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ORIGINAL ARTICLE

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Coronal and apical lesions, environmental factors: study in a modern and an archeological population

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Abstract Apical periodontitis (AP) are frequent findings in contemporary dental practice in association with dental pathology or dental care. They have also been studied from an anthropological background. The purpose of this study was to compare the prevalence of apical and dental lesions in an archeological Middle Ages sample and a modern population, and to evaluate the influence of environmental factors. Both the archaeological sample group and dental practice subjects were from southern France. The study included full mouth surveys of 252 individuals (2,780 teeth) from a historic necropolis and 223 subjects (5,678 teeth) randomly selected from the Gard area. Tooth wear, caries, and AP were accounted for clinically and radiographically according to specific indexes. Significant differences were found between period and age in the archeological sample as regards the main risk factors for AP. Antemortem teeth loss and dental wear had been reduced, whereas caries rates and AP had increased between archaeological and modern population. The AP ratio was associated with the level of dental care in the modern population. Although significant variations could be observed between archaeological periods, the rupture in E3 (sixteenth and seventeenth centuries) leads to consider the associated population as a premodern. However, it was found that although cultural and alimentary factors seemed to be the main risk factors in an archeological population, dental care seemed to have a strong influence on AP ratio in modern ones.

Keywords Apical periodontitis · Dental anthropology · Risk indicators · Radiography

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Introduction

Coronal and periapical lesions pose a constant risk for disease that is seldom life-threatening in contemporary populations but can lead to long-term complications [1]. Most practitioners interpret periapical lesions, usually resulting from endodontic infection, as disease risk indicators [18] in function-of-living conditions and conservative dental treatment. In this regard, study of coronal and periapical lesions in historic populations has demonstrated that dietary habits [27] and socioeconomic status [15, 16] are paramount factors. Similar findings have been obtained in prehistoric populations who never benefited from dental treatment, such as hunter-gatherers [9, 17, 20, 32].

Periapical lesions have been associated with extensive dental wear and caries with exposure of the pulp [2, 6, 25]. Modern techniques for assessing tooth wear [26, 33, 34], dental caries [13], and periapical lesions [2] allow good comparison of populations [5, 7]. To our knowledge, however, no study has compared coronal wear, dental caries, and periapical lesions in an archeological and contemporary population. The main limitation for such study is the limited availability of sufficiently well-preserved archeological samples.

The present study is based on a large sample population that were compiled from an extensive collection of skeletal remains from historic and prehistoric populations in southern France. The twofold goal of this study was (1) to analyze and compare the type and extent of tooth wear, dental caries, and periapical lesions in an archeological and contemporary population, and (2) to evaluate the relation with environmental factors.

Materials

Contemporary sample

The contemporary sample for this study was composed of people living in the Gard department of southern France. A representative cross section was obtained based on demographic data from the 1990 general population census of the Institut National de la Statistique et des Etudes Economiques (INSEE). Individual data included age, tooth type, and dental records. Sex was not taken into consideration because gender is not a significant factor in paleoondontological study and has rarely been implicated in the prevalence of dental disease [21]. An anonymous identification number was assigned to each file and a sample of 223 individuals were randomly drawn from the population.

Archeological sample

The archeological sample for this study was assembled from skeletal remains exhumed from the historic necropolis dating from the fourth to the seventeenth century A.D. at the Notre-Dame-du-Bourg, Digne, Alpes de Haute-Provence (scientific director, B. Mafart). Specimens were grouped according to three chronological periods, i.e., fourth to tenth century (E1), eleventh to fifteenth century (E2), and sixteenth and seventeenth centuries (E3). Specimens were selected based on the state of preservation of the upper maxillary and corresponding mandible. The archeological sample included a total of 252 individuals (2,805 teeth) identified according to grave number and time period. Age groups were determined by studying cranial suture closure according to the technique proposed by Masset [24].

Methods

The techniques used to study both samples were the same except for minor variations aimed mainly at taking into account the effects of dental care in the contemporary sample and postmortem changes in the archeological sample. Coronal defects were assessed by clinical examination and apical lesions by radiography.

In the contemporary sample, teeth replaced by adjoining prostheses, implants, and pontics were excluded from study. The quality of dental treatment (coronal restoration, endodontic filling) was evaluated by clinical examination and by panoramic or digital alveolar views.

In the archeological sample, only antemortem remaining teeth and antemortem teeth loss (reshaped and reconstructed bone alveoles) according to the criteria recommended by Hillson [13] were taken into account.

The distribution of the two study samples according to time period and age group was represented using the method described by Miles [25] for comparison of populations from different time periods (Table 1).

Evaluation of wear

Wear was graded according to the Brabant [4] index as follows:

- Level 0: no wear, no loss of surface features
- Level 1: wear limited to enamel
- Level 2: presence of dentin clusters
- Level 3: most dentin still covered
- Level 4: involvement of pulpal horns or pulpal exposure

Evaluation of caries

In both samples, clinically detectable caries were taken into account, and in some cases radiographic assessment was performed to obtain further data.

Radiographic assessment of periapical defects

Periapical lesions were assessed by calculating the periapical index (PAI) [29] based on retro-alveolar or orthopantomogram (OPM) radiographic views that were routinely performed in both samples. Individuals were considered to have a sound periapex if PAI≤2 and diseased if PAI>2. All OPM views were made with a P.M. Proline de 2002 cc generator (Planmeca, Helsinki, Finland) and retro-alveolar views were made using a X PHILIPS ORALIX 65-kV generator equipped with a digital sensor (CCD VISULIX, GENDEX) coupled to acquisition and image processing software (VIXWIN 2-3, GENDEX). Standard radiographic views were interpreted on an x-ray view box by the same investigator using a magnifying glass (magnification ×2.5). Coronal disease and demineralized apical lesions were identified and counted regardless of the extent of involvement.

Table 1 Individuals distribution per period and age

Sample	Archeological series, 252 individuals			Modern series, 223 individuals
	NDB E1	NDB E2	NDB E3	
Period	4th–10th century	11th–15th century	16th–17th	20th century
Age 12–25 years	9	21	23	18
Age 26–36 years	7	3	40	77
Age>36 years	19	41	36	128
Undet. age	1	12	10	

NDB Notre Dame du Bourg (archeologic site), *Undet. age* undetermined age

Table 2 Archeological and modern subject samples used for comparison in archeological and modern populations

Sample	Archeological series, 252 individuals			Modern series, 223 individuals
	NDB E1	NDB E2	NDB E3	
Period	4th–10th century	11th–15th century	16th–17th century	20th century
Individuals	36	107	109	223
Teeth	355	1,183	1,267	5,678
Antemortem teeth loss	72	342	519	1,458
Postmortem teeth loss	725	1,899	1,702	

NDB Notre Dame du Bourg (archeologic site)

Statistical analysis

Within-observer concordance was calculated using Cohen's kappa test (SPSS software). Qualitative variables were compared using the Kruskal–Wallis test (SAS software). Categorical variables were compared using the chi-square test and Fisher's exact test (SAS software). Differences were considered as significant at the conventional level of p=0.05.

Results

Antemortem tooth loss

In the contemporary sample, the mean number of teeth per individual was 25.5 and the total number of teeth was 5,678. Both these figures were consistent with corresponding data in other French populations [3]. Antemortem tooth loss, within each age group, was significantly ($p<10^{-6}$) higher in the archeological sample than in the contemporary sample: 33 vs. 26% (Table 2). In the archeological sample, a significant increase ($p<10^{-3}$) in antemortem tooth loss was observed over the three time periods: 19% during the E1 period, 29% during the E2 period, and 42.7% during the E3 period. The prevalence of tooth loss was statistically lower ($p<10^{-6}$) in the contemporary sample than in the most recent archeological sample, i.e., the E3 group from the sixteenth and seventeenth centuries.

Tooth wear

Coronal wear was more extensive in the archeological than contemporary sample population ($p<10^{-4}$) regardless of time period or age group (Table 3). The extent of wear was high during all three time periods. The most extensive wear was observed in the E2 group (eleventh to fifteenth century), but statistical analysis showed no significant difference between the successive time periods (p=0.49). The extent of wear increased with age in the archeological population. The age–period interaction was tested using two-way analysis of variance. Findings showed a significant interaction (p=0.01), thus indicating that the impact of "age" on tooth wear differed between periods.

Dental caries

The prevalence of dental caries in the archeological population increased with age (Table 4). Differences were significant between the last two age groups overall (p=0.04) and between the E1 and E2 time periods (p=0.03). Comparison within each age group in E1, E2, and E3 showed a constant increase in the prevalence of dental caries. The difference between the E2 and E3 was significant ($p<0.05$).

The highest prevalence of dental caries in the contemporary sample was observed in the young adult age group between 26 and 36 years, and all differences between age groups were significant ($p<10^{-3}$).

Comparison of the sample population from the most recent archeological time period (E3) and contemporary population showed a lower prevalence of caries in the contemporary population regardless of age. This difference was significant for the second and third age groups ($p<0.02$).

Periapical lesions

Within these time periods, the prevalence of teeth with apical lesions (PAI>2) increased with age (Table 5). A significant increase ($p<0.03$) was observed between the first two age groups in all sample subgroups except the one from the E1 time period (p=0.86). The difference between

Table 3 Dental wear (mean value) per period and age

Sample	Archeological series, 252 individuals			Modern series, 223 individuals
	NDB E1	NDB E2	NDB E3	
Period	4th–10th century	11th–15th century	16th–17th century	20th century
Age 12–25 years	1.24	1.35	1.40	1.00
Age 26–36 years	1.60	2.92	1.86	1.04
Age>36 years	2.19	2.37	2.23	1.35
Undet. age		2.12	1.60	

Archeological and modern populations
NDB Notre Dame du Bourg (archeologic site), *Undet. age* undetermined age

Table 4 Caries prevalence by teeth

	Archeological series, 252 individuals				Modern series, 223 individuals
	NDB E1	NDB E2	NDB E3	NDB	
Age 12–25 years [*n*/*N* (%)]	10/138 (7.2)	29/343 (8.4)	44/335 (13.1)	88/816 (10.8)	52/538 (9.7)
Age 26–36 years [*n*/*N* (%)]	4/77 (5.2)	34/473 (7.2)	100/491 (20.4)	138/1,041 (13.2)	351/2,187 (16.0)
Age>36 years [*n*/*N* (%)]	21/140 (15.0)	40/343 (11.7)	36/403 (21.3)	147/886 (16.6)	395/2,953 (13.5)
Undet. age [*n*/*N* (%)]	0/0 (0.0)	4/24 (16.7)	6/38 (15.8)	10/62 (16.1)	
Total [*n*/*N* (%)]	35/355 (9.9)	107/1,183 (9.0)	236/1,267 (18.6)	378/2,805 (13.5)	801/5,678 (14.1)

Archeological and modern populations
NDB Notre Dame du Bourg (archeologic site), *Undet. age* undetermined age

the intermediate and old age groups was significant only in the archeological sample population from the E2 time period (p=0.02) and in the contemporary sample ($p<10^{-4}$). The prevalence of teeth with apical lesions showed a constant increase through the periods but differences were not significant overall. Conversely, there was a significant difference between the historic sample from the E3 (sixteenth and seventeenth century) and contemporary sample.

Comparison of successive time periods showed no significant difference between young and intermediate age groups (p>0.07 and p>0.11, respectively). In the old age group (>36 years), the prevalence of teeth with apical defects was significantly higher in the contemporary population than in the sample population from the E3 time period ($p<10^{-4}$).

In the contemporary sample the prevalence of teeth with apical disease (PAI>2) correlated with the quality of dental treatment (Table 6). Prevalence ranged from 7 to 68% depending on type of therapy and number of teeth treated. A PAI>2 was observed in 5.4% of untreated teeth. The prevalence of PAI>2 was significantly lower ($p<10^{-6}$) for untreated teeth than treated teeth regardless of the type of treatment. The highest prevalence of apical defects was found in teeth with only endodontic treatment, i.e., without coronal restoration ($p<10^{-6}$). Teeth with coronal and endodontic treatment showed the highest prevalence of apical lesions associated with inadequate coronal and endodontic treatment (53%) and the lowest prevalence (6.8%) ($p<10^{-6}$) associated with both adequate coronal and endodontic treatment.

Discussion

This study comparing dentition in a historic sample population from the Notre-Dame-du-Bourg grave site and a contemporary sample population from the nearby Gard department demonstrated significant variations in apical health indicators, i.e., PAI>2, wear, and caries. The most notable finding was a tendency for decreased prevalence of tooth wear and increased prevalence of dental caries. Previous studies have implicated tooth wear and dental caries as the main risk factors for apical lesions in archeological populations [17, 28]. Although antemortem tooth loss is a valuable indicator of oral health in archeological populations, nothing can be inferred about the causes of tooth loss. In our study, antemortem tooth loss peaked in the group from the most recent archeological time period (E3) and then decreased in the contemporary sample population. A likely explanation for this decrease is the use of dental care and prevention of coronal and apical lesions in the contemporary sample.

The prevalence of dental caries has increased over the centuries. In this study, a significant difference was observed between the earliest time periods (E1 and E2) and the most recent time period (E3). This suggests that the E3 period (sixteenth to seventeenth century) is closer to the contemporary sample insofar as prevalence of dental caries is concerned even after taking into account lack of dental care during the E3 time period. Our findings also showed that dental caries affected the youngest (12–25 years old) and younger individuals (26–36 years old) in the contemporary population.

Table 5 Apical periodontitis prevalence by teeth

	Archeological series, 252 individuals				Modern series, 223 individuals
	NDB E1	NDB E2	NDB E3	NDB	
Age 12–25 years [*n*/*N* (%)]	6/138 (4.3)	12/343 (3.5)	10/335 (3.0)	28/816 (3.4)	8/538 (1.5)
Age 26–36 years [*n*/*N* (%)]	3/77 (3.9)	33/473 (7.0)	57/491 (11.6)	93/1,041 (8.9)	204/2,187 (9.3)
Age>36 years [*n*/*N* (%)]	12/140 (8.6)	40/343 (11.7)	47/403 (11.7)	99/886 (11.2)	466/2,953 (15.8)
Undet. age [*n*/*N* (%)]	0/0 (0.0)	2/24 (8.3)	3/38 (7.9)	5/62 (8.1)	
Total [*n*/*N* (%)]	21/355 (5.9)	87/1,183 (7.3)	117/1,267 (9.2)	225/2,805 (8.0)	678/5,678 (11.9)

Archeological and modern populations
NDB Notre Dame du Bourg (archeologic site), *Undet. age* undetermined age

Table 6 Ratio of apical periodontitis with respect to therapeutic status

Therapeutic status	No. of teeth	No. of teeth with PAI>2	% PAI>2
Coronal filling only	718	70	9.7
Adequate	533	41	7.7
Inadequate	185	29	15.7
Root canal filling	54	32	59.2
Adequate	41	28	68.3
Inadequate	13	4	30.8
Coronal filling adequate and root filling adequate	340	23	6.8
Coronal filling adequate and root filling inadequate	510	199	39.0
Coronal filling inadequate and root filling adequate	72	15	20.8
Coronal filling inadequate and root filling inadequate	283	150	53.0
No treatment	3,587	114	5.4

Modern population

Our data are subject to the same caution as all archeological studies and to uncertainty linked to postmortem tooth loss. However, tooth loss involved mainly incisors and canines, which have been shown to be less susceptible to caries [22]. Our contemporary sample data demonstrated a lower prevalence of dental caries. However, the effects of dental therapy may have concealed the real prevalence of caries that have been treated (probably most of the coronal restored teeth).

In contrast with dental caries, tooth wear showed a decrease over time in our samples. This finding is consistent with the hypothesis of caries attrition competition [23] based on the assumption that a beneficial effect of tooth wear is to avoid development of caries. High wear in the archeological population and lower wear in the contemporary population can be linked to the fact that the cumulative effects of attrition with age were not the same in each period. During the medieval period the diet was highly abrasive since the staple food was hard bread made from coarsely meal flour and salted meats [19]. As a result of this diet the occlusal profile disappeared rapidly. By modifying occlusal contact, loss of profile changed mandibular dynamics and reduced traumatic damage during closure. These diseases and their progression are related to incidental dietary and sociocultural factors [11]. In the archeological population, risk factors were enhanced by higher calorie and food intake requirements [19]. Such enhancement was confirmed by local improvement in the demographic and dietary setting in the archeological sample from the E3 time after Middle Ages [8].

The prevalence of coronal and apical lesions showed parallel variations over the centuries. Apical lesions progressed similarly to dental caries in the E3 time period closest to the contemporary sample. Lack of treatment during that period increased the risk of coronal lesions (caries and wear) without reducing periapical lesions. In the absence of detectable coronal lesions, some authors [17] implicated cracking of the enamel and dentine due to tooth trauma and intensive tooth use [14] as a risk factor for apical lesions. A few clinical cases have demonstrated the possibility of spontaneous repair of apical lesions without treatment [35]. Possible explanations for such spontaneous repair include changes in the equilibrium of the pathogenic flora, sudden reaction of host defense mechanisms, or reduction in intracystic pressure leading to a decrease in cortical bone defect and thus an improvement in the radiographic appearance of lesion.

Our results indicate that the prevalence of periapical lesions has continued to increase in the contemporary population despite the availability of dental therapy. As in previous epidemiological studies involving Western populations [10], the increase in our contemporary population was most evident in the upper age group (older than 36 years). Lesions often occurred in association with inadequate treatment [12] that is favorable to bacterial percolation. Periapical lesions pose a public health problem due to their adverse impact not only on general health status but also on to performance and outcome of therapy [12] in comparison with teeth without apical lesions.

In this study the prevalence of periapical lesions was high in the population from the E3 time period when adequate dental care did not exist. That prevalence was higher than in the two early age groups (12–25 and 26–36 years old) of the contemporary population. In their study of risk factors for apical lesions, Kirkevang and Wenzel [18] showed that undergoing numerous treatment sessions led to a higher prevalence of apical lesions than no treatment. These two findings confirm the idea that the quality of therapy has a great impact on the incidence of periapical disease. Indeed, defects in root canal filling in association with defects in coronal restoration have also been shown to promote apical lesions [30]. Observations in our contemporary population confirm this phenomenon since the prevalence of apical lesions was eight times higher in association with inadequate coronal/apical care. More generally, a correlation has been established between the incidence of infection due to pulpal deterioration and apical lesions [31] in both archeological and contemporary populations.

The comparison of archeological and contemporary populations provided better insight into the environmental factors affecting the prevalence of corono-apical lesions. In archeological populations, diet was the main risk factor for coronal or apical lesions. Indeed, differences in the quality and quantity of food intake could account for most of the variations in prevalence observed between our historic

populations. Previous studies [5, 7, 9] on the etiology of apical lesions observed in these populations have placed less emphasis of such risk factors than on septic contamination by the endodontic route. In contemporary populations with Western lifestyles, physiologic wear has almost totally disappeared but the high prevalence of caries persists. Depending on diet and hygiene, coronal disease is a risk factor for apical lesions. Under certain conditions, dental care can be an additional risk factor [18, 30, 31].

This study demonstrates that coronal and periapical disease has always existed and that its potential for development is high when tissue integrity is lost. Properly performed dental therapy can reduce the prevalence of lesions by durably restoring dental integrity and limiting retention of infectious agents thus avoiding coronal and endodontic contamination.

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