel the prism structure appeared to be thin and porous (Fig. 5). The prisms had a petrified appearance without any evidence of crystallites.

The dentin showed filled dentinal tubules. The overall appearance gave the impression of a tightly packed structure partly with holes and porous areas.

The two Danish teeth appeared to have a normal enamel structure and a normal enamel surface. However, the prisms in these specimens also looked slightly petrified compared with normal enamel. The prisms close to the dentin–enamel border looked more compact than those close to the surface.

The dentin of the Danish teeth had a compact appearance with a porous band across the tooth. Dentinal tubules were found in the compact-looking dentin (Fig. 6).

Discussion

This study has shown evidence of stress to the mother and the child after birth, recognized as incremental lines in the enamel. Furthermore, postmortem changes in enamel and dentin have been shown to result from environmental effects on the dental hard tissues.

The neonatal line was found in all sectioned primary teeth, which is in accordance with findings from modern materials (4–8), and the overall morphologic appearance

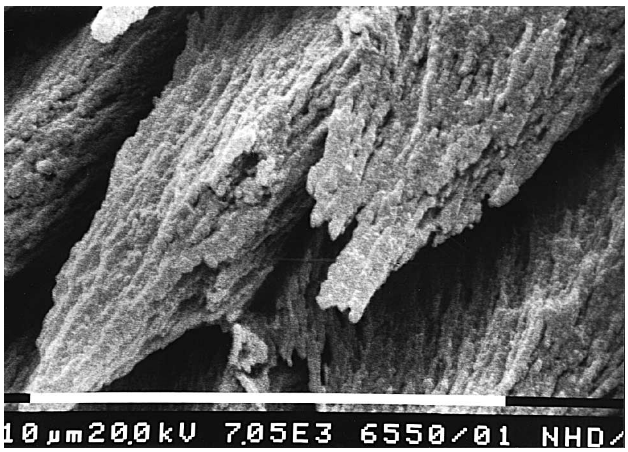

Fig. 4. Scanning electron microscope image of a ground section of a tooth from the Swedish material showing the structure of prisms and crystallites of the inner enamel (magnification, ×7000).

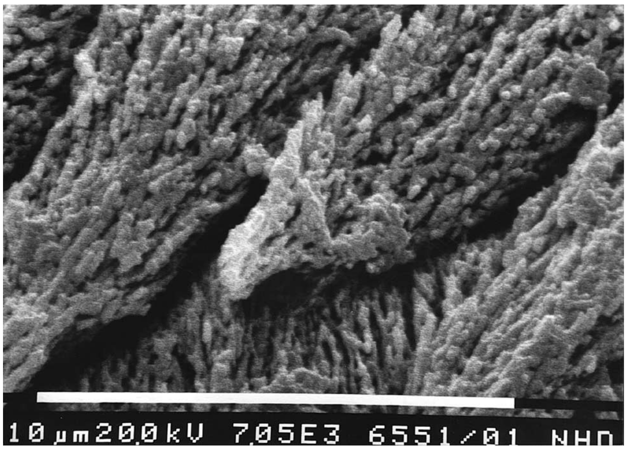

Fig. 5. Ground section of a tooth from the Swedish material showing thin and porous enamel prisms (magnification, ×7000).

thus did not differ from that of normal modern primary enamel (4–8).

The common occurrence of marked incremental Retzius lines in the primary second molars and permanent first molars indicate mild disturbances of enamel formation during the first 1 or 2 years of life.

Although severe stressors were present in the population, it is likely that infants were less severely affected by seasonal food shortages than older children and were in part protected against contagious diseases by mother's milk before weaning.

The odontologic study also indicates that the Annelund people belonged to a farming community. The attrition pattern differed from that of the earlier Mesolithic hunters in southern Scandinavia (11). It is assumed that hunting was very important in central Sweden during an earlier Neolithic period, the single-grave period (15). The populations were passing through a transitional stage of change from hunter to farmer and often experienced changes in ecologic relationships that altered their disease pattern (16, 17).

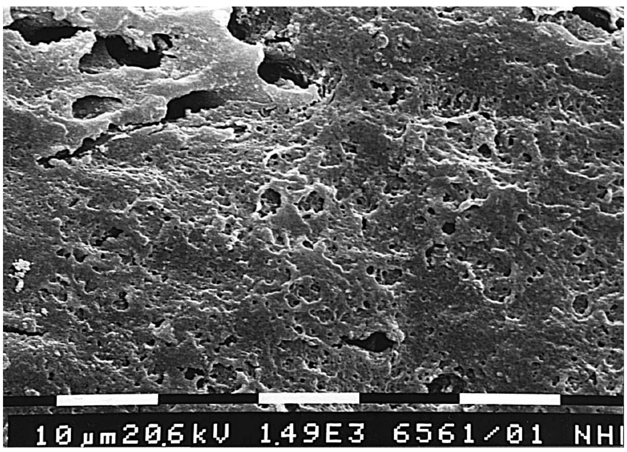

Fig. 6. Scanning electron microscope image of a ground section of a tooth from the Danish material showing dentin with a compact appearance and areas with pores (magnification, ×1000).

The abundance of enamel hypoplasias in this material can be explained by the fact that the highest frequency of macroscopic enamel hypoplasias was found on the primary incisors and canines. Therefore, it is unlikely that any such enamel aberrations would be found in a limited number of primary molars. Nevertheless, it could be expected that calcium disorders in children living under primitive conditions could manifest themselves in the degree of mineralization and, in more severe cases, even make the ameloblasts more prone to disturbances. In several studies of past human populations, high frequencies of enamel hypoplasias have sometimes been reported (1). One must thus bear in mind that symmetric and chronologic enamel hypoplasias may be indicators of a systemic disturbance, whereas single or non-chronologic enamel hypoplasias could reflect local traumatic events (4–8, 18, 19). Furthermore, hypoplasias found on the canines appear to be a normal anatomic variation also found in modern investigations (7).

The presence of interglobular dentin has been explained by impairment of the phosphate metabolism in a normocalcemic state (20, 21). It is evident that during periods of life the children had systemic disorders influencing both the calcium and phosphate homeostasis. It was also noted that, to a great extent, the pulp chambers appeared obliterated.

The occlusal surface of the primary molars was abraded to a flat surface, indicating that the consumed food material contained abrasive elements. This might also explain the pronounced obliteration of the pulp chambers. It is likely that much of the food was hard and sometimes grit-contaminated. The flat attrition facets sometimes found also indicate that bruxism existed in those days.

It is important to realize that the structural defects observed in this material do not reflect the living conditions of the population in general. The highest frequency of enamel defects is usually found among individuals who died in childhood or at a juvenile age.

The seven teeth from Enköping appeared to have been subjected to environmental influences at their burial site, which had affected both the dentin and the enamel. The changes in the enamel seemed to suggest that the environment at the burial site was acidic, as both the teeth and the sections had a brownish discoloration. The teeth from the Danish sites appeared to have a normal color, and no disintegration of the dentin was seen, unlike the Swedish material. However, the dentin appeared to have a homogeneous structure, showing no or few dentinal tubules. It is not unlikely that dentin, with a different and substantially greater organic content than enamel, would undergo changes over time. The character of these changes from the structural or chemical point of view is not known.

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