# Ecological Aspects of Past Human Settlements in Europe

Edited by

Pia Bennike, Éva B. Bodzsár and Charles Susanne


Budapest 2002

# Biennial Books of *EAA*

THE OFFICIAL PUBLICATION OF
THE EUROPEAN ANTHROPOLOGICAL ASSOCIATION

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ISSN 1586-3468
ISBN 963 463 546 6

Published by Eötvös University Press
Budapest, Hungary

Printed by Argumentum, Budapest, Hungary

# Dental Disease as an Indicator of Ecological Factors in Medieval Skeletal Populations from Slovakia

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**Summary:** This paper summarizes results of previous odontological research into the medieval ($7^{th}$–$15^{th}$ c. AD) populations in Slovakia and presents conclusions concerning the diachronic and geographical differences in their dental disease. The dental remains from 16 cemeteries were used. The remains were divided into four chronological (Avar Period, Great-Moravian Period, Hungarian Conquest Period, Arpadian Period) and two geographical groups (east Slovakia, southwest Slovakia). The dental data, such as caries, ante-mortem tooth loss (AMTL), caries intensity, caries frequency and others, were compiled from more than 1,000 adult dentitions. The statistical analyses revealed only two kinds of significant differences within the data compared. Both differences related to females: 1) tooth-count caries rate (%C) in east and southwest Slovakia (with higher rate in east), 2) individual-count caries-AMTL rate (%indCE) across diachronic groups (showing a significant quadratic [parabolic] trend with ascending portion from Hungarian Conquest Period to Arpadian Period). Furthermore, statistical analysis of the female data showed significant quadratic trend in caries intensity (I-CE) and caries frequency (F-CE), suggesting an increase in their prevalence from the Great-Moravian to the Arpadian Period. However, most of the data obtained indicate that due to both similar ecological conditions and subsistence activities the diet of the medieval populations investigated did not substantially vary.

**Key words:** Odontology, paleopathology, ecology, Middle Ages, Central Europe.

## Introduction

Dental status analysis has the potential to shed light on the diet and ecological conditions that influenced the life of past populations. However, at present there are no comprehensive data available concerning the dental health of medieval skeletal populations from the territory of Slovakia. Even though in the past 40 years some data regarding this issue were published, the majority of such data only provided a certain and minor part of a routine anthropological analysis of several skeletal series (e. g. Thurzo 1969, 1972; Avenariová 1971, Hanáková and Stloukal 1976, Jakab

1977, 1978; Vondráková 1994). Some of the studies published in 1960s and 1970s by stomatologists (e.g. Andrik and Müncnerová 1961, Andrik 1979), or in the past decade by anthropologists (Bodoriková et al. 1998, Beňuš 1999, Bodoriková et al. 1999, Beňuš and Thurzo 2001), dealt only with dental health. Since the dental anthropology of the medieval skeletal populations has never been reported in detail, the objective of this paper is to summarize and analyse the knowledge in this field both from the chronological (cultural) and geographical point of view. Besides, it is to be stated that some data of the original sources are presented here in corrected and/or completed form.


*Figure 1:* Geographical locations of investigated medieval sites in Slovakia.

*Table 1:* Survey of investigated cemeteries.

| Site | References | Group | Archaeol. date | Chronol. group |
|---|---|---|---|---|
| Želovce (ZEL) | Hanáková, Stloukal 1976 | Southwest | 7th–8th c. AD | 1 |
| Šebastovce (SEB) | Bodoriková 1999 | East | 7th–9th c. AD | 1 |
| Lupka (LUP) | Thurzo 1969 | Southwest | 9th c. AD | 2 |
| Devín-Za kostolom (DZK) | Beňuš n.d. | Southwest | 9th c. AD | 2 |
| Závada-Chríby (ZCH) | Jakab 1983 | Southwest | 9th c. AD | 2 |
| Nitra-Pod Zoborom (NPZ) | Jakab 1978 | Southwest | 9th–10th c. AD | 2 |
| Tvrdošovce (TVR) | Thurzo 1980 | Southwest | 9th–10th c. AD | 2 |
| Pobedim-Hradištia (PHR) | Jakab n.d. | Southwest | 9th–10th c. AD | 2 |
| Zemné-Gúg (ZEG) | Jakab 1980 | Southwest | 10th c. AD | 3 |
| Malé Kosihy II. (MAK) | Vondráková 1994 | Southwest | 10th–11th c. AD | 3 |
| Pobedim-Na laze (PNL) | Thurzo 1972 | Southwest | 10th–11th c. AD | 3 |
| Abrahám (ABR) | Stloukal et al. 1971 | Southwest | 11th c. AD | 3 |
| Bratislava-Hrad (BRH) | Avenariová 1971 | Southwest | 10th–12th c. AD | 4 |
| Nové Zámky (NOZ) | Jakab 1977 | Southwest | 10th–12th c. AD | 4 |
| Devín-Hrad (DHR) | Beňuš 1999 | Southwest | 11th–12th c. AD | 4 |
| Ducové (DUC) | Hanáková, Stloukal 1984 | Southwest | 10th–15th c. AD | 4 |

According to the archaeological dating and archaeological-cultural background, the entire material consists of four main chronological (cultural) groups: 1) $7^{th}$–$9^{th}$ c. AD (Avar Period), 2) $9^{th}$–$10^{th}$ c. AD (Great-Moravian Period), 3) $10^{th}$–$11^{th}$ c. AD (Hungarian Conquest Period), 4) $11^{th}$–$12^{th}$ ($15^{th}$, in one case) c. AD (Arpadian or Bjelo-Brdo Culture Period, Figure 1, Table 1). Due to the problems with precise dating and the existence of some chronologically overlapping populations, the boundaries between the successive individual periods could not be quite distinct and accurate.

This chronological division suggests that the inhabitants of the medieval Slovakia were of different ethnic origin, and – in accordance with their life style – also their subsistence strategies should have been be more or less different. The diet of the nomadic populations, represented in Slovakia by Avars (Avar Period) and Old Hungarians (Hungarian Conquest Period) at that time, should have traditionally contained high proportion of meat and dairy protein, including some vegetables and fruits. On the other hand, the sedentary Slavic tribes living in Great-Moravian Empire should have mostly consumed agricultural products rich in carbohydrates (starch and sugars) supplemented with milk, dairy products and meat. These two partially contrasting subsistence strategies should be adequately reflected in prevalence of dental disease.

As revealed by the monitoring of the cariogenic potential of the diet, had the food contained both starch and sugar (carbohydrates), such food would have been highly cariogenic (e.g. Newbrun 1982, Hillson 1996, Larsen 1997). Conversely, protein, fat, phosphorous and calcium (Mundorff-Shrestha et al. 1994), as well as fish (Hillson 2001) in the diet are associated with a low dental caries rate. For that reason, lower dental disease prevalence in Avar and Old-Hungarian populations can be anticipated. (For the Arpadian Period, see the Discussion.)

Bearing in mind that "The unique cultural and ecological context in which human societies develop and function will produce regional differences... " (Lukacs 1996), the sites investigated are divided into two geographic groupings: the east-Slovakian (the Šebastovce cemetery), and the southwest-Slovakian grouping (all the remaining cemeteries). As a result of favourable circumstances, a sufficient number of individuals (dentitions) are represented in the east-Slovakian Šebastovce cemetery which allowed for the statistical analysis to take place (Table 2).

We believe that there are at least two (one ecological and one ethnic-cultural) assumptions for this fundamental site division: 1) orographic and/or geological differences (e.g. agricultural and climatic conditions, iron ore deposits, concentration of fluoride in ground water) between southwestern Slovakia (Danubian Lowland) and eastern Slovakia (Košice Basin); 2) different direction and character of Avar invasion: Danubian Lowland was occupied by tribes that crossed the Danube from southwest (from Pannonia), Košice Basin – more or less enclosed geographical region (Zábojník 1995) – was taken by tribes that came from south (from the area of the Upper Tisza river along the Hernád and Bodrog rivers) (Avenarius 1974, V. Turčan, pers. comm., 2002). Besides, each human population (incl. a tribe) is characterized by unique genetic composition (Hildebold et al. 1989) which also influences the dental health.

*Table 2:* Basic distribution of investigated teeth and dentitions.

| Site | Teeth | | | Dentitions | | | Group |
|---|---|---|---|---|---|---|---|
| | Males | Females | Pooled | Males | Females | Pooled | |
| ZEL | 1918 | 3156 | 5074 | 104 | 178 | 282 | 1 |
| SEB | 966 | 1537 | 2503 | 54 | 85 | 139 | 1 |
| Total | 2884 | 4693 | 7577 | 158 | 263 | 421 | 1 |
| LUP | 362 | 411 | 773 | 19 | 20 | 39 | 2 |
| DZK | 355 | 212 | 567 | 33 | 27 | 60 | 2 |
| ZCH | 242 | 86 | 328 | 13 | 7 | 20 | 2 |
| NPZ | 195 | 279 | 474 | 11 | 16 | 27 | 2 |
| TVR | 114 | 207 | 321 | 8 | 10 | 18 | 2 |
| Total | 1268 | 1195 | 2463 | 84 | 80 | 164 | 2 |
| PHR | 188 | 395 | 583 | 12 | 27 | 39 | 3 |
| ZEG | 394 | 372 | 766 | 21 | 24 | 45 | 3 |
| MAK | 1556 | 1555 | 3111 | 104 | 120 | 224 | 3 |
| PNL | 401 | 398 | 799 | 21 | 21 | 42 | 3 |
| ABR | 454 | 370 | 824 | 32 | 23 | 55 | 3 |
| Total | 2993 | 3090 | 6083 | 190 | 215 | 405 | 3 |
| BRH | 514 | 317 | 831 | 27 | 20 | 47 | 4 |
| NOZ | 165 | 245 | 410 | 13 | 16 | 29 | 4 |
| DHR | 569 | 672 | 1241 | 48 | 60 | 108 | 4 |
| DUC | 4862 | 4485 | 9347 | 51 | 60 | 111 | 4 |
| Total | 6110 | 5719 | 11829 | 139 | 156 | 295 | 4 |
| Grand total | 13255 | 14697 | 27952 | 571 | 714 | 1285 | 1–4 |

## Material and Methods

The data included in this analysis were retrieved from publications dealing with anthropological (partly also odontological) analyses of Slovak cemeteries dated from $7^{th}$ to $15^{th}$ c. AD

Due to different methodical approaches and different focus on dental disease by individual authors, as well as the limitations of this paper, we can only offer here the very basics of the dental status. Thus, we are not in a position to present interesting topics here, such as enamel hypoplasia, abscesses, traumatic injuries, periodontal disease, etc. We focus on primary dental pathologies represented by carious lesions (expressed in form of tooth-count caries rate [*% C*], individual-count caries rate [*% indC*]), and ante-mortem tooth loss AMTL (expressed in form of alveolar-count AMTL rate [*% E*], individual-count AMTL rate [*% indE*]). These simple characteristics are completed with the complex rates summarizing both the caries and AMTL prevalence: caries intensity (I-CE = *% C + % E*), individual-count caries-AMTL rate (*% indCE*), and caries frequency (F-CE = *% indC + % indE + % indCE*).

As the published data sources do not specify the method of caries scoring, ou communications with most of the authors (except I. Avenariová who was no available at the time) has shown that the authors included only clear cavities – as i the case in most studies (Hillson 1996) – rather than white and brown spot lesions Although the "cavity" caries rates should have been underestimated in comparison with the data acquired by the white-and-brown spot method, interrelations of the data presented (obtained by the equal "cavity" method) are not affected.

Statistical analysis was performed by S-PLUS at the Department of Probability and Mathematical Statistics, Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava. For the purposes of the statistical analysis, the generalized linear (GL) models were used allowing an accommodation of both the non-normal response distribution and transformation to linearity. Of the variety of distributions supplied by S-PLUS for GL modeling, we chose the so-called Poisson log-linear models (Christensen 1997). The canonical link for the Poisson family is $g(\lambda) = log(\lambda)$, where $\lambda$ is mean of Poisson distribution, and the main use of this family is to fit surrogate Poisson log-linear models which, in fact, are the multinomial frequency data. These models were directly applied to the rates of dental pathologies subject to study. We created several model types for each of the seven rates subject to study (*%C, %E, I-CE, %indC, %indE, %indCE, F-CE*). Consequently, by using the residual deviance, we chose the best model to compare the explanatory variables (which form the model matrix): sex (M = male, F = female), time intervals (time1 = 1st group, time2 = 2nd group, time3 = 3rd group, time4 = 4th group), geographical regions (east, south-west), and interactions between these factors. By using the residual deviance and decomposition techniques, we then chose the best model. (Unfortunately, in the case of the Avar-Period *% indCE* rate, there were no data available for us.)

GL models (for specific rates, the best model type was only one for both females and males) (Vanables and Ripley 2000) are given in a very simple form: $g(\lambda) = \beta_0 + \beta_1 G + \beta_2 T + \beta_3 GT$, $g(\lambda) = \beta_0 + \beta_1 G + \beta_2 T$, $g(\lambda) = \beta_0 + \beta_1 G$, $g(\lambda) = \beta_0 + \beta_1 T$, and $g(\lambda) = \beta_0 + \beta_1 S$, where T stands for time intervals, *G* for geographical regions, and S for sex.

We used the *F*-test ($\alpha = 0.05$) for testing $H_0$: $\beta_i = 0$, where $\beta_i s$ are regression coefficients in front of the explanatory variables. If we decide to reject $H_0$, then $\beta_i s$ are statistically significant. Consequently, by means of the Tukey and LSD method (multiple comparison, Fisher's LSD method for comparison of two factors, Tukey method for comparison of more than two factors), where intervals excluding *0* are marked with '****' (this means that there is a statistical significance for the differences in *i* and *j* factors), – we have set 95- % simultaneous confidence intervals for specified linear combinations.

The time trends are analysed by a method of linear regression models (LM). We used F-CE and I-CE factors (both for females and males) as a response variable *y*, and a model matrix is formed by time intervals; $y = \beta_0 + \beta_1 T + \beta_2 T^2$ for quadratic time trend, and $y = \beta_0 + \beta_1 T$ for linear time trend (Vanables and Ripley 2000). Using a coefficient of determination and decomposition techniques, we chose the best LM. Then we used the *F*-test ($\alpha = 0.05$) for testing $H_0$: $\beta_i = 0$, where $\beta_i s$ are regression coefficients. If we decide to reject $H_0$, then $\beta_i s$ are statistically significant.

## Results

As revealed by the basic distribution of investigated teeth and individuals presented in Table 2, both the chronological and geographic groups are represented by a sufficient number of cases, hence their statistical testing should provide for reliable information on the dental state of the investigated populations. The prevalence of investigated dental pathologies is presented by sexes and Table 3 gives overview of the individual skeletal series. Of all the seven dental pathological rates, the caries intensity *I-CE* and the caries frequency *F-CE* are most important.

As far as the caries intensity is concerned, the rates of individual cemeteries within the pooled sample, and in the female sample (Table 3) are relatively homogeneous, they range from 12.8 % to 32.1 % and from 14.1 % to 30.8 %, respectively; the conspicuously high rate of the Tvrdošovce cemetery (TVR) in the male sample (*I-CE* = 46.6 %) is insignificant due to small number of individuals (i.e. dentitions) in this skeletal population (8 males, 10 females, see Table 1).

The rates of caries frequency *F-CE* (Table 3, last column) are less homogeneous; within the pooled sample their values range from 53.0 % to 95.3 %, which means that more than half of all excavated medieval inhabitants suffered from at least one carious tooth or AMTL. Oddly enough, among the male samples there are two cemeteries (TVR = Tvrdošovce, DHR = Devín-Hrad) with no single dentally "intact" individual. As far as the Devín-Hrad cemetery is concerned, a high number of females (95.0 %), too, suffered from dental caries and/or AMTL.

When viewing all the cemeteries as a diachronic and geographic unit, there are no statistically significant sex differences, either in *I-CE* (M = 23.83, F = 21.09, p-level = 0.674), or in F-CE (M = 74.3, F = 70.1, p-value=0.863).

The *F*-tests presented in Table 4 (ns: p-value >0.1; *: p-value from interval [0.05; 0.1], **: p-value from interval [0.01; 0.05]), used to testing the reliability of obtained data in the sense of diachronic and/or geographic trends, reveal that almost all of the factors under consideration are insignificant.

The geographical *(G)* and time *(T)* factors are significant (see Table 4) in two cases only (*% C, % indCE*) observed with females. As suggested by the 95-% confidence intervals for differences in estimates for these factors, the first case is represented by geographical differences (Figure 2), the second by quadratic trend with descending portion from Great-Moravian Period to Hungarian Conquest Period, and ascending portion from Hungarian Conquest Period to Arpadian Period.

The caries rate *%C* suggests that the diet of the east-Slovakian Avar-Period females may have differed not only for the contemporary local male inhabitants, but also for inhabitants from other regions of Slovakia. Apparently, the female diet should have contain higher percentage of carbohydrates.

The significance of the *%indCE* rate (p-value = 0.091) in Table 4 suggests that there are differences between chronological groups. This finding was confirmed by significant quadratic trend (p-value = 0.029, (Figure 3).

*Table 3:* Dental pathology rates in Slovak medieval skeletal populations.

| Site | %C | %E | I-CE | % indC | % indE | % indCE | F-CE |
|---|---|---|---|---|---|---|---|
| | | | | Males | | | |
| ZEL | 4.8 | 11.5 | 16.3 | na | na | na | 70.2 |
| SEB | 14.1 | 12.4 | 25.5 | na | na | na | 90.7 |
| LUP | 5.8 | 14.4 | 20.2 | na | na | na | 47.4 |
| DZK | 7.6 | 11.4 | 19.0 | 17.4 | 30.4 | 21.7 | 69.6 |
| ZCH | 4.5 | 9.7 | 14.2 | 0.0 | 30.8 | 30.8 | 61.6 |
| NPZ | 9.7 | 14.0 | 23.7 | 0.0 | 9.1 | 54.5 | 63.6 |
| TVR | 16.7 | 29.9 | 46.6 | 1.5 | 12.5 | 75.0 | 10.,0 |
| PHR | 3.2 | 7.9 | 11.1 | 16.7 | 58.3 | na | 75.0 |
| ZEG | 4.8 | 9.0 | 13.8 | 14.3 | 23.8 | 23.8 | 61.9 |
| MAK | 4.9 | 11.0 | 15.9 | na | na | na | 75.0 |
| PNL | 10.2 | 10.7 | 21.0 | na | na | na | 71.4 |
| ABR | 4.0 | 29.7 | 33.7 | 6.2 | 62.6 | 25.0 | 93.8 |
| BRH | 3.9 | 8.9 | 12.0 | na | na | na | 48.2 |
| NOZ | 5.5 | 20.3 | 25.8 | 7.7 | 46.2 | 15.4 | 69.3 |
| DHR | 7.2 | 14.5 | 21.7 | 21.7 | 43.5 | 34.8 | 100.0 |
| DUC | 10.4 | 23.0 | 33.4 | 6.6 | 37.3 | 47.7 | 91.6 |
| | | | | Females | | | |
| ZEL | 5.6 | 13.6 | 19.2 | na | na | na | 68.0 |
| SEB | 13.1 | 10.5 | 23.6 | na | na | na | 91.8 |
| LUP | 10.0 | 10.0 | 20.0 | na | na | na | 60.0 |
| DZK | 10.4 | 11.5 | 21.8 | 0.0 | 23.1 | 53.8 | 76.9 |
| ZCH | 8.1 | 10.1 | 18.2 | 0.0 | 0.0 | 57.1 | 57.1 |
| NPZ | 10.4 | 10.4 | 20.8 | 0.0 | 0.0 | 68.8 | 68.8 |
| TVR | 4.8 | 11.2 | 16.0 | 0.0 | 20.0 | 50.0 | 70.0 |
| PHR | 7.3 | 6.8 | 14.1 | 33.3 | 18.5 | 14.8 | 66.6 |
| ZEG | 8.9 | 6.8 | 15.7 | 16.7 | 20.8 | 25.0 | 62.5 |
| MAK | 7.3 | 13.5 | 20.8 | na | na | na | 78.3 |
| PNL | 10.1 | 11.6 | 21.7 | na | na | na | 76.2 |
| ABR | 5.4 | 19.2 | 24.6 | 13.0 | 43.5 | 21.7 | 78.2 |
| BRH | 6.0 | 11.4 | 17.4 | na | na | na | 60.0 |
| NOZ | 9.8 | 8.9 | 18.7 | na | 18.8 | 62.5 | 81.3 |
| DHR | 8.5 | 22.3 | 30.8 | 12.5 | 22.5 | 60.0 | 95.0 |
| DUC | 8.4 | 22.4 | 30.8 | 8.0 | 41.8 | 36.6 | 86.4 |
| | | | | Pooled | | | |
| ZEL | 5.3 | 12.8 | 18.1 | na | na | na | 68.8 |
| SEB | 11.5 | 11.2 | 22.7 | na | na | na | 91.3 |
| LUP | 8.0 | 12.0 | 20.1 | na | na | na | 53.8 |
| DZK | 7.9 | 13.1 | 20.9 | 26.7 | 36.7 | 20.0 | 83.4 |
| ZCH | 5.5 | 9.8 | 15.3 | 0.0 | 20.0 | 40.0 | 60.0 |
| NPZ | 10.1 | 12.0 | 22.1 | 0.0 | 3.7 | 63.0 | 66.7 |
| TVR | 4.6 | 16.2 | 20.8 | 4.8 | 14.3 | 66.7 | 85.8 |
| PHR | 5.9 | 6.9 | 12.8 | 30.0 | 30.0 | 10.0 | 70.0 |
| ZEG | 6.8 | 7.9 | 14.7 | 15.6 | 22.2 | 24.4 | 62.2 |
| MAK | 6.1 | 12.2 | 18.3 | na | na | na | 74.4 |
| PNL | 6.2 | 11.2 | 17.4 | na | na | na | 73.8 |
| ABR | 4.6 | 25.5 | 30.9 | 9.1 | 54.6 | 23.6 | 87.2 |
| BRH | 4.2 | 8.7 | 12.9 | na | na | na | 53.0 |
| NOZ | 8.0 | 14.1 | 22.1 | 3.4 | 31.0 | 41.4 | 75.8 |
| DHR | 7.9 | 16.8 | 24.6 | 17.6 | 48.1 | 29.6 | 95.3 |
| DUC | 9.5 | 22.7 | 32.1 | 7.3 | 39.6 | 42.2 | 89.0 |

For symbols explanation see text.

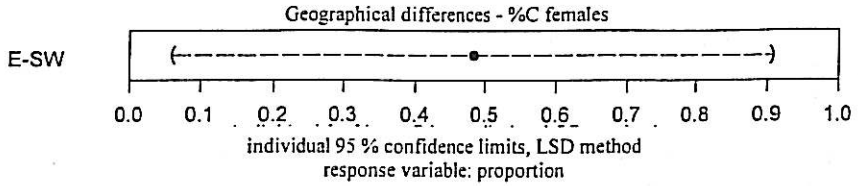



*Figure 2*: Simultaneous 95-% confidence intervals for tooth-count caries rate (%C F). Interval excluding *0* means that there is a statistical significance for differences of geographical factors East (E) and Southwest (SW). The solid point shows the value of difference between E and SW, its positivity suggests that the rate of E group is higher than SW rate.

*Table 4:* Significance of differences between geographical and diachronic groups, respectively (*F*-test with p-values).

| Rates | Geogrgroup/F | Timegroup/F | Geoggroup/M | Timegroup/M |
|---|---|---|---|---|
| %C | 0.037** | 0.902ns | 0.115ns | 0.726ns |
| %E | 0.671ns | 0.138ns | 0.725ns | 0.922ns |
| I-CE | 0.585ns | 0.185ns | 0.731ns | 0.960ns |
| %indC | – | 0.807ns | – | 0.911ns |
| %indE | – | 0.604ns | – | 0.820ns |
| %indCE | – | 0.091* | – | 0.405ns |
| F-CE | 0.114ns | 0.125ns | 0.346ns | 0.783ns |

F – females, M – males, ns – non significant, *% C* – tooth-count caries rate, *% indC* – individual-count caries rate, *% E* – ante-mortem tooth loss (expressed in form of alveolar-count AMTL rate), *% indE* – individual-count AMTL rate, I-CE = *% C* + *% E* – caries intensity, *% indCE* – individual-count caries-AMTL rate, F-CE = *% indC* + *% indE* + *% indCE* – caries frequency.

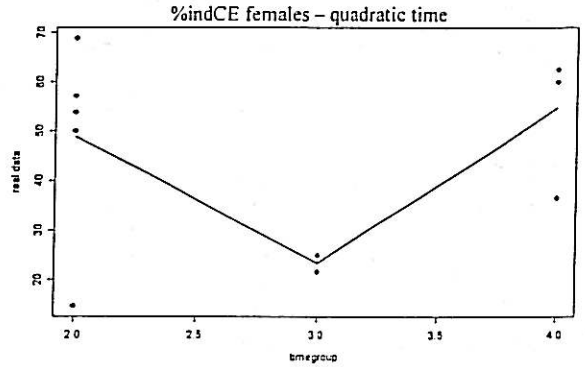



*Figure 3:* Chronological trend of individual-count caries rate *(%indCEF)* represented by regression curves.
Solid curve: the quadratic (statistically significant) trend, rhomboids: real data in chronological groups 2 – 4 [Time2 – 9th-10th c. AD (Great-Moravian Period), time3 – 10th-11th c. AD (Hungarian Conquest Period), time4 – 11th-12th (in one case, 15th c. AD) (Arpadian or Bjelo-Brdo Culture Period)].

*Table 5:* Differences in tooth-count caries rate and individual-count caries rate between geographical groups (LSD method) and timegroups (Tukey method), respectively (95% confidence interval for differences of most important factors *i* and *j*).

| Factor | Group *i*- group *j* | Estimate | Std. Error | Lower Bound | Upper Bound |
|---|---|---|---|---|---|
| %C F | ****E-SW | 0.484 | 0.197 | 0.061 | 0.907 |
| %indC F | time2-time3 | 0.739 | 0.366 | -0.306 | 1.780 |
| | time2-time4 | -0.113 | 0.213 | -0.722 | 0.495 |
| | time3-time4 | -0.853 | 0.369 | -1.910 | 0.203 |

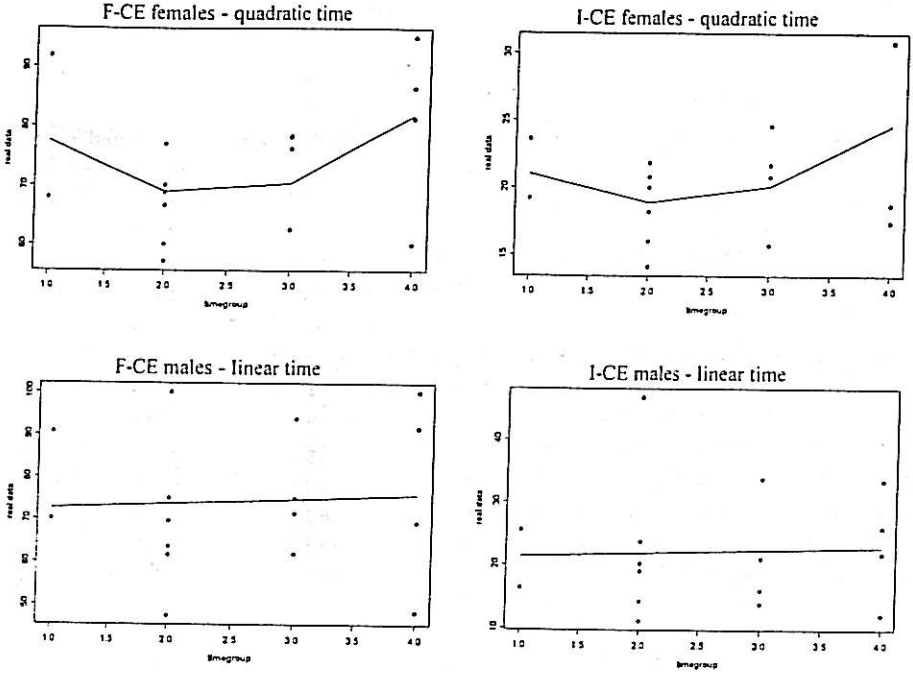
F: females, *% C*: tooth–count caries rate, *% indC*: individual–count caries rate, time1: 7th–9th c. AD (Avar Period), time2: 9th–10th c. AD (Great–Moravian Period), time3: 10th–11th c. AD (Hungarian Conquest Period), time4: 11th– 12th (exceptionally 15th c. AD) (Arpadian or Bjelo–Brdo Culture Period)

*Table 6:* Differences in caries frequency and caries intensity between time groups (Tukey method)
(95-% confidence interval for differences of timegroups *i* and *j*).

| Factor | Group *i*–group *j* | Estimate | Std. Error | Lower Bound | Upper Bound |
|---|---|---|---|---|---|
| I-CE F | time1-time2 | 0.146 | 0.176 | -0.377 | 0.669 |
| | time1-time3 | 0.034 | 0.184 | -0.514 | 0.581 |
| | time1-time4 | -0.132 | 0.180 | -0.665 | 0.401 |
| | time2-time3 | -0.113 | 0.142 | -0.535 | 0.310 |
| | time2-time4 | -0.278 | 0.136 | -0.681 | 0.126 |
| | time3-time4 | -0.165 | 0.146 | -0.600 | 0.269 |
| I-CE M | time1-time2 | -0.072 | 0.393 | -1.240 | 1.100 |
| | time1-time3 | -0.009 | 0.420 | -1.260 | 1.240 |
| | time1-time4 | -0.105 | 0.414 | -1.330 | 1.120 |
| | time2-time3 | 0.063 | 0.308 | -0.852 | 0.979 |
| | time2-time4 | -0.033 | 0.299 | -0.922 | 0.856 |
| | time3-time4 | -0.096 | 0.334 | -1.090 | 0.895 |
| F-CE F | time1-time2 | 0.183 | 0.115 | -0.158 | 0.523 |
| | time1-time3 | 0.079 | 0.120 | -0.278 | 0.437 |
| | time1-time4 | -0.010 | 0.118 | -0.361 | 0.342 |
| | time2-time3 | -0.103 | 0.094 | -0.382 | 0.176 |
| | time2-time4 | -0.192 | 0.092 | -0.464 | 0.080 |
| | time3-time4 | -0.089 | 0.099 | -0.382 | 0.204 |
| F-CE M | time1-time2 | 0.146 | 0.195 | -0.433 | 0.725 |
| | time1-time3 | 0.063 | 0.205 | -0.546 | 0.672 |
| | time1-time4 | 0.040 | 0.204 | -0.566 | 0.647 |
| | time2-time3 | -0.083 | 0.159 | -0.554 | 0.389 |
| | time2-time4 | -0.106 | 0.158 | -0.574 | 0.363 |
| | time3-time4 | -0.023 | 0.170 | -0.528 | 0.482 |

F: females, M: males, I-CE = *% C + % E*: caries intensity, F-CE = *% indC + % indE + % indCE*: caries frequency; time1: 7th–9th c. AD (Avar Period), time2: 9th–10th c. AD (Great-Moravian Period), time3: 10th–11th c. AD (Hungarian Conquest Period), time4: 11th–12th (exceptionally 15th c. AD) (Arpadian or Bjelo-Brdo Culture Period)

Interactions of *T* and *G* are insignificant. Estimates of factor-differences, standard errors of factor-differences, the *95- %* confidence interval for estimates of factor-differences are shown in Tables 5 and 6 (these tables present a sample of factors from Tables 3 and 4). The estimates in Table 5 show detailed significant rates from Table 4. The estimates in Table 5 present the rates of both sexes, while the female rates – despite the insignificance of chronological differences of this factors in Table 4 – have significant quadratic trend (*F-CEF* p-value = 0.042, *I-CEF* p-value = 0.044) (Figure 4). This figure shows a small decrease of *I-CE* and *F-CE* rates between the first (Avar-Period) and the second (Great-Moravian) group, and then an increase of these rates up to the fourth (Arpadian-Period) group. The linear (non significant) trend in males is illustrated by a horizontal line.




Solid line: the quadratic (statistically significant) trend in females expresed by a parabolic curve, the linear (non significant) trend in males expressed by a horizontal line; rhomboids: real data in chronological groups 1–4 [Time1: 7th–9th c. AD (Avar Period), time2: 9th–10th c. AD (Great-Moravian Period), time3: 10th–11th c. AD (Hungarian Conquest Period), time4: 11th–12th (in one case, 15th c. AD) (Arpadian or Bjelo-Brdo Culture Period)].

*Figure 4*: Chronological trends of caries frequency (F-CE) and caries intensity (I-CE) represented by regression curves and lines.

## Discussion

Until now, information on the diet and dietary customs of the medieval inhabitants of today's Slovakia has been rare. There is no doubt that the diet of the autochthonous sedentary medieval Middle-European populations – from the Neolithic onwards, i.e. since the origination of agriculture – was mostly based on the agricultural products rich in carbohydrates (starch and sugars) supplemented with milk, milk products and meat.

For example, Beranová (1988), who took the historical sources and archaeological finds as her starting point, wrote a monograph on Slavs living in Great-Moravian Empire (southwest Slovakia was a part of it), where she described fermented wheat (or rye in northern regions) bread, as well as millet pulp or porridge, as the basic meals; during the festivals the people were believed to consumed both the salty baker's goods and pastry. Meals were sweetened with honey and dried fruit. According to Beranová (1988), the second, perhaps no less important part of the diet was the meat of domestic animals – beef, pork and mutton; horse meat was consumed mostly in east-Slavonic plains.

As Ratkoš (1990:99) argued, "the title role in diet was played by vegetables (cabbage, turnip, leguminous plants, onion, carrot, etc.,) grown in enclosed fields, followed by the cooked or baked corns, as well as meat from domestic animals. ... As a continual dietary supplement the hunting and fishing sources were exploited." [English by M. T.] In his classical book on the life of old Slavs, Niederle (1911) writes that the Slavs consumed mostly milk and its products, leguminous plants, fruits and cereals. However, no one of the authors was able to estimate a more precise relation in the consumption of carbohydrates and proteins.

The diet of inhabitants who lived on the territory of Slovakia during the Avar and Hungarian Conquest Periods may have been somewhat different, because an admixture of nomadic Mongoloid individuals of Avar and/or Hungarian origin can be expected. However, the proportion of individuals with Mongoloid traits was relatively low. The estimated percentage of Mongoloid traits obtained either by Lipták's method (Lipták 1953, 1955), or by the Face Flatness Index (Debets 1961) in a pooled sample from the Avar Period cemeteries in Slovakia, varies from 0 % to c. 21 %, with a mean of 11.5 % (Thurzo 1977, Thurzo and Korbačková 1983).

Upon constitution of the Avar Empire, Avars settled down and lived together with autochthonous Slavic inhabitants (Avenarius 1974, Čilinská 1992). This substantial change was accompanied by a subsistence shift from a nomadic to a sedentary way of life. Despite this, seasonal moving of parts of the inhabitants with their herds cannot be excluded (Pohl 1988).

We suppose that, in accordance with the sedentary subsistence, the diet of the inhabitants of Avar Empire should not substantially vary from the diet of the Great-Moravian population dated slightly later. However, corresponding to their herding and hunting activities (Pohl 1988), their food could contain a higher proportion of proteins.

Of the skeletal populations investigated in this study and dated to the Hungarian Conquest Period, only the series from Abrahám has been analyzed from the point of

view of Mongoloid traits (Thurzo 1977): the pooled sample revealed about 7 % of them. According to Točík (1979) and Hanuliak (1992), the ancient Hungarians did not occupy a depopulated territory during their immigration into the southern Slovakia in the 10th c. AD, and lived for some time in a more or less distinct symbiosis with the autochthonous Slavic inhabitants. Because of the same life style of both ethnics, there is no reason to believe that their diet was different.

Conclusions of Točík (1979) and Hanuliak (1992) can be applied without change to the inhabitants settled on the territory of Slovakia in 11$^{th}$–12$^{th}$ c. AD (Arpadian or Bjelo-Brdo Culture), when the proportion of Slavic people was to be even higher: the proportion of Mongoloid traits in 1,240 individuals, coming mostly from Hungarian territory, was only about 4 % (Thurzo 1977).

Oddly enough, the same percentage of non-European (probably Mongoloid) traits has been found by using the Face Flatness Index in a Slavic population living in the 9$^{th}$ c. AD (i. e. after the disintegration of the Avar Empire towards the end of 8$^{th}$ c. AD) at Mikulčice, Moravia (Gomolčák 1988). This finding suggests the following: 1) there were some people with non-European traits among Avars who penetrated to the southern Moravia in the 7$^{th}$ c. AD, 2) the traces of these traits "survived" until 9$^{th}$ c. AD However, except for one supposed "Negroid" individual found at the Mikulčice cemetery (Strouhal and Stloukal 1973), to this day there is no other anthropological or historical-archaeological evidence to confirm this (Stloukal and Vyhnánek 1976).

As regards the diet of medieval inhabitants of Slovakia, results of the present odontological analysis are in accordance with archaeological studies that analyzed this problem. Both sources of data suggest that Avarian and old-Hungarian immigrants lived together with autochthonous agricultural populations and mostly consumed the same diet.

In the present state of knowledge it is not possible to estimate, whether or not the higher caries rate *%C* of east-Slovakian Avar-Period females may be linked with the higher percentage of Mongoloid features (Mongoloid individuals) in Šebastovce females – as opposed to the Šebastovce males – observed some years ago (Thurzo and Korbačková 1983, Thurzo 1987). Because this finding is in contradiction with the traditional view of the diet of Avar-Period populations presented earlier in this paper, it deserves further special anthropological-odontological study.

A small decrease of *%indCE* rate from the second (Great-Moravian Period) to the third (Hungarian Conquest Period) chronological group, and then an increase of these rate up to the fourth (Arpadian-Period) group, indicates that carious lessions of the Hungarian-Conquest population was lower than that in the Great Moravian Period. During the Arpadian Period, their prevalence increased again. This finding could be linked with different diet and subsistence strategies during the individual chronological periods, especially in Hungarian Conquest Period with the presence of nomadic old-Hungarians, as mentioned earlier.

## Conclusions

This analysis of some dental pathologies in 16 medieval cemeteries on the territory of Slovakia (altogether 27.952 teeth from 1,285 individuals were investigated) has revealed several results:

1) In general, there are no significant differences in the main pathological dental characteristics (caries intensity *I-CE* and caries frequency *F-CE*) between males and females, as well as between chronological and/or geographic groups. Thus, in most groups taken into consideration we did not find any chronological or geographical factors that would have an explicit influence on dental health. These results are in accordance with archaeological studies suggesting that Avar and old-Hungarian immigrants lived together with autochthonous agricultural populations and consumed the same diet.

2) Since the prime factor of import in gender differences in dental disease prevalence appears to be the sexual division of labor – entailing divergent activity and dietary patterns (Lukacs 1992) – the absence of significant differences between the genders in most groups compared does not suggest different activities and diets between males and females.

3) The tooth-count caries rate (*% C*) of the east-Slovakian Avar-Period females, as opposed to contemporary local male inhabitants, and also to the inhabitants of other regions of Slovakia, is significantly different; this finding suggests that the diet of these females might differ from both the contemporary local males and the inhabitants of other regions of Slovakia. Because of higher caries rate, their diet – apparently – must have contained higher percentage of carbohydrates. Since this finding contradicts the traditional view which supposes larger protein proportion in the diet of originally nomadic Avars and proportionate lower rate of dental diseases, it deserves a further special study.

4) The significance of the individual-count caries-AMTL rate (*%indCE*) suggests a small decrease of the rate from the Great-Moravian Period to the Hungarian Conquest Period, and then an increase up to the Arpadian-Period. This finding indicates that the prevalence of carious lessions of the Hungarian-Conquest population was lower than that during the Great Moravian Period. Afterwards, during the Arpadian Period, it increased again.

5) Despite the absence of significant differences in most of the pathological dental characteristics, some significant odontological chronological trends have emerged. These quadratic time trends show a small decrease of *I-CE* and *F-CE* rates from the Avar- to the Great-Moravian Period, and subsequently, an increase of these rates up to the Arpadian-Period. Because of the highest caries rate among females of the Avar-Period population in east-Slovakian Šebastovce cemetery, the Avar-Period females seem to be more afflicted by carious dental diseases than the later Great-Moravian Period populations.

6) Data sampled in this study could form an appropriate basis for future research in the field of dental anthropology. Only a more detailed and subtle analysis (scoring different types, classes or generations of teeth, recording caries position), completed by other dental pathologies and anomalies (enamel hypoplasia, traumatic injuries of

teeth and jaws, periodontal disease, transposition of teeth, dental attrition, interproximal grooves, crowding of teeth, presence and grade of calculus, etc.), could bring further information concerning the influence of ecological conditions on the oral state of medieval skeletal populations on the territory of Slovakia.

**Acknowledgements:** We are grateful to the editors of the 2nd volume of EAA Biennial Book for the invitation to participate in this project. This research was supported in part by grant No. 1/7154/20 provided by the Slovak VEGA grant agency.

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