Atypical dental wear patterns in individuals exhumed from a medieval Islamic necropolis of Santarém (Portugal)

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Abstract To infer the diet and cultural behaviours of Islamic communities during the medieval period in Portugal, 43 adult skeletons (13 females, 27 males, and 3 individuals of undetermined sex) from the medieval Islamic necropolis of Santarém were analysed. A total of 779 teeth were macroscopically observed to score dental wear and dental alterations as enamel chipping, notching, transversal grooves observed on the mesiodistal occlusal surfaces (TGMOS), and lingual surface attrition of the maxillary anterior teeth (LSAMAT). Occlusal wear was moderate. Chipping was recorded in 13.08% (98/749) teeth from 28 individuals, and notching affected 3.87% (29/749) belonging to 17 individuals. Five subjects have transverse grooves, observed on the mesiodistal occlusal surfaces in 3% (23/750) of the teeth. LSAMAT was observed in 41.25% (66/160) of the anterior upper teeth belonging to 20 individuals. Combinations of different alterations were investigated: LSAMAT–chipping, LSAMAT–TGMOS, and LSAMAT–chipping–TGMOS. These could be related to hard food, extra-masticatory behaviours, chewing unknown substances, or trauma.

Key words: extra-masticatory patterns, Islamic, notching, chipping, medieval Portugal

Introduction

During an individual’s life their dentition is in permanent interaction with the environment and can suffer diverse alterations due to diet or tooth–tool use (Molnar, 1971; Scott et al., 1991), which may reflect individual or collective habits (Alt and Pichler, 1998). Tooth wear patterns can vary regionally and/or according to the social–economic status in a way that reflects access to available resources in terms of both quantity and quality (Alt and Pichler, 1998; Toso et al., 2019). Additionally, these changes can have a diachronic and even historic character and can be classified as active or passive depending on whether they were intentional or unintentional actions, respectively (Alt and Pichler, 1998; Molnar, 2011).

Intentional modifications include ablation, filing, decorating, and early dentistry, while unintentional ones include dietary, parafunctional, occupational, traumatic, and habitual dental marks (Molnar, 2011). Unintentional or non-masticatory modifications may comprise a variety of unusual patterns (chipping, notching, grooving, linear grooves, interproximal grooves, cuts, scrapes, polished surfaces, striations, etc.) which have been identified in prehistoric individuals in Morocco (Bonfiglioli et al., 2004), Alaska (Scott and Winn, 2011), the Middle East (Fiorenza and Kullmer, 2013), and in European samples of various historical periods (Bonfiglioli et al., 2004; Belcastro et al., 2007; Scott and Winn, 2011; Silva et al., 2016; Fidalgo et al., 2020).

Dental wear can result from direct contact between teeth (attrition), teeth and an outside object (abrasion), and from erosion due to chemical dissolution (Hillson, 1996). Chipping occurs when the strength of enamel is exceeded by the bite force pressure between the upper and lower teeth (Scott and Winn, 2011). The resultant fracture can be related to masticatory and non-masticatory activities (Milner and Larsen, 1991). Notching appears when the crown is worn down, in the vestibular–lingual direction, due to contact with some type of soft object forming a smooth-edged notch and, similarly to chipping, is associated with extra-masticatory practices on soft materials such as sinew, wood, or thread when stringing bows (Bonfiglioli et al., 2004).

The study of dental wear patterns provides knowledge of past populations, including their habits, cultural behaviours, diet, health, and way of life (Molnar, 2011). Such a study has
now been achieved, for the first time, in a medieval Islamic skeletal collection unearthed from Portugal. The study of this segment of the medieval population has been very overlooked in Portuguese research. Additionally, in the literature, these atypical patterns are usually mentioned as isolated cases and/or recorded as curiosities (Molnar, 2011). The present paper aims to identify atypical dental wear patterns, such as chipping, notching, transverse mesiodistal grooves, and lingual surface attrition of the maxillary anterior teeth (LSAMAT) that could reflect non-masticatory and/or dietary habits in an Islamic community from medieval Portugal.

Brief historical context
In 711 an army of Muslim Berbers led by Musa invaded the Iberian peninsula and in seven years had conquered a large territory called Al-Andalus (Catarino, 1993). Santarém (Figure 1), strategically located, surrounded by deep valleys, and near the River Tago, presented a challenge to the forces of 'Abd al-Aziz, to whom the city capitulated in 714 (Conde, 2007). Nevertheless, the city's citizens were allowed to keep their properties and benefits, some administrative autonomy, and freedom of worship (Conde, 2007). The medina (city in Arabic) flourished under Islamic rule intrinsically connected with commercial and craft activities (Brandi, 1992). Those occurred in the suq, or market, in small tents open to the streets, considered a place of social gathering alongside mosques that also had religious, civic, education, assistance, and hygiene functions (Conde, 2007). Nearby were located the residential houses, baths, and libraries (Conde, 2007).

In 1147, Afonso Henriques, the first king of Portugal, conquered Santarém, and the Islamic occupation was limited to the south until the 13th century when Islamic domination ended (Torres, 1992; Conde, 2007).

Main urban cities, such as Santarém, were preferred places by Berbers, Arabs, and Syrians, and would have had the biggest Muslim population density (Catarino, 1997/1998). A small commercial town could have converted to Islam in one generation, while a deeper-rooted Christian city could have taken many generations (Torres, 1992). The Santarém necropolis or maqbara, located in what is now Cândido dos Reis Square (LCR), had shown a dichotomy in religious funeral rituals that reflected the population diversity in the city (Matias, 2009).

The archaeological work was carried out between July 2004 and September 2006, exposing 9681 m² of graveyard area with occupation from the 8th to 12th centuries (Matias, 2009). The Islamic deceased were dispossessed of any assets and laid down in a simple narrow trench on the right lateral decubitus facing Mecca (Torres and Macias, 1996). The position of the body allowed for the identification of 422 individuals buried according to Islamic ritual (Figure 2) and 217 based on canonical Christian practices (Matias, 2009). The exhumed Islamic sample comprised 48 non-adults and 193 adults (86 females and 107 males) (Matias, 2009).

Material and Methods
The sample consists of the 779 teeth from 43 adult individuals (27 males, 13 females, and 3 of unknown sex) divided into the following age groups: five young adults (20–35
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years), 25 middle-aged (35–50 years), one elderly (50+ years), and 12 adults in which (Table 1) it was not possible to estimate the age range (see Rodrigues, 2013).

The dentition was macroscopically observed with the aid of a magnifying hand lens. Occlusal dental wear was scored according to Smith (1984), as adapted by Silva (1996), that is, stage 0 was used to grade unworn teeth, while stage 1 was applied to the teeth with polished facets with no dentine exposure. Teeth affected by large caries, taphonomy, and post-mortem crown damage were categorized as not observable. Post-mortem and ante-mortem alterations were based on their colour and appearance according to Scott and Winn (2011).

Chipping corresponds to an ante-mortem irregular crack comprising enamel or enamel and dentine, located on the vestibular, lingual, or interproximal edge or crest of the tooth (Bonfiglioli et al., 2004). It was registered based on Bonfiglioli et al.'s (2004) method which classifies the teeth on a three-point scale. Notching consists of an indentation including the tooth mesial or occlusal edge, which may involve the whole surface, and was also assessed by the Bonfiglioli et al. (2004) method. A well-defined transversal groove observed on the mesiodistal occlusal surfaces (TOMOS), usually located on the upper and lower anterior teeth, was scored as present/absent/not observable. Additional locations were also registered if observed. The LSAMAT, first described by Turner and Machado (1983) was also recorded. Data sets were analysed in IBM SPSS Statistics 22.0; data found to be not normally distributed were compared using the Mann–Whitney U-test. The chi-squared test was also used when comparing the data sets, especially when more than two categoric, independent groups were present.

Results

Among 1137 alveoli present, 779 teeth were preserved, 292 (25.68%) were lost ante-mortem (69/292, 23.63% anterior teeth; 223/292, 76.37% posterior teeth), 39 (3.43%) post-mortem, and in 27 (2.37%) the state of preservation of the alveolus did not allow diagnosis (Table 2).

### Table 1. Sex and age profile of the individuals studied

| Sex    | Young adults | Middle-aged | Elderly | Adults | N  | %    |
|--------|--------------|-------------|---------|--------|----|------|
| Male   | 3            | 18          | 1       | 5      | 27 | 62.79|
| Female | 2            | 6           | 0       | 5      | 13 | 30.23|
| Unknown| 0            | 1           | 0       | 2      | 3  | 6.98 |
| Totals | 5            | 25          | 1       | 12     | 43 | 100  |

### Table 2. Dentition and alveolus distribution by sex of the individuals

| Sex    | Present | Ante-mortem loss | Post-mortem loss | Not observable | Totals |
|--------|---------|------------------|------------------|----------------|--------|
|        | n       | %                | n                | %              | n      | %    | n     | %    | n     | %    |
| Male   | 524     | 67.27            | 182              | 62.33          | 27     | 69.23| 22    | 81.48| 755   | 66.4 |
| Female | 232     | 29.78            | 91               | 31.16          | 11     | 28.21| 5     | 18.52| 339   | 29.82|
| Unknown| 23      | 2.95             | 19               | 6.51           | 1      | 2.56 | 0     | 0     | 43    | 3.78 |
| Totals | 779     | (68.51)          | 392              | (25.68)        | 39     | (3.43)| 27    | (2.37)| 1137  | 100  |
Table 3. Occlusal wear scored based on Smith method (1984) modified by Silva (1996) on the upper and lower teeth

| Teeth         | Occlusal wear score | N    |
|---------------|---------------------|------|
|               | 0      | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
| Maxilla       | n %    | n %  | n %  | n %  | n %  | n %  |
| I             | 1      | 0.91 | 6    | 5.45 | 15   | 13.64| 24   | 21.82| 35   | 31.82| 15   | 13.64| 4    | 3.64 | 8    | 7.27 | 2    | 1.82 | 110  |
| C             | 1      | 1.79 | 2    | 3.57 | 17   | 30.36| 11   | 19.64| 11   | 19.64| 9    | 16.07| 4    | 7.14 | 0    | 0    | 1    | 1.79 | 56   |
| PM            | 3      | 3.26 | 7    | 7.61 | 26   | 28.26| 19   | 20.65| 11   | 11.96| 17   | 18.48| 7    | 7.61 | 1    | 1.09 | 1    | 1.09 | 92   |
| M             | 1      | 0.93 | 9    | 8.33 | 45   | 41.67| 26   | 24.07| 8    | 7.41 | 5    | 4.63 | 9    | 8.33 | 4    | 3.71 | 1    | 0.93 | 108  |
| Total         | 6      | 1.64 | 24   | 6.56 | 103  | 28.14| 80   | 21.86| 65   | 17.76| 46.56| 13.55| 5    | 1.37 | 366  |
| Mandible      |        |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| I             | 0      | 0    | 4    | 3.51 | 17   | 14.91| 41   | 35.96| 30   | 26.32| 15   | 13.16| 1    | 0.88 | 1    | 0.88 | 5    | 4.39 | 114  |
| C             | 1      | 1.39 | 7    | 9.72 | 13   | 18.06| 14   | 19.44| 19   | 24.33| 16   | 15.53| 8    | 7.77 | 0    | 0    | 0    | 0    | 103  |
| PM            | 7      | 6.88 | 22   | 21.36| 14   | 13.59| 24   | 23.33| 16   | 15.53| 12   | 11.65| 8    | 7.77 | 0    | 0    | 0    | 0    | 103  |
| M             | 0      | 0    | 8    | 8.25 | 26   | 26.86| 23   | 23.71| 24   | 24.74| 8    | 8.25 | 5    | 5.15 | 3    | 3.09 | 0    | 0    | 97   |
| Total         | 8      | 2.07 | 41   | 10.62| 70   | 18.13| 102  | 26.42| 89   | 23.06| 47   | 12.18| 17   | 4.44 | 6    | 1.55 | 6    | 1.55 | 386  |
| Overall       | 14     | 1.86 | 65   | 8.64 | 173  | 23.01| 182  | 24.22| 154  | 20.48| 93   | 12.37| 41   | 5.45 | 19   | 2.53 | 11   | 1.46 | 752  |

I, incisors; C, canines; PM, premolars; M, molars.

Table 4. Distribution of dental wear patterns by sex of the individuals

| Dental alterations | Males (N = 27) | Females (N = 13) | Unknown sex (N = 3) | Total (N = 43) |
|--------------------|----------------|------------------|---------------------|---------------|
| Chipping           | 21             | 77.78            | 7                   | 53.85         | 28             | 65.12 |
| Notching           | 13             | 48.15            | 4                   | 30.77         | 0              | 39.53 |
| TGMOS              | 3              | 11.11            | 2                   | 15.38         | 0              | 11.63 |
| LSAMAT             | 13             | 48.15            | 4                   | 30.77         | 3              | 46.52 |

N, number of individuals; n, number of teeth with wear patterns.

Atypical dental wear patterns

Chipping was recorded in 28 individuals (28/43, 65.12%); 21 males and 7 females. Teeth from males (Table 4, Table 5, Table 6, Table 7) presented higher frequency of chipping (71/507; 14%) than teeth from females (27/219; 12.3%) but the difference was not statistically significant ($\chi^2 = 0.6255$).

This pattern (Table 3) was visible in 13.08% (98/749) of the teeth, 20.16% (73/362) in the upper and 6.46% (25/386) in the lower ones, with statistical significance ($U_{42,385} = 606,446,500; P < 0.001$). Grade 1 predominated in 82.65% (31.08) of the teeth followed by grade 2 (11.98; 11.22%) and grade 3 (6/98; 6.12%). In the maxilla, this alteration was exhibited by 42.33% (69/163) of the anterior teeth, and 2.01% (4/199) of the upper posterior ones. Both upper central incisors and right lateral incisors displayed the highest frequency, 61.81% (34/55) and 59.26% (16/27), respectively. In the mandible, it was recorded on 12.15% (22/181) of the anterior teeth, and 1.46% (3/206) of the posterior ones. Central incisors showed the highest frequency (13/51; 25.49%), followed by the right lateral incisors (4/28; 14.28%). The comparison between upper incisors (56/109; 51.37%) versus lower incisors (19/108; 17.59%) showed statistical significance ($U_{109,108} = 3897.500; P < 0.001$), as well as anterior (91/344; 26.34%) versus posterior dentition (7/405; 1.7%) ($U_{344,405} = 52,436,500; P < 0.001$).

Notching was identified in 17 (17/43, 39.53%) individuals, 13 males and 4 females. Twenty-one (Table 4, Table 5, Table 6, Table 7) were from male individuals ($n = 507; 4.14%) and 8 from females ($n = 219; 3.63%$), but no statistical significance was found ($\chi^2 = 0.0105; P = 0.918$). Notching (Figure 4) was recorded in 3.87% (29/749) of the teeth. In the maxilla, it was identified in 4.14% (15/362) teeth, and in 3.62% (14/387) of the mandibular ones, but without statistical significance ($\chi^2 = 0.0336; P = 0.854$). Grades 1 and 2 (12/25; 48%) reveal the same frequency, while grade 3 (5/25; 20%) was the lowest. The highest frequency in the maxillary teeth was scored in the anterior dentition (13/63; 7.93%) over the posterior ones (2/19; 1.01%). Notching was registered, respectively, 5.52% (10/181) and 1.94% (4/206) of the lower anterior and posterior dentition. The presence of notching in the anterior (23/344; 6.69%) versus posterior teeth (6/405; 1.48%), showed statistical significance ($\chi^2 = 12.1751; P < 0.001$).

Two individuals, a male and a female, showed one notch, of semicircular shape, between the lower canine and the first premolar on the left.

Table 5. Distribution of atypical dental wear patterns in the dentition of the individuals

| Dental alterations | Males | Females | Unknown | Total |
|--------------------|-------|---------|---------|-------|
|                   | $n$   | %       | $n$     | %     |
| Chipping           | 507   | 71      | 219     | 27    |
| Notching           | 507   | 21      | 4.14    | 219   | 8    |
| TGMOS              | 508   | 13      | 2.56    | 219   | 10   |
| LSAMAT             | 101   | 48      | 47.52   | 52    | 15   |

N, number of teeth examined; n, number of teeth with wear patterns.
quadrant and right quadrant, respectively (Figure 5). The upper teeth of the male individual were not observable while the groove in the female teeth did not show any correspondence with the upper ones.

TGMOS were registered in five individuals (5/43, 11.63%); three males (n = 27), and two females (n = 13). This pattern was identified in 13 (13/508; 2.56%) teeth of males (Table 4, Table 5, Table 6, Table 7), while 10 belonged to females (10/219; 4.58%), but the differences were not statistically significant (χ² = 1.4105; P = 0.234). The pattern was scored in 3% (23/750) of the total of teeth (Figure 6), and only in the maxilla (23/363; 6.34%), but almost exclusively in the anterior dentition (incisors and canines, 22/164; 13.4%), except for one right first upper premolar (1/199; 0.50%).

LSAMAT was observed in 20 (20/43, 46.52%) individuals, with males (13/27, 48.15%) revealing the highest frequency (Table 4, Table 5, Table 6, Table 7) when compared to females (4/13, 30.77%). These alterations were scored in 41.25% (66/160) anterior upper teeth, 47.52% (48/101) in males, 28.85% (15/52) in females (significant: χ² = 4.2034; P = 0.04), and in 42.86% (3/7) of individuals of unknown sex (Figure 6, Figure 7). Exceptionally, the middle-aged male 521 had this pattern on the anterior teeth and the left UPM1. Additionally, a similar pattern was observed on the left LC belonging to the middle-aged male 164.

The analyzed sample revealed that 83.72% (36/43) of the individuals showed different types of atypical dental wear of varying frequency (Table 6). Of those, 27.91% (12/43) individuals, three females and nine males, had chipping and
Table 7. Individuals affected by chipping, notching, TGMOS and LSAMAT

| Sk. | Sex | Age     | Chipping | Notching | TGMOS* | LSAMAT* |
|-----|-----|---------|----------|----------|--------|---------|
| 153 | M   | adult   | 21, 23, 31, 41, 42* |        | 21     |         |
| 160 | M   | adult   | 12       |          |        |         |
| 395 | M   | adult   | 21, 22   |          |        |         |
| 544 | M   | adult   | 12, 21, 25, 26 |         |        |         |
| 147 | M   | elderly  | 11, 13, 21, 23 | 43, 44  |        | 11, 12, 21, 22 |
| 135 | M   | middle age | 11, 13, 33, 48 | 11     |        |         |
| 164 | M   | middle age |         |        |        | 33     |
| 173 | M   | middle age | 31, 32, 41 | 33, 34, 42 |        |         |
| 179 | M   | middle age | 11, 12, 31, 41 |        |        | 11, 12, 21, 22 |
| 181 | M   | middle age | 11, 21 |        |        |         |
| 185 | M   | middle age | 12     | 11, 12, 13, 33, 45 |        | 11, 13, 22 |
| 201 | M   | middle age |         |        |        |         |
| 355 | M   | middle age |         |        |        | 11     |
| 363 | M   | middle age | 11, 12, 21 | 14     | 11, 12, 21 | 11, 12, 21 |
| 369 | M   | middle age | 11, 13, 31, 32, 41 | 43     |        | 11, 12, 21, 22 |
| 387 | M   | middle age | 35     |        |        | 21, 22 |
| 388 | M   | middle age | 11, 12, 21, 22, 23, 25 | 23 | 11, 12, 13, 21, 22, 23 |
| 390 | M   | middle age | 11, 12, 13, 21 | 11, 17 |        |         |
| 399 | M   | middle age | 11, 12, 13, 21, 22, 23, 42 |         | 11, 12, 13, 21, 22, 23 | 11, 12, 13, 21, 22, 23 |
| 402 | M   | middle age | 11, 12, 14, 21 | 21 | 11, 12, 21, 22 | 11, 12, 21, 22 |
| 406 | M   | middle age | 35     |        |        |         |
| 521 | M   | middle age | 11, 12, 13, 21, 22 |        |        | 11, 12, 13, 21, 22, 23, 24 |
| 146 | M   | young adult | 11, 12 | 31, 32 |        |         |
| 407 | M   | young adult | 11, 12, 21 | 13 |        | 11, 12, 13, 21, 22, 23 |
| 157 | F   | adult     | 12, 13 |        |        |         |
| 389 | F   | adult     | 12, 13, 21, 22, 23, 31, 33, 41, 42, 43 |        | 12, 13, 21, 22, 23 |         |
| 484 | F   | adult     | 21, 22 | 43, 44 |        | 21, 22 |
| 136 | F   | middle age | 11, 12, 21 | 22, 31, 33 |        | 11, 12, 21, 22 |
| 192 | F   | middle age |         | 22     | 11, 13, 14, 21, 22, 11, 13, 21, 22 |
| 368 | F   | middle age | 11, 41 |        |        |         |
| 520 | F   | middle age | 12     |        |        |         |
| 529 | F   | middle age | 11, 12, 21, 23 |        |        | 11, 12, 13, 21, 23 |
| 158 | F   | young adult | 11, 21, 31, 41, 42 |        |        |         |
| 159 | I   | adult     |         |        |        | 22     |
| 361 | I   | adult     |         |        |        | 21     |
| 507 | I   | middle age |         |        |        | 13     |

* Bold: teeth affected with more than one atypical wear. * FDI World Dental Federation dental notation system.

LSAMAT on 22.50% (36/160) of the upper teeth. A combination of TGMOS with LSAMAT was observed on 10.63% (17/160) of the upper anterior teeth from four (4/43, 9.30%)
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Discussion

The mean grade of 3.33 of dental wear for these individuals suggests moderate occlusal wear, consistent with the consumption of more processed foods. Manual millstones were widely used to grind wheat grains and other cereals for bread or porridge which would have led to the permanency of grains and contributed to occlusal attrition (García, 1983; Torres, 1992; Wasterlain, 2006).

Male individuals showed more dental wear than females. This could reflect sex differences in food consumption and/or division of labour. In other studies (Jurmain, 1990; Bonfiglioli et al., 2003; Wasterlain, 2006), as for the Islamic sample of El Fossar (Novelda, Spain), more wear in males than females was reported (Gómez González, 2012). The anterior dentition, especially the upper ones, revealed substantial occlusal wear (grade 4), suggesting that incisors (35/110; 32%) could have been used for extra-masticatory purposes. This is reflected in dental alterations such as chipping, notching, TGMOS, and LSAMAT. The exuberant wear of the anterior dentition could also suggest the need to shift the masticatory process for the anterior teeth due to ante-mortem loss of the posterior ones (Bonfiglioli et al., 2003) which was consistent with the posterior tooth loss observed in this sample. An excess of vitamin C through the ingestion of citrus juices, pomegranate jams, and others, documented by historical/archaeological evidence from various archaeological sites of the time (Mawaldi et al., 2008, Zaouali, 2009; Alonso et al., 2014) could also have contributed to dental wear, as could vomiting and chronic regurgitation (Irish and Turner 1987, Robb et al., 1991, Turner et al., 1991). These practices were condemned by a Syrian physician of the time, Ibn al-Nafis (1210–1288), as part of his advice on how to maintain a healthy mouth (Mawaldi et al., 2008). He also compiled other restrictions in his manuscript *Mujiz Al-Qanun* that would have been beneficial for reducing dental wear such as sour fruits, sweets (as dried figs), misuse of drink/food, inflicting sudden changes of temperature, and breaking hard objects (nuts and almonds) (Mawaldi et al., 2008). Stable isotope analyses from Islamic individuals from medieval Lisbon (Portugal), 80 km southwest of Santarém, revealed a diet that included the main domesticated animals and fish (Toso et al., 2019). In the Islamic medieval site of Alcáçova of Santarém, zooarchaeological records reported domesticated animals, as game (Davis, 2006). A sample from the Christian individuals recovered in Santarém (from the same necropolis as the studied Islamic individuals), dating from the 16th–18th centuries, displayed the highest frequency of grade 2 (105/382, 27.5%) of dental wear (Tereso, 2009). Similarly, grade 2 (91/320, 28.44%) was also observed for the Christian medieval sample from Ribeira de Santarém (a suburban area adjacent to the River Tagus) (Pombal, 2006). Both showed slightly less dental wear than the present study. The medieval Christian sample of São João de Almedina (Coimbra, Portugal) showed similar dental wear (\(\bar{x} = 3.86\)) (Carvalho, 2013) to the individuals under analysis (\(\bar{x} = 3.33\)). According to Cunha (1994), these values resulted from vigorous mastication whilst eating dried meat, unclean fish, and cereals, as well as from poor hygiene.
Atypical dental wear

Chipping affected more than half of the individuals (65.12%), which differs from the 11th- to 18th-century Christian sample of the cathedral of Santa Maria (Vitoria, Spain) that showed a lower frequency (24.1%) (Scott and Winn, 2011). These differences were unexpected due to their geographic proximity and shared history. That could be due to the long chronological period of the Spanish sample, which extends from the medieval period to the Industrial Revolution (Scott and Winn, 2011). To date, limited research has been published on Islamic samples regarding the various atypical patterns identified. In Portuguese territory, chipping was recorded in individuals dated to the Late Neolithic/Chalcolithic period (Silva et al., 2019), individuals (two males, one unknown individual) dating from the Middle Bronze Age necropolis of Casas Velhas (Melides) (Silva et al., 2016), and two females from the Middle Bronze Age necropolis of Torre Velha 3 (Serpa) (Fidalgo et al., 2020). In the Santarém sample, this pattern affected both sexes (14%, males, 12.3% females), which suggests similar dietary and or masticatory habits, as reported for the Spanish sample (Scott and Winn, 2011).

Maxillary teeth chipping was more frequent than mandibular teeth chipping, and this difference was statistically significant. The same was also observed for the Spanish sample but without statistical significance (Scott and Winn, 2011). Chipped teeth in the present study revealed significant variations between anterior (26.4%) and posterior (1.7%) dentition which were also consistent with the Spanish sample (Scott and Winn, 2011).

Chipping could have occurred due to persistent food consumption of hard particles which can wear the teeth but also chip the enamel (flour with unprocessed grains and stones, snail shells, nuts, fruit stones, etc.) (Bonfiglioli et al., 2004; Wasterlain, 2006; Silva et al., 2016). This pattern can also result from various types of trauma (fight, fall) (Bonfiglioli et al., 2004; DiAngelis et al., 2012), as well as extramasticatory behaviours which comprised quotidian or craft activities (sewing, shoemaking, carpentry, riding, etc.), using lines and pins (Cruwys et al., 1992), and also chewing unknown substances (leather, for tool-making and repairing, etc.) (Bonfiglioli et al., 2004). The prevalence of chipping on the right lateral incisors suggests a predominance of the right hand being used to insert biting objects into the mouth.

Notching was present in 39.53% of the individuals, 13 males (19/507, 3.74%) and 4 females (8/219, 3.63%), which suggests similar habits and/or occupational activities of both sexes. Notches were more frequent (with statistical significance) on the anterior dentition of both jaws. Comparative data in the literature are limited, considering geographic proximity and chronology. Exceptions are Anglo-Saxon (Cruwys et al., 1992) and Epipalaeolithic Taforalt (Morocco) (Bonfiglioli et al., 2004) samples, with a lower number of individuals (n = 8 and n = 2, respectively), where notching mostly affected males (with one possible female) which is different to the present Islamic Santarém sample. Notches were potentially linked with ingestion of dried-roasted seeds (watermelon, pumpkin, and sunflower) which occur in social Arab gatherings nowadays (Amin et al., 2007; Al-Habibeh et al., 2011). Further, the consumption of hard-shelled nuts (walnuts, pistachios, and almonds) during the Islamic period (Catarino, 1993) could have caused notches due to constant pressure being applied between the incisal edges of upper and lower anterior teeth to break shells (Al-Habibeh et al., 2011). Constant ingestion of dried seeds and hard shells over a chipped crown could increase the chipping area to form a notch. In addition, they could originate from a simple habit of keeping a small wooden stick between the teeth and occasionally chewing on it (toothbrush stick made of Salvadora persica and toothpick) (Brandi, 1992; Molnar, 2011).

The two notches identified between the lower canine and first premolar of two individuals (one of each sex) might be linked with holding a strange object pressed against the mandibular teeth while the mouth was kept open. A similar notch alteration affecting both jaws was observed in a Suri nam female, which was caused by holding a pipe in the teeth (Cruwys et al., 1992). The same cause may not be consistent with the grooves observed in two individuals from Santarém because the female individual did not show such alteration in the upper teeth while the upper teeth of the male individual were not observable. This alteration was potentially caused by hygiene behaviours, such as the previously mentioned toothbrush stick made of S. persica.

TGMOS were identified in five individuals (11.63%), three males and two females, which suggests a non-masticatory activity using the anterior upper teeth (13.4%, 22/164). Such activity could be due to weaving (Cybulski, 1974), basket-making, mat processing (Molleson, 1994), making fishing nets, funerary and fowling bags, rope (Larsen, 1985), processing plants or fibres (Minozzi et al., 2003), and wetting cotton or wool yarn (Erdei, 2008). Previously, studies suggested that this pattern was more commonly found in females than males (Cybulski, 1974; Molleson, 1994; Erdei, 2008; Lorkiewicz, 2011; Fidalgo et al. 2020). Although other studies reported this alteration to affect only males (Larsen, 1985; Minozzi et al., 2003), or both sexes (Schulz, 1977; Larsen et al., 1998), the letter was consistent with the current findings, with a prevalence of cases in the anterior upper teeth, and apparently not related to gender-based division of labour. A single tooth with this pattern belonging to a female, from the Middle Bronze Age, was documented on Portuguese territory (Fidalgo et al., 2020). TGMOS could be the result of maintaining a cylindrical plant/fibre, such as cotton or linen, running in the mesiodistal direction. These plants/fibres are known to have been agronomically processed in the Iberian peninsula at this time (Catarino, 1993). Moreover, willow, reed, and date palms were also used to produce baskets, mats, and ropes, as well as a variety of household objects, which were made by men and women in domestic environments for personal and/or commercial use (Milwright, 2017).

LSAMAT was first reported in prehistoric native South Americans (Turner and Machado, 1983; Irish and Turner, 1987) and West Africa individuals (Irish and Turner, 1997) associated with a high prevalence of cariogenic lesions and attributed to consumption of abrasive carbohydrates (manioc and sugar cane). In Europe, LSAMAT shows lower frequencies and generally is not associated with cariogenic lesions (Alt and Ficher, 1995; Porr and Alt, 2006; Silva et al., 2016; Fidalgo et al., 2020). The Islamic individuals studied from Santarém reveal a high frequency per individual of LSAMAT.
(20/43, 46.52%) in both sexes, which could therefore be related to extra-masticatory behaviours. Regurgitated gastric acid was mentioned in the literature as LSAMAT aetiology (Turner II et al., 1991), although the almost nonexistent (apart from one tooth) compatible alterations in the posterior dentition discounted it as a cause. The use of fine abrasive metal tools for teeth polishing recommended by the physician Albucasis (936–1032) from the Al-Andalus (Pirotta, 2004) could also explain this pattern, although it is difficult to confirm this in archaeological samples. In Portuguese territory, Fidalgo et al. (2020) also documented this pattern in three individuals (two females and one of unknown sex) dating from the Middle Bronze Age necropolis of Torre Velha 3.

Exceptionally, LSAMAT was recorded simultaneously with chipping (36/160, 22.50%), as well as LSAMAT and TGMOS (17/160, 10.63%), in both sexes. In the literature such associations between various atypical dental wear patterns have not been mentioned. Similarly, the triple-pattern atypical wear (LSAMAT–chipping–TGMOS) present in three males was most likely connected to extra-masticatory occupations rather than with diet. The presence of more than one atypical wear pattern could be due to various phases of craft labour or distinct occupational activities mentioned above. The use of the mouth to process the fibres, especially in the narrow incisal edge, could cause the fibre to slide to the lingual surface which became more worn by the repeated movement. Further research of ethnographic and skeletal samples could clarify the aetiologies of the various atypical wear patterns observed.

Conclusions

Atypical dental wear can be an indicator of diet particularities but can also be related to daily activities and/or professional occupations during the medieval Islamic period in the Iberian peninsula. The individuals inhumed according to Islamic rites from the medieval urban context of Santarém reveal a high frequency (33.72%) of atypical dental wear in both sexes which includes chipping, notching, TGMOS, and LSAMAT. These could be related to the persistent ingestion of hard food (dried-roasted, hard-shelled nuts and seeds) and/or extra-masticatory behaviours that comprised quotidian or craft activities (weaving, basket-making, net processing, sewing, shoemaking, carpentry, etc.), chewing substances (leather, fibres, plants, tool-making and repairing, metal tools for teeth polishing, stick/smoking pipe, etc.), or trauma. The specific causes for such alterations are impossible to establish, especially in archaeological samples. However, ethnographic and craft archive research from medieval towns may be advantageous for a better understanding of these alterations, in addition to further studies of Islamic medieval samples from the Iberian peninsula.

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