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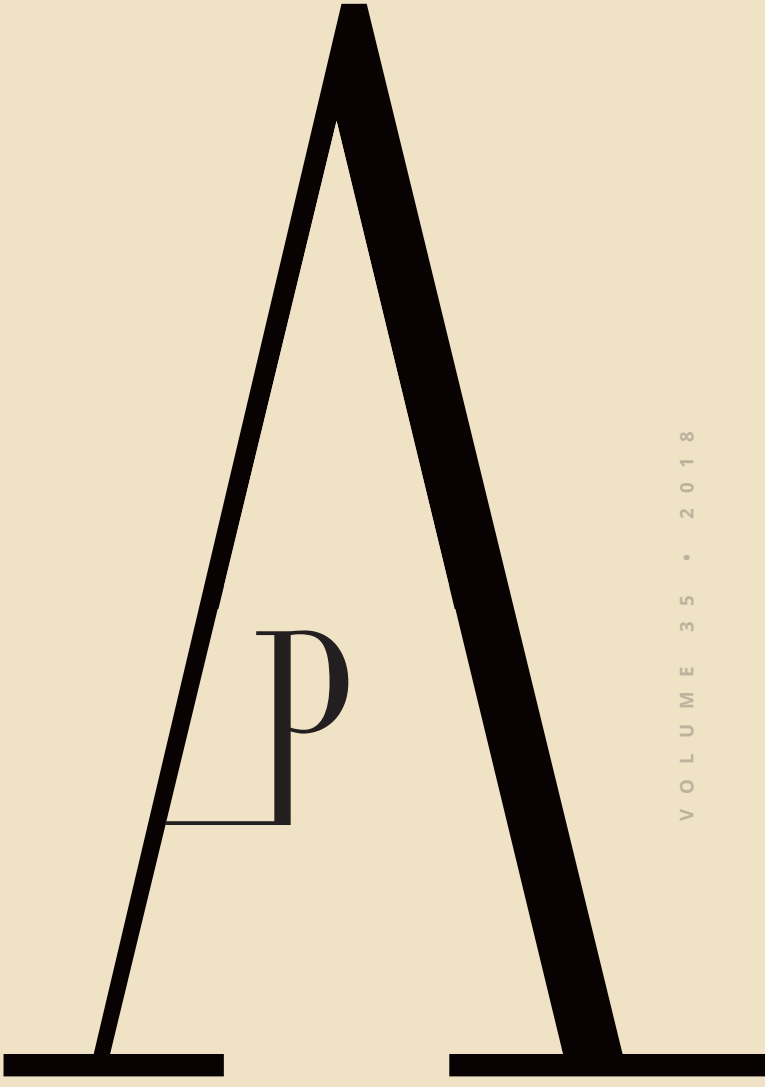

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# Dental pathology and occlusal wear in Valença, Portugal (Modern and Contemporary Ages) — preliminary interpretations

## Patologia dentária e desgaste oclusal em Valença, Portugal (Idade Moderna e Contemporânea) — interpretações preliminares



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**Abstract** Teeth are a valuable information source in bioarchaeology. Dental pathology informs on diet, habits, hygiene and treatment in the past. A churchyard necropolis in the strategically important Valença fortress, of medieval origin, was excavated in 2010. The dental pathology of 30 individuals (19 adults: seven males, seven females, five undetermined sex) is preliminarily interpreted in this work. Caries frequencies are moderately high (47.3% of teeth) yet, cavitated lesions (29.4% of teeth), ante-mortem tooth loss (AMTL) (36.3% of alveoli) and calculus index (CI) (0.687) are high. Females show higher CI, caries and AMTL frequencies than males. Periapical granulomas/cysts affect 25% of adult individuals (non-adults are not affected). Periodontitis affects 65.4% of teeth; males are more affected than females. Mean occlusal wear score is 3.5 (SD=1.1). Despite their young

**Resumo** Os dentes providenciam informação valiosa em bioarqueologia. A patologia dentária informa sobre dieta, hábitos, higiene e tratamentos no passado. A necrópole da Igreja de Santa Maria dos Anjos, na Fortaleza estratégica de Valença, foi escavada em 2010. Neste trabalho, as lesões dentárias de 30 indivíduos (19 adultos: sete masculinos, sete femininos, cinco alofísicos) são interpretadas preliminarmente. A frequência de cáries é moderadamente alta (47,3% dos dentes), mas as lesões cavitadas (29,4%), a perda dentária ante-mortem (PDAM) (36,3% dos alvéolos) e o índice de tártaro (IT) (0,687) são elevados. Os indivíduos femininos apresentam frequências de IT, cáries e PDAM mais elevadas que os masculinos. Os granulomas/quistos periapicais afetam 25% dos adultos (os não-adultos não são afetados). A periodontite atinge 65,4% dos dentes e os indiví-

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age (mostly up to 7 years), non-adults show relatively high frequencies of caries (11.0% of teeth) and cavitated caries (2.6% of teeth). Results suggest moderate to high fermentable carbohydrate intake. Females likely had a different diet than males. Oral hygiene and treatment were inexistent or scarce. Regular use of teeth as tools was unlikely. Early industrialization's influence on the diet of the rural and peripheral border town of Valença was incipient.

**Keywords**: Dental anthropology; caries; periodontal disease; periapical inflammation; calculus; ante-mortem tooth loss.

duos masculinos são mais afetados que os femininos. O desgaste oclusal médio é de 3,5 (DP=1,1). Apesar da idade jovem (maioritariamente até 7 anos), os não-adultos apresentam frequências relativamente elevadas de cáries (11,0% dos dentes) e cáries cavitadas (2,6%). Os resultados sugerem consumo moderado a elevado de hidratos de carbono fermentáveis e que os indivíduos femininos teriam uma dieta diferente dos masculinos. Hábitos de higiene e tratamentos orais eram inexistentes ou raros. O uso regular dos dentes como ferramenta era improvável. A influência da industrialização inicial na dieta de Valença foi incipiente.

**Palavras-chave:** Antropologia dentária; cáries; doença periodontal; inflamação periapical; tártaro; perda dentária ante-mortem.

## Introduction

Teeth are a very valuable and durable source of information on past human populations (Hillson, 2005; Scott, 2008). Knowledge on phenetic, development and health status may be acquired by adequate research considering teeth and bones of the masticatory system (Hillson, 2005; Scott, 2008; Silva, 2012).

Pathological issues, such as caries, periodontal disease or calculus, and physiological processes, such as dental wear, can be very informative on dietary and cultural habits, as well as on hygiene practices and access to treatment (Kerr, 1988; 1991; Hillson, 2005; Molnar, 2008, 2011; Liu et al., 2010).

Valença is a Portuguese rural setting in the northern border with Spain, a natural border delimited by the Minho River. Valença's geographical position made it strategic for the defense of the Portuguese territory, which prompted the erection of its medieval fortress and successive improvements (Fontes et al., 2013). Despite its strategic relevance, it is a peripheral locality.

The purpose of this paper is to interpret the dental and oral health status

and occlusal wear of a small 18th and 19th centuries Valença sample to provide preliminary information on the dietary and hygienic habits of this population.

## Sample

In 2010, 30 individuals were exhumed from the churchyard of Santa Maria dos Anjos church, in Valença (Minho, Portugal), within the (originally) medieval fortress erected near Minho River, the natural frontier with Spain. The archaeological excavation occurred in the context of the Projeto de Requalificação Urbana do Centro Histórico de Valença (Valença's Historical Center Urban Requalification Project) archaeological research and impact evaluation of which the Unit of Archaeology of the University of Minho is responsible for (Fontes et al., 2013).

The 30 individuals' age was determined according to common standards for non-adult (Stloukál and Hanáková, 1978 in Ferembach et al., 1980; Schaefer et al., 2009; AlQahtani et al., 2010) and adult individuals (Lovejoy et al., 1985, adapted by Buckberry and Chamberlain, 2002; Brooks and Suchey, 1990, adapted by Hartnett, 2010a; MacLaughlin, 1990; Isçan and Loth, 1993, adapted by Hartnett, 2010b; Rissech et al., 2006, adapted by Calce, 2012). Sexual diagnosis was performed on adult individuals (Giles, 1964; Ferembach et al., 1980; Buikstra and Ubelaker, 1994; Silva, 1995; Wasterlain, 2000; Bruzek, 2002). The sample is made up of 19 adults and 11 non-adult individuals. Adults are seven male and seven female individuals (as well as five individuals of undetermined sex, of which only one preserves teeth, maxillae and mandible). Ages at death vary between adults (eight individuals), young adults (six individuals), mature adults (four individuals) and older adult (one individual). Non-adults are ten individuals of up to 7 years at death and one between 9 and 12 years at death.

Ceramic fragments, coins and metal military buttons provided relative chronology which places this necropolis between the 18th and 19th centuries. All individuals are presumably of low socioeconomic status since burial in the churchyard was likely destined to lower class individuals (Cruz, 2011).

## Methods

Data on oral pathology was collected by scoring all Valença individuals for several variables: (1) the position (occlusal, mesial, distal, lingual and buccal; the position of gross lesions was termed 'crown') and size of caries lesions (adaptation of Hillson, 2001); (2) ante-mortem tooth loss; (3) periapical inflammation (Dias and Tayles, 1997; Dias et al., 2007); (4) periodontal disease (Kerr, 1988); and (5) calculus (Greene et al., 2005). Occlusal wear was also recorded (Molnar, 1971, adapted by Smith, 1984).

Differences between sides of the dentition, upper and lower teeth, and anterior and posterior teeth were tested using Pearson's chi-squared ($\chi^2$) test or

the Mann-Whitney U rank-sum test (for occlusal wear only). Both statistics were calculated with IBM SPSS Statistics (v.23).

## Results

### Caries

All adult individuals show at least one caries lesion. Their permanent dentition presents 47.3% teeth (n=87 of 184) with caries lesions. Cavities are evident in 29.4% (n=54) of all permanent teeth. Upper teeth are significantly more affected than lower teeth ($\chi^2$=4.566; p=0.033) (Table 1). There are no significant differences between anterior and posterior teeth or between the left and right dentitions (Table 1).

Differences between female (66.7%) and male (35.6%) individuals are highly significant ($\chi^2$=15.458; p<0.001) (Table 2).

Table 3 shows the frequencies of each lesion type. More than 48% of all identified lesions are incipient (white/opaque staining); cavities are mostly small or medium sized.

The surfaces most affected by caries are the interstitial spaces (mesial: 21.2%; distal: 20.7%) (Table 4). Lingual lesions and gross coronal caries are the rarest (lingual: 1.1%; crown: 2.7%).

The number of lesions per individual varies between one and 28 (Figure 1). Most individuals present either six (25.0%) or nine (16.7%) carious lesions. The mean is 9.7 lesions per individual. There are 15.3 permanent teeth per individual, and 7.3 of them present at least one caries lesion per individual.

The decidual dentition of non-adult individuals were also scored for caries lesions (11.0%) and cavities (2.6%). Much like the permanent dentition of adults,

**Table 1.** Caries distribution on Valença adults' dental regions and full permanent dentition.

| Dental region | Affected teeth | Scored teeth | % | $\chi^2$ |
|---|---|---|---|---|
| Upper | 45 | 80 | 56.3 | $\chi^2$=4.566 |
| Lower | 42 | 104 | 40.4 | p=**0.033** |
| Anterior | 33 | 79 | 41.8 | $\chi^2$=1.687 |
| Posterior | 54 | 105 | 51.4 | p=**0.194** |
| Left | 47 | 94 | 50.0 | $\chi^2$=0.569 |
| Right | 40 | 90 | 44.4 | p=0.451 |
| Full dentition | 87 | 184 | 47.3 | -- |
| Full dentition (cavities only) | 54 | 184 | 29.4 | -- |

Bold and underlined: p<0.05; $\chi^2$=Chi-Square.

**Table 2.** Caries distribution on Valença adults' permanent dentition by sex.

| Sex | Affected teeth | Scored teeth | % | $\chi^2$ |
|---|---|---|---|---|
| Female | 40 | 60 | 66.7 | $\chi^2$=15.458 |
| Male | 42 | 118 | 35.6 | p<**0.001** |
| Undetermined sex | 5 | 6 | 83.3 | -- |

Bold and underlined: p<0.05; $\chi^2$=Chi-Square.

**Table 3.** Percentage of each type of caries lesion on Valença adults' permanent dentition.

| Type of lesion | Affected surfaces | Observed lesions | % |
|---|---|---|---|
| Smooth white/opaque staining | 26 | 116 | 22.4 |
| Rough white/opaque staining | 30 | 116 | 25.9 |
| Small cavity | 30 | 116 | 25.9 |
| Medium-sized cavity | 21 | 116 | 18.1 |
| Large cavity | 1 | 116 | 0.9 |
| Gross caries | 2 | 116 | 1.7 |
| Gross caries with exposed pulp chamber | 6 | 116 | 5.2 |

**Table 4.** Surface distribution of caries lesions on Valença adults' permanent dentition.

| Surface | Affected surfaces | Scored surfaces | % |
|---|---|---|---|
| Occlusal | 10 | 105 | 9.5 |
| Mesial | 39 | 184 | 21.2 |
| Distal | 38 | 184 | 20.7 |
| Buccal | 22 | 184 | 12.0 |
| Lingual | 2 | 184 | 1.1 |
| Crown | 5 | 184 | 2.7 |

upper teeth are significantly more often affected by caries than their lower counterparts ($\chi^2$=4.120; p=0.042) (Table 5). Again, there are no significant differences between anterior and posterior teeth or between left and right deciduous teeth, despite relatively large differences in frequencies.

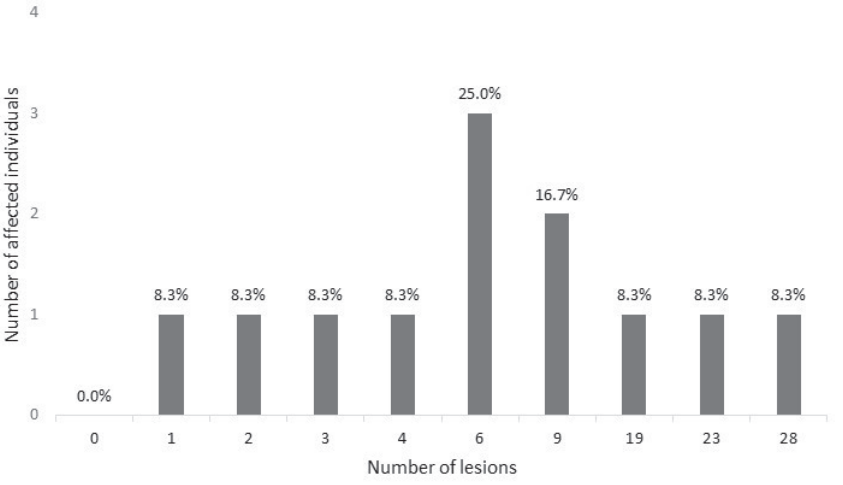


**Figure 1.** Number of caries lesions of the permanent dentition.

The lesions are described as either rough white/opaque staining, the predominant type (15/19: 78.9%), or small cavities (4/19: 21.1%). The lesion distribution (Table 6) shows generally low frequencies, topped by occlusal (5.9%) and mesial (5.2%) surfaces and showing absence of lesions on lingual areas and involving the whole crown.

Most non-adults (55.6%) present healthy dentitions (Figure 2), while most affected individuals show between five

**Table 5.** Caries distribution on Valença non-adults' decidual dentition.

| Dental region | Affected teeth | Scored teeth | % | $\chi^2$ |
|---|---|---|---|---|
| Upper | 12 | 73 | 16.4 | $\chi^2$=4.1202 |
| Lower | 5 | 81 | 6.2 | p=**0.042** |
| Anterior | 7 | 86 | 8.1 | $\chi^2$=1.6673 |
| Posterior | 10 | 68 | 14.7 | p=**0.197** |
| Left | 12 | 76 | 15.8 | $\chi^2$=3.448 |
| Right | 5 | 78 | 6.4 | p=0.063 |
| Full dentition | 17 | 154 | 11.0 | -- |
| Full dentition (cavities only) | 4 | 154 | 2.6 | -- |

Bold and underlined: p<0.05; $\chi^2$=Chi-Square.

and seven lesions (33.3% of all individuals). Lesions average 2.1 per non-adult individual. There are 17.1 decidual teeth per individual and 1.9 of those teeth were affected by caries (per individual).

## Ante-mortem tooth loss

Tooth loss during the life of the individual removed more than one third (36.3%) of the permanent teeth from the Valença adult sample (Table 7). Ante-mortem tooth loss affected upper and lower teeth in a statistically equivalent fashion. The same occurred between left and right teeth, and anterior and posterior teeth. However, the difference between anterior and posterior teeth is close to significance and shows posterior teeth were loss almost 10% more often than anterior teeth.

**Table 6.** Surface distribution of caries lesions on Valença non-adults' decidual dentition.

| Surface | Affected surfaces | Scored surfaces | % |
|---|---|---|---|
| Occlusal | 4 | 68 | 5.9 |
| Mesial | 8 | 154 | 5.2 |
| Distal | 3 | 154 | 1.9 |
| Buccal | 4 | 154 | 2.6 |
| Lingual | 0 | 154 | 0.0 |
| Crown | 0 | 154 | 0.0 |

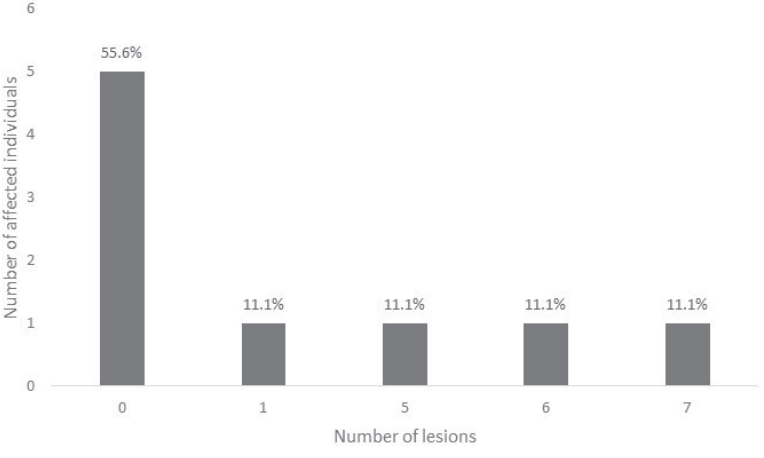


**Figure 2.** Number of caries lesions of the decidual dentition per non-adult individual.

Female (51.4%) and male (24.4%) individuals show highly significant differences in ante-mortem tooth loss (Table 8)

## Periapical inflammation

Infections of the apical tissues affected 25% of adult individuals from Valença. Non-adult individuals do not show these types of lesions. In total, 13.6% of all individuals (n=3; a female, a male and an undetermined sex individual) show at least one periapical inflammatory lesion. Periapical granulomas affect 13.6% of adults, while one individual (8.3% of adults) shows an apical periodontal cyst (Table 9). There are no instances of periapical abscesses or osteomyelitis.

## Periodontal disease

Gingivitis and periodontitis distribution in the septa of adult individuals are explored in Tables 10 and 11. The full sample displays merely 4.5% healthy septa. Gingivitis affects 30.1% of all septa, while

**Table 7.** Ante-mortem tooth loss distribution on Valença adults' dental regions and full permanent dentition.

| Dental region | Affected teeth | Scored tooth sockets | % | $\chi^2$ |
|---|---|---|---|---|
| Upper | 48 | 131 | 36.6 | $\chi^2$=0.013 |
| Lower | 63 | 175 | 36.0 | p=0.908 |
| Anterior | 37 | 121 | 30.6 | $\chi^2$=2.809 |
| Posterior | 74 | 185 | 40.0 | p=0.094 |
| Left | 55 | 154 | 35.7 | $\chi^2$=0.042 |
| Right | 56 | 152 | 36.8 | p=0.837 |
| Full dentition | 111 | 306 | 36.3 | -- |

$\chi^2$ =Chi-Square

**Table 8.** Ante-mortem tooth loss distribution on Valença adults' permanent dentition by sex.

| Sex | Affected teeth | Scored tooth sockets | % | $\chi^2$ |
|---|---|---|---|---|
| Female | 72 | 140 | 51.4 | $\chi^2$=23.444 |
| Male | 39 | 160 | 24.4 | p<**0.001** |
| Undetermined sex | 0 | 6 | 0.0 | -- |

Bold and underlined: p<0.05; $\chi^2$ =Chi-Square

**Table 9.** Periapical inflammation distribution in the Valença sample and subsamples (adults, non-adults, males, females and individuals of undetermined sex).

| Sample | n | Healthy % (and n) | Periapical granuloma % (and n) | Apical periodontal cyst % (and n) | Periapical abscess % (and n) | Osteomyelitis % (and n) |
|---|---|---|---|---|---|---|
| Full | 22 | 86.4 (19) | 13.6 (3)* | 4.5 (1)* | 0.0 (0) | 0.0 (0) |
| Adults | 12 | 75.0 (9) | 25.0 (3)* | 8.3 (1)* | 0.0 (0) | 0.0 (0) |
| Non-adults | 10 | 100.0 (10) | 0.0 (0) | 0.0 (0) | 0.0 (0) | 0.0 (0) |
| Female adults | 5 | 80.0 (4) | 20.0 (1)* | 20.0 (1)* | 0.0 (0) | 0.0 (0) |
| Male adults | 6 | 83.3 (5) | 16.7 (1) | 0.0 (0) | 0.0 (0) | 0.0 (0) |
| Undetermined sex (adults) | 1 | 0.0 (0) | 100.0 (1) | 0.0 (0) | 0.0 (0) | 0.0 (0) |

*An adult female presents lesions of two different types.

periodontitis is present in 65.4%. All four adult individuals with more than 15 observable septa show >50% periodontitis. Upper and lower teeth, like left and right teeth, do not present significant differences. Still, the right side presents greater frequency of periodontitis (69.4%) and there are some differences between upper and lower teeth: (1) only lower teeth show healthy septa (8.1%), (2) gingivitis is more frequent in upper septa, and (3) periodontitis is almost 8% higher in lower tooth septa. Female and male individuals show highly significant differences in periodontal disease distribution. Male individuals show no healthy septa (compared to 14% of females) and female individuals do not present grade 5 (compared to 4.7% of males). Periodontitis is shown on 51.2% of female septa and 71% of male septa.

## Calculus

Calcified plaque is found in the Valença adults with a mean calculus index (CI) of 0.687 (Figure 3). Lower anterior teeth are the most affected (CI=0.862), while the least affected are the upper anterior teeth (CI=0.469). Female individuals (CI=0.978) show much higher CI than males (CI=0.540).

## Occlusal wear

The mean occlusal wear score for the adult Valença sample is 3.5 (SD=1.1) (Table 12). Comparing upper to lower teeth and left to right teeth no significant differences were found in mean wear. Male and female individuals are also very similar in occlusal wear (Table 13), however, the anterior and posterior teeth are significantly different (U=3077.5, p=0.020) (Table 12).

**Table 10.** Periodontal disease distribution on Valença adults' dental regions and full permanent dentition.

| Dental region | No. of septa | 1 | 2 | 3 | 4 | 5 | $\chi^2$ | df | p | 3 to 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper | 59 | 0.0 | 39.0 | 39.0 | 18.6 | 3.4 | 8.623 | 4 | 0.071 | 61.0 |
| Lower | 74 | 8.1 | 23.0 | 39.2 | 27.0 | 2.7 | | | | 68.9 |
| Left* | 64 | 4.7 | 31.3 | 32.8 | 28.1 | 3.1 | 2.832 | 4 | 0.586 | 64.0 |
| Right* | 62 | 3.2 | 27.4 | 46.8 | 21.0 | 1.6 | | | | 69.4 |
| Full sample | 133 | 4.5 | 30.1 | 39.1 | 23.3 | 3.0 | | -- | | 65.4 |

*Midline septa not included; 1 – score indicating healthy septa; 2 – gingivitis; 3 to 5 – periodontitis; $\chi^2$ =Chi-Square; df: degrees of freedom.

**Table 11.** Periodontal disease distribution on Valença adults' permanent dentition by sex.

| Sex | No. of septa | 1 | 2 | 3 | 4 | 5 | $\chi^2$ | df | p | 3 to 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Female | 43 | 14.0 | 34.9 | 46.5 | 4.7 | 0.0 | 23.095 | 4 | <**0.001** | 51.2 |
| Male | 86 | 0.0 | 29.1 | 37.2 | 29.1 | 4.7 | | | | 71.0 |
| Undetermined sex | 4 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | | -- | | 100.0 |

Bold and underlined: $p<0.05$; $\chi^2$ =Chi-Square; df: degrees of freedom.

## Discussion

### Caries

Caries develop when carbohydrates are fermented by plaque bacteria. These bacteria produce organic acids during fermentation, which cause progressive demineralization of dental tissues (Hillson, 2005). Most decay is not visible, since it occurs beneath the surface until cavitation (Hillson, 2001; 2005).

The Medieval sample of São João de Almedina (uptown Coimbra, Portugal) shows a very high frequency of teeth with carious lesions (93.2%) (Carvalho, 2013), much higher than Valença (47.3%). Each Medieval Coimbra individual has 9.9 carious teeth, in average, which is higher than Valença (7.3). Cavities correspond to 42.4% of this Coimbra sample's teeth, still greater than Valença (29.4%). Upper (98.5%) and lower teeth (96.9%) present similar caries frequencies, while Valença's upper teeth are significantly more affected than lower teeth (56.3% and 40.4%, respectively). Side differences are negligible in Medieval Coimbra (left: 96.8%; right: 98.2%) and in Valença (left: 50.0%; right: 44.4%). In Medieval Coimbra, contrasting with Valença, male individuals (90.2%) presented greater caries frequencies than females

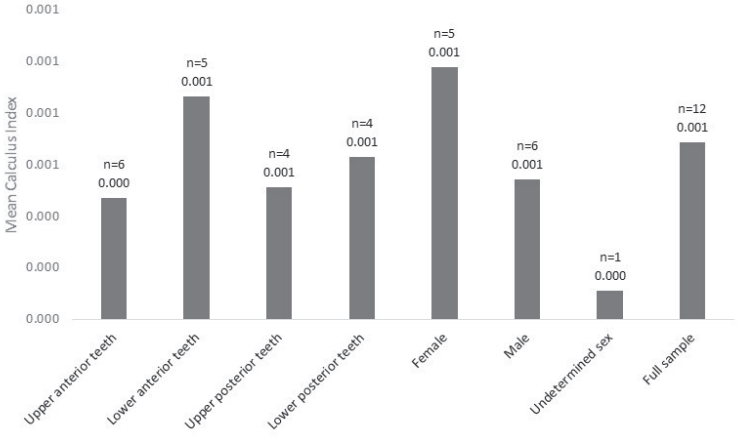


**Figure 3.** Calculus index distribution on Valença adults' permanent dentition (by dental region, by sex, and full sample score).

**Table 12.** Occlusal wear scores on Valença adults' dental regions and full permanent dentition.

| Dental region | No. of teeth | Minimum score | Maximum score | Mean score | Standard deviation | U | p |
|---|---|---|---|---|---|---|---|
| Upper | 74 | 1 | 6 | 3.5 | 1.1 | 3498.5 | 0.385 |
| Lower | 102 | 1 | 6 | 3.4 | 1.1 | | |
| Anterior | 78 | 2 | 6 | 3.6 | 0.9 | 3077.5 | **0.020** |
| Posterior | 98 | 1 | 6 | 3.3 | 1.2 | | |
| Left | 90 | 1 | 6 | 3.4 | 1.1 | 3853.0 | 0.959 |
| Right | 86 | 1 | 6 | 3.5 | 1.1 | | |
| Full dentition | 176 | 1 | 6 | 3.5 | 1.1 | -- | |

U: Mann-Whitney U rank-sum test; Bold and underlined: p<0.05.

**Table 13.** Occlusal wear scores on Valença adults' dental regions and full permanent dentition.

| Sex | No. of teeth | Minimum score | Maximum score | Mean score | Standard deviation | U | p |
|---|---|---|---|---|---|---|---|
| Female | 54 | 1 | 6 | 3.4 | 1.1 | 3116.0 | 0.955 |
| Male | 116 | 1 | 6 | 3.4 | 1.0 | | |
| Undetermined sex | 6 | 3 | 5 | 4.7 | 0.8 | -- | |

U: Mann-Whitney U rank-sum test.

(87.2%). When individual counts are considered, the medieval sample presents less affected individuals (91.3%) (Carvalho, 2013) than Valença (100%).

A contemporary identified sample from Coimbra presents higher frequencies of teeth affected by carious lesions (62.0%) (Wasterlain, 2006; Wasterlain et al., 2009) than Valença. On average, 11.5 teeth per Contemporary Coimbra individual were affected by caries. However, when considering cavities only, Valença presents higher frequency of caries (29.4%) than Coimbra (27.9%), underlining differences in the proportion of incipient lesions (Valença: 48.3%; Coimbra: 55.0%). Upper teeth (67.9%) present higher frequencies than lower teeth (56.5%), like Valença's. Male and female individuals show significantly different frequencies of teeth affected by caries and, much like Valença, females present more carious teeth (females: 64.2%; males: 60.1%). Differences in proportion are, however, much greater in Valença (females: 66.7%; males: 35.6%). When considering individual counts, frequencies are similar between Contemporary Coimbra (99.4%) (Wasterlain, 2006) and Valença (100%).

Caries distribution is not directly comparable between the samples from Valença and Coimbra. In the present study, Hillson's (2001) method was simplified, so each surface (occlusal, mesial, distal, lingual, and buccal) was only scored once, without differentiation between enamel contact areas and root surface areas, for example. Still, general comparisons will be attempted.

Medieval Coimbra shows relatively high caries frequencies on all surfaces. Occlusal surface (71.2%), occlusal pits (67.1%) and occlusal attrition facets (52.6%) present much higher caries frequency than the occlusal surface on Valença individuals (9.5%). Mesial (51.4%) and distal (54.8%) contact areas along with mesial (23.1%) and distal (22.4%) root surfaces do not present such high frequencies relative to other surfaces as Valença's mesial (21.2%) and distal (20.7%) surfaces, which were the most affected surfaces in this rural context. Lingual smooth enamel (58.3%) and root (26.5%) surfaces show very high absolute and relative frequencies in Medieval Coimbra, when compared to present results (1.1%). Medieval Coimbra's buccal smooth enamel (62.5%) and root (30.6%) surfaces again show much higher absolute frequencies, yet relative to other surfaces, Valença also presents high frequencies (12.0%).

Contemporary Coimbra presents more similar caries frequency distribution to Valença. Occlusal surface (22.9%), occlusal pits (17.8%) and occlusal attrition facets (16.0%) are still higher than the present sample, yet much lower than Medieval Coimbra. Mesial and distal contact areas (32.9%), and mesial and distal root surfaces (6.0%), assume higher relative frequencies when compared with other surfaces, more akin the mesial and distal surfaces of Valença. Lingual smooth enamel (3.3%) and root (2.8%) surfaces present reduced frequencies, paralleling Valença. Buccal smooth enamel (9.7%) and root (8.8%) surfaces of Contemporary Coimbra have

lower frequencies than occlusal surfaces, pits and attrition facets, unlike Valença, which presents the opposite relative frequencies.

The frequencies and their pattern of distribution are more similar in the comparison between Contemporary Coimbra and Valença. Medieval Coimbra shows higher frequencies and greater concentration of caries on occlusal surfaces, pits and attrition facets. On the other hand, upper teeth are more affected in Valença and Contemporary Coimbra. This is likely due to the impact of the physiological cleansing effect of saliva, which is more effective on lower teeth, more involved in saliva (Wasterlain, 2006).

Valença (18th–19th centuries) is chronologically intermediate to these Medieval (12th–16th centuries) and Contemporary (19th–early 20th centuries) samples, despite a slight overlap with Contemporary Coimbra.

Carbohydrates are a major factor in caries development, and were traditionally found in fruit, honey (Carvalho, 2013) and corn (Wasterlain, 2006) before the introduction of pure sugar in most diets (Müller and Hussein, 2017). Despite the importance of diet, the gradual decrease in the frequencies of cavities in the present comparison is probably related to various factors such as age structure, socioeconomic status, economic environment, and possibly methodological issues.

Differences in the age structures of the samples may have an impact. For example, the Contemporary Coimbra sample is controlled for age and sex distribution (Wasterlain, 2006). However, since life expectancy increased during the period covered by these samples (Valério, 2001), in all likelihood the average age of the samples increased with time. Greater average age would likely be related to an increase in cavity frequency, so age structure is unlikely to have played a part in the found cavity frequency decrease, except if a consequent increase in AMTL caused carious teeth to be removed from analysis (e.g., Wols and Baker, 2004). Even if ignoring the possible influence of AMTL, age structure could still have had implications on the reported data, since the inclusion of all caries (including incipient lesions) shows Contemporary Coimbra presents intermediate frequencies when compared to Valença and Medieval Coimbra. Different caries frequency patterns could also be related to methodological differences (Hillson's 2001 method was adapted for the present study by scoring caries on only five clinical surfaces when the origin of the lesions was detected).

The Contemporary Coimbra identified sample (Wasterlain, 2006) and the Valença sample are presumably of low socioeconomic status, while Medieval Coimbra is mostly composed of middle class individuals (Carvalho, 2013). Socioeconomic distinctions impact access to certain foodstuffs, as does the difference in economic setting (rural vs. urban) of Valença and Coimbra. However, the consideration of these factors (chronology, age structure, social status, and economic environ-

ment) shows only one consistent pattern: cavities decrease over time, suggesting progressive changes in dietary habits between the samples and across time.

Caries data from deciduous teeth originate from very young individuals (only one individual is older than 7 years at death, at 9-12 years). Still, almost half of them are affected by caries, and a third are affected by five to six lesions. Despite the relative rarity of cavities (2.6% of deciduous teeth; 21.1% of lesions), the frequency of caries is high for young non-adult individuals, which informs on caries' susceptibility in the sample.

During periods of economic transition, changes may not be linear; access to diverse sources of food and different economic environments can affect dietary change. Chinese hunter-gatherers (2.5% cavities) and early agriculturalists (6.8% to 8.0% cavities) exemplify how the transition to agricultural economies increased cariogenic cavity frequencies due to greater access to carbohydrates (Liu et al., 2010). On the other hand, the small differences between hunter-gatherer (6.4% cavities) and early agricultural (6.7% cavities) samples from the Levant underline how this transition can also be uneventful if early agriculturalists still partially depend on hunting and gathering or if the carbohydrates introduced in the diet are less cariogenic (Eshed et al., 2006). This Levantine example parallels the uneven transition of processed foods during industrialization, which could have affected Valença and Coimbra differently.

A recent meta-analysis (Müller and Hussein, 2017) focused on caries and the transition between pre- and post-18$^{th}$ century Europe suggested that the impact of this transition on caries (and other oral health indicators) was minor. Part of the justification to this conclusion is the slower rate of change in rural settings, which promotes continuity in nutritional, social and medical factors despite industrialization (Müller and Hussein, 2017).

In light of this, differences between Medieval and Contemporary Coimbra samples (both from the same urban context) are likely explained by differences in diet that were directly brought about by industrialization. These dietary discrepancies could partly be explained by socioeconomic differences, yet are most likely due to a more generalized access to simple carbohydrates of the more recent sample. The intermediate frequencies found for Valença's cavity lesions and the lowest frequencies of overall caries are possibly related to its rural setting and, to a lesser extent, to its chronological intermediacy. Access to processed sugars and higher levels of fermentable carbohydrates (along with presumably higher life expectancy) raised the frequencies of cavities and of affected individuals (Liu et al., 2010); yet, the introduction and generalization of the consumption of such foodstuffs was moderated by Valença's more marginal, rural setting and low socioeconomic status.

Müller and Hussein (2017) also found that female individuals do not consistent-

ly show greater caries frequencies (Müller and Hussein, 2017), which could be related to the etiology of such differences. Instead of hormonal factors, sexual differences in caries frequencies may be related to the sociocultural differentiation of the sexes. Valença, a rural sample, shows greater caries difference between the sexes than the Coimbra urban samples. This result could thus be related to dietary differences between the sexes, possibly related to their different social status.

## Ante-mortem tooth loss

Ante-mortem tooth loss is caused by trauma, dental pathology (caries, periodontal disease, periapical inflammation) or severe dental wear (Wasterlain, 2006). Given the known occlusal wear of the Valença sample, of a moderate level (3.5), this factor is unlikely to have played an important part on AMTL. Unlike occlusal wear, caries are frequently identified in Valença permanent teeth. The distribution of both caries and AMTL in the dentition and between male and female individuals is relatively similar (the major difference is in upper and lower teeth, which are significantly different for caries and not AMTL). Caries could therefore have been a relevant AMTL cause.

Medieval Coimbra lost 20.7% of teeth ante-mortem, less than Valença (36.3%). Upper teeth (35.1%) show higher tooth loss than lower teeth (20.4%), unlike Valença, where the dental arches display similar ante-mortem tooth loss (AMTL) frequency (upper: 36.6%; lower: 36.0%). Anterior teeth (between 4.0% and 15.3%) were lost in lower frequencies than posterior teeth (between 14.8% and 49.0%), which is similar in Valença (anterior AMTL: 30.6%; posterior AMTL: 40.0%), despite higher anterior AMTL. Left (21.6%) and right (20.9%) Medieval Coimbra teeth were lost in similar proportion, like Valença's (left: 35.7%; right: 36.8%). Female individuals (26.7%) lost more teeth than males (18.0%); the same pattern was verified in Valença (females: 51.4%; males: 24.4%), despite the much greater proportion of AMTL in Valença female individuals. Individuals of undetermined sex lost much more teeth ante-mortem in Medieval Coimbra (36.3%) (Carvalho, 2013) than Valença (0.0%).

Contemporary Coimbra shows a level of AMTL (37.5%) very similar to Valença. Also, like Valença, AMTL frequencies are similar for upper (38.6%) and lower (36.5%) teeth, and for left (37.8%) and right (37.2%) teeth. Loss of posterior teeth is also higher than anterior AMTL. Women (40.8%) loss teeth more frequently than men (34.3%) in both samples, Contemporary Coimbra (Wasterlain, 2006) and Valença.

The differences between the sexes are again (see "Caries" subsection in the Discussion section) more pronounced in Valença than any of the Coimbra samples. AMTL, if related to caries, could deepen the differences between female and male individuals' caries frequencies. This hypothesis underlines the importance of

the dietary differences between males and females in Valença.

In general, AMTL is high in Valença, which can be related to both high caries prevalence and periodontal disease (Wasterlain, 2006). AMTL can also be related to the use of teeth as tools in low cariogenic diets (Liu et al., 2010); this explanation is unlikely applicable to Valença.

Prehistoric Levant provides an example of low caries level (less than 7% cavities) coupled with low AMTL (3.7% in hunter-gatherers to 4.5% in agriculturalists) (Eshed et al., 2006). US civil war veterans (who died in the early 20th century) show high cavity frequency (24.4%) co-occurring with high AMTL (57.2%) (Wols and Baker, 2004). In the Croatian Adriatic coast, the change from Late Antiquity to the Early Medieval period (with a presumed increase on carbohydrate intake) shows a rising trend in both cariogenic cavities and AMTL (Šlaus et al., 2011). Frequencies of AMTL increase between Medieval Coimbra and Valença, then again between Valença and Contemporary Coimbra. This pattern is the opposite from the cavity pattern found for caries, which could be related to a slower progression of caries lesions (eventually leading to AMTL) in Medieval Coimbra, possibly related to a consumption of less cariogenic foodstuffs (fermentable carbohydrates). This difference could also be justified by the higher socioeconomic status, with the presumed consequence of better immune response, of Medieval Coimbra individuals.

## Periapical inflammation

Dental pulp can infect through exposure, due to trauma, severe dental wear and caries (Dias and Tayles, 1997; Wasterlain, 2006). Pulp infection always propagates towards the root apex, if it cannot be fought by the immune system (Dias and Tayles, 1997). The apical region, surrounding the root apex, will react in a variable inflammatory fashion (Dias and Tayles, 1997).

Medieval Coimbra (São João de Almedina) presents alveolar inflammatory reaction in 31.4% of the sample (Carvalho, 2013). Despite of the low frequency of periapical inflammation on the full sample (13.6%), 25% of Valença adults show evidence for this pathology (absent in non-adults). The medieval sample shows healing lesions on 5.6% of the sample (all male individuals), while Valença shows only active lesions. Male (46.1%) individuals were more affected than female individuals (31.3%); in Valença, females (20.0%) show a slightly higher, yet similar periapical inflammation frequency than males (16.7%). Individuals of unidentified sex show the lowest frequency (16.6%) in Medieval Coimbra, while Valença's only individual whose sex could not be estimated presents alveolar bone inflammation.

Contemporary Coimbra has evidence of periapical inflammation on 55.3% of the sample, a much higher frequency than Valença (Wasterlain, 2006). Periapical granulomas or apical periodontal cysts correspond to 23.3% of the sample, which

is similar to Valença. The difference in the frequencies found between the samples is related to the presence of healing lesions (10.7%) and periapical abscesses (3.5%) in the Contemporary sample, but also to individuals affected by combined lesions (17.8%), which were reported separately. Male (56.0%) and female (54.7%) individuals show similar frequencies, like in Valença.

Differences between Valença (with low frequency of periapical inflammation) and the Coimbra samples could be related to issues of taphonomy or method. Mandibular and maxillary bones were often lost, and, when recovered, they mostly conserved all teeth in their alveoli or presented ante-mortem loss (post-mortem tooth loss was just 4.2%). As noted by Wasterlain (2006), macroscopic scoring of periapical inflammation is prone to underreporting. Since the scorer is inexperienced, that problem could be more evident.

Despite taphonomic issues with alveolar bone and the faults of macroscopic lesion scoring, the difference in periapical inflammation frequencies between Valença and Contemporary Coimbra is possibly explained by caries frequencies, which can be mediated by occlusal wear. Caries are one of the main factors resulting in periapical inflammation (Wasterlain, 2006; Carvalho, 2013). For example, prehistoric Levantine samples with low caries frequencies (less than 7% cavities) show only around 1.5% periapical inflammation per tooth (Eshed et al., 2006). On the other side, US civil war veterans show both high cavity frequency (24.4%) and high periapical inflammation (28.0%) (Wols and Baker, 2004). Mean occlusal wear shows a clear difference between Valença (3.5) and Contemporary Coimbra (2.6), which can potentially affect the progression of occlusal caries. Occlusal caries are lower in Valença (9.5%) compared to Contemporary Coimbra (surface: 22.9%, pits: 17.8%, attrition facets: 16.0%). The combination of these factors could have kept Valença's individuals from complications related to pulp infection.

The slightly higher periapical inflammation frequency in the sample from Medieval Coimbra may be due to the much higher occlusal caries frequencies (surface: 71.2%, pits: 67.1%, attrition facets: 52.6%), which effect was weakened by moderate mean occlusal wear (3.9) and by the higher socioeconomic status of this middle class urban sample (granting these individuals better access to adequate nutrition and healthcare, possibly leading to a more effective immune reaction to infections).

## Periodontal disease

Periodontal disease is the organism's inflammatory reaction to the accumulation of bacterial plaque around the gingivae. This accumulation is due to lack of hygiene and dental treatment (Hillson, 2005). When the inflammatory reaction is of low scale, mainly confined to soft tissues and with minor impact on the alveolar bone, it is called gingivitis (Kerr, 1991; Hillson, 2005). Lesion progression is caused by

hypersensitivity and disproportional immune reaction and affects the conjunctive tissues holding teeth on the alveolar bone, or periodontium (Hillson, 2005).

The sample from Medieval Coimbra is more affected by gingivitis (32.1%) than the Valença sample (30.1%); yet the former sample presents more healthy septa (8.4%) and less periodontitis (59.5%) than Valença (healthy septa: 4.5%; periodontitis: 65.4%). Medieval Coimbra's lower septa (60.1%) present higher frequencies of periodontitis than upper septa (58.6%), the same relationship found in Valença septa (upper: 61.0%; lower: 68.9%). Medieval Coimbra presents more comparable frequencies, however. Gingivitis is higher on upper septa (upper: 32.4%; lower: 31.9%) in Medieval Coimbra; the pattern is, again, the same as Valença (upper: 39.0%; lower: 23.0%), despite the much closer frequencies in the medieval sample. Left septa (53.4%) show lower frequencies of periodontitis than right septa (59.4%), a result similar in pattern and proportion to Valença's (left: 64.0%; right: 69.4%). Again, the pattern for gingivitis reverses the one for periodontitis. Male septa (gingivitis: 32.6%; periodontitis: 63.6%) show higher frequency of periodontal disease (through a much higher periodontitis frequency) than female septa (gingivitis: 33.2%; periodontitis: 48.7%), which is similar to Valença males (gingivitis: 29.1%; periodontitis: 71.0%) and females (gingivitis: 34.9%; periodontitis: 51.2%). Septa of undetermined sex individuals from Medieval Coimbra show very high levels of periodontitis (gingivitis: 26.8%; periodontitis: 71.8%) (Carvalho, 2013), like Valença's (gingivitis: 0.0%; periodontitis: 100%).

Periodontal disease in Contemporary Coimbra septa was more frequently characterized as gingivitis (60.1%) than periodontitis (14.2%), while 25.7% of septa are healthy. These results are in substantial contrast to Valença's. In Contemporary Coimbra, upper (gingivitis: 62.9%; periodontitis: 14.4%) and lower (gingivitis: 57.4%; periodontitis: 14.0%) septa present relatively close impact of periodontal disease, despite the higher frequency of gingivitis on upper septa. This differs from Valença, where periodontitis is more evident on lower septa. Periodontal disease is similar on the left and right septa of Contemporary Coimbra individuals, which is comparable to Valença. Females (gingivitis: 58.9%; periodontitis: 13.6%) present lower levels of periodontal disease than males (gingivitis: 61.1%; periodontitis: 14.7%) on this Contemporary sample (Wasterlain, 2006), which pattern is similar to Valença's, despite the differences in proportion (Valença males' periodontal disease is significantly higher than females').

The relative similarity between Medieval Coimbra (an urban middle class sample) and Valença (a 18$^{th}$–19$^{th}$ century rural lower class sample) is likely related to generally low oral hygiene and poor (or inexistent) dental treatments. Valença also presents higher AMTL, which removed (potentially diseased) septa from the analysis. So, it is possible that Valença's periodontal disease status was poorer than

Medieval Coimbra's. Still, these results suggest neither sample had ample access to oral hygiene or dental medicine.

Contemporary Coimbra results are very different to Valença's. Valença shows much higher periodontitis, as well as much less healthy septa and gingivitis (soft tissue inflammation). Coupled with resembling frequencies of AMTL, these results suggest dental hygiene and care were very uncommon in a rural and peripheral community (18th–19th century Valença) when compared to Coimbra (late 19th–early 20th century) urban sample or Medieval Scotts (Kerr, 1991), which display a similar pattern to Contemporary Coimbra's. The difference between Valença and Medieval Scotland could be related to host immune response, since the Scottish are also expected to have had poor oral hygiene and little access to dental treatment (Kerr, 1991).

Valença shows significant difference in periodontal disease distribution between the sexes. AMTL affected female individuals to a significantly higher degree. Tooth loss may be related to how male individuals (who lost fewer teeth ante-mortem) present higher periodontal disease frequencies.

## Calculus

Dental calculus forms from the mineralization of bacterial plaque and mineral materials in the mouth (Lieverse, 1999). The accumulation of dental plaque is partly related to hygiene habits, since plaque mineralization is diminished by cleaning one's teeth (Hillson, 2005). Plaque mineralization is related to the presence of calcium phosphate in saliva. The resulting calculus is of uncertain etiology, although its prevalence can be related to food texture (Hillson, 2005) since soft, processed foods do not promote its mechanical removal. Calculus has also been linked to carbohydrate consumption and lack of protein in the diet (Greene et al., 2005), despite the etiological complexity of plaque mineralization demanding cautious dietary interpretations (Lieverse, 1999).

When comparing Valença to two Predynastic Egyptian samples (Hierakonpolis and Naqada) and a Meroitic Nubian sample (Semna South), Valença's results are more similar to the latter. The most pressing distinction lies in the comparison between male and female individuals, given that Semna South presents little difference between the sexes, with a generally higher male calculus index (CI) (Greene et al., 2005), while Valença displays higher female CI.

Calculus formation is not exclusively linked with a single causal factor, such as diet (Lieverse, 1999). However, Valença presents generally higher CI results than the Egyptian samples that had greater access to protein. Semna South, presenting similar overall CI to Valença, had restricted access to protein. This pattern suggests Valença individuals (mainly females) could have had limited access to protein and does not deny previous findings that suggest these individuals relied mostly on carbohydrates.

Calculus distribution in the dentition of Valença individuals underlines the role of saliva, since upper posterior teeth and lower anterior teeth, nearer salivary glands (Lieverse, 1999), show the greatest amount of calculus buildup in their respective dental arches. Saliva promotes calculus formation (Lieverse, 1999; Hillson, 2005), so lower teeth may show greater calculus indexes due to the greater accumulation of saliva around them.

## Occlusal wear

Teeth wear since the moment they erupt into the mouth, through contact with other materials (e.g., other teeth, food, abrasives in the diet), and through diverse processes (e.g., attrition, abrasion and erosion) that can be resumed as "dental wear", since these processes are complementary and difficult to distinguish (Soames and Southam, 2005). Wear can be related with diet, age and/or the non-masticatory use of teeth (Wasterlain, 2006).

Carvalho (2013) found a mean occlusal wear score of 3.9 for the Medieval Coimbra sample of São João de Almedina, higher than Valença's (3.5; SD=1.1). Neither Medieval Coimbra (upper=3.9; lower=3.9) nor Valença (upper=3.5; lower=3.4) show different wear scores for upper and lower dentitions. The same pattern is found in Medieval Coimbra (left=3.8; right=3.9) and Valença (left=3.4; right=3.5) for both sides of the dentition. São João de Almedina males (4.0) showed higher mean wear than female individuals (3.3), unlike Valença (female=3.4; male=3.4). Individuals of undetermined sex (4.4) show similar results to Valença (4.7).

Contemporary Coimbra presents a mean occlusal wear score of 2.6 (SD=1.2). In the comparison between upper and lower teeth, in Contemporary Coimbra the results were reported by tooth; incisors, first and second molars showed higher mean wear score in the mandible (for men, the opposite was found for canines and premolars) (Wasterlain, 2006). Anterior teeth, like Valença's (anterior=3.6; posterior=3.3), showed significantly higher mean wear score than posterior teeth. The left side of the dentition showed slightly higher mean wear than the right. Females show significantly less occlusal wear than males in Contemporary Coimbra (Wasterlain, 2006).

Dental wear diminishes in the mentioned samples according to their chronology: the oldest sample (Medieval Coimbra) presents the highest mean wear, while the most recent sample (Contemporary Coimbra) shows the lowest. Valença is intermediate, despite a still moderate mean wear score, which corroborates previous comments regarding dietary similarity to medieval times. Still, the small difference between Medieval Coimbra and Valença is possibly due to Valença's access to some processed foods. Chinese Neolithic and Bronze/Iron Age hunter-gatherers and early agriculturalists without access to processed foods show mean wear scores similar to Medieval Coimbra and Valença (3.5 to 4.0) (Liu et al., 2010).

Valença's low occlusal caries frequency is probably related to the moderate occlusal wear score, which testifies to the (at least partial) obliteration of the cusp and fissure system. Differences in wear level between anterior and posterior teeth could be related to the use of the dentition as a third hand, bruxism or predominance of vegetables in the diet (Wasterlain, 2006). The latter hypothesis is more likely, due to sample context, lack of specific wear patterns indicating cultural use of the dentition, and low likelihood of widespread bruxism in the sample.

Lack of differences between the sexes may be interpreted as contradicting differences in diet between the sexes. Still, either different diets can be similarly abrasive, or higher male masticatory force can compensate for slight differences in abrasion.

## Conclusions

A small sample of 18th and 19th century individuals from Valença (northern border of Portugal) was studied to preliminarily interpret the oral health status of this rural population. Caries frequency is lower than other Portuguese samples, which is likely related to the sample's presumed low socioeconomic status and to the reduced access of rural peripheral regions to processed foodstuffs in the early Industrial period. However, cavities and AMTL have high frequencies; this is likely related to the progressively greater access to processed food and increasing mean age at death. This finding is corroborated by the relatively high frequency of caries in young individual's decidual teeth.

Women have higher caries and AMTL frequencies than males, which could be related to dietary (and social) differences between the sexes. Nearly equal wear scores suggest these dietary differences between the sexes did not pertain to the abrasiveness of the foods available and consumed by either sex.

Occlusal caries present low frequencies, despite high overall caries presence. This could be mediated by occlusal wear, which is moderate in Valença. This wear score is related to the relatively abrasive diet, more similar to medieval than Industrial processed foods. The relatively low frequency of periapical inflammation could also be related to this samples' mean occlusal wear causing reduced occlusal caries presence.

Periodontal disease and calculus high levels also provide insight on oral care, suggesting that the Valença sample, of peripheral rural origin, had very poor oral hygiene and very scarce access to dental treatment. Alongside relatively high caries frequencies, calculus accumulation supports a high carbohydrate diet. Moderate occlusal wear and high calculus indexes suggest that general and/or continued non-masticatory use of teeth was unlikely in this small sample from Valença.

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