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# Socioeconomic Influence on Caries Susceptibility in Juvenile Individuals with Limited Dental Care: Example from an Early Middle Age Population (Great Moravia, 9<sup>th</sup>-10<sup>th</sup> Centuries A.D., Czech Republic)

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## 1. Introduction

Dental growth is recognized to be less influenced by environmental factors than by genetics (Halcrow & Tayles, 2008; Saunders et al., 2000; Scheuer & Black, 2000a). However, it has been demonstrated that dental health is partly conditioned by the differential enamel susceptibility of environmental attack (sugars, bacterial flora, etc.) (Hillson, 1979; Johansson et al., 1994; König & Navia, 1995; Navia, 1994). In an earlier article published in *HOMO*, 2010, vol. 61, p. 421-439, our results showed that there is some influence of lifestyle on dental health of juvenile individuals (Garcin et al., 2010). Four populations belonged from rural and urban, coastal and inland lifestyles were compared in that paper. We would like, in this chapter, to refine these results with the evaluation of the influence of socioeconomic status on dental health in juvenile individuals with limited dental care. The point of view is focused on tooth development and enamel quality rather than strict caries analyses.

The influence of socioeconomic status on health is a very common topic on living populations (e.g. Alvarez & Navia, 1989; Greksa et al., 2007; Klein and Palmer, 1941; O'Sullivan et al., 1992; Van de Poel et al., 2007). One of the main biases to study these populations is the difficulty to define the environmental framework of the analysis. It is nearly the same in past populations but they have the advantage of the sample size (especially on children). However, most studies on past and historic populations evaluating both dental enamel hypoplasia and caries, are based on adult remains only (Barthelemy et al., 1999; Belcastro et al., 2007; Cucina et al., 2006; Esclassan et al., 2009; Palubeckaité et al.,

2002; Wright, 1997), while it is well accepted that juveniles, and thus their skeletons, are the most sensitive to social and environmental conditions (Bennike et al., 2005; Humphrey & King, 2000; Lewis, 2007; Lewis & Gowland, 2007; Pinhasi et al., 2005). That is why this new study is focused only on juveniles. Several biases must be taken into account with this type of analysis (e.g. Hillson, 2001), but they will be discussed later in the chapter.

We will assess the dental health of juvenile individuals. To be clear till the beginning of this chapter, the main definitions used in this study are given below:

- Enamel hypoplasia is a macroscopically observable quantitative dental defect where enamel thickness has locally decreased on the surfaces of tooth crowns (Clarkson, 1989). As enamel is not remodeled during one's lifetime once it had been formed, hypoplasia provides significant information about stress during development of the dentition (Ubelaker, 1978).
- *"Dental caries may be defined as the localized destruction of tooth tissue by bacterial action"* (Gibbons and van Houte, 1975). Carious lesions lead a process which begins by the enamel surface, and which can conduct, without any care, to the tooth loss (Hillson, 1979). Carious lesions in past populations bring information about their adaptation to their physical and cultural environment (Erdal and Duyar, 1999).
- Both dental traits suffer from the scoring techniques used to evaluate them (Hillson, 2001; Ulijaszek and Lourie, 1997), and comparisons must be careful, when the dental evaluation differs from the samples under study. That is why we have attached a great importance to our methods of recording and analysis.
- Both dental caries and enamel hypoplasia are linked to time (Hillson, 1979; Reich et al., 1999), but in a different way. For dental caries, it is the severity which is the marker of time. Longer the individual will survive; more serious will be the lesion. That is why the age-at-death estimation is important to compare the health state of the juveniles. For dental enamel hypoplasia, the time is important for the moment of appearance of the defect. Thus, it is directly linked to the enamel development. Age-at-death estimation will be used in this way to define when the individuals have suffered from biological stress. This information of time will provide other discussion topics and give different analyses of dental development and care.

The aim of this study is to compare two contrasting populations (upper social class *vs.* middle social class in a settlement in expansion), in order to understand how these biological traits are linked to socioeconomic conditions. Bearing in mind the limitations of such studies, such as the osteological paradox effect (Wood et al., 1992) and some methodological biases (Hillson, 2001), special care has been taken in order to ensure the reproducibility of the results and reliable interpretations. We also would like to discuss the difficulty to differentiate the environmental part from the genetic part in dental mineralization and thus in enamel susceptibility to develop caries and hypoplasias.

## 2. Materials under study

In anthropological studies, skeletal samples are often limited for reliable statistical comparisons (little sample size), and thus we interpret result with many biases. It is all the more so real when we attempt to compare individuals with different lifestyle and/or socioeconomic status.

In this way, the archaeological site of Mikulčice-Valy (cf. Fig. 1) offers many advantages and the Great Moravian Empire is a specific historical period which allows studying the transition between a rural life and a progressive urbanization.

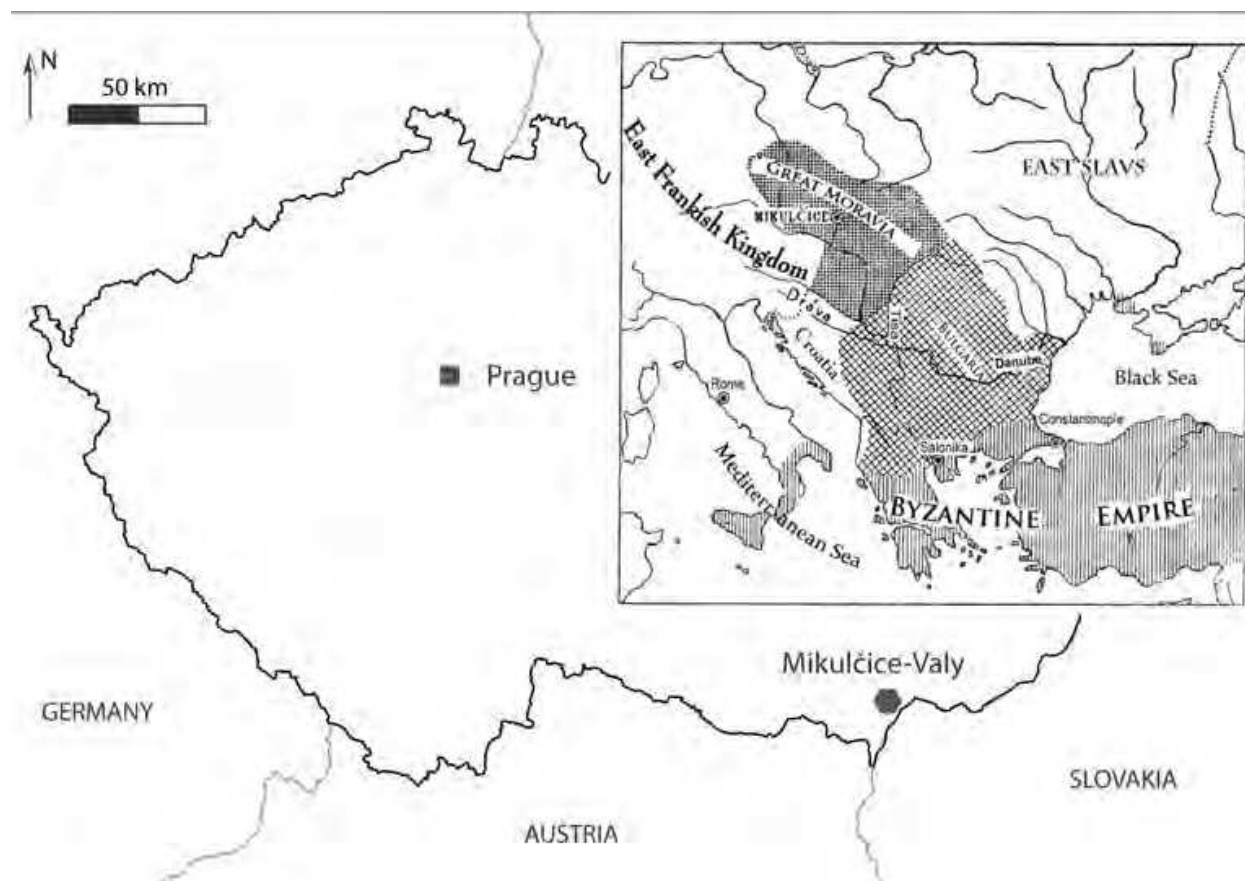


Fig. 1. Situation of the archaeological site under study in relation to current Czech Republic and the location of the Great Moravia in medieval Europe (box adapted from Havelkova et al., 2011).

## 2.1 Historical background

Till the end of the 8<sup>th</sup> century, life in Eastern Europe is rather rural with no clear organization and subject to the different waves of migration. Great Moravia was the first Slavic state formation. It was accompanied with a progressive Christianization. The Great Moravian Empire was founded by the Prince Mojmir the 1<sup>st</sup> (833-846) (Böhm et al., 1963), from different Slavic populations of the northern Danube River. They took advantage from the conflicts between Frankish and Avars in order to found a structured state, bringing together different principalities (Leger, 1868). On the whole, the hierarchic organization is similar to those in Western Europe, with a clear dependency of the peasant farmer to the aristocratic class (Poláček, 2008). With its small territory, the Great Moravian Empire is a privileged area to study the mutation between rural lifestyle to urbanization. Moreover, the principalities are founded around centres of power such as Staré Město, Nitra, or Dvín (Conte, 1986). Mikulčice-Valy was one of these power centres, bringing together the different socioeconomic classes at that time.

## **2.2 Mikulčice-Valy, how to gather different socioeconomic status in a same archaeological site?**

The archaeological site of Mikulčice-Valy is the vastest site in Czech Republic, which is registered as national cultural heritage, and has competed for the World's heritage centre of Unesco since 2001 (<http://whc.unesco.org>). Situated at 7 km southern from the town Hodonín, near the border of Slovakia, the power centre of Mikulčice was established at the beginning of the 6<sup>th</sup> century and knew its height between the 9<sup>th</sup> and 10<sup>th</sup> centuries (Poláček, 2000; Třeštík, 2001).

### **2.2.1 The power centre organization**

The power centre of Mikulčice is a large fortified settlement, discovered at the end of the 19<sup>th</sup> century. It is constituted by remains of a palace, at least 12 churches accompanied by several cemeteries, representing more than 2500 burials (Poláček, 2000; Poláček & Marek, 2005; Třeštík, 2001). The remains of the palace were found at the top of some hill above the ancient channel of the Morava River (Fig.2).

The different churches were built around the palace and the basilica (church n°3 on the plan). Archaeological remains suggest that the highest social class (aristocratic part of the population and churchmen) was buried in the cemeteries near these areas. Further the other churches are, lower are the socioeconomic status of the people buried in the adjacent cemeteries.

This organization shows that we could study different social groups in a same site belonging to the same historical period. This is the case and an incredible chance for an anthropological study. However, we must be cautious, because in such settlement moving from urbanization, the limits of each burial place are often difficult to separate and cultural data are missing to exactly differentiate each part of the population. That is why the collections under study come from clear different part of the site in order to have different socioeconomic classes.

### **2.2.2 Mikulčice “Bazilika”, burying the upper social class**

The cemetery directly linked to the basilica (named “Bazilika”) is of the richest burial place of the area. Many archaeological remains were found suggesting that the upper class was buried here (Poláček et al., 2006). Around the Basilica (III<sup>rd</sup> church) were discovered 564 burials (Poláček, 2008). There are 314 adults, 221 non-adult individuals and 29 individuals with un-estimated age (Stloukal, 1967). The sample under study comprises 217 juvenile individuals (the last four are too poor preserved to be included in the data), ranging from birth to adolescence. In the figures and table, this sample is named Mikulčice Bazilika and is abbreviated “MkB”.

### **2.2.3 Mikulčice “Kostelisko”, the suburb of the fortifications**

The second area under study is the burial place named “Kostelisko”. It takes place in the suburb of the acropolis and is considered as the servants, craftsmen of the castle (Velemínský, 2000; Velemínský et al., 2005). It corresponds to a lower social class than the

individuals buried around the basilica. Once again, we must be cautious because of the possible mixture between the parts of the population and the part of the cultural way of thinking that we have no clues.

The second sample under study comprises 425 burials holding 235 juvenile individuals. The skeletons, correctly preserved, present the same age-at-death range than the “Basilika” sample. In the figures and table, this sample is named Mikulčice Kostelisko and is abbreviated “MkK”.

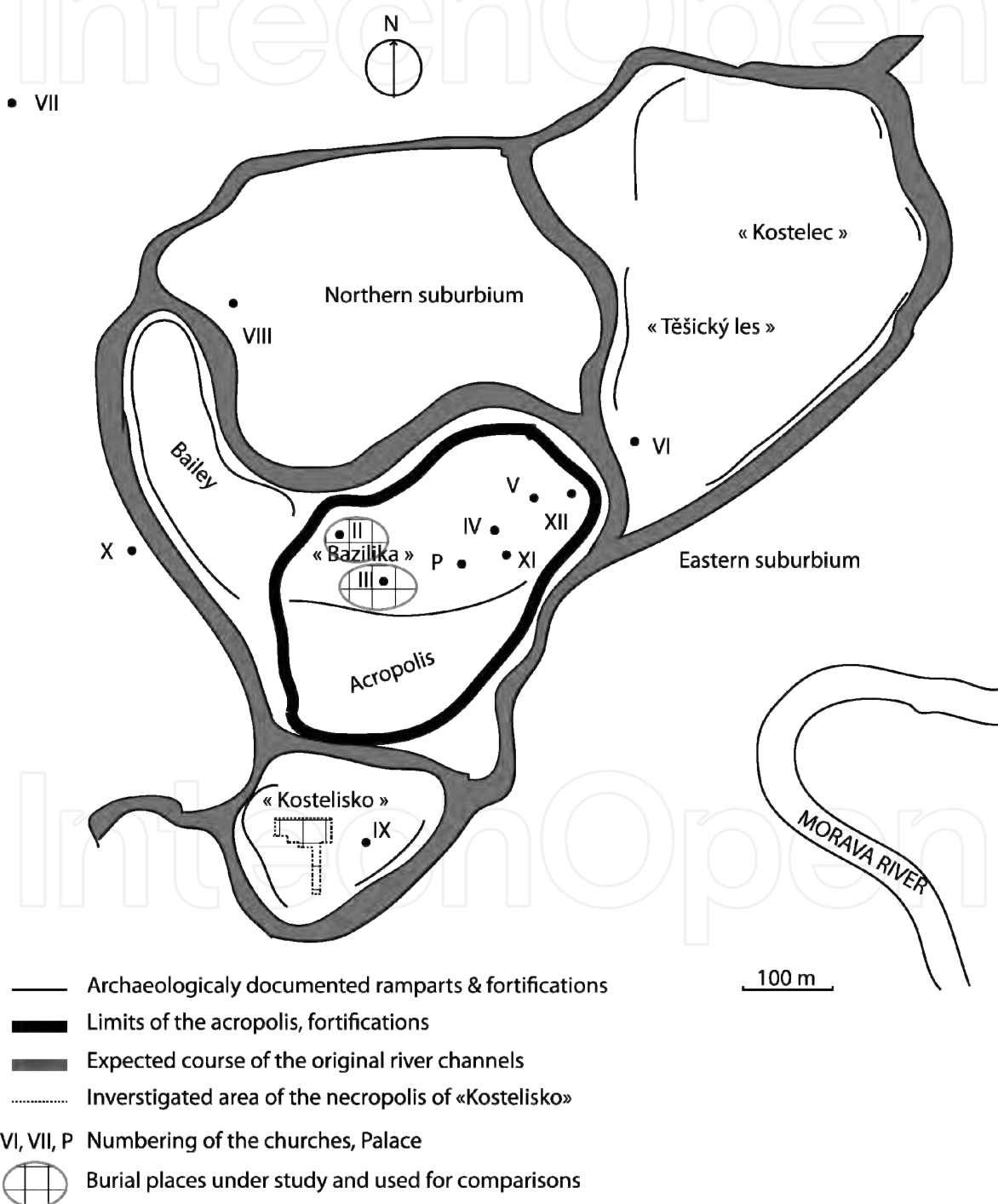


Fig. 2. Mikulčice-Valy, general plan of the site and topography (adapted from Poláček, 2008)

### 2.2.4 Comparison with other data

The two first samples show contrasting socioeconomic status, whether we consider that the populations were clear separated in the Mikulčice settlement. In order to compare the “urban” samples with a clear different lifestyle, we chose to study a third sample coming from a rural cemetery in the hinterland of Mikulčice.

The archaeological site of Prušánky, is situated at less than 10 km from Mikulčice. This geographical closeness does not reflect proximity in the lifestyle. Indeed, the cemetery associated at this site represents a rural population (Beeby et al., 1982). The location near the power center induces clear exchanges between the two community, but the lifestyle is different. This second site seemed to be self-sufficient (Klanica, 2006a). 676 burials accompanied by Moravian archaeological remains were excavated (Klanica, 2006b).

The last sample under study comprises 173 juvenile individuals from newborn to late adolescent. In the figures and table, this sample is named Prušánky and is abbreviated “Pk”.

Thus the three samples show different socioeconomic status:

- MkB, the “aristocratic” and churchmen sample, representing the highest social class of the site;
- MkK, the “middle social class” (above all “craftsmen), who are poorer than the individuals of MkB;
- And Pk, the rural place, where the lifestyle contrasts with the two others.

Their teeth should reflect these life conditions and socioeconomic status. All the skeletal remains are deposited in the Department of Anthropology of the National Museum in Prague.

## 3. Methods

This study is only based on dental health and lifestyle and on the potential influence of the socioeconomic status on caries prevalence and enamel composition. However, it has been completed by an analysis on the same influence but on bone growth and composition.

The resulting dental sample consists of 6123 observed teeth. Table 1 gives the details for each sample.

### 3.1 Recording dental health and defects

In dental stress and caries assessment it is clearly desirable to record the least subjective stages and observations, in order to minimize the intra- and inter-observer errors (Danforth et al., 1993), both of which are often significant. The intra- and inter-observer error, for the protocol proposed below, has been tested and has been published in a previous paper (Garcin et al. 2010). As the protocol is the same in this study, we do not remind the results but we expose the features quoted and the statistical procedures employed for comparisons.

Both dental caries and enamel hypoplasia have been recorded because they give different information on enamel susceptibility to develop lesions. International dental charts were used to identify the teeth (such as n° 18 to 11 for upper right permanent teeth).

Sample	Deciduous teeth	Permanent teeth	Total
MkB	894	651	1545
MkK	1103	1790	2893
Pk	823	862	1685
Total	2820	3303	<b>6123</b>

Table 1. Tooth samples for each site

### 3.1.1 Dental caries

The presence of caries was scored in all tooth types that is to say on deciduous and permanent teeth when detected macroscopically. When there was a doubt on caries development because of the tooth preservation, the development of the lesion was tested by a dental probe.

Four features were observed and scored for the lesions:

- The number of caries per tooth;
- The area & side where the lesion occurred: occlusal, buccal, lingual or interproximal lesions.
- The location of the lesion on the anatomical tooth: the root, the cement-enamel junction (also referred as cervical region or neck), and the crown;
- And finally, the severity of the lesion was quoted on a three-stages scale (fig. 3):
  - Stage 1: small lesion which affects only the enamel and less than 10% of the tooth surface;
  - Stage 2: medium lesion which affects both enamel and dentin and spread from 10% to 50% of the tooth surface;
  - Stage 3: large lesions penetrating all the dental tissues, enamel, dentin and pulp. They take more than 50% of the tooth surface.

These simple stages are easy to define, thus the results of scoring would be less prone to errors, because in archaeological record there are some cases of complex observations (Hillson, 2001), even if we cannot totally avoid subjectivity in such study. This subjectivity is all the more right when we attempt to analyze dental enamel hypoplasia.

### 3.1.2 Dental enamel hypoplasia

Hypoplastic defects occur in three forms: linear, pitting and plane. However, their expression is different on deciduous and permanent dentition (Lukacs et al., 2001a; Lukacs et al., 2001b; Ogden et al., 2007). We chose to take into consideration the enamel hypoplasia only on the permanent teeth for the quoted features. Nevertheless, a paragraph in the results will be devoted to the different expressions of enamel hypoplasia on deciduous teeth. The presence of macroscopically observed enamel hypoplasia was noted in all types of permanent teeth.

Four characteristics have been recorded:

- The number of hypoplasia per tooth;
- The type of hypoplasia: linear, pitting or plane;
- The severity of the defect on a three-stages scale (only for linear defects) (fig. 4):



- Stage 1: the defect is macroscopically detectable, but is less than 0.1mm width;
- Stage 2: the defect is obvious, but the enamel is not distorted around the line;
- Stage 3: is the most severe with formation of shoving on the enamel surface;
- The location of the defect is the third of the affected crown: cemento-enamel junction third, middle third or occlusal third.

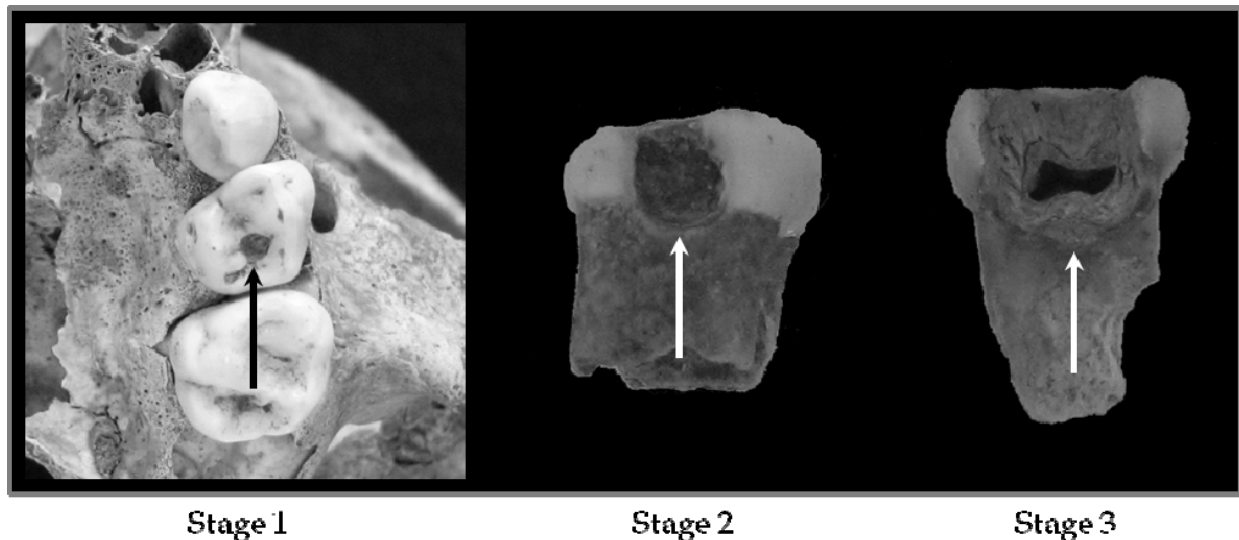


Fig. 3. Illustration of the three-stage severity scale for scoring dental caries (photos: V. Gonzalez-Garcin)

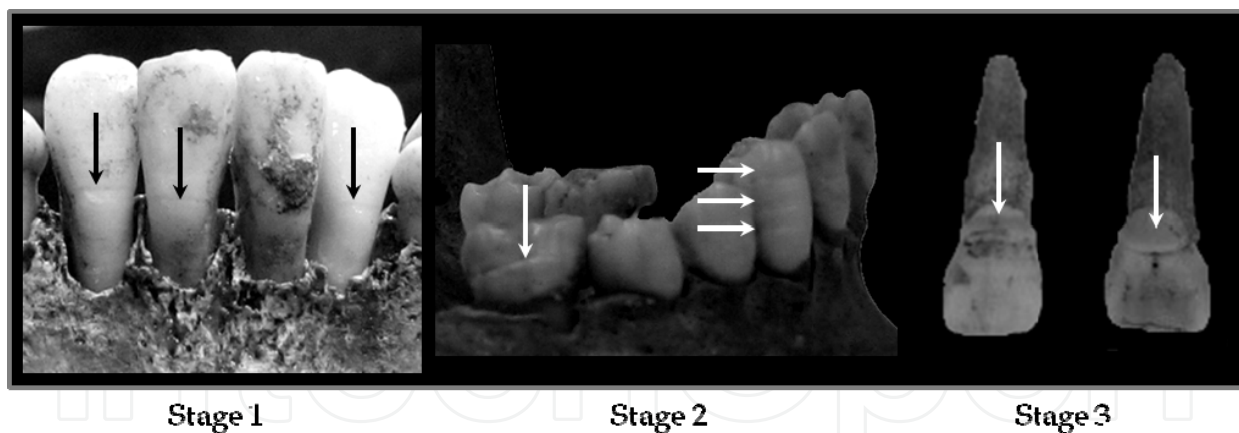


Fig. 4. Illustration of the three-stage severity scale for scoring dental enamel hypoplasia (photos: V. Gonzalez-Garcin)

The distance between the cement-enamel junction and the defect for the calculation of the time of appearance of the defect (Reid & Dean, 2000), was not taken because we only made macroscopical analysis. Charts relative to age differ according to different authors and thus mineralization is not really taken into account. In such large studies, with this method the stages cannot provide accurate chronological sequences (Fitzgerald & Saunders, 2005; Hillson & Bond, 1997; Ritzman et al., 2008). However, a global chart has been made in order to evaluate which developmental stage is the most concerned by enamel hypoplasia.

### 3.2 Estimating age-at-death

In archaeological samples, the first step for anthropological studies is the age-at-death estimation. This estimation will be useful to compare the different sites, because, dentition is also related to age. Currently, the most reliable methods to estimate an age are those based on dental mineralization and developmental stages (Boldsen et al., 2002; Ritz-Timme et al., 2000; Scheuer & Black, 2000b; Schmitt, 2005). We chose to estimate age-at-death in our sample with the method of Moorrees et al. (1963a,b), because we are working on teeth and we wanted a uniform method and no combination of several methods. Moreover, we just needed some different stages to compare our sites, that is why we classified the individuals in 5 age classes (usually used in historical demography): 0, 5-9, 10-14, and 15-19 years.

A last comparison has been made using the dental mineralization sequences. This approach use the mineralization stages of Moorrees et al. (1963a,b), as a base for determining a dental sequence. These basic sequences (one for each individual) are in a second time grouped following the big tooth developmental phases in order to simplify the data (many combinations are possible). Six final groups are defined and used for comparison:

- Group 1: from the beginning of deciduous crown formation to the end of the emergence of all deciduous teeth;
- Group 2: latency period of deciduous teeth. The permanent incisors and the first permanent molars complete their crown formation.
- Group 3: this group corresponds to the mixed dentition. The first deciduous teeth are replaced by permanent incisors (most standard sequence). The first molar emerges anatomically\*. This is the first step of permanent teeth emergence.
- Group 4: stability period where the roots of permanent teeth (incisors and first molars) complete their formation. The roots of the other teeth just initialize their mineralization.
- Group 5: secondary phase of tooth emergence for permanent canine, premolars and second molars.
- Group 6: completion of the permanent dentition (except third molars which were not taken into account).

The illustration of the six resulting groups is presented in fig. 5.

### 3.3 Statistical procedures

The analyses were performed in three steps. First, in order in order to calculate the frequencies of dental enamel hypoplasia, the total number of available teeth, fully erupted and/or isolated, has been used for observation. Tooth germs in both the mandible and maxilla were not taken into account. With the same objective, frequencies of dental caries were calculated using only the teeth in occlusion. The usual calibrations (Erdal & Duyar, 1999; Hillson, 2001; Lukacs, 1995) adjusting the proportions of tooth type and *ante mortem* tooth loss were applied.

In a second time, inter-population comparisons were conducted using the non-parametric  $\chi^2$  statistical. Finally, we studied the interrelationship between caries and hypoplastic defects

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\* The emergence is a localized phenomenon, which corresponds to the appearance of the tooth in the mouth. We distinguish the clinical emergence where the tooth pierces the gingival tissue from the anatomical emergence where the tooth passes over the alveolar bone.

in order to evaluate the role of enamel structure on caries development. All statistical procedures and calculations were carried out by using Statsoft® Statistica version 7.1 and Microsoft® Office Excel 2007.

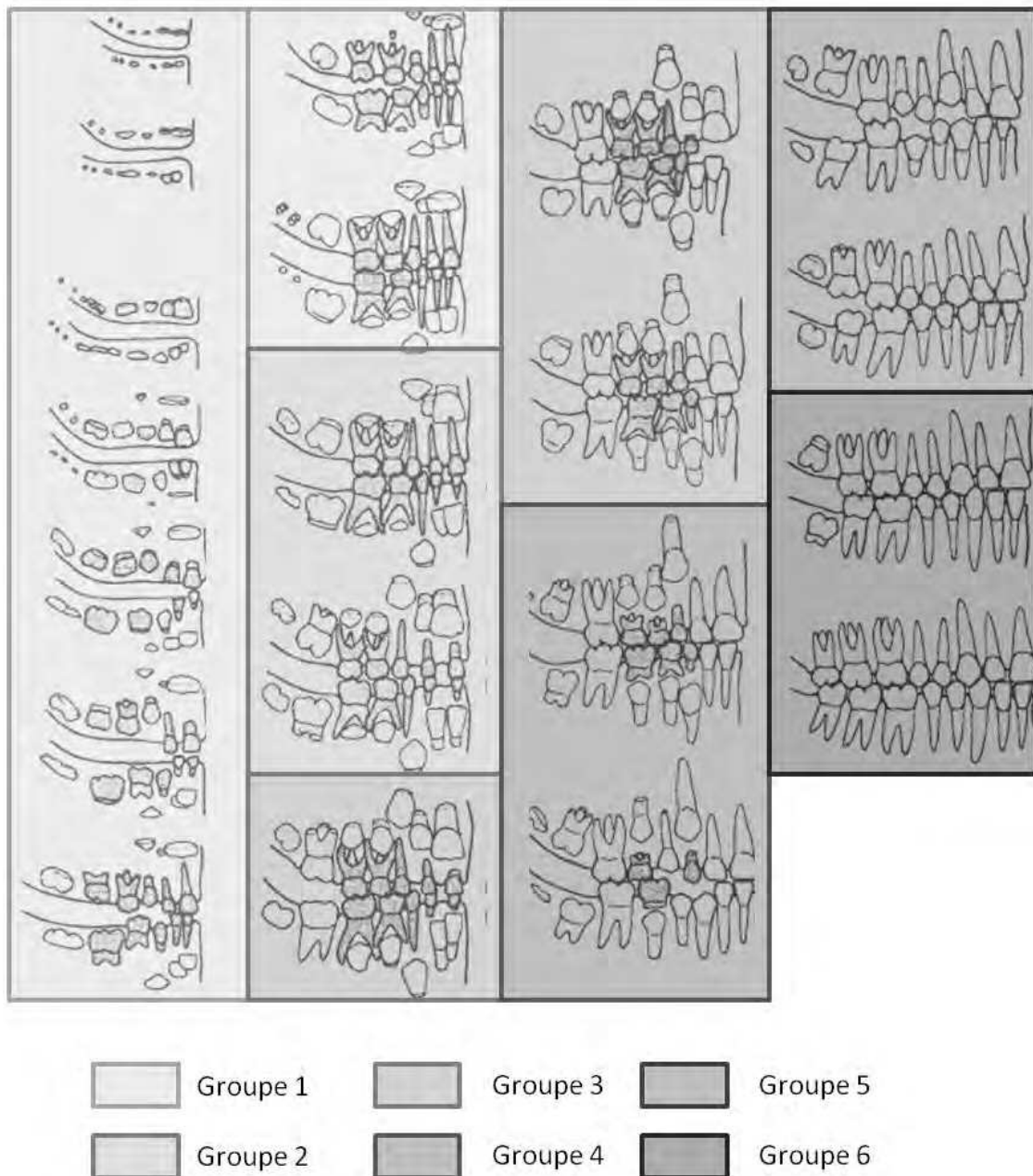


Fig. 5. Representation of the established groups from the dental mineralization sequences (adapted from Ubelaker, 1978)

#### 4. Results

As mentioned in our previous paper, intra- and inter-observers errors must be taken into account, but although they have an impact on the results, those are always discussed with these biases (Garcin et al. 2010).

### 4.1 Prevalence of dental caries

Frequencies of caries in all observable teeth are presented in figure 6 & 7. The evaluated teeth are those observable in the oral cavity and/or in occlusion. This information is different for dental enamel hypoplasia, because tooth germs, when isolated, were also evaluated for this second dental trait.

As often mentioned, posterior teeth are more affected than anterior teeth, which confirm the differential susceptibility of the molars to be suffering from dental caries (Klein & Palmer, 1941; Oyamada et al., 2008; Saunders et al., 1997). But it is interesting to point out that some individuals are attained by carious lesions on anterior deciduous teeth in both area of Mikulčice. These lesions are often related to higher enamel susceptibility to develop dental caries, even on permanent teeth (Li & Wang, 2002; O’Sullivan & Tinanoff, 1993).

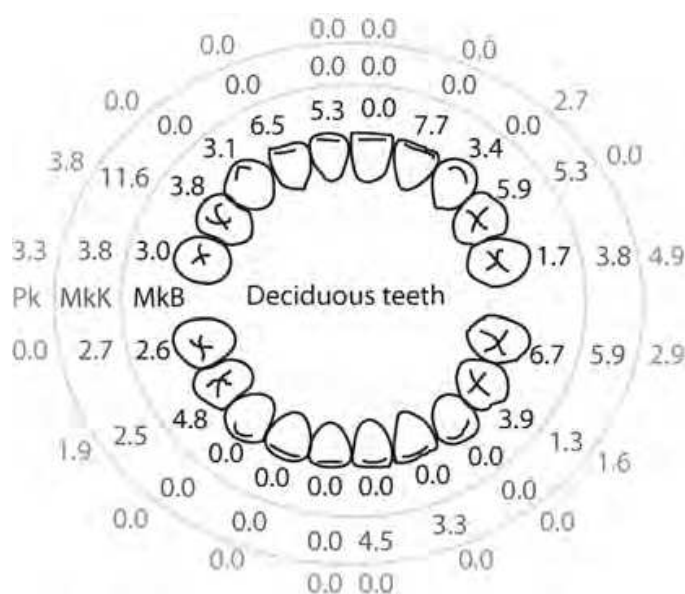


Fig. 6. Caries frequencies per tooth type in the three collections (deciduous dentition)

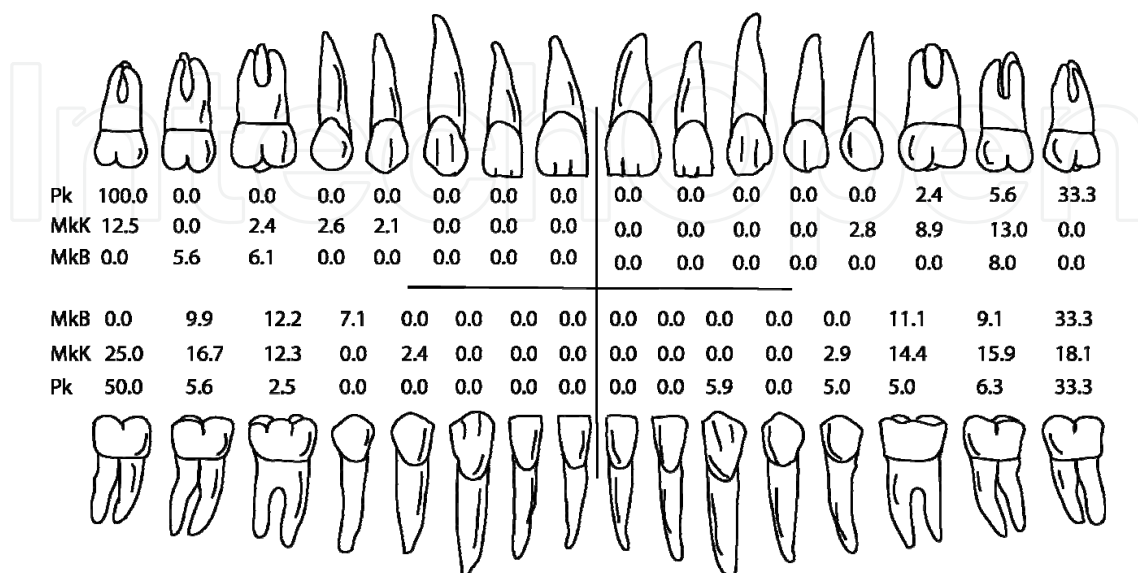


Fig. 7. Caries frequencies per tooth type in the three collections (permanent dentition)

In terms of global calibrated prevalence, there is a difference between the Mikulčice areas and Prušánky in the caries frequencies on both deciduous and permanent teeth. The frequency of dental caries in the deciduous and permanent teeth from Prušánky was statistically significantly lower ( $\chi^2 = 4.49$ ;  $p = 0.03$  for permanent teeth and  $\chi^2 = 9.08$ ;  $p < 0.01$  for deciduous teeth) than in those from the two other collections. Table 2 shows the prevalence and the comparisons between features in the three collections.

	Mikulčice Bazilika	Mikulčice Kostelisko	Prušánky
Prevalence on deciduous teeth	0.03	0.03	<b>0.01</b>
Prevalence on permanent teeth	0.03	0.04	<b>0.02</b>
Location of the lesions			
Occlusal - crown	0.36	0.34	0.52
Interproximal - crown	0.24	0.15	<b>0.11</b>
Interproximal - crown & neck	0.25	0.19	<b>0.11</b>
Large caries (more than 2/3 of the tooth affected)	<b>0.02</b>	0.09	0.15
Other locations	0.13	0.23	0.11
Severity of the lesions			
1	0.51	0.57	0.40
2	0.45	0.34	0.44
3	0.04	0.09	<b>0.13</b>

Table 2. Caries prevalence and differences in caries descriptive features between the three collections (statistically significant differences are in bold)

Concerning the lesions traits, the most common are the occlusal caries in all sites. Once again, the site of Prušánky differs from the others. Indeed, there are less interproximal lesions in this collection than in the others ( $\chi^2 = 8.48$ ;  $p < 0.03$  for the crown and  $\chi^2 = 8.70$ ;  $p < 0.03$ ). Furthermore, another significant difference is shown for the severity of the lesion. But this time, the trend is reversed. Individuals of Mikulčice Bazilika have less severe lesions (stage 3) than in the two other collections ( $\chi^2 = 8.63$ ;  $p < 0.03$ ). The large caries are less frequent in Mikulčice Bazilika individuals. Prušánky's individual are the most affected. Is there a relationship between the severity of the lesions, the diet, and/or the dental care? This notion will be discussed later. Apart this last trait, we can observe that individuals from the two areas of Mikulčice have very similar features even if their socioeconomic status differs. The rural lifestyle seems to have more impact on dental health than socioeconomic status. The tooth development is also very important in the comprehension of the caries susceptibility. That is why dental enamel hypoplasia will give another type of information.

#### 4.2 Expression of the dental enamel hypoplasia

Contrary to the caries, dental enamel hypoplasia have been observed on all permanent teeth, even tooth germs. They will give information on crown development. Before discussing the differences between the collections, a paragraph on hypoplasia on deciduous teeth summarizes the encountered cases.

#### 4.2.1 Dental enamel hypoplasia on deciduous canines

Dental enamel hypoplasia on deciduous teeth were observed on four individuals from Mikulčice Bazilika. Any other individual presents hypoplasia in the other collections. All the cases correspond to what is named "localized enamel hypoplasia of human deciduous canines" (Clarkson, 1989; Taji et al., 2000). The figure 8 shows some of the observed cases.

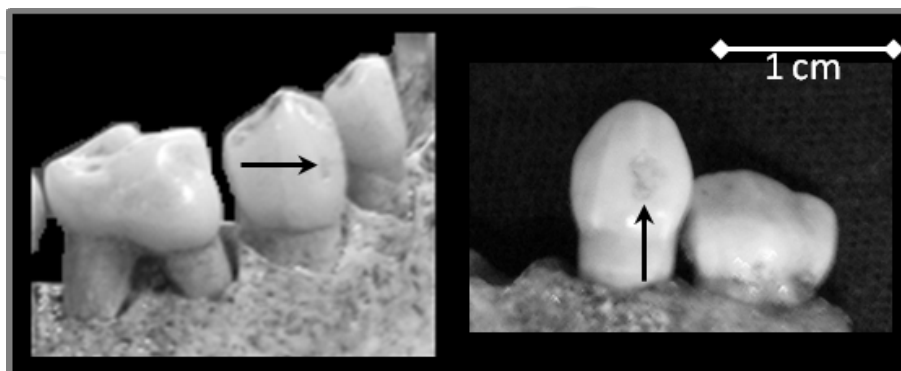


Fig. 8. Illustration of two localized enamel hypoplasia on deciduous lower canines

Some discussions exist on the aetiology of this sort of enamel defect (Skinner & Hung, 1989; Sweeney et al., 1971): genotype or environment? This point will be taken back in the next part of the chapter. All defects are localized on lower canine and are bilateral on 50% of the cases. The two unilateral cases show less marked than the bilateral ones. These four cases give argument for the difference of enamel susceptibility following the socioeconomic status.

#### 4.2.2 Results on dental enamel hypoplasia on permanent teeth

We took into account only linear enamel hypoplasia (LEH), because pitting defects were defeated (less than 2% in each collection, 0% at Mikulčice Bazilika). The comparison of LEH global prevalences between collections show a significant difference between Mikulčice's areas, and Prušánky (Table 3).

	Mikulčice Bazilika	Mikulčice Kostelisko	Prušánky
Total prevalence	<b>0.12</b>	0.18	0.16
Frequency of individuals affected (%)	10.59	<b>30.63</b>	17.91
Severity			
1	0.63	0.52	<b>0.29</b>
2	0.32	0.47	<b>0.61</b>
3	0.05	0.01	0.10
Part of the affected crown (beginning from the cervical region)			
Proximal third	0.21	0.29	0.34
Mesial third	0.59	0.55	0.57
Distal third	0.15	0.14	0.09
Whole height of the crown	0.04	0.02	0.00

Table 3. Linear enamel hypoplasia prevalence and differences in defect descriptive features between the three collections (statistically significant differences are in bold)

The whole prevalence (taking into account all observed teeth) is significantly lower in Mikulčice Bazilika ( $\chi^2 = 8.61$ ;  $p < 0.03$ ). If we consider the frequency of individuals affected, the greatest frequency is at Mikulčice Kostelisko with more than 30% of individuals ( $\chi^2 = 9.81$ ;  $p < 0.01$ ). If we consider the prevalence per tooth type, the results are given by the figure 9.

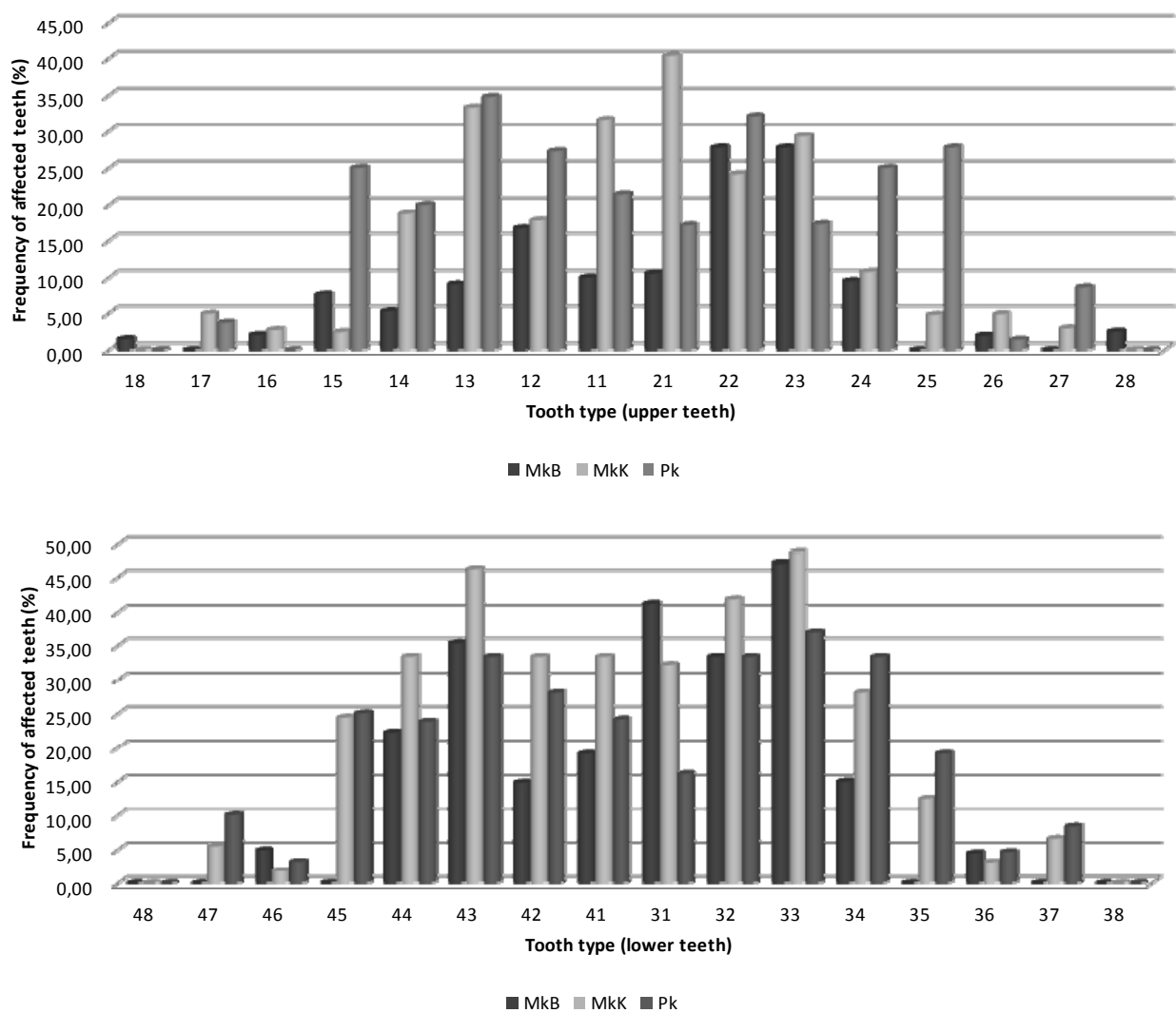


Fig. 9. Frequency of enamel hypoplasia per tooth type in the three collections

These graphs clearly show that there is a differential susceptibility in tooth type for developing LEH (Goodman & Armelagos, 1985; Palubeckaitė et al., 2002; Wright, 1997). Anterior teeth (incisors & canines) are more affected by the defect than posterior teeth (premolars & molars). On the whole, canines are the most affected. Even if differences between sites could be shown, they are not statistically significant (number of teeth per tooth type differs, thus graphic results are misleading). We can see that posterior teeth are also affected, demonstrated that these individuals suffered from non specific stress during late infancy period, that is to say during the time of formation of posterior tooth crowns. This point is important for the next paragraph concerning the relationship between the lesions, the defects, and the age-at-death.

Concerning the other features, the severity of the defects are obviously the same in the two areas of Mikulčice. The trend is inverted for Prušánky. There are more medium defects (stage 2) than slight defects (stage 1) in this collection ( $\chi^2 = 14.16$ ;  $p < 0.01$  &  $\chi^2 = 20.15$ ;  $p < 0.01$ ). Once again, the lifestyle seems to be more expressed by dental stress than the socioeconomic status. But what is more surprising is that this is the only feature which differs from the others. On the whole, the three collections present the same trend in LEH expression.

The last information given by table 3, is that the part of the affected crown does not show any statistical difference ( $p > 0.05$  for all statistical tests). This means that there is globally no difference on the period when the biological stress arose. The specific study with age estimation gives other information. Few individuals present teeth with all the crown height affected by multiple LEH. The stress period are thus isolated and occurred seldom more than two times during the crown formation. The next part presents when this stress took place in the crown formation, and its relationship with age-at-death.

#### 4.2.3 Age influence and relationship between caries lesions and hypoplastic defects

Two approaches were lead to evaluate the age influence on dental health and development:

- The first one is the representation of the mean age when the stress occurred (on lower permanent teeth). Figure 10 show these periods of stress for each collection. The data were calculated from those of Reid and Dean (2000) and Skinner & Goodman (1992). We also used the records on the affected third (table 3). Only the highest frequency is mentioned in order to leave the figure readable. This figure takes into account only the crown mineralization, thus the stress which is arisen during puberty is not mentioned.

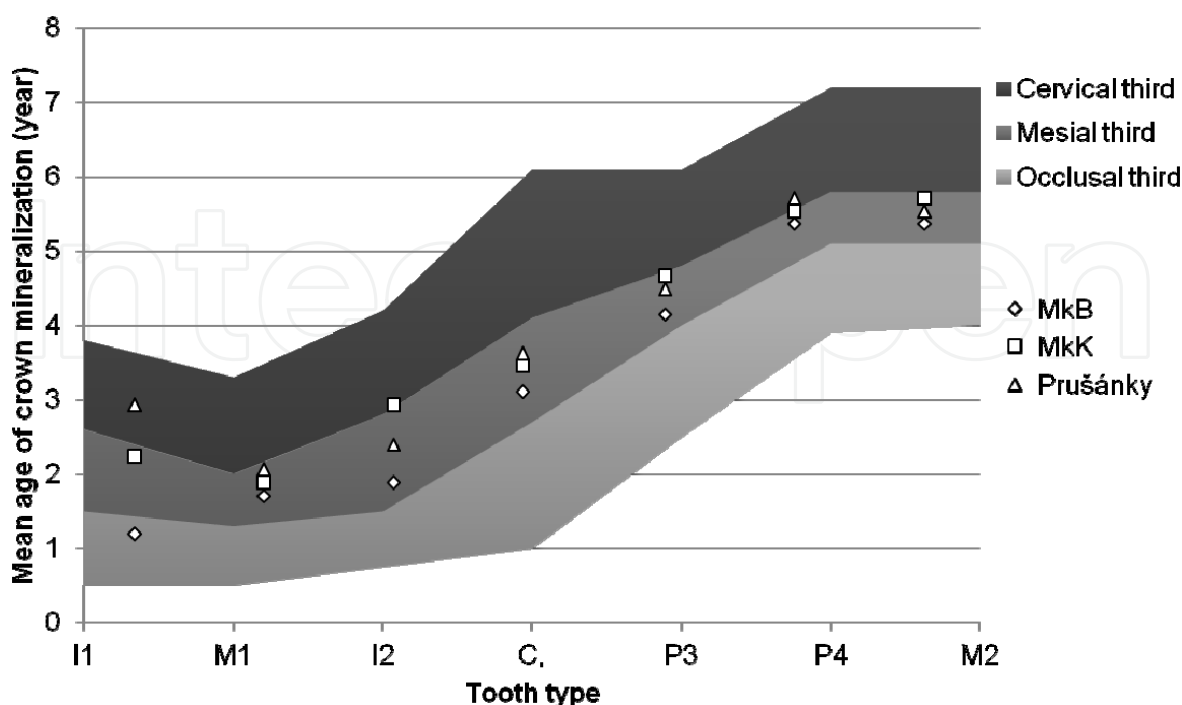


Fig. 10. Frequency of enamel hypoplasia per tooth type in the three collections



- It is noticeable that few stress arose during the occlusal third mineralization (light grey), apart for the first incisor in Mikulčice Bazilika. The individuals were subjected to stress during infancy, and especially between 2 and 6 years, and the stress concerns mainly the mesial third of the crowns for all collections. These results can be transposed to upper teeth. There is no statistical difference between collections for these stress periods ( $p>0.05$  for all statistical tests). Even if this approach is not very precise, it gives a good mean of comparison. Here, Mikulčice Bazilika seems to be different because the stress periods arose sooner in the mineralization stages than in the other collections. If we compare now the prevalence of dental lesions and defects in age classes, the frequencies are represented in figure 11.

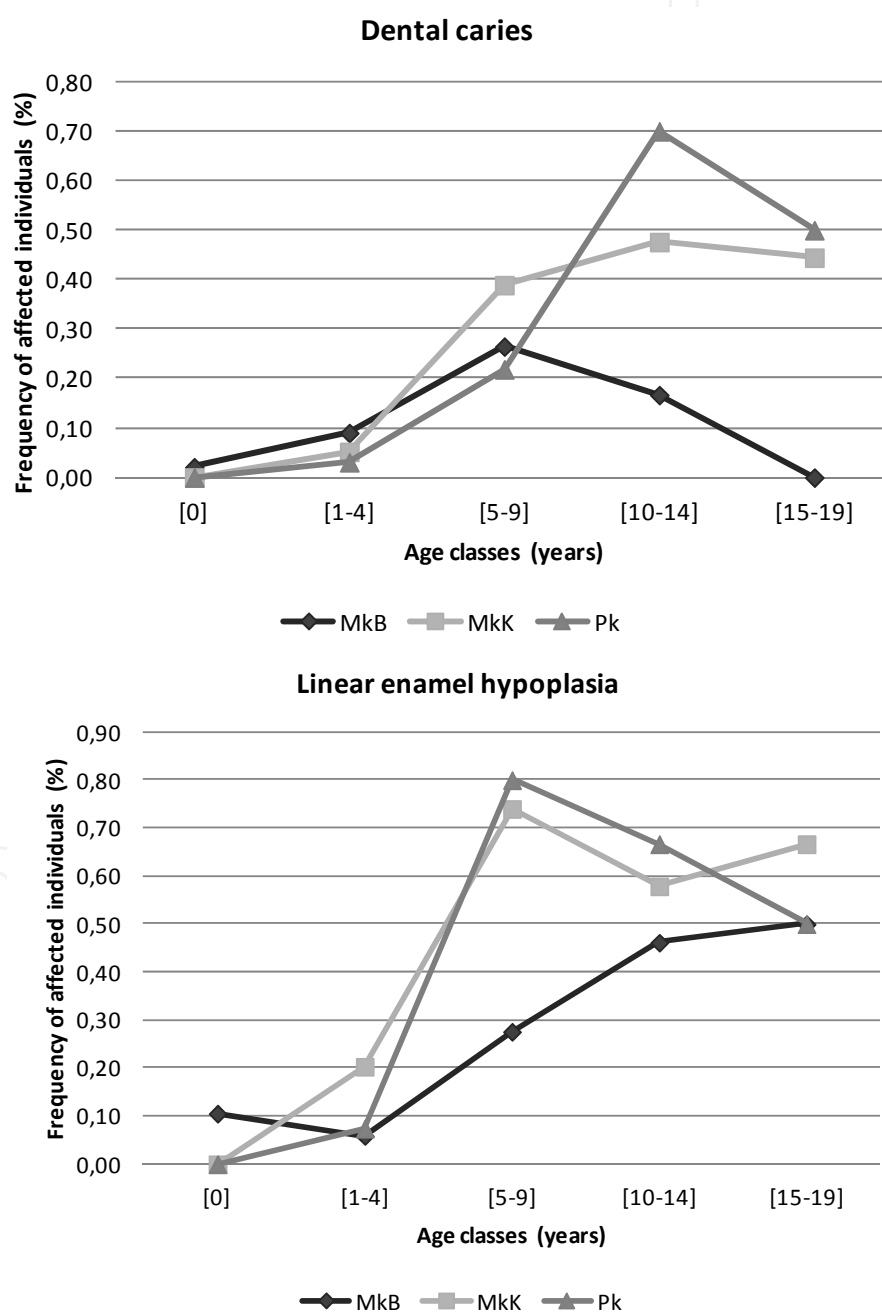


Fig. 11. Frequency of dental caries, and linear enamel hypoplasia per age class

When we compare the three collections by age class, it is noteworthy to remark that the individuals of Mikulčice Bazilika differ from the others for the classes 10-14, and 15-19 years for the caries lesions and for the class 5-9 for the LEH. Frequencies are significantly different between sites ( $p < 0.05$ ). For the dental caries, it should be an evidence of a better dental care in higher socioeconomic status populations. For LEH, less individuals are affected during the juvenile period, is the environment less stressing in higher socioeconomic status? These points will be discussed in the next part.

The second approach compares the dental features according to the tooth mineralization sequences describe in the methods. It is another mean to precise the last results, without using age estimation but biological traits. Table 4 gives the comparison for both dental caries & LEH.

These more biological data (we avoid age-at-death estimation) confirm precedent results, giving significant differences for the individuals of Mikulčice Bazilika in both dental caries and LEH. Indeed, the group 5 and 6 of Mikulčice Bazilika are significantly less affected by caries lesions than those of Mikulčice Kostelisko and Prušánky. The last graph gave a trend; here we have a reliable result. We also notice a difference in group 4 and 5 for the LEH. The arguments of dental care and attenuated stress for these stages of development are thus strengthened.

Group	Mikulčice Bazilika		Mikulčice Kostelisko		Prušánky	
	Caries	LEH	Caries	LEH	Caries	LEH
1	0.00%	5.26%	0.00%	8.82%	0.00%	0.00%
2	7.14%	23.08%	4.17%	22.73%	10.52%	21.05%
3	27.27%	41.67%	31.82%	57.14%	27.27%	36.36%
4	20.00%	<b>20.00%</b>	25.00%	90.90%	20.00%	80.00%
5	<b>11.11%</b>	<b>55.56%</b>	50.00%	78.13%	23.07%	78.57%
6	<b>0.00%</b>	62.46%	88.89%	73.68%	61.53%	61.53%

Table 4. Frequency of dental caries, and linear enamel hypoplasia per dental mineralization group (significant differences are in bold)

To sum up, few differences between the collections are highlighted: one on global prevalence of LEH, and two on location and severity of dental caries. However, if we compare more biological traits, related to tooth development and enamel susceptibility, then, some trends to discuss appear.

## 5. Discussion

Three main topics will be discussed in this last part. The first one deals with the assets and the drawbacks of archaeological collections in a study of dental health. The second develops the influence of socioeconomic status on dental mineralization. And finally, we will discuss the differential enamel susceptibility to be affected from defects and lesions.

### 5.1 Archaeological collections: assets and drawbacks in the study of socioeconomic influence on dental health

There are many studies on the influence of lifestyle and/or socioeconomic status on dental health (Bodoriková et al., 2005; Duray, 1990; Kim & Durden, 2007; Vodanovic et al., 2005). However, they concern both living and past populations. Moreover, the protocol of

observation and statistical analyses differ from one to another. Thus, it is very difficult to compare the results and to be confident in our interpretations. That is why we chose to work only on huge archaeological samples, even if they also have some downsides. The tooth sample size in archaeological collections are mostly important (several hundreds of teeth), especially for medieval cemeteries. Large burials places are excavated, giving many individuals, including juveniles. The sample size is sufficient to provide reliable statistical results. Nevertheless, regarding the bone and teeth preservation, data are as often as not missing, and we do not have all dentition for each individual (Duyar & Erdal, 2003; Hillson, 2001). That is why different calibrations are calculated to adjust the frequencies and to take into account the missing data.

The second advantage of archaeological collection is that we can have homogeneous collections, that is to say that population of a same cemetery comes from a global same lifestyle and the admixture (thus the influence of genetic part) is less pronounced than in living population. However, in such collection, we have the problem of age-at-death estimation. When studies based on living populations have accurate age of the subjects under study, in our case estimations (even with reliable methods) give at best age classes (Albert and Greene, 1999; Cole, 2003; Heuzé & Cardoso, 2008; Lewis & Gowland, 2007). This study uses a little the age-at-death estimation that is why we try to free from this bias using dental mineralization stages. The obtained results and differences highlighted show that this is a way to work to enhance the quality and reliability of our study.

The third point to discuss also deals with reliability, but on the recording methods. It has been mentioned in the second part of this chapter that we have evaluated the intra- and inter-observer error of our protocol for both caries lesions and enamel hypoplasia. To go back on the terms of Ulijaszek & Lourie (1997), we must compare something comparable. Yet, recording dental caries and enamel hypoplasia is always a little bit subjective. The data must be as quantitative as possible and thus at least qualitative (Landis & Koch, 1977). The results of intra- and inter-observer errors in our last study (Garcin et al., 2010), show that even if the results are satisfactory, we cannot completely be completely free from this bias (Berti & Mahaney, 1995; Danforth et al., 1993; Hillson, 1992).

Being aware from these main biases, we can discuss the influence of socioeconomic status on dental health and development.

## **5.2 Have you spoken of a possible socioeconomic influence on dental health and development?**

Our results show that except an inferior global prevalence of LEH and less invading caries in the higher socioeconomic status collection, there is no difference between the individuals of Mikulčice. On the other hand, Prušánky individuals differ from the other more often, especially on dental caries. Do these results intend that the lifestyle have more influence on dental health than the socioeconomic status? We explained in the materials paragraph that it is quite difficult to define a clear socioeconomic status in archaeological populations even if they are relative homogeneous. To answer clearly this question in the big site of Mikulčice, it should be interesting to compare all parts of the area. However, comparing the prevalence of LEH in other mediaeval/modern groups in Europe (Coulon et al., 2008; Herold, 2008; Šlaus et al., 2002) it is apparent that our values are relatively low, but overall features are similar to the other studies. It is the same for the caries lesions even if the results are hardly

comparable (Espeland et al., 1988; Rudney et al., 1983; Watt et al., 1997; Williams & Curzon, 1985). Nevertheless, our results counteract several other studies (on past and present populations), which claim that the socioeconomic status influence the health (Goodman et al., 1988; Hauser, 1994; Henneberg et al., 2001; Kim & Durden, 2007). Although a direct parallel is difficult, this is a striking result. We must keep in mind the limits of such studies and thus accept that we give only trends, especially on the relationship between the dental development and the socioeconomic status. To our point of view, in past population, we should take into account the global lifestyle rather than searching to define a clear socioeconomic status. Besides we found in our last studies clear differences between rural and urban lifestyle, what was confirmed by many studies (Betsinger, 2007; Budnik & Liczbinska, 2006; Riva et al., 2009; Van de Poel et al., 2007; Williams & Galley, 1995). We also must take in mind that in past population, we must deal with the “osteological paradox” (Byers, 1994; Wood et al., 1992; Wright & Yoder, 2003). The juvenile individuals we study are those who have not survived and who have never reached the adulthood (Saunders & Hoppa, 1993). On the contrary, the individuals showing dental defects and lesions survived sufficiently a long time to develop the trait we wanted to record. Thus, healthy past populations are not necessarily those who the most suffer from biological stress and who had the best dental care. That is why it is interesting to focus on biological traits only, avoiding abusive interpretations. The relationship between dental development and health seem to be a good track to go into in depth.

### 5.3 Dental mineralization, enamel susceptibility, and health

Until now, relatively few studies have considered the possible relationship between enamel hypoplasia and dental caries (Khan et al., 1999; Schneider, 1986; Sweeney et al., 1969; Walker & Hewlett, 1990). Even if tooth susceptibility is different for the two indicators, we could imagine that enamel with defects is more sensible to bacterial attacks. This hypothesis was examined by establishing a chart given the frequency by age class having one of the traits or both traits under study (Table 5).

This table clearly shows that there is slight correlation between caries and hypoplasia. Indeed, the individuals of Mikulčice Kostelisko and Prušánky can develop both traits in the same time but it is not a sweeping statement. Only older age classes (after 5 years old) show the possible relationship, but most of the defects and lesions appear separately. What is striking is that the individuals having the localized hypoplasia on deciduous teeth also have LEH on permanent teeth, and also caries lesions. This caries susceptibility seem to be related to hypocalcified teeth (Duray, 1990), and repeated stress periods. This observation was also made in several studies, but not only on human but also in Great Apes (Lukacs, 1999a; Lukacs, 1999b; Lukacs, 2001; Skinner & Goodman, 1992). Moreover, most of the authors link this observation to a low nutritional status (Norén, 1983; Skinner & Hung, 1989; Sweeney et al., 1971; Taji et al., 2000). Even if genetics mainly lead dental development, the environmental conditions and stress periods also influence the dental mineralization and thus the enamel susceptibility to be affected by caries. Even if it is difficult to demonstrate, it seems that after passing a certain threshold, the underlying aetiological factors resulting in caries and enamel hypoplasia interact, creating a vicious cycle – physiological balance is disturbed through pathogens and inadequate nutrition, compromising metabolism and the immune system. This makes the afflicted individual susceptible to further infections and ultimately even more unable to cope with additional stresses (Obertova, 2005; Obertova &

Thurzo, 2008). This last remark corroborates our comparisons with the biological groups, which show that juveniles are more likely to develop both traits on permanent teeth.

Even if this study raises only some trends and being aware of its limits, we do not want misinterpret, the relation to age and indirect influence of the socioeconomic status on defects and lesions are obvious. We must find now the methodological and theoretical framework to prove them.

## 6. Conclusion

The goal of the present research was to obtain information about the influence of the socioeconomic status on dental health and development by determining the prevalence and characteristics of enamel hypoplasia and caries in two Great Moravian populations at Mikulčice and Prušánky.

Collection / Age group	CAR0 / LEH0 <i>n</i>	Frequency	CAR1 / LEH1 <i>n</i>	Frequency	CAR1 / LEH0 <i>n</i>	Frequency	CAR0 / LEH1 <i>n</i>	Frequency	Total
Mikulčice Bazilika									
0	41	<b>0.85</b>	0	0.00	1	0.02	6	0.13	48
1-4	83	<b>0.83</b>	0	0.00	9	0.09	8	0.08	100
5-9	24	<b>0.70</b>	1	0.03	8	0.24	1	0.03	34
10-14	12	<b>0.66</b>	1	0.06	2	0.11	3	0.17	18
15-19	6	<b>1.00</b>	0	0.00	0	0.00	0	0.00	6
ND	10	<b>0.91</b>	0	0.00	0	0.00	1	0.09	11
Total	176	<b>0.81</b>	2	0.01	20	0.09	19	0.09	217
Mikulčice Kostelisko									
0	36	<b>1.00</b>	0	0.00	0	0.00	0	0.00	36
1-4	63	<b>0.82</b>	3	0.04	1	0.01	10	0.13	77
5-9	15	0.28	20	<b>0.37</b>	1	0.02	18	0.33	54
10-14	8	<b>0.38</b>	8	<b>0.38</b>	2	0.10	3	0.14	21
15-19	2	0.22	3	<b>0.33</b>	1	0.11	3	<b>0.33</b>	9
ND	31	0.25	1	0.25	1	0.25	1	0.25	4
Total	155	<b>0.66</b>	35	0.15	6	0.03	35	0.15	231
Prušánky									
0	48	<b>1.00</b>	0	0.00	0	0.00	0	0.00	48
1-4	59	<b>0.91</b>	0	0.00	2	0.03	4	0.06	65
5-9	11	0.36	6	0.19	1	0.03	14	<b>0.44</b>	32
10-14	2	0.20	5	<b>0.50</b>	2	0.20	1	0.10	10
15-19	0	0.00	0	0.00	1	<b>0.50</b>	1	<b>0.50</b>	2
ND	16	<b>1.00</b>	0	0.00	0	0.00	0	0.00	16
Total	136	<b>0.79</b>	11	0.06	6	0.03	36	0.12	173

CAR 0: absence of caries; CAR 1: presence of caries; LEH 0: absence of hypoplasia; LEH 1: presence of linear hypoplasia; ND: non defined age-at-death.

Table 5. Prevalence of caries against LEH per age group in the three collections (the highest frequencies are in bold)

Dental analysis revealed a slightly influence of socioeconomic status on dental health. In addition, considering the observed prevalence of the hypoplastic lesions and caries in the analysed skeletal samples, a pattern emerged suggestive of probable influence of lifestyle and high importance of studying biological traits rather than using age-at-death estimation.

Two main prospects are highlighted from this research: the need of analyzing the whole sample of Mikulčice-Valy in order to compare other socioeconomic status in big dental samples, and integrated new methods in population studies to avoid abusive interpretations and more reliable comparisons. The large sample size of juveniles and preservation of the skeletal material make the early medieval Great Moravian populations at Mikulčice and Prušanky unique in their ability to demonstrate the distribution of two dental indicators, dental caries and enamel hypoplasia. We are convinced that the study of non-adult skeletal and dental remains is one of the best mean to increase our knowledge of the environmental and genetic parts in the human development, and certainly one of the most challenging and exciting area of research in Physical Anthropology and Bioarchaeology.

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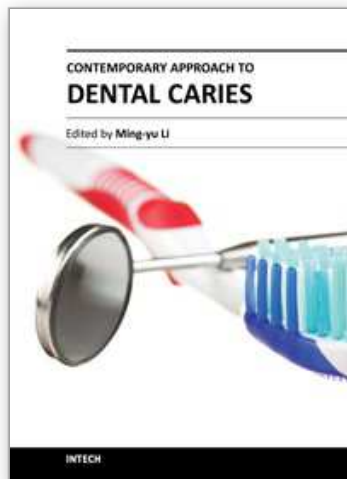
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