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# Factors Affecting Postmortem Tooth Loss

**ABSTRACT:** Unassociated human bones are a particular problem during the exhumation of mass graves and a factor that limits anthropological and paleopathological analyses from archaeological contexts. Extensive anthropological literature has focused on the complex taphonomic factors that influences bone assemblages, but little attention has been paid to postmortem tooth loss and factors affecting this process. The following study focuses upon the influence of different factors on postmortem tooth loss. Three samples were investigated in the study: a medieval church cemetery containing 110 individual skeletal remains, and two samples from a series of mass graves made within the same time period in 1999, containing 402 bodies. The frequency of postmortem tooth loss was analyzed relative to postmortem interval for each sample, excavation methods, age distribution, and presence of bone loss associated with periodontal disease. Our results indicate that the degree of alveolar bone loss significantly affected both antemortem and postmortem tooth loss and that the frequency of postmortem tooth loss has the strongest correlation to time since death. These findings suggest that additional care should be taken when exhuming remains from older contexts.

**KEYWORDS:** forensic science, mass graves, exhumation, tooth loss, periodontal disease

While tooth enamel is the most resistant skeletal tissue to postdepositional decay in the burial environment, human remains are often exhumed missing teeth. An explanation may be that teeth, if dislodged from their anatomical position while buried or during excavation, may not be recognized by excavators. This points to the importance of excavation methodology, especially in graves of a forensic context, where forensic archaeologists are not engaged.

Some studies have focused upon tooth loss as a mechanism for estimating the postmortem interval (1). The patterns of tooth loss are consistent with general soft tissue decomposition with regards to seasonality of deposition and the immediate environment. Decomposition of the soft tissue surrounding the teeth leaves a space around the associated root, which in turn becomes loose, allowing tooth loss.

Condition of the supporting structures of teeth may also influence its easy separation from alveolar bone and, consequently facilitates postmortem tooth loss. The attachment apparatus of teeth consists of cementum, the periodontal ligament, bone lining the alveolus, and part of the gingiva. In periodontal diseases, the pathological conditions affecting the supporting structures of teeth in intermitent fashion, all of these structures may be severely damaged leading to periodontal attachment loss, alveolar bone loss and ultimately, possible tooth loss (2). Bone destruction in periodontal disease is the consequence of spreading the inflammation from gingiva into alveolar bone. The process is followed by bone resorption causing a thinning of the surrounding bony trabeculae, enlargement of the marrow spaces, and reduction in bone height (3). New bone formation is also a response of alveolar bone to inflammation, but in periodontal disease, there is the predominance of bone resorption over formation (3).

In this study, we analyzed the contribution of postmortem interval, excavation methods, and antemortem increased tooth mobility due to alveolar bone loss, to the rate of postmortem tooth loss of the skeletal remains from both archaeological and forensic context.

## Material and Methods

Three samples were investigated in the study: a skeletal series from the church cemetery, located in northern Serbia, dated by archaeologists between the tenth and sixteenth centuries (Sample A), and two samples from a contemporary series of mass graves, situated near Belgrade. The late-medieval cemetery of Stara Torina was excavated in 1990 by an experienced team of archaeologists. The mass graves, all part of the same event, made within the same time period in 1999, were excavated in 2001 (Sample B), and in 2002 (Sample C). The mass grave samples B and C in our investigation consisted of four ramp style grave pits laying approximately 10 m from each other. Bodies within these mass graves were commingled. Sample B was a single mass grave excavated using the "pedestal method" where the soil around the body mass is removed allowing the bodies to be viewed and accessed from different angles. The excavation was carried out under the leadership of forensic pathologists with prior mass grave experience, but without archaeological guidance. The second mass-grave sample (C), a compilation of the three other mass graves, were excavated using the "stratigraphical method" that retains the grave walls while removing the bodies in the reverse order from how they were placed in the grave (4). The excavation was conducted by experienced forensic archaeologists in 2002. The taphonomic conditions were of same type for both mass grave samples: subjects were exposed to dry and hot conditions during the summer months and to cold continental climate during the winter months. In addition, relevant soil and grave conditions were the same between the two samples.

Anthropological analysis was performed for all three samples by medically trained forensic anthropologists. For this study, we selected adult skeletons with at least a complete mandible,

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and/or maxillae. The total sample comprises 401 maxillae and 443 mandibles, which belonged to 512 individuals; 111 of them were without maxilla, and 69 with no mandible. All individuals from forensic sample B (144 individuals) were males, while sample C (258 individuals) comprised 235 males, 16 females and 7 individuals of unidentified sex. The archaeological sample A (110 individuals) consisted of 9 males, 16 females and 85 individuals of unidentified sex.

Individual age assessment was based on morphological changes of the pubic symphisis following Suchey-Brooks (5) that divides individuals into six categories. For males they are: I (18.5 ± 2.1 years), II (23.4 ± 3.6 years), III (28.7 ± 6.5 years), IV (35.2 ± 9.4 years), V (45.6 ± 10.4 years), and VI (61.2 ± 12.2 years). For females they are: I (19.4 ± 2.6 years), II (25.0 ± 4.9 years), III (30.7 ± 8.1 years), IV (38.2 ± 10.9 years), V (48.1 ± 14.6 years), and VI (60.0 ± 12.4 years). Sex determination was based on dimorphic features of the os coxae (6). Forensic cases often have enough soft tissue to make sex determination easier; however, the commingled skeletal material from the archaeological context, unable matching of the skulls with the hip bones, causing a majority of skeletons to be classified as "unidentified sex."

For periodontal disease assessment, panoramic radiographs were used (Siemens, Orthopanthomograph 10E unit). Despite the limitations in diagnosis of the earliest signs of periodontal disease in clinical patients, radiographs were sensitive enough to detect the alveolar bone changes that occur in periodontitis: crestal irregularities, triangulation, reduction of height of interseptal alveolar bone, areas of alveolar bone loss and different types of infrabony pockets (7). In addition, macroscopic examination was employed for assessment of root exposure, pitting of the alveolar bone, presence of infrabony pockets, and loose teeth. Based on radiological and macroscopic criteria, all cases were divided into three categories:

> I—No radiological manifestation of periodontal disease, or presence of early signs of periodontal disease: subgingival calculus deposits, interruption in the continuity of the lamina dura along the interdental alveolar crest, alveolar bone loss with distance between cementoenamel junction (CEJ) and alveolar crest less than 3 mm, and widening of periodontal space.
>
> II—Moderate periodontal disease: generalized horizontal bone loss with a distance of 3–5 mm between CEJ and alveolar crest, and/or presence of triangulation (wedge-shaped radiolucent area on the crest of alveolar bone in combination with further widening of periodontal ligament space) i.e., vertical bone defects corresponding to infrabony pockets.
>
> III—Severe periodontal disease: generalized horizontal bone loss with CEJ—alveolar crest distance more than 5 mm, and/or at least one infrabony pockets that reach the tooth root apex, increased tooth mobility, tooth migration, and generalized alveolar bone radiolucency.

Statistical analysis of the data were made with Chi-square, Kendall test, robust rank-order (Wilcoxon matched pairs test for comparing two dependent samples), and Spearman rank-ordered correlation tests.

## Results

The frequencies of AMTL and PMTL in investigated samples are shown on Table 1. The frequency of AMTL was significantly higher ($p < 0.01$, Chi = 482.34) in contemporary samples (B–21.8% and C–36.78%) than in the archaeological population (9.75%). Contrary, PMTL affected the archaeological samples more frequently (34.5%) than contemporary samples B (12.07%) and C (12.35%). These differences are statistically significant ($p < 0.01$, Chi = 212.5 for A:B, and Chi = 14.52 for A:C), as well as the difference between samples B and C ($p < 0.01$, Chi = 20.68).

TABLE 1—*Frequencies of AMTL and PMTL in investigated samples.*

| | AMTL | | PMTL | | Present Teeth | | |
|---|---|---|---|---|---|---|---|
| Sample | *n* | % | *n* | % | *n* | % | Total |
| A | 247 | 9.75 | 874 | 34.50 | 1412 | 55.74 | 2533 |
| B | 858 | 21.80 | 475 | 12.07 | 2602 | 66.12 | 3935 |
| C | 2531 | 36.78 | 850 | 12.35 | 3500 | 50.86 | 6881 |
| Total | 3636 | | 2199 | | 7514 | | 13349 |

Stara Torina (archaeological) = Sample A.
Batajnica 2 (mass grave) = Sample B.
Batajnica 3, 5, 7 (mass graves) = Sample C.

TABLE 2—*Distribution of AMTL in different teeth groups.*

| | Sample A | | | Sample B + C | | |
|---|---|---|---|---|---|---|
| Teeth Group | *n* | % | Total | *n* | % | Total |
| 11 + 21 | 9 | 5.17 | 174 | 96 | 15.29 | 628 |
| 31 + 41 | 9 | 6.05 | 148 | 126 | 17.07 | 738 |
| 12 + 22 | 10 | 5.74 | 174 | 110 | 17.52 | 628 |
| 32 + 42 | 4 | 2.70 | 148 | 111 | 15.06 | 737* |
| 13 + 23 | 5 | 2.90 | 172* | 102 | 16.32 | 625*† |
| 33 + 43 | 4 | 2.70 | 148 | 100 | 13.57 | 737† |
| 14 + 24 | 14 | 8.40 | 174 | 204 | 32.54 | 627† |
| 34 + 44 | 5 | 3.37 | 148 | 168 | 22.76 | 738 |
| 15 + 25 | 14 | 8.04 | 174 | 231 | 36.84 | 627* |
| 35 + 45 | 10 | 6.76 | 148 | 247 | 33.47 | 738 |
| 16 + 26 | 25 | 14.36 | 174 | 310 | 49.36 | 628 |
| 36 + 46 | 22 | 14.86 | 148 | 487 | 65.99 | 738 |
| 17 + 27 | 37 | 21.36 | 174 | 250 | 39.81 | 628 |
| 37 + 47 | 16 | 10.81 | 148 | 318 | 43.09 | 738 |
| 18 + 28 | 36 | 23.37 | 154* | 238 | 40.75 | 584* |
| 38 + 48 | 27 | 21.26 | 127* | 291 | 42.98 | 677* |
| Total | 247 | 9.75 | 2533 | 3389 | 31.33 | 10816 |

* Total teeth observed excluding the teeth missing due to hypodontia.
† Total teeth observed excluding the teeth missing due to impaction.

Distribution of AMTL in different age groups is presented on Table 2 and Fig. 1. Two Kendal tests were performed, first between samples B and C, and then between the archaeological sample A and a combined B and C sample. Results between samples B and C showed that the orders and frequencies of AMTL in the different teeth groups are strongly associated ($T = 0$, $Z = 3.516$, $p = 0.000438$). The analysis between sample A and the combined B and C samples indicated that in both the modern and archaeological populations, the loss of molars was more frequent ($p < 0.01$) compared with other teeth groups. A Robust rank-ordered test showed no differences between modern and archaeological populations considering the order of loss of different teeth groups.

PMTL most frequently affected the central maxillary incisors, followed by the other three groups of incisors, while first and second molars from both jaws were least exposed to PMTL (Table 3, Fig. 2). In both the modern and archaeological populations, loss of incisors and canines was significantly greater in comparison with premolars and molars ($p < 0.01$, Chi = 114.74). The strong association between the order of tooth loss in population B and C (Kendal

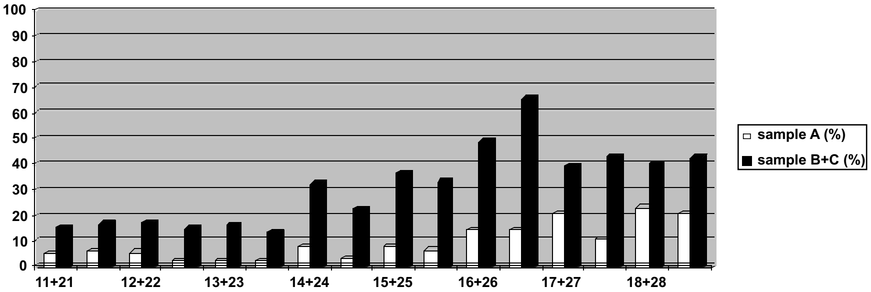

FIG. 1—*Distribution of AMTL in different teeth groups (Table 2).*

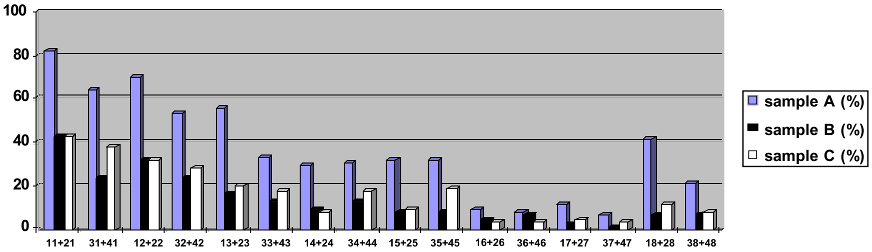

FIG. 2—*Frequencies of PMTL in different teeth groups (Table 3).*

TABLE 3—*Frequencies of PMTL in different teeth groups.*

| | Sample A | | | Sample B | | | Sample C | | |
|---|---|---|---|---|---|---|---|---|---|
| Teeth Group | *n* | % | Total | *n* | % | Total | *n* | % | Total |
| 11 + 21 | 137 | 83.03 | 165 | 96 | 43.24 | 222 | 135 | 43.55 | 310 |
| 31 + 41 | 90 | 64.74 | 139 | 57 | 23.46 | 243 | 141 | 38.21 | 369 |
| 12 + 22 | 116 | 70.73 | 164 | 70 | 32.59 | 215 | 97 | 32.01 | 303 |
| 32 + 42 | 78 | 54.16 | 144 | 59 | 23.98 | 246 | 110 | 28.95 | 380 |
| 13 + 23 | 95 | 56.68 | 167 | 36 | 16.74 | 215 | 64 | 20.78 | 308 |
| 33 + 43 | 48 | 33.33 | 144 | 33 | 13.36 | 247 | 72 | 18.46 | 390 |
| 14 + 24 | 47 | 29.75 | 160 | 18 | 10.00 | 180 | 21 | 8.64 | 243 |
| 34 + 44 | 44 | 30.76 | 143 | 31 | 12.92 | 240 | 59 | 17.88 | 330 |
| 15 + 25 | 52 | 32.50 | 160 | 14 | 8.33 | 168 | 23 | 10.09 | 228 |
| 35 + 45 | 45 | 32.60 | 138 | 17 | 8.25 | 206 | 55 | 19.30 | 285 |
| 16 + 26 | 15 | 9.93 | 149 | 7 | 5.15 | 136 | 6 | 3.30 | 182 |
| 36 + 46 | 11 | 8.73 | 126 | 7 | 6.80 | 103 | 5 | 3.38 | 148 |
| 17 + 27 | 16 | 11.67 | 137 | 5 | 3.01 | 166 | 10 | 4.72 | 212 |
| 37 + 47 | 9 | 6.81 | 132 | 3 | 1.68 | 179 | 9 | 3.73 | 241 |
| 18 + 28 | 49 | 41.52 | 118 | 10 | 6.90 | 145 | 24 | 11.94 | 201 |
| 38 + 48 | 22 | 22.00 | 100 | 12 | 7.23 | 166 | 19 | 8.64 | 220 |
| Total | 874 | 38.23 | 2286 | 475 | 15.44 | 3077 | 850 | 19.54 | 4350 |

Total: number of teeth present in jaws at a moment of death of individuals.

TABLE 4—*Frequencies of AMTL in different age groups.*

| | Sample A | | | | Sample B + C | | | |
|---|---|---|---|---|---|---|---|---|
| Age Category* | *N* | AMTL | % | Total | *N* | AMTL | % | Total |
| 1 | 7 | 4 | 2.17 | 184 | 40 | 28 | 2.48 | 1128 |
| 2 | 8 | 6 | 2.92 | 205 | 28 | 37 | 4.92 | 752 |
| 3 | 5 | 14 | 12.72 | 110 | 48 | 197 | 14.99 | 1314 |
| 4 | 7 | 24 | 11.76 | 204 | 125 | 866 | 25.06 | 3456 |
| 5 | 6 | 26 | 16.25 | 160 | 119 | 1386 | 45.71 | 3032 |
| 6 | 1 | 2 | 12.50 | 16 | 35 | 827 | 83.37 | 992 |
| ? | 76 | 171 | 10.34 | 1654 | 7 | 48 | 33.80 | 142 |

* Mean age at death: 1 (18.5 ± 2.1 years), 2 (23.4 ± 3.6 years), 3 (28.7 ± 6.5 years), 4 (35.2 ± 9.4 years), 5 (45.6 ± 10.4 years), and 6 (61.2 ± 12.2 years).

*N*: number of individuals observed (selection of cases with assessed age), including edentate persons.

Total: number of teeth observed excluding the teeth missing due to hypodontia and impaction; in some individuals preserved were only maxilla or mandible.

?: individuals with no age assessment.

TABLE 5—*Frequency of edentulous jaws in different age categories.*

| | Sample A | | Samples B + C | |
|---|---|---|---|---|
| Age Category* | Maxilla | Mandible | Maxilla | Mandible |
| 4 | 0 | 0 | 1 | 1 |
| 5 | 0 | 0 | 11 | 13 |
| 6 | 0 | 0 | 19 | 18 |
| ? | 0 | 1 | 1 | 1 |

* There was no edentate jaws in categories 1, 2, and 3.

?: Individuals with no age assessment.

$T = 0.84$, $p < 0.01$), and also between archaeological and contemporary populations (Kendal $T = 0.72$, $p < 0.01$) is demonstrated. There was no difference found in overall PMTL frequency between maxillary and mandibular teeth.

Analysis of the distribution of tooth loss in different age groups (Tables 4 and 6) showed that age significantly influenced the frequency of AMTL ($p < 0.01$, Chi = 20.65) in all three samples, but such a correlation was not found in the PMTL frequency. Table 5 showed that the majority of maxillae and mandible with complete loss of natural teeth belonged to the individuals of fifth and sixth age category, while in the first three categories no one individual was edentate. The influence of periodontal disease on AMTL and PMTL was assessed in cases where panoramic radiography was taken. It was shown (Table 7) that the frequency of phase II and phase III periodontal disease was significantly higher in the archaeological population than in contemporary samples ($p < 0.01$, Chi = 21.25). The degree of periodontal disease significantly influenced AMTL in all investigated samples (Chi = 23.712, $p < 0.01$ for sample A;

TABLE 6—*Frequencies of PMTL in different age groups.*

| | Sample A | | | | Sample B | | | | Sample C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | *N* | PMTL | % | Total | *N* | PMTL | % | Total | *N* | PTML | % | Total |
| 1 | 7 | 41 | 22.77 | 180 | 24 | 78 | 11.89 | 656 | 16 | 62 | 13.96 | 444 |
| 2 | 8 | 73 | 36.80 | 199 | 15 | 37 | 9.39 | 394 | 13 | 41 | 12.77 | 321 |
| 3 | 5 | 48 | 50.00 | 96 | 16 | 40 | 12.46 | 321 | 32 | 138 | 17.34 | 796 |
| 4 | 7 | 51 | 28.02 | 182 | 51 | 176 | 16.54 | 1064 | 74 | 226 | 14.82 | 1526 |
| 5 | 6 | 51 | 38.05 | 134 | 34 | 132 | 22.68 | 582 | 85 | 318 | 29.89 | 1064 |
| 6 | 1 | 4 | 28.65 | 14 | 2 | 11 | 35.48 | 31 | 33 | 35 | 26.12 | 134 |
| ? | 76 | 606 | 40.86 | 1483 | 2 | 1 | 3.45 | 29 | 5 | 30 | 46.15 | 65 |

Age: Mean age at death: 1 (18.5 ± 2.1 years), 2 (23.4 ± 3.6 years), 3 (28.7 ± 6.5 years), 4 (35.2 ± 9.4 years), 5 (45.6 ± 10.4 years), and 6 (61.2 ± 12.2 years).

*N*: Number of individuals observed (selection of cases with assessed age) excluding edentate persons.

Total: Number of teeth present in jaws at a moment of death of individuals (PMTL + present teeth).

?: Individuals with no age assessment.

TABLE 7—*Frequencies of AMTL and present teeth in different phases of periodontal disease.*

| | Sample A | | | | Samples B + C | | | |
|---|---|---|---|---|---|---|---|---|
| Phase | *N* | AMTL | Present | Total | *N* | AMTL | Present | Total |
| I | 33 | 59 | 351 | 687 | 101 | 243 | 2263 | 2799 |
| II | 49 | 90 | 717 | 1185 | 88 | 585 | 1595 | 2464 |
| III | 27 | 93 | 343 | 647 | 45 | 481 | 587 | 1238 |

*N*: Number of individuals observed (excluding edentulous individuals and individuals with no data of periodontal disease).

Present: Number of teeth present in jaws at a moment of observation.

Total: Number of teeth of observed individuals (excluding impacted teeth and hypodontia).

TABLE 8—*Frequencies of PMTL in different phases of periodontal disease.*

| | Sample A | | | Sample B | | | Sample C | | |
|---|---|---|---|---|---|---|---|---|---|
| Phase | *N* | PMTL | Total | *N* | PMTL | Total | *N* | PMTL | Total |
| I | 33 | 277 | 628 | 52 | 135 | 1354 | 49 | 158 | 1202 |
| II | 49 | 378 | 1095 | 23 | 62 | 483 | 65 | 222 | 1396 |
| III | 27 | 211 | 554 | 25 | 62 | 422 | 20 | 108 | 335 |

*N*: Number of individuals observed (excluding edentulous individuals and individuals with no data of periodontal disease).

Total: Number of teeth present in jaws at a moment of death of individuals.

Chi = 517.986, $p < 0.01$ for samples B + C). The contribution of degree of periodontal disease to the observed distribution of PMTL (Table 8) was statistically significant ($p < 0.01$) in all three samples (Chi = 15.568, $p < 0.01$ for sample A; Chi = 8.204, $p < 0.05$ for sample B; Chi = 69.904, $p < 0.01$ for sample C;). Finally, to evaluate a correlation between AMTL and PMTL in each individual, a Spearman rank-ordered correlation test was used. The analysis showed that there was no significant association between the number of individual AMTL and PMTL in either archaeological or modern populations.

## Discussion

In the only previous investigation of Serbian medieval skeletal samples (8), it was shown that AMTL affected 70.4% of individuals, with the highest prevalence on the lower molars, and the lower incisors the least involved. The method of tooth count for AMTL was not presented in the previous study, making the comparison with our results difficult. However, available data for the late medieval UK archaeological populations (9) showed that the mean AMTL was 11.7% (ranged from 3.2% to 17.6%), which corresponds to our results for archaeological sample (Tables 1 and 2). The lower frequency of AMTL in archaeological sample compared with the contemporary samples could be explained by the age distribution of individuals in the investigated populations, although this analysis is limited because the majority of individuals from archaeological context were of unknown age. Table 4 shows that in the archaeological sample nearly two thirds of observed teeth belonged to the individuals from the first three age categories (i.e., they were less than 30 years old), while in contemporary samples less than one third of observed teeth derived from that young of individuals. Other possible explanations, such as difference in diet, oral hygiene, use of dental service etc., are probably of secondary importance, knowing that tooth loss strongly correlate with age of individuals.

In the survey of dental health of the population of Belgrade between 1982 and 1986 (10), it was found that among 45056 persons investigated, 1913 (4.2%) were edentate. The distribution in different age groups showed that percent of individuals who lost all of their natural teeth varied as following: 0.7% in the group between 27 and 45 years, 10.3% in the group between 46 and 65 years, and 52.9% in the group older than 65 years. In the recent study on the retention of natural teeth among older adults (over 65 years) in United States (11) indicated that the percent of individuals who retained most of their teeth (loosing five or fewer teeth) was ranged from 27% (in West Virginia) to 64% (in Utah). The differences in tooth retention varied also by selected characteristics: education, incomes, ethnicity, cigarette smoking, general health, and diabetes. On the other hand, the percent of older adults who lost all of their natural teeth also varied from about 13% (in Hawaii and California) to over 40% (in Kentucky and West Virginia). In our contemporary samples, 20 people (57.14%) belonging to the sixth category (61.2 ± 12.2 years) were edentulous, while among the remaining 15 subjects, only one individual (2.86%) retained most of his/her natural teeth in the mandible, but his/her maxilla was not available for our examination. The results indicate poorer dental health than in any part of U.S., but similar to the oral heath in urban population of Belgrade.

The frequency of PMTL in our material showed significant differences between samples. The higher frequency of PMTL in the archaeological sample corresponds to the fact that for long postmortem intervals, complete decomposition of the soft tissue allows for tooth loss. The teeth that become dislodged could easily be lost during the excavation process. The additional year of postmortem interval sample C experienced in the mass graves, compared with sample B, allowed for more soft tissue decomposition including the attachment apparatus of teeth, and probably influenced the difference in frequency of PMTL between these two samples. On the other hand, the excavation method of sample C remains, as well as the skills and experience of field experts, was much more appropriate than those applied to the sample B excavation. However, an expected correlation between the excavation methodologies and PMTL frequencies between samples B and C was not found. The results suggest that the postmortem interval influenced PMTL more than the excavation method. This is opposite to our experience with entire skeletal material where the number of unassociated bones was significantly higher by an almost 4:1 ratio (sample B:sample C) (4).

The strong correlation between the orders of tooth loss in all investigated samples emphasized the differences in the root morphology as a very significant factor related to PMTL. Contrary to multi-rooted teeth, which are more stable in the jaws, the single-rooted teeth often fall out during burial and excavation (9). In our material, central maxillary incisors were the most frequently exposed to PMTL (Table 3). Similar findings were reported by other investigators (12). Shape of the central maxillary root is usually conical, rounded in any horizontal section, and it is less frequently (compared with the other groups of incisor) curved or titled distally. This morphology, with its limited mechanism for tooth retention, could cause maxillary incisors to fall out from their sockets in dry skulls than the other incisor groups. The difference in the trabecular arrangement of the supporting bone between the maxilla and mandible does not seem to be a reason for the higher incidence of PMTL of central maxillary incisors. Although the network pattern of the trabecular bone in the maxilla lacks the distinct trajectory pattern seen in mandibles, it seems to be compensated for by a greater number of trabeculae in any given area (7).

As was expected, the investigated molars were the least involved in PMTL. Upper molars usually have three roots, which are most divergent in first molars, less in second and least in third. The different axes of each molar root assist the stability of that tooth in the jaw, requiring application of force from three different directions to extract it from its socket. In addition, the tips of the buccal roots curve towards one another, whereas the palatal root is directed orally. The lower molars have two roots, usually locked firmly into their sockets, which are situated very close to the cortical laminae, and in dry bones commonly remain in situ (13).

Studies of the association between incident AMTL and prior periodontal attachment level showed that attachment loss was strongly predictive of tooth loss, with increases in risk for each millimeter in attachment loss (14). The majority of studies have shown some general conditions and disease, such as osteoporosis, diabetes mellitus and cigarette smoking, to be associated with loss of alveolar crestal height and tooth loss (15,16). Periodontal diseases predominantly affect people of advanced age (excluding juvenile forms of the disease), and its prevalence in different populations depends on the criteria used to define the disease. The comparison between the populations is often difficult because periodontal epidemiology literature lacks consitency in methodology of measuring and interpret signs of periodontal disease (2). In the clinical surveys, the severity of chronic periodontitis was measured by various combination of the following methods: periodontal index, measuring the depth of periodontal pockets by periodontal probe, and measuring of the attachment loss at different sites on teeth (3). The radiographic assessment of bone loss is rarely used in estimating the prevalence of periodontitis because of ethical and practical considerations (3). For the purpose of this study, we applied a modified classification recommended by the American Academy of Periodontics (7). The results (Table 6) revealed a higher degree of signs of periodontal disease in the archaeological population than in the modern population: 30.3% percent of individuals in sample A showed first degree of periodontal disease, while in samples B and C 43.2% of individuals were in this group. In the extensive study of oral health of contemporary population in Belgrade (10) with periodontal index used to measure periodontal disease. The results of the survey pointed out that 44.8% of population showed severe periodontal destruction. However, because of methodological differences in this clinical survey and our radiological examination, making any comparison in prevalence and severity of periodontal disease is difficult.

There are controversial data in the anthropological literature regarding differences in alveolar bone loss between modern and ancient populations (17,18). Nevertheless, many reports documented that comparison of the earlier and later populations (Mesolithic and Iron Age populations, or Anglo-Saxon, and Medieval British populations) reveals an increase in tooth loss and prevalence of periodontal disease resulting from an increase in consumption of plant carbohydrates, improvements in the milling of flour for bread and increased consumption of sugar generaly (17,19–21). The interpopulation variations are usually interpreted in terms of oral hygiene practices, availability of dental treatment and nature of diet (13). In the only report of periodontal disease of medieval population in Serbia (8), it was suggested that 79.0% of individuals showed alveolar bone loss associated with periodontal disease, which is consistent with our results for archaeological sample. Our results regarding higher frequency of alveolar bone loss in the archaeological sample than in the contemporary samples is complex to explain, especially considering the archaeological sample's lower frequency of AMTL. We assumed three potential explanations for this:

- The selection of cases with radiography used for the study of periodontal disease in samples B and C probably was not representative for the whole sample;
- The periodontal disease probably was overestimated in archaeological material because increased root exposure may be rather due to continuing eruption from severe attrition, than the periodontal disease. Other investigators suggested the same when dealing with ancient skeletal material (22). In addition, another cause (besides the periodontitis) of periodontal destruction followed by alveolar bone resorption is trauma from occlusion. Chronic trauma from occlusion most often develops from gradual changes in occlusion produced by tooth wear, malocclusion, and parafunctional habits (3). Considering that our archaeological sample showed more extensive tooth wear than contemporary samples, this factor could be used in interpretation of the results.
- Porous alveolar bone already damaged by periodontal disease is more sensitive to decay during the postmortem interval. Accelerated rate of decomposition of alveolar bone compared to other healthy parts of the jaws could mimic the more severe periodontal disease.

Statistical analysis of the data demonstrated that the degree of periodontal disease significantly affected both the AMTL and PMTL. This is an expected result knowing that periodontal disease is one of the major cause of AMTL in the past as it is today, and that increased tooth mobility at a moment of death of individual increases risk of tooth exfoliation.

Our findings suggest that the older the grave context is, the more care should be taken when exhuming the remains or risk loosing teeth in the soil matrix. Screening of soils below and around the cranium for teeth is highly suggested. If separate from the body, the skull should be placed in a separate bag to prevent further loss of teeth. In that case the skull bag should then be placed in the body bag or container where the rest of the same body is stored to avoid mingling of skeletal material. Upon mortuary examination, the pathologist and/or anthropologist should also take care in examining soil and clothing removed with the body during exhumation for any errant dentition.

The focus of mass grave exhumations is on identification, cause and manner of death, and recording of criminal activity. Data gathered during such investigations that may be used for research is of secondary importance. Bearing this in mind and the fact that little has been published in the scientific literature on PMTL in buried contexts, this study may be viewed as a starting point for future research into PMTL. Future observations during forensic investigations, archaeological excavations, or possible controlled experiments could shed further light on PMTL.

## Conclusion

The results of the study indicate that postmortem interval significantly influences the PMTL. Even a one year longer postmortem time for soft tissue decomposition resulted in higher frequency of PMTL. This factor was of greater importance than excavation methodology, although our experience with unassociated bones, on the same material, was opposite.

PMTL most frequently affected the central maxillary incisors, followed by the other three groups of incisors, while first and second molars from both jaws were least exposed to PMTL. The age of individuals influenced the AMTL but not PMTL. The degree of alveolar bone loss associated with periodontal disease affected significantly the both AMTL and PMTL.

It is suggested that increased care be taken during excavation of older graves to avoid possible loss of exfoliated teeth. In addition, further controlled research and published observations into PMTL of buried remains may assist in our understanding of this phenomenon.

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