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TEMPORAL CHANGES IN FREQUENCY OF ENAMEL HYPOPLASIA IN THE MIDDLE EUPHRATES VALLEY (SYRIA)

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Abstract: The Middle East is an important region for archaeological as well as anthropological research. Excavations which take place in this region are aimed at providing answers for numerous significant issues connected with the origins of human civilisation. The research of a French-Syrian team and Polish bio-archaeologists, conducted in the area of the Middle Euphrates (East Syria) have provided interesting fossil material which served as a basis for the attempted reconstruction of a historical population which inhabited the area from the Age of Bronze up to the early Middle Ages. The aim of the research was to establish the relationship between the occurrence of the hypoplasia of tooth enamel and malnutrition, understood mainly as a low- protein diet.

Theoretically then, the frequency of hypoplasia in the areas along the middle Euphrates should be higher in the late Bronze period and in the beginning of the Neo-Assyrian period – the times identified with the Aramaic invasion and the great agrarian crisis. It should also be higher during the Roman and Byzantine periods. On the other hand, hypoplasia should be less frequent in the populations from the periods of relative welfare and stability, i.e. the early and middle Bronze, and the latter Neo-Assyrian period. Finally, it should rarely occur in the Islamic period, characterised by political stability.

The presented research concerns the analysis of hypoplasia from three archaeological sites: Tell Ashara, Tell Masaikh oraz Gebel Mashtale. The dating of the sites embraces the period from the Middle Bronze Age up to the Islam Period.

The performed analyses show that the frequency of hypoplasia directly corresponded with the political and social situation in the Ashara region. Historical data, along with the found dental material show that during the periods of political instability, which led to food crises, the frequency of hypoplasia increased. On the other hand, in the periods noted for greater stability and welfare, proportion of individuals affected by hypoplasia visibly decreased.

Key words: enamel hypoplasia, Middle Euphrates, stress, dental anthropology

Introduction

The Middle East is an important territory for archaeological research. Excavations which take place there are aimed at providing answers to many important questions concerning the origins of human civilisation. The area along the Middle Euphrates, the territory of Northern Mesopotamia, where the trade route from the Levant to Anatolia

must have led, is considered one of the most interesting localities in this respect. Research in this region is carried out by a French-Syrian team, headed by Olivier Rouault from the University Lyon 2 – Lumière and Maria Grazia Masetti-Rouault from Ecole des Hautes Etudes, Paris. Polish bioarchaeologists are also involved in the project.

The middle part of the river Euphrates runs through the area which in the 19th century was still rather scarcely populated. Land cultivation is possible only in a very narrow zone, in the closest vicinity of the river, so the people who inhabited this region were mainly nomadic or semi-nomadic shepherds. It is worth remembering, though, that in the past an important mercantile route led through this area (and still leads as a smuggling tract from and to Iraq); therefore, what has been a half-deserted terrain (now it is again a fertile land due to artificial irrigartion) used to be a land with urban settlements (two large urban centres in Terqa/Tell Ashara and Mari/Tell Hariri). These premises allow us to argue that in the periods of peace and relative political stability – when trade was possible – the quality of life in those settlements must have been considerably higher that in unstable periods when the economy of the region was isolated.

It was decided that the above assumption should be tested. There are various methods of determining the level of environmental stress, and one of them is the analysis of enamel hypoplasia in prehistoric populations of the region (Russell 1966, Hutchinson and Larsen 1990, Skinner and Goodman 1992, Hillson 1996).

Hypoplasia or hypoplasty denotes a disturbance of the proper development of tooth enamel. The irregularities in the structure of hard tooth tissue consist in:

1. the lower level of mineralisation (hypomineralisation);
2. underdevelopment (hypoplasia);
3. hyper-development (hyperplasia).

Hypoplasia is the most common irregularity comes across in teeth. It concerns qualitative changes in the basic substance of enamel. In the etiology of hypoplastic changes in tooth enamel three main classes of factors have been listed, namely: general (systemic), local and genetic.

In the first type the irregularity can be caused by such systemic stress as malnutrition, resulting in an insufficient supply of indispensable components (mineral salt, proteins, vitamins), childhood diseases and endocrine imbalance (thyroid, parathyroid, pituitary gland and the pancreas). The influence of the factors that may inhibit the development of the teeth and the processes of their mineralisation is usually connected with the first year of a child's life, so it affects most often incisors, canines and the first molars whose mineralisation takes place at the earliest stage (Fanning and Brown 1971, Osborn 1973, Goodman and Armelagos 1985, Hodges and Wilkinson 1990, Dean and Beynon 1991; Table 1). A microscopic study of the teeth affected by hypoplasia show that their enamel is much thinner and may contain some colouring substance. The enamel prisms are disorganised, and the interprism substance is thicker.

We may distinguish the following kinds of hypoplasia, depending on their clinical presentation:

1. hypoplastic spots/maculae – white or brown patches on the surface of the enamel;
2. hypoplastic pits – they may occur in one or many lines;
3. hypoplastic furrows – in the form of grooves on the surface of the crowns which may reach dentin;
4. crescentic hypoplasia – plicate incisal edges;
5. hypoplastic plaques (partial aplasia of the enamel) – lack of enamel on a certain part of the surface.

Table 1. The time of forming permanent teeth.

	I1	I2	C	P1	P2	M1	M2	M3
Germ formation	ca. 5th month of fetal life			ab	9–12 m ab	4th fetal month	9–12 m ab	ca. 5th yr
Beginning of mineralisation	ca. 3 months	ca. 6 months	ca. 6–9 months	ca. 2 years.	ca. 3 years.	after birth	ca. 2,5 years.	ca. 7–10 ys
Crown formation	ca. 4–5 ys	ca. 5 ys	ca. 6 ys	ca. 6–7 ys	ca. 6–8 ys	ca. 3–4 ys	ca. 8 ys	ca. 13–15 ys
Eruption	ca. 6–7 ys	ca. 7–8 ys	ca. 11–12 ys	ca. 10–12 ys	ca. 11–12 ys	ca. 6 ys	ca. 12–13 ys	ca. 17 ys
Final root formation	ca. 10 ys	ca. 10 ys	ca. 13–15 ys	ca. 13 ys	ca. 14 ys	ca. 9–10 ys	ca. 15 ys	after 18 ys

m: months, ab: after birth, ys: years

Hypoplasia is marked by defects of enamel or cavities, located in those parts of the teeth where the enamel was formed when the pathogenic factor occurred. This general (systemic) type of hypoplasia is of a metabolic character because enamel formed after the occurrence of the pathogenic factor has the right structure. The defects of enamel are usually restricted to a certain location on a tooth's surface.

The second group of factors which cause hypoplasia are local factors. These factors cause enamel defects of single teeth. Isolated areas affected by the underdevelopment of enamel are visible in the form of shallow hollows or recesses and suggest that the pathogenic factor occurred only for a short period of time and damaged only those ameloblasts which were then involved in producing the enamel. The recurrence of the pathogenic factor leads to the formation of many hypoplastic focuses on the enamel. Such a situation can be caused by dentinitis of deciduous teeth, which lead to the inflammation of the periapical tissue and damage the germ of a permanent tooth.

Finally, the third group of factors causing hypoplasia include genetic anomalies. They may cause an incomplete development of enamel (Amelogenesis imperfecta). Other genetic defects impairing the development of dentine include, for example the underdevelopment of dentin (Dentinogenesis imperfecta) or dentin displasia.

Literature on the subject mentions different types of Amelogenesis imperfecta and describes different symptoms in the buccal cavity which are connected with those types. Generally, symptoms include dental shape change caused by reduced convexity. The enamel is thin, hard, glossy, sometimes coloured yellow-brown, and enamel erosions may also occur (Kreshover 1944, Sweeney et al. 1969, Ten Cate 1985, Suckling 1989, Ensor and Irish 1995, Hillson 1996).

The presented characteristics of these distinct types of hypoplasia are an important prerequisite for the attempts aimed at reconstructing dietary behaviour, and indirectly also the economic and social status of the examined population. In this respect, the changes classified as general-systemic hypoplasia are the most relevant. They are relatively easy to observe in ancient tooth, and often used in many analyses.

Theoretical Model

In the late 3rd millennium BC the region along the middle Euphrates valley was inhabited by the multi-ethnic, so-called "dimorphic society" of the nomadic and semi-

nomadic pastoralists who lived in the steppe, and by the agriculturalists who inhabited the river valley (Liverani 1973, Rowton 1974). Trade was then controlled by the two main towns of that area: Mari (Tell Hariri) and Terqa (Tell Ashara) which flourished especially in the period after the fall of the Sumerian kingdom of the Ur III dynasty ca. 2000 BC. The fall of this kingdom was caused by the migration of the Amorites from Syria (Buccellati 1966, Owen 1992). Before the destruction of Mari by Hammurapi from Babylon (ca. 1760 BC), the trade route along the Euphrates River constituted the most important passage from Southern Mesopotamia to Anatolia and Syria. Further on, the region was controlled by the Hurrian state of Mitanni (Chavalas 1992, Rouault 1992). In spite of earlier tradition, the intensity of trade contacts decreased in a rapid way, eventually almost to disappear, due to the nomadic Arameans who caused the deepest agricultural crisis in the whole of Mesopotamia in the period between ca. 1200 and 900 BC (Brinkman 1968, Lyonnet 1996). The recovery of trade was possible due to the expansion of the Neo-Assyrian state which in the 9th and 8th century took control over the entire Northern Mesopotamia (Smith 1965, Malamat 1973). The region of Terqa in that period was again inhabited by a quite numerous population of farmers, although trade never became as important as it had been in the early 2nd millennium. The Neo-Assyrian period witnessed many mass deportations, such as those described in the Bible (Oded 1979). After the fall of Assyria in 612/606 BC, the region of Terqa became a part of the greater empires of Babylon, Persia, the kingdom of Alexander the Great and his successors. After the rise of the Roman Empire, the entire Northern Mesopotamia turned into a theatre of war between the Romans and the Parthians, later replaced by the Sasanians (Dillemann 1962). Such events as the expedition of Traian (113–117 AD) and the capture of Dura Europos by the Romans (165 AD) are only some examples of almost constant acts of hostility between the two powers. Due to these events, the region along the middle Euphrates was inhabited mainly by soldiers and nomadic tribes. (Oates 1968, Keall 1975, Goodblatt 1987, Rostovseff 1989, Simpson 2000). The depopulation of the area increased also because of the great plague after 541 AD (Dols 1977). In the mid 7th century, control over the region was easily taken over by the Caliphate. The following six centuries were a period of relative stability during which another, quite important, trade and military route ran across the area of Terqa. However, the Abbasid state was destroyed by the Mongolians before the mid-13th century AD (Oates 1968, Gibson 1972) and so the valley of the middle Euphrates was almost completely deserted for many centuries to come. It started to flourish again in the early 20th century when nomadic tribes (begun to settle) returned once again to this region.

Theoretically then, the frequency of hypoplasia in the areas along the middle Euphrates should be higher in the late Bronze period and in the beginning of the Neo-Assyrian period, i.e. the times identified with the Aramean invasion that resulted in a great agrarian crisis. It should also be higher during the Roman and Byzantine periods when the aforementioned region became an unstable frontier zone affected by continuous wars and conflicts. On the other hand, hypoplasia should be less frequent in the populations in the periods of relative welfare and stability, i.e. in the early and middle Bronze period when a popular trade route ran along the middle Euphrates. It should also be less common in the latter Neo-Assyrian period which was characterised by remarkable state investments. Finally, it should rarely occur in the Islamic period, characterised by political stability (Table 2).

Table 2. Brief chronology of the middle Euphrates valley.

Dating	Period	Comments
2100–1900 BC	Shakanaku	Immigration of Amorites from Northern to Southern Mesopotamia along the Euphrates
1900–1700 BC	Old Babylonian	Flourishing kingdoms of Mari and Terqa along middle Euphrates valley; important trade route along the Euphrates
1500–1200 BC	Late Bronze Age	Mitanni and Middle Assyrian kingdoms
900– 600 BC	Neo-Assyrian	Assyrian province; development of agriculture in the region; small-size trade along the Euphrates
200– 650 CE	Late Roman/Byzantine	Frontier area between the Eastern Empire and the Sasanian kingdom; numerous military conflicts
650–1200 CE	Early Islamic	Important trade and military route along the Euphrates linking Baghdad with Syria and Anatolia
1850–1950 CE	Modern	Small-scale agriculture and pastoralism; growing importance of trade with southern Mesopotamia

Material and Methods

The presented research concerns the teeth of individuals found in three neighbouring sites of east Syria (Province Der-er-Zor): Tell Ashara, Tell Masaikh and Gebel Mashtale in the years 2002–2005. The fossils were described in the excavation house. The fossil material can de divided into five chronological groups. (Sołtysiak 2003, 2005, 2006, Sołtysiak and Tomczyk 2006, Tomczyk and Sołtysiak 2006a, b; Figure 1).

The oldest period, identified as Shakanaku/Old Babylonian, coincides with the Middle Bronze period (ca. 2100–1800 BC). Slightly later than that was the Late Bronze/Neoassyrian period (1500–700 BC). This was followed by the Late Roman/Byzantine (200–650 AD), Early Islamic (650–1200 AD) and Modern periods (1850–1950 AD). A large number of the teeth are dated generally from the Pre-Islamic/Early Islamic period, which means that these teeth can come either from the Hellenistic, Late Roman and the Early Islamic period. The following tables present the number of individuals in the particular periods and the overall numbers of the examined teeth (Tables 3–4).

Table 3. Size of chronological samples.

Site	Shakanaku/ Old Babylon	Late Bronze/ Neoassyrian	Late Roman/ Byzantine	Pre-Islamic/ Early Islamic	Early Islamic	Modern	Σ
T. Masaikh	8	3	15	48	9	0	83
G. Mashtale	0	0	1	2	3	0	6
Terqa	20	2	0	0	4	17	43
Σ	28	5	16	50	16	17	132

During last year's excavation season (2005) the material was brought to Poland where it underwent a more thorough analysis in the anthropological laboratories of Cardinal Stefan Wyszyński University in Warsaw. The teeth of 80 individuals were examined: 21 from Tell Ashara, 48 from Tell Masaikh and 11 from Gebel Mashtale. Since the sample was small, they will be used in further analyses.

Table 4. Number of examined teeth.

	I1	I2	C	P1	P2	M1	M2	M3	Σ
Maxilla R	67	63	77	72	70	70	58	34	511
Maxilla L	62	61	66	68	57	55	58	35	462
Mandibula R	64	68	70	81	72	68	65	44	532
Mandibula L	59	62	75	67	69	62	66	41	501
Σ	252	254	288	288	268	255	247	154	2006

The analyses included a description of the type of tooth, the extent of its wear, the measurements of the tooth crown and a determination of the type of hypoplasia. The type of hypoplasia was defined according to the modified scale of enamel defects: 0 – no hypoplasia, 1 – small irregularities without marked lines; 2 – small lines; 3 – considerable lines; 4 – considerable irregularities; 5 – vertical lines; 6 – complete destruction of the enamel (Clarkson and O'Mullane 1989, Buikstra and Ubelaker 1994, Ensor and Iris 1995, Blakey and Armelagos 1997). As no instances of vertical lines or complete destruction of the enamel were recorded, in the tables showing the final results the 4th, 5th and 6th degrees were omitted.

Since the examined sample was relatively small, more detailed examination (e.g. the measurement of the distances between the given hypoplastic lines) will be carried out in the future. Thus, only the degree of hypoplasia has been estimated so far.

Results

The following table (Tables 5–6) shows the prevalence of hypoplasia in the examined series. Both in the mandible and the maxilla, hypoplasia is more frequent on the front teeth (incisors, canines and premolars) than on the molars. The described defect of the enamel is definitively more prominent in the Late Roman/Byzantine period.

As the series was relatively small, a weighted mean for all teeth was used, with equal weights for each category. This procedure was chosen in order to avoid problems concerning the uneven preservation of the different groups of teeth.

Table 7 shows the percent frequency of hypoplasia occurrence in the particular periods. Worth noticing is the fact that the differences between the frequency for particular teeth are statistically insignificant.

Taking into account the above data, a general tendency can be observed (Figure 2). The frequency of hypoplasia is similar in the Shakanaku/Old Babylonian and Early Islamic periods, whereas it obviously increases in the Late Roman period and is considerably lower in the Modern period.

The data displayed in Figure 3, Tables 8–10 suggest that there is no clear difference between the sexes in the largest chronological sample (joined Pre-Islamic/Early Islamic and Early Islamic periods), although the frequency of hypoplasia is slightly higher for the females.

Worth stressing is the lack of significant differences between sexes in the five most numerous samples (χ^2=3.34, p<0.9).

Table 5. Frequency of enamel hypoplasia in the chronological samples (maxilla).

Chronology	I^1				I^2				C				P^1				P^2				M^1			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Shak./OB	8	3	1	0	8	6	2	0	7	1	4	2	9	4	2	0	9	3	1	0	15	0	1	0
Neo-Assyr.	0	1	1	0	0	1	0	0	0	2	1	0	5	0	0	0	2	0	0	0	2	0	0	0
Late Roman	4	2	3	1	7	2	2	0	5	3	3	2	5	3	3	1	7	2	2	0	9	1	2	0
PI/Islamic	10	15	5	1	8	19	3	0	7	12	13	2	15	12	5	0	21	8	3	0	19	3	1	0
Early Islamic	3	5	0	1	5	2	1	1	2	3	3	3	6	3	2	0	8	0	0	0	6	1	1	0
Modern	6	6	0	0	5	6	0	0	1	6	4	0	10	1	0	0	10	1	0	0	13	1	0	0

Table 6. Frequency of enamel hypoplasia in the chronological samples (mandible).

Chronology	I_1				I_2				C				P_1				P_2				M_1			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Shak./OB	7	2	2	0	5	6	1	0	4	2	4	3	10	2	2	0	14	1	1	0	15	1	1	0
Neo-Assyr.	0	2	0	0	0	1	1	0	1	1	1	0	4	0	0	0	2	0	0	0	1	0	0	0
Late Roman	8	2	3	0	6	2	3	0	6	2	2	4	10	0	4	0	7	2	2	0	9	3	1	0
PI/Islamic	13	11	4	0	11	15	6	0	7	14	12	2	27	7	4	0	26	8	3	0	20	2	3	0
Early Islamic	5	3	0	0	7	2	1	0	2	3	4	1	8	0	1	0	7	3	0	0	9	1	0	0
Modern	5	6	0	0	5	7	0	0	2	8	3	0	12	2	0	0	10	1	0	0	12	0	0	0

Table 7. Percent frequency of enamel hypoplasia in the chronological samples.

Chronology	I^1	I^2	C*	P^1	P^2	M^1	I_1	I_2	C*	P_1	P_2	M_1
Shak./OB	8	12	43	13	8	6	18	8	54	14	6	6
Late Roman	40	18	38	33	18	17	23	27	43	29	18	8
PI/Islamic	19	10	44	16	9	4	14	19	40	11	8	12
Early Islamic	11	22	55	18	0	12	0	10	50	11	0	0
Modern	0	0	36	0	0	0	0	0	23	0	0	0
X^2=	7.43	2.97	0.92	4.89	3.28	3.48	4.40	4.53	2.74	5.55	3.75	2.82
p<	0.20	0.90	0.95	0.30	0.90	0.50	0.50	0.50	0.90	0.30	0.50	0.90

Table 8. Frequency of enamel hypoplasia in males and females from the Pre-Islamic/Early Islamic sample (maxilla).

Sex	I^1				I^2				C				P^1				P^2				M^1			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Males	4	8	2	1	3	8	3	1	4	3	8	3	10	6	2	0	13	4	0	0	9	3	1	0
Females	8	6	2	1	7	6	1	0	2	7	6	2	7	3	5	0	11	2	2	0	10	0	0	0

Table 9. Frequency of enamel hypoplasia in males and females from the Pre-Islamic/Early Islamic sample (mandible).

Sex	I^1				I^2				C				P^1				P^2				M^1			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Males	8	3	1	0	8	6	1	0	4	5	7	0	12	3	1	0	10	6	0	0	13	3	0	0
Females	7	6	3	0	7	4	6	0	4	8	4	3	15	2	3	0	15	4	1	0	10	0	1	0

Table 10. Percent frequency of enamel hypoplasia in males and females from the Pre-Islamic/Early Islamic sample.

Sex	I^1	I^2	C^*	P^1	P^2	M^1	I_1	I_2	C_*	P_1	P_2	M_1
Males	20	27	61	11	0	8	8	7	44	6	0	0
Females	18	7	47	33	13	0	19	35	37	15	5	9
χ^2=	0.03	1.93	0.70	2.42	2.42	0.80	0.61	3.18	0.17	0.69	0.82	1.51
P<	0.90	0.20	0.50	0.20	0.20	0.50	0.50	0.10	0.90	0.50	0.50	0.30

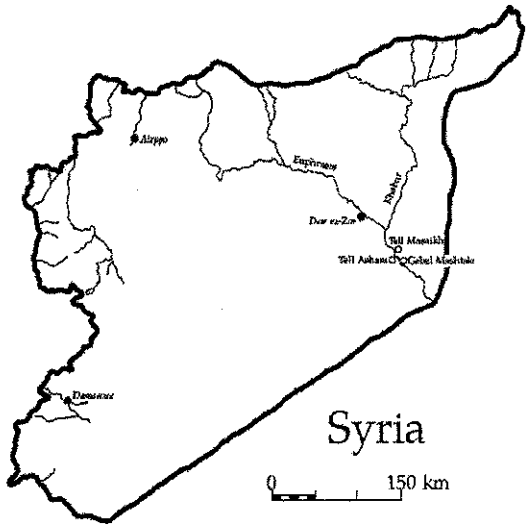

Figure 1: The map of Syria

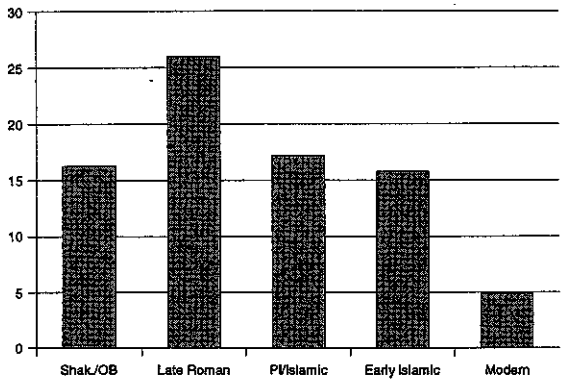

Figure 2: Mean percent frequency of enamel hypoplasia in the chronological samples.

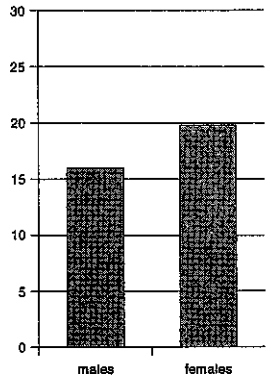

Figure 3: Mean percent frequency of enamel hypoplasia. in males and females from Pre-Islamic/Early Islamic sample

On the other hand, there exists a small difference between the age groups (two groups: up to 20 and above 20 years, χ^2=7.84, p<0.1), due mainly to the great number of younger individuals in the Shakanaku/Old Babylonian period in which they constitute 32% of the entire group (9/28); they are second in numbers in the Early Islamic period (3/16=19%), and the least numerous in the Pre-Islamic/Early Islamic period (4/50=8%).

Discussion and Conclusions

The performed analyses show, first, that the examination of the frequency of hypoplasia is a potentially useful tool for determining the changes in the quality of life. Second, it was proved that the occurrence of hypoplasia – generated by general-systemic factors, such as malnutrition or the diseases and infections encountered in childhood – directly corresponded with the political and social situation in the Ashara region. Historical data, along with the found dental material show that during the periods of political instability, which led to food crises, the frequency of hypoplasia increased. On the other hand, in the periods noted for greater stability and welfare the proportion of the individuals affected by hypoplasia visibly decreased.

The analysed sample is too small to reconstruct in detail the changes in life standards. It can be shown, however, that in the Late Roman/Byzantine period the frequency of hypoplasia increased, which most probably can be linked with the effects of political instability. Meanwhile, the decrease of hypoplasia in the Modern period is due to a much better quality of life in this period. A similar frequency of hypoplasia in the Bronze Age and Early Islamic period indicates that both these periods witnessed a relative stabilisation of the quality of life due to the presence of the South-North main trade route. The observed differences seem to have no connection either with sex or age in the compared samples, although there is a larger group of young individuals in the Bronze age, as has already been mentioned. Since tooth enamel is formed in childhood and it does not undergo any further changes in later life, the age of the individuals does not bear any real significance on the analysis of this phenomenon.

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