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RESEARCH ARTICLE

Endemic warfare and dental health in historic period archaeological series from Croatia

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Abstract

This study assesses the prevalence and distribution of caries, antemortem tooth loss, abscesses, calculus, alveolar bone resorption, and tooth wear in two large composite archaeological series from Croatia in order to determine the effects that long-term, endemic warfare had on dental health and nutrition. The first series consists of dental material belonging to three cemeteries dated to the late medieval period (1100–1400), a period characterised by rapid social development, increased urbanisation, growth of trade, and an increase of monetary economy. The second belongs to three cemeteries from the early modern period (1400–1700) during which time Croatia was exposed to incessant Ottoman raiding and the gradual subjugation and incorporation of various Croatian territories into the Ottoman Empire.

Analyses of 4,789 permanent teeth belonging to adult males and females show significantly lower frequencies of carious lesions, abscesses, alveolar resorption, and heavy dental wear during the early modern period suggesting a significant change in alimentary habits with, surprisingly, better nutrition and a higher dependence on proteins during the period that Croatia was involved in low-intensity, endemic warfare.

The improvement in dental health noted in the Ottoman period series was the result of a combination of circumstances that includes mass emigration of local populations caused by incessant Ottoman raiding, the resulting economic decline and wholesale abandonment of these territories, and the subsequent resettlement of these territories by a new group of peoples known as Vlachs who practised a different subsistence strategy based on pastoralism and cattle farming.

KEYWORDS

Croatia, dental health, early modern period, late medieval period, paleodontology, warfare

1 | INTRODUCTION

Health changes experienced by populations exposed to warfare have come to the forefront of research in light of recent increases in socio-political instability in modern populations (Panter-Brick, 2010; Pedersen, 2002). Besides dramatic increases in mortality and morbidity rates, warfare has also been linked to increased rates of malnutrition and significant changes in subsistence strategies caused by the intentional sabotaging of resources, reduced mobility, closing of markets, and the loss of effective labour organisation and resource utilisation (Kemkes, 2006; Pizarro, Silver, & Prause, 2006).

In archaeological contexts, teeth and their pathologies provide excellent material for bioarchaeologists studying past population diet and nutrition (Belcastro et al., 2007; Hillson, 1996; Larsen, 1997; Lukacs, 2007; Šlaus, Bedić, Rajić Šikanjić, Vodanović, & Domić, 2011). Despite this, little is known about the dental health of archaeological populations involved in warfare.

Croatian archaeological series from the 15th–18th centuries provide a unique opportunity to study the effects that long-term, low-intensity warfare had on the nutrition of the populations it afflicted. This is due to the fact that from the beginning of the 15th century AD, Croatia came into direct contact with the rapidly expanding Ottoman Empire. The period prior to that, between the 12th and the 14th century, was a period of relative peace and prosperity characterised by social development, the establishment of new towns and international trade, colonisation of merchants, and peasants from western Europe, and the spread of literacy (Budak & Raukar, 2006). From, however, the latter half of the 14th century, the Ottoman Empire expanded rapidly into the Balkans, and following their conquest of Bosnia (1463), came into direct contact with Croatia. From that time on, until the end of the 17th century, Croatia was embroiled in continuous low-intensity, endemic warfare with the Ottoman Empire. The main features of this low-intensity warfare were raids carried out by irregular light cavalry units of the Ottoman army known as akinji who employed superior mobility and guerilla style tactics to plunder, attack trading centres and routes to disrupt enemy supply and transportation, capture captives that were sold as slaves, and generally terrorise local populations in an attempt to depopulate an area before the advance of regular Ottoman forces (Goodwin, 2006). Contemporary chroniclers describe the depredations carried out by the akinji in considerable detail noting the years in which the raids were carried out (just for the period between 1400 and 1500, 37 raids were documented in Dalmatia), and the number of individuals and livestock carried off (Antoljak, 1996). Thus, one raid carried out in 1415 resulted in the capture of 30,000 individuals (Mijatović, 2005), another in 1471 in the capture of 20,000 individuals and 80,000 livestock, and another in 1500 in the capture of 3,000 individuals and 2,500 livestock (Hrabak, 1986).

Although there is a great deal of historical information on Ottoman attacks, and some on population migrations, there is little data on how these changes may have affected nutrition. To this purpose, this study will test how incessant, low-intensity warfare affected nutrition by analysing dental health in two composite skeletal series from continental Croatia: the first, a pre-Ottoman period series consisting of three sites dated to the period between the 11th and the 14th century and the second, an Ottoman period series consisting of three cemeteries dated between the 15th and the 18th century.

2 | MATERIALS AND METHODS

The dental material analysed in this study originates from six cemeteries located in continental Croatia (Figure 1). The three pre-Ottoman cemeteries: Stenjevec, Zvonimirovo, and Josipovo all belong to the Bijelo Brdo culture and were in use from the 11th to the 13th century (Simoni, 2004; Tomičić, 1997).

The Bijelo Brdo culture was a multi-ethnic culture, which covered an area that includes modern Slovakia, Hungary, Slovenia, continental Croatia, north Serbia, and western Romania, consisting of various Slavic- and Hungarian-speaking peoples whose main archaeological features are skeletal burials arranged in parallel rows and similar types of pottery and jewellery (Tomičić, 1997). In terms of subsistence strategy, the culture was characterised by small villages practising a rural and sedentary way of life based on subsistence agriculture (Simoni, 2004). Analyses of the recovered archaeological artefacts, grave architecture, and available historical sources suggest that the vast majority of the recovered individuals belonged to lower social categories (Simoni, 2004; Tomičić, 1997).

Osteological material from the Ottoman period series derives from three cemeteries: Žumberak, Virje, and Torčec that were in use from

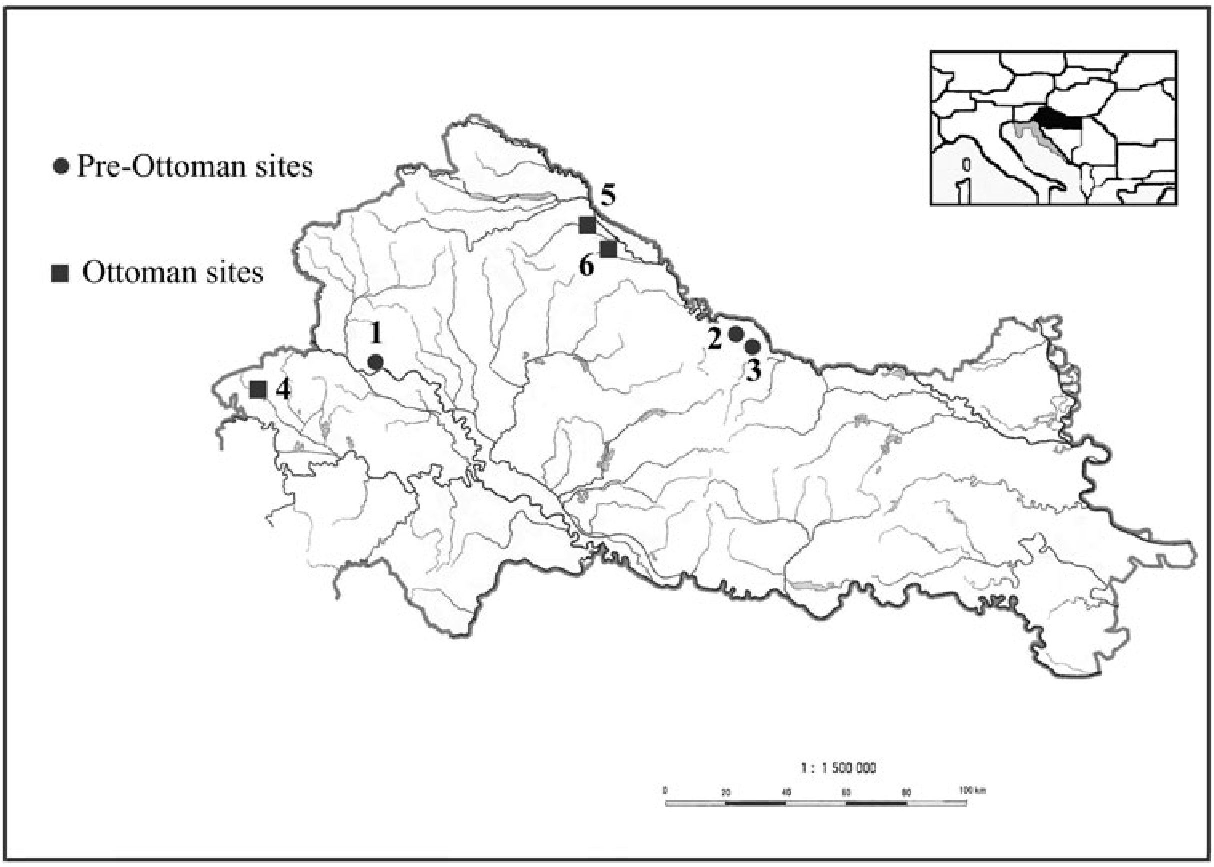

FIGURE 1 Map of Croatia with the geographical position of the analysed sites. Numbers correspond to the following sites: 1—Stenjevec, 2—Zvonimirovo, 3—Josipovo, 4—Žumberak, 5—Virje, and 6—Torčec

the 15th to the 18th century (Azinović Bebek, 2009; Čimin, 2013; Krznar, 2013). In archaeological terms, these sites are characterised by small cemeteries located besides parish churches in which most of the deceased were buried in wooden coffins. These sites were also inhabited by a multi-ethnic group of peoples that consisted of the remaining local population and a new migrant group of peoples known as "Vlachs." These were nomadic and seminomadic pastoralist communities relocated, "en masse," by the Ottomans from their ancestral homelands in the Easter Balkans and Black Sea region, to settle the deserted, war-afflicted regions of first Bosnia and then Croatia (Valentić, 1990). In return for manning the fortified military border, they were granted tax concessions and exemption from labour dues (Raukar, 1997). As with the pre-Ottoman series, analyses of recovered archaeological artefacts show no evidence of higher social status individuals, and therefore, for the purposes of this analysis, all individuals, from both composite series, are treated as a single social category.

Altogether, the dentition of 273 adult individuals over 18 years of age was examined, 112 belonging to the pre-Ottoman and 161 to the Ottoman period series. The number of skeletons, sex distribution, and number of analysed teeth and alveoli in the composite series is presented in Table 1.

The sex and age of each individual were determined using standard anthropological criteria. Sex determination was based on cranial and pelvic morphology (Bass, 1987; Bruzek, 2002; Buikstra & Ubelaker, 1994; Murail, Bruzek, Houet, & Cunha, 2005; Phenice, 1969). Age was estimated using pubic symphysis morphology (Brooks & Suchey, 1990), auricular surface morphology (Lovejoy, Meindl, Pryzbeck, & Mensforth, 1985), ectocranial suture closure (Meindl & Lovejoy, 1985), and sternal rib end changes (Işcan, Loth, & Wright, 1984, 1985). All individuals were assigned to one of two composite age categories: younger adults falling between 18 and 35 years and older adults comprising an open ended 36+ years age category.

The following dento-alveolar pathologies were recorded: caries, Antemortem tooth loss (AMTL), abscesses, calculus, alveolar bone resorption, and tooth wear. Only individuals with at least eight teeth and tooth sockets in each jaw were included in the analysis (Novak, 2015). All pathologies were analysed by teeth and alveoli.

Dental caries is the localised demineralization of dental hard tissues by organic acids that develops as a result of bacterial fermentation of dietary carbohydrates (Larsen, 1997). Carious lesions were considered present only when there was a clear defect in the tooth tissue. Other tooth surface defects such as pits and deep fissures were disregarded, as were colour changes of the enamel, sticky fissures, and early decalcification without loss of enamel. It is recognised that carious formation is a continuous process that proceeds slowly and that macroscopically visible lesions or defects in the tooth surface represent a late stage of the disease (Hillson, 2001). However, we chose not to include precavitated or incipient lesions in our analysis to reduce problems of variability in scoring. All teeth were examined macroscopically under a bright light using magnification of up to 10×, and the number of lesions, as well as their location, was recorded for each tooth.

Ante mortem tooth loss is complex and multicausal process caused by advanced dental caries, nutritional deficiency diseases, dental wear, cultural or ritual ablation, and trauma (Lukacs, 2007). In this data set, a tooth was scored as lost ante mortem if the tooth socket showed any sign of alveolar bone resorption (Ortner & Putschar, 1981). If there was no evidence of remodelling, the tooth was considered to be lost post mortem. At this point, it must be noted that unlike the other pathologies analysed in this study—where frequencies are based on the number of teeth or alveoli present—frequencies for ante mortem tooth loss are calculated based on the

TABLE 1 The age and sex distribution in the analysed sample

	Pre-Ottoman			Ottoman		
	Number of individuals					
Age (years)	Males	Females	Total	Males	Females	Total
18–35	24	26	50	37	17	54
36+	32	30	62	63	44	107
Total	56	56	112	100	61	161
Grand total						273
	Number of teeth					
Age (years)	Males	Females	Total	Males	Females	Total
18–35	538	577	1,115	841	384	1,225
36+	568	451	1,019	858	572	1,430
Total	1,106	1,028	2,134	1,699	956	2,655
Grand total						4,789
	Number of alveoli					
Age (years)	Males	Females	Total	Males	Females	Total
18–35	580	637	1,217	906	436	1,342
36+	771	671	1,442	1,412	919	2,331
Total	1,351	1,308	2,659	2,318	1,355	3,637
Grand total						6,296

number of ante mortem absent teeth (per tooth socket available for examination). Special attention during recording was given to missing data, for example, unerupted/not present third molars, as well as for fractured bones with missing sockets.

Dental abscesses are caused by inflammation and infection of the root canal, most commonly related to caries, calculus formation, and attrition, leading to the accumulation of pus that drains through the alveolar bone (Lukacs, 1989). Identifying alveolar abscesses is complicated by the fact that cavities in the bone around the root of a tooth may also result from periapical granulomas or benign cysts (Dias & Tayles, 1997). The presence of a drainage sinus is, however, generally accepted as evidence of an abscess in skeletal samples (Roberts & Manchester, 2007). Accordingly, alveolar abscesses were diagnosed only when the presence of a perforating fistula and a sinus in the bone at the apex of the tooth root were unambiguously established.

Dental calculus forms as a consequence of the mineralization of the bacterial plaque that is attached to the surface of a tooth (Hillson, 1996). A detailed macroscopic examination of teeth deposits was implemented to distinguish between true dental calculus and post mortem deposits from sand or soil. Dental calculus was recorded and separated into three levels using criteria proposed by Brothwell (1981): slight (a slight line of calculus), moderate (up to 50% of the tooth surface is covered in calculus), and severe (between 50% and 100% of the tooth surface is covered in calculus).

Periodontal disease is characterised by inflammation and destruction of gum tissue, the periodontal ligament, root cementum, and alveolar bone, and can be caused by various infectious agents found in dental plaque (DeWitte, 2012). It results in the gradual destruction of periodontal tissues and alveolar bone and is identified in skeletal material by the loss of alveolar bone that exposes the underlying trabecular bone and thereby produces porosity (Clarke, Carey, Sirkandi, Hirsch, & Leppard, 1986) or causes the alveolar crest to recede relative to the cemento-enamel junction of the associated dentition (Larsen, 1997). A tooth was considered positive for alveolar bone resorption only when the alveolar bone showed changes in the cortical surface, revealing either porous cancellous spaces or an altered alveolar crest, and the distance between the cemento-enamel junction and the alveolar crest was more than 2 mm (DeWitte, 2012; Novak, 2015). For more details on possible problems related to using linear measurements to determine periodontal disease, see Hildebolt and Molnar (1991) and DeWitte (2012).

Degree of dental wear was recorded according to Smith (1984), who uses an eight-stage system to describe degree of wear on all teeth. In this analysis, teeth were grouped as posterior (molars and premolars) and anterior teeth (canines and incisors), whereas degrees of dental wear set as mild (Smith's Degrees 1 and 2), intermediate (Degrees 3 and 4), and heavy (Degrees 5 to 8). Here, we present only the results for heavy wear.

Frequencies were calculated for each type of lesion recorded, and statistical comparisons by age and sex were performed using the χ^2 test employing Yates correction when appropriate. All statistical analyses were performed using the SPSS statistical package version 22.0.

3 | RESULTS

The pre-Ottoman series consists of 56 males and 56 females yielding a male/female ratio of 1:1 (Table 1). The Ottoman series consists of 100 males and 61 females giving a male/female ratio of 1:0.6. Both samples are biased towards older age categories. The percentage of individuals older than 36 years in the pre-Ottoman series is 55.4%, in the Ottoman series 66.5%.

3.1 | Dental caries

In both series, males and females exhibit similar frequencies of dental caries (Table 2).

Similarly, in both series, carious lesions are more frequent in the posterior dentition. In the pre-Ottoman series, 86.8% of caries are present in posterior dentition, and in the Ottoman series, the frequency is 87.4%.

Comparisons between the series (Table 3) show significantly higher caries frequencies in the pre-Ottoman series at the level of complete samples, as well as in the older age category. Analyses controlling for sex show that these differences were primarily the result of significantly higher male caries frequencies in the pre-Ottoman period. No differences were noted between complete female samples, or in the younger female age category, but older females from the pre-Ottoman series exhibit the same trend noted in males and have significantly higher caries rates than older females from the Ottoman time period.

3.2 | AMTL

AMTL frequencies (Table 2) in the pre-Ottoman series are significantly higher in females than in males at all levels: in younger adults, older adults, and at the level of complete samples (χ^2 values from 10.52 to 34.85; $p < .01$), whereas in the Ottoman series, males and females exhibit similar AMTL frequencies.

In contrast to dental caries, comparisons between the series show significantly higher frequencies of AMTL in the Ottoman series in five of nine analysed categories, including in the total male category, total female category, and at the level of complete samples (Table 3).

3.3 | Abscesses

Abscesses frequencies (Table 2) are in both series very similar in males and females.

Comparisons between the series (Table 3) show similar abscess frequencies at the level of complete samples, and this trend is repeated in all other categories with the exception of abscess frequencies in older females and, in all older adults, where individuals from the pre-Ottoman exhibit higher frequencies than those from the Ottoman series (χ^2 = 4.59; $p < .05$ for older females and χ^2 = 4.49; $p < .05$ for all older adults).

3.4 | Calculus

In both series, males exhibit significantly higher calculus frequencies than females (Table 2) at all levels (χ^2 values ranging from 4.40 to

TABLE 2 Frequencies of dental and periodontal pathologies in the pre-Ottoman and Ottoman series by age and sex

	Pre-Ottoman						Ottoman					
Age	Males	%	Females	%	Total	%	Males	%	Females	%	Total	%
Dental caries												
≤35	78/538	14.5	66/577	11.4	144/1,115	12.9	110/841	13.1	38/384	9.9	148/1,225	12.1
36+	114/568	20.1	106/451	23.5	220/1,019	21.6	130/858	15.2	95/572	16.6	225/1,430	15.7
Total	192/1,106	17.4	172/1,028	16.7	364/2,134	17.1	240/1,699	14.1	133/956	13.9	373/2,655	14.0
AMTL												
≤35	17/580	2.9	46/637	7.2	63/1,217	5.2	46/906	5.1	14/436	3.2	60/1,342	4.5
36+	128/771	16.6	200/671	29.8	328/1,442	22.7	422/1,412	29.9	295/919	32.1	717/2,331	30.8
Total	145/1,351	10.7	246/1,308	18.8	391/2,659	14.7	468/2,318	20.2	309/1,355	22.8	777/3,673	21.2
Abscesses												
≤35	14/580	2.4	12/637	1.9	26/1,217	2.1	27/906	3.0	7/436	1.6	34/1,342	2.5
36+	63/771	8.2	66/671	9.8	129/1,442	8.9	101/1,412	7.2	62/919	6.7	163/2,331	7.0
Total	77/1,351	5.7	78/1,308	6.0	155/2,659	5.8	128/2,318	5.5	69/1,355	5.1	197/3,673	5.4
Calculus												
≤35	455/528	86.2	456/561	81.3	911/1,089	83.7	805/825	97.6	371/380	97.6	1,176/1,205	97.6
36+	536/554	96.8	388/427	90.9	924/981	94.2	763/800	95.4	451/534	84.5	1,214/1,334	91.0
Total	991/1,082	91.6	844/988	85.4	1,835/2,070	88.7	1,568/1,625	96.5	822/914	89.9	2,390/2,539	94.1
Alveolar resorption												
≤35	107/309	34.6	95/294	32.3	202/603	33.5	130/559	23.3	152/337	45.1	282/896	31.5
36+	275/311	88.4	147/168	87.5	422/479	88.1	418/553	75.6	199/306	65.0	617/859	71.8
Total	382/620	61.6	242/462	52.4	624/1,082	57.7	548/1,112	49.3	351/643	54.6	899/1,755	51.2

TABLE 3 Comparisons of occurrence of dental features in the analysed series

Dental feature	Pre-Ottoman versus Ottoman males			Pre-Ottoman versus Ottoman females			Pre-Ottoman versus Ottoman total		
	N	χ^2	*p*	*N*	χ^2	*p*	*N*	χ^2	*p*
Dental caries									
≤35	1,379	0.44	.503	961	0.42	.516	2,340	0.29	.584
36+	1,426	5.48	<.05[a]	1,023	7.16	<.01[a]	2,449	13.33	<.001[a]
Total	2,805	5.13	<.05[a]	1,984	2.81	.093	4,789	7.99	<.01[a]
AMTL									
≤35	1,486	3.50	.061	1,073	7.14	<.01[a]	2,559	0.54	.458
36+	2,183	45.99	<.001[b]	1,590	0.84	.357	3,773	28.16	<.001[b]
Total	3,669	54.17	<.001[b]	2,663	6.20	<.05[b]	6,332	42.22	<.001[b]
Abscesses									
≤35	1,486	0.23	.625	1,073	0.01	.916	2,559	0.28	.594
36+	2,183	0.60	.436	1,590	4.59	<.05[a]	3,773	4.49	<.05[a]
Total	3,669	0.02	.879	2,663	0.80	.368	6,332	0.55	.457
Calculus									
≤35	1,353	63.61	<.001[b]	941	55.34	<.001[b]	2,294	133.68	<.001[b]
36+	1,354	1.25	.262	961	8.22	<.01[a]	2,315	7.67	<.01[a]
Total	2,707	29.26	<.001[b]	1,902	8.47	<.01[b]	4,609	44.19	<.001[b]
Alveolar resorption									
≤35	868	12.39	.001[a]	631	10.25	.001[b]	1,499	0.58	.443
36+	864	19.86	.001[a]	474	26.64	<.001[a]	1,338	45.99	<.001[a]
Total	1,732	23.85	.001[a]	1,105	0.44	.506	2,837	10.92	<.001[a]

[a]Differences between the pre-Ottoman and Ottoman series are the result of significantly higher frequencies in the pre-Ottoman period.

[b]Differences between the pre-Ottoman and Ottoman series are the result of significantly higher frequencies in the Ottoman period.

45.30; $p < .01$) except for younger individuals in the Ottoman series where males and females exhibit the same calculus frequencies (97.6%).

Comparisons between the series (Table 3) show that in six of nine categories, calculus rates are higher in the Ottoman than in the pre-Ottoman series. Among these categories are those that define total calculus frequencies in the two series, total male calculus frequencies, and total female calculus frequencies.

No significant differences are, however, noted when the severity of calculus is compared between the series (Table 4).

3.5 | Alveolar resorption

Alveolar resorption frequencies (Table 2) in the pre-Ottoman series are, at the level of the complete sample, significantly higher in males than in females (χ^2 = 8.86; $p < .01$), whereas in the Ottoman period sample, females exhibit significantly higher frequencies of alveolar resorption than males (χ^2 = 4.38; $p < .05$).

Comparisons between the series (Table 3) indicate significantly higher alveolar resorption rates in the pre-Ottoman series in six of nine analysed categories, including at the level of total samples, in total male alveolar resorption frequencies, and in all older adults.

3.6 | Dental wear

Of the 2,134 permanent teeth from the pre-Ottoman sample, 2,072 (or 97.1% of the total sample) were sufficiently preserved to be examined for the presence of dental wear. In the Ottoman sample, 2,573/2,655 teeth (96.9%) had sufficiently preserved occlusal surfaces.

TABLE 4 Calculus by severity in the pre-Ottoman and Ottoman series

	N of teeth affected				Calculus rates (%)				
Series	1[a]	2	3	Sum	1	2	3	Total	Total[b]
Pre-Ottoman	1,774	60	1	1,835	96.7	3.3	0.05	88.6	2,070
Ottoman	2,331	59	0	2,390	97.5	2.5	0.0	94.1	2,539

[a]Calculus Levels 1–3 according to Brothwell (1981); 1 = slight; 2 = moderate; and 3 = severe.

[b]Total number of teeth examined.

In both samples, males and females display very similar frequencies of heavy dental wear with no significant differences in any of the analysed categories.

At the level of complete samples (Table 5), the frequencies of heavy wear in both series are very similar: 628/2,072 or 30.3% of teeth in the pre-Ottoman series exhibit wear equivalent to, or greater than Smith Stage 5, compared to 785/2,573 or 30.5% of teeth in the Ottoman series.

When, however, heavy wear is analysed by mandible and maxilla, as well as by posterior and anterior teeth (Table 6), significant differences between the series are revealed. Nine differences are noted in total, all of them in the younger age category. The pattern emerging from these analyses is very uniform; in all instances, higher frequencies of heavy dental wear were recorded in the pre-Ottoman sample.

The most pronounced differences appear to be in the mandible. Heavy dental wear is uniformly higher in younger adults in the pre-Ottoman sample both at the level of complete male and female samples, and at the level of total samples, and in anterior teeth where the same pattern of significantly higher dental wear in pre-Ottoman individuals is also noted.

4 | DISCUSSION

At the level of the complete data set, sex differences are noted in alveolar resorption, calculus, and AMTL frequencies. Males in both series exhibit higher calculus frequencies than females; females exhibit higher AMTL frequencies than males in the pre-Ottoman series; and alveolar resorption frequencies are higher in males in the pre-Ottoman and in females in the Ottoman series. As the recorded differences are not consistent, and both sexes exhibit similar frequencies of caries, abscesses, and heavy dental wear, it would appear that males and females in the analysed series had similar nutrition.

TABLE 5 Frequency of heavy tooth wear (Smith's Stages 5–8) by age and sex

	Pre-Ottoman						Ottoman					
Age	Males	%	Females	%	Total	%	Males	%	Females	%	Total	%
Maxilla												
18–35	18/237	7.6	34/294	11.6	52/531	9.8	22/361	6.1	4/175	2.3	26/536	4.9
36+	144/252	57.1	128/225	56.9	272/477	57.0	197/328	60.1	123/210	58.6	320/538	59.5
Total	162/489	33.1	162/519	31.2	324/1,008	32.1	219/689	31.8	127/385	33.0	346/1,074	32.2
Mandible												
18–35	31/291	10.7	25/266	9.4	56/557	10.1	18/458	3.9	3/203	1.5	21/661	3.2
36+	150/299	50.2	98/208	47.1	248/507	48.9	259/498	52.0	159/340	46.8	418/838	49.9
Total	181/590	30.7	123/474	25.9	304/1,064	28.6	277/956	29.0	162/543	29.8	439/1,499	29.3
Anterior teeth												
18–35	29/186	15.6	32/213	15.0	61/399	15.3	14/315	4.4	0/143	0.0	14/458	3.1
36+	125/209	59.8	115/192	59.9	240/401	59.9	234/371	63.1	133/240	55.4	367/611	60.1
Total	154/395	39.0	147/405	36.3	301/800	37.6	248/686	36.2	133/383	34.7	381/1,069	35.6
Posterior teeth												
18–35	20/342	5.9	27/347	7.8	47/689	6.8	26/504	5.2	7/235	3.0	33/739	4.5
36+	169/342	49.4	111/241	46.1	280/583	48.0	222/455	48.8	149/310	48.1	371/765	48.5
Total	189/684	27.6	138/588	23.5	327/1,272	25.7	248/959	25.9	156/545	28.6	404/1,504	26.9

TABLE 6 Comparisons of occurrence of tooth wear in the analysed series

Tooth wear	Pre-Ottoman versus Ottoman males			Pre-Ottoman versus Ottoman females			Pre-Ottoman versus Ottoman total		
	N	χ^2	*p*	*N*	χ^2	*p*	*N*	χ^2	*p*
Maxilla									
18–35	598	0.30	.581	469	11.46	<.001[a]	1,067	8.9	<.01[a]
36+	580	0.38	.533	435	0.06	.797	1,015	0.53	.466
Total	1,178	0.17	.672	904	0.24	.622	2,082	0.001	.974
Mandible									
18–35	749	12.07	<.001[a]	469	11.49	<.001[a]	1,218	22.99	<.001[a]
36+	797	0.18	.667	548	0.006	.938	1,345	0.08	.774
Total	1,546	0.42	.512	1,017	1.70	.191	2,563	0.12	.726
Anterior teeth									
18–35	501	17.12	<.001[a]	356	21.80	<.001[a]	857	38.43	<.001[a]
36+	580	0.47	.491	432	0.70	.402	1,012	0.005	.943
Total	1,081	0.76	.387	788	0.14	.699	1,869	0.69	.404
Posterior teeth									
18–35	846	0.07	.780	582	5.03	<.05[a]	1,428	3.31	.068
36+	797	0.01	.916	551	0.14	.702	1,348	0.01	.909
Total	1,643	0.55	.456	1,133	3.64	.056	2,776	0.41	.518

[a]Differences between the pre-Ottoman and Ottoman series are the result of significantly higher frequencies in the pre-Ottoman period.

Comparisons between the series show that caries frequencies are significantly higher in the pre-Ottoman series. Most analyses report a correlation between caries rates and diet (Larsen, 1997; Larsen, Shavit, & Griffin, 1991; Lillie, 1996). High caries rates are typically correlated with greater consumption of carbohydrates, whereas low rates of caries are correlated with low carbohydrate diets. The reason for this is that microorganisms in the bacterial plaque metabolise carbohydrates, thus lowering the pH of the oral cavity and favouring the destruction of the hard tissues of the tooth (Powell, 1985). Diets that contain high levels of proteins and fat are, on the other hand, though to inhibit caries.

The significantly different caries rates between the pre-Ottoman and Ottoman series suggest markedly different alimentary habits, with a significant decrease of carbohydrates in the Ottoman period diet.

In both series, carious lesions are more common in the posterior dentition. This trend has previously been recorded in numerous studies (Malčić et al., 2011; Šlaus et al., 2011; Watt, Lunt, & Gilmour, 1997) and can be explained by the fact that bacterial plaque accumulates more easily on surfaces with pits and cracks and is also less easily removed from these surfaces by saliva flow and the actions of the tongue and cheeks (Powell, 1985).

Abscess frequencies are also significantly higher in the pre-Ottoman sample in all older adult categories. This is consistent with the higher caries rates recorded in this series. The most common etiologic factors of abscesses in archaeological populations are caries, heavy wear, and trauma (Dias & Tayles, 1997).

In contrast to the trend noted in caries and abscess frequencies, calculus is significantly more prevalent in the Ottoman period series. Calculus formation is related to both diet and nondietary factors (Hillson, 2001). Among the nondietary factors linked to its formation are the mineral content of drinking water, poor oral hygiene, rate of salivary flow, culturally derived patterns of behaviour, and the utilisation of teeth as tools (Lieverse, 1999). The association between diet and calculus is not clear-cut, and high calculus rates have been recorded in both high-carbohydrate and high-protein diets (Lieverse, 1999; Lillie & Richards, 2000). In combination with caries rates, however, calculus has been used to evaluate the relative contribution of carbohydrates versus proteins to the diet. High calculus rates combined with low caries rates are representative of populations subsiding on high-protein/low-carbohydrate diets whereas high calculus rates combined with high caries rates are typical of populations subsiding on high-carbohydrate/low-protein diets (Lillie, 1996).

In this context, comparison between the series that show lower caries and higher calculus rates in the Ottoman, compared to higher caries and lower calculus rates in the pre-Ottoman series, is consistent with the previously recorded trend in caries and abscess frequencies that suggest a diet richer in proteins during the Ottoman period.

The higher frequency of heavy wear in younger adults in the pre-Ottoman series suggests a diet with more abrasive, hard, fibrous foods that required vigorous mastication. Dental wear rates are, however, multifactorial and depend not only on numerous factors including the consistency and texture of food but also on potentially differing food preparation techniques, as well as the age and sex of the individuals consuming them (Walker, Dean, & Shapiro, 1991). The significantly higher rates of heavy wear in the pre-Ottoman series recorded in the anterior dentition raise the possibility that nondietary factors, possibly some as yet unidentified activities specific to young adults, may have contributed to the wearing down of their front teeth.

Alveolar resorption is significantly higher in the pre-Ottoman series in six of nine analysed categories, including at the level of total samples, all older adults, and all male categories. The aetiology of alveolar resorption is multifactorial and includes dietary, hygienic, environmental, and genetic components. Additionally, Clarke et al. (1986) have noted differences between premodern and modern populations regarding the most common causes of alveolar resorption. According to their results, although the primary etiologic factor of alveolar resorption in contemporary societies is bacterial plaque, in archaeological populations, factors such as heavy attrition (resulting from occlusal trauma), pulp damage, infection, and mineral imbalance appear to be more important. As calculus rates are higher in the Ottoman than in the pre-Ottoman series, it would appear that factors other than bacterial plaque contributed to the elevated rates of alveolar resorption during the pre-Ottoman period. Potential contributors include systemic diseases such as scurvy, osteoporosis, diabetes and immunodeficiency diseases, and chronic occlusal trauma (Garcia, Henshaw, & Krall, 2001). The significantly higher rates of heavy wear noted in the pre-Ottoman series suggest that chronic occlusal trauma may have been a significant contributing factor. This is consistent with previous data suggesting a high-carbohydrate/low-protein diet possibly consisting of more abrasive, hard, fibrous foods requiring vigorous mastication—and hence, greater occlusal trauma, during the pre-Ottoman period.

AMTL frequencies are higher in the Ottoman series. Determining the causes of AMTL in archaeological populations is difficult. Potential causes include caries, abscesses, heavy wear, calculus, alveolar resorption, metabolic diseases such as scurvy, and trauma (Hillson, 2000; Ortner & Putschar, 1981). The fact that in this data set AMTL frequencies are higher in the Ottoman series is surprising given that not only caries but also alveolar resorption, abscess, and heavy wear frequencies are all higher in the pre-Ottoman sample. Calculus frequencies, more severe in the Ottoman series, may have contributed to this, but a much more likely cause is the gradual development of dentistry that began in the 15th century. From the middle of the 17th century, some towns (Dubrovnik, Zadar, and Zagreb) had permanently employed dentists (Raguž & Keros-Naglić, 1999), and although they possessed no means to treat infected teeth, they were adept at extracting them. Additionally, such procedures were, from the first half of the 17th century, commonly performed by barbers (Belicza, 1991). It is therefore possible that individuals with severe carious lesions in the Ottoman period series had those teeth extracted during their lifetime causing the higher frequency of AMTL in this sample.

Cumulatively, the collected data suggest a significant change in alimentary habits with, surprisingly, better oral health and a higher dependence on proteins during the period that Croatia was involved in low-intensity, endemic warfare. At first glance, this appears counterintuitive as there is abundant historical evidence documenting the havoc and destruction caused by persistent Ottoman raiding and the gradual incorporation of various Croatian territories into the Ottoman Empire.

To recap briefly, the prior late medieval period was characterised by social development, urbanisation, and an increase of monetary economy (Raukar, 1997). All of these improvements were, however, still based on a primitive agrarian economy. Historical sources dealing with the everyday life of common people are rare, but it appears that the diet of most people was based on staple crops such as wheat, barley, and millet in combination with seasonable fruits and vegetables raised in gardens (Šoštarić & Šegota, 2010). Meat and fish were, because of their prohibitive cost, relatively scarce.

From, however, the beginning of the 15th century, when Croatia first came into contact with the Ottoman Empire, to 1699 when the Ottomans ceded control of most of Central Europe to the Habsburg Monarchy, the past inhabitants of Croatia were subjected to continuous, low-intensity, endemic warfare. Akinji raids were the driving force behind this process and were both frequent and devastating in their impact on the local population as is clear not only from historical sources but also from trauma analyses (Šlaus, Novak, Vyroubal, & Bedić, 2010). The raids targeted livestock and local inhabitants that were captured and sold as slaves and, not surprisingly, caused massive emigrations as well as a collapse in the economy reflected in the rapid decline of agrarian and artisan products, the complete disappearance of long-distance trade activity and a sudden expansion in the slave trade (Vinaver, 1953). The level of depopulation caused by the combination of incessant akinji raiding and resulting famines reached apocalyptic dimensions in some parts of Croatia, and it is estimated that from 1463 to 1593, Croatia suffered a loss of more than 60% of its native population (Jurković, 2004).

The depopulated areas of Croatia were settled by an ethnically heterogeneous group of peoples knows as Vlachs. These were nomadic or seminomadic sheep herders and cattle raisers who, although predominantly Christian, enjoyed a special social status in the Ottoman Empire. Because of their military prowess, they were granted tax privileges and employed both as auxiliary troops in the Ottoman army, and to repopulate the abandoned, newly conquered territories as border military colonies (Valentić, 1990). Most sites near the military border, and Žumberak, Torčec, and Virje fall within this category, were thus populated by a mixture of remaining local inhabitants and newly arrived Vlach populations (Adamček, 1969; Bognar & Bognar, 2010). Cattle farming and sheep herding, occasionally supplemented by plunder during war campaigns, were the predominant economy.

In this context, it is apparent that the manifest improvement in dental health noted in the Ottoman period series was the result of the following set of circumstances: (a) mass emigration of local populations caused by incessant akinji raiding during the 15th century; (b) the resulting economic decline and abandonment of these territories; and (c) the subsequent arrival of a new group of peoples knows as Vlachs in the 16th century, who practised a different subsistence strategy based on pastoralism and cattle farming. While the preceding local populations subsided in rural environments and practised a subsistence strategy based on agriculture with a corresponding diet that was high in carbohydrates, low in proteins, and had relatively abrasive, hard, fibrous foods that required vigorous mastication, the newly arrived migrant Vlach populations had a diet that was, in relative terms, lower in carbohydrates and higher in proteins. Cumulatively, these factors resulted in lower levels of carious lesions, abscesses, alveolar resorption, and heavy dental wear in the Ottoman period series.

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