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From Early to Late Modern Societies (Late 16th - Early 20th Century): Shifts in Dental Health Status in Two Populations from Southeastern France.

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Abstract

In France, bioarcheological research has long overlooked the early and late modern periods, which witnessed major transformations impacting population structure and leading to the dawn of modern industrialized societies. Two recently excavated large cemeteries in Provence present a unique opportunity to investigate on a large scale the impact on health and living conditions brought about by the Industrial Revolution and consequently track health status changes from the 16th to the early 20th century.

The sample includes 642 individuals from the early modern cemetery of Saint-Jacques, La Ciotat (1581-1831) and the late modern cemetery of Les Crottes, Marseille (1784-1905). This study aims to document dental health markers and compare the results between both assemblages, considering *ante-mortem* tooth loss, wear, caries, abscesses, calculus, periodontitis and linear enamel hypoplasia. The available archaeological and historical sources for these recent periods provide a full documentation in which to interpret and discuss the biological analysis, thus enabling an inclusive bioarcheological approach.

Results revealed similarities between both samples. Differences are more subtle than expected and are seen through the increase in carious lesions and in linear enamel hypoplasia. The former seem to indicate changes in diet with the introduction of new foodstuffs and manufacturing processes during the Industrial Revolution. The latter could reflect the increase in early childhood stress, perhaps due to new feeding practices around weaning and breastfeeding or a poorly diversified diet. Finally, the increasing number of stress events could suggest a noxious sanitary and infectious environment. During the 19th century, Marseille experienced strong demographic and urban growth, resulting in overcrowded areas where sanitation facilities were insufficient or absent. Moreover, the activity of this important trading seaport might have promoted the transmission and appearance of epidemic diseases despite scientific and medical advances, which would have a real impact only from the 20th century onwards.

Key words: Dental health, early and late modern periods, Industrial Revolution, southeastern France, dental caries, hypoplasia, bioarchaeology

1. INTRODUCTION

In France, early and late modern societies have been scarcely investigated by archaeologists and have long been overlooked in bioarcheological research. However, this period covering five centuries, from the Renaissance to the 20th century, witnessed extensive transformations, that would change population structure, leading to the dawn of contemporary industrialized societies. Changes occurred in socio-economic areas as the Industrial Revolution took off, but also in political and cultural fields. These

changes led to massive consequences on living conditions and health, as scientific and technical progress triggered major medical advances. Hence, such a context would perfectly illustrate the influences and constant interactions between cultural aspects, lifestyles and anatomy and biology. Indeed, the Industrial Revolution constitutes a major and profound shift on human biology, eventually transforming the pathologies from which populations suffer. Notably, the industrial period saw the onset of the epidemiological transition (Omran, 1983), characterised by a radical change in the pathocenosis (Grmek, 1969), modifying the epidemiological structure of populations. This slow process would involve the decline of all infectious and deficiency diseases, which were initially the main causes of death, in favour of chronic and degenerative diseases (Meslé and Vallin, 2000 ; Picheral, 1996).

As rescue archaeology developed, this period slowly entered the scope of bioarcheological studies. The recent excavation of two cemeteries in southeastern France has provided a large skeletal assemblage, including 1 777 individuals from primary burials. This sample offers a unique opportunity to investigate on a large scale the evolution of health during this particular period and specifically at the beginning of industrialization.

The study aims to define and compare the dental health of early and late modern populations in order to determine the impact on health and living conditions brought along by the Industrial Revolution. The many available archaeological and historical sources for such recent historical periods provide a fully documented context in which to interpret and discuss the biological analysis, thus enabling an inclusive bioarcheological approach, with the desire to understand “the causes and consequences of adaptative and behavioral shift in the [recent] past” (Larsen 1997), following carefully the evolution of the pathocenosis throughout History, and especially during this important transition period.

2. MATERIAL

The samples for this research come from two cemeteries, one in La Ciotat and the other in Marseille, two cities located in southeastern France and about 30 km distant from each other (Figure 1).

2.1. The selected populations

The first collection comes from the 2009 archaeological excavation of the *Cimetière St Jacques* in La Ciotat (LC HOP), mainly in use during the *Ancien Régime*, from 1681 to 1831 (Richier, 2011). The assemblage includes 1245 individuals from primary burials but only 423 were included in this study because they were the ones that still retained their dentition.

The second collection is from the *Cimetière des Crottes* in Marseille (MPC), chiefly in use during the 19th century, from 1784 to 1905 (Richier and Weydert, 2016). The excavation led to the discovery of 532 individuals buried in wooden coffins of which 219 were included in this study because they had preserved dental remains.

Both populations are complementary chronologically, allowing the reconstruction of a complete sequence from the end of the 16th to the early 20th century. Besides, thanks to the stratification of the archaeological sites, distinct burial phases were defined and precisely dated. It was therefore possible to carefully study the changes over time in dental health indicators (Figure 1).

Both samples share common features: they are located in a close geographical area, they come from urban contexts and mainly represent modest socio-economic backgrounds. Demographic and economic take off

occurred in both cities, in La Ciotat through maritime commerce and in Marseille during the 19th century with the Industrial Revolution.

2.2. The bone assemblage

The complete sample studied includes 642 individuals, of which 430 are adults and 212 juveniles (aged < 20 years old). The age at death of adults was estimated through changes in the pubic symphysis (Schmitt, 2008) and auricular surface (Lovejoy et al., 1985; Schmitt, 2005). For juveniles, age at death was evaluated through dental development (Moorrees et al., 1963a and b; Ubelaker, 1989), diaphyseal length (Adalian et al., 2002; Maresh, 1970) and epiphyseal fusion (Scheuer and Black, 2000; Veschi and Facchini, 2002). According to their estimated age at death, individuals were placed into one of the age categories listed in Table 1. Sex was determined for adults only, using coxal bones, through the combination of measurements defined in the DSP method (Murail et al., 2005) and the five morphological criteria described by Bruzek (2002). Statistical discriminant function analyses were also performed on long bone measurements to assess sex when the hip bones were not preserved (Murail et al., 1999; Perrin, 2019, 2021). Basic demographic information concerning the individuals under study is provided in Tables 1 and 2.

In La Ciotat, three phases were outlined thanks to a very legible stratification of the cemetery backfill and dated through the study of grave goods and archival data. In Marseille, four phases were identified by the stratigraphic study, combined with the analysis of grave management and funerary organisation. They were dated via historical sources, and especially the dates of the successive extensions of the cemetery.

3. METHODS: DENTAL INDICATORS OF HEALTH

Dental status analysis is considered a valuable tool for the evaluation of health and seven markers or pathologies, routinely used in bioarchaeology, were selected and used to compare the two samples. Through their various aetiologies and pathogenesis, they altogether provide an overview of diet, biological stress, daily habits, hygiene and dental care, some of the key features of the health concept (Rose et al., 1978; Goodman et al., 1984; 1988; Irish and Scott, 2016; Hillson, 1996; 2019). The methodology's originality relies on adapting the study of dental markers to early and late modern populations. Furthermore, medical, medical-historical or historical studies have contributed to preconceived ideas about the secular changes of these markers at the dawn of the 19th century, which should be tested here thanks to the available bone assemblage, considered as a more direct source of information. Besides, the use of well-documented historical and archaeological sources available for such recent archaeological sites was necessary to the bioarchaeological approach.

Dental wear, the progressive loss of the constituent tissues of the tooth, through abrasion, attrition and erosion (Burnett, 2016, Hillson, 1996 ; 2000 ; 2019 ; Kaidonis, 2008) was recorded according to the eight stages described by Smith (1984). Its interest lies in the information it can provide on cultural practices (Bocquentin, 2003; Henderson and Walker, 2012; Kvaal and Derry, 1996), diet reconstruction and changes (Molnar, 1971; Smith, 1984; Larsen, 1995), but also in its interaction with oral pathologies. Worldwide, the general drastic decrease in tooth wear would have occurred recently (Kaidonis et al., 1992). It will be interesting to document this possible change with a precise chronological frame and its possible impact on dental pathologies, in particular on caries.

Ante-mortem tooth loss (AMTL) was considered through the level of alveolar resorption. Despite various aetiologies (pathological, mechanical, curative or cultural), the quality of oral hygiene and access to care remain crucial factors (Larsen, 1997) which fully justify their use in this work.

Cariou lesions are considered a privileged marker to reconstruct human feeding behavior as the nature of the diet remains the main aetiology (Hillson, 1979; Cohen and Armelagos, 1984). Indeed, carbohydrates are particularly cariogenic (Powel, 1985 ; Hillson, 1996 ; Lucaks, 2008 ; Hillson, 2018). Caries has been extensively used to track possible dietary changes, particularly with the consumption of cultivated cereals from the adoption of agriculture (Larsen, 1997). For modern periods, the major dietary changes mainly concern the increase of sugar consumption or processed food (Moore and Corbett 1975; Corbett and Moore, 1976; Flandrin and Montanari, 1996) and many anthropological studies have shown an increase in this type of lesion from the modern period onwards (Muller and Hussein, 2017). Cariou lesions were recorded in accordance with Hillson (2001) and the protocol is presented in Table 3 (Perrin, 2019, 2021).

The presence of periapical lesions, usually resulting from dental caries, pronounced attrition or tooth fracture (Dias and Tayles, 1997; Hillson, 2019) was evaluated and the different types of lesions (Dias and Tayles, 1997) have been grouped under the generic term abscess.

Calculus formation is multifactorial, but anthropological studies have focused on two etiologies. The first one is the level of dental hygiene, since calculus deposit refers to the mineralisation of dental plaque (Hillson, 1996; 2019). Its recording could highlight possible dental hygiene practices, at a time when the use of toothbrushes and toothpastes are being introduced (Clément, 2008; 2010). The second one lies in the nature of the diet: a high protein intake would promote its formation (Hillson, 1996 ; 2019 ; Lieverse, 1999) and the 19th century is supposed to witness a growing increase in meat consumption (Flandrin, 1996c).

Periodontal disease is “an inflammatory condition that affects any or all portions of the periodontium” (Wasterlain et al., 2011), caused mainly by the presence of dental plaque (Hillson, 1996 ; 2018 ; Wasterlain et al., 2011 ; Nelson, 2016) and the aggravating factors are those that influence its presence, quantity and composition, including oral hygiene, diet or the presence of calculus. Calculus deposits and periodontal disease were recorded using the three stages defined by Brothwell (1981).

Finally, linear enamel hypoplasia (LEH) was assessed on each observable tooth, following Bocquentin (2003; Table 3). These defects form bands of decreased enamel thickness and provide a nonspecific indicator of stress, during tooth crown formation: during childhood. A wide range of aetiologies have been recognised, but the main ones are nutritional or vitamin deficiencies (chronic or episodic malnutrition or undernutrition) and infectious or parasitic diseases (Goodman and Rose, 1990; Hillson, 1996; 2005; 2018; Lewis, 2007). They are then often linked to socio-economic status and considered a good indicator of the health status of former populations.

Combining the number of linear defects on every tooth and their age of appearance, a minimal number of stress episodes was defined for each individual.

A population-based approach involving the calculation of frequencies per tooth and prevalence per individuals (Waldron, 1994; 2007) allows for a paleoepidemiological analysis. Comparisons between frequency and prevalence in the two samples relied on Chi² independent tests, Fisher’s exact test and odd ratio analysis. To investigate the severity of the different pathologies and the number of stress episodes, mean scores of severity and mean number of episodes were created for each individual, then compared using Student’s t test. Statistical analysis was performed using R.

4. RESULTS

4.1. Common features

In both samples, frequencies per teeth exhibit similar patterns (Perrin, 2019, 2021) following a classical distribution of dental lesions according to the different types of teeth (Irish and Scott, 2016; Hillson, 1996; 2019). Molars are the teeth most lost *ante-mortem* and most affected by carious lesions. The lower incisors bear a larger amount of the calculus deposits, particularly on the lingual surfaces, whereas canines and upper incisors mainly show LEH.

When comparing total frequencies, nearly every dental marker reveals differences (Table 4), suggesting that, except for AMTL and abscesses, dental pathologies are more frequent in the late modern sample of *Le Cimetière des Crottes*. Teeth from this population also exhibit less intense dental wear: stages 6 to 8 from the Smith recording system (1984) seem rarer. However, even if differences are statistically significant, frequencies remain quite close between both samples. These results, which are based on the calculation of frequencies per tooth, could be partially influenced by the potential presence of few individuals whose teeth bear many and/or severe pathologies. Hence, this set of data must be weighted, or rather supplemented by an individual-based approach. Therefore, we will retain differences only when expressed in both frequencies per tooth and prevalence per individual.

Considering the prevalence per individual, no difference is to be observed in the expression of the majority of dental markers between both samples (Figure 2; Figure 3). Moreover, the distribution of dental lesions according to age at death and sex are quite similar. Except for LEH, dental pathology prevalence and severity tend to increase with age (Figure 2; Figure 3; Perrin, 2019, 2021). In both samples, no significant difference between sexes was noticed regarding each dental indicator (Perrin, 2019, 2021).

Results emphasize similar tendencies. Indeed, both samples exhibit very limited dental wear. Stages 2 and 3 (from Smith, 1984) are the most common and mean scores by individuals are quite low (Figure 2). Both populations experienced a very large amount of AMTL. Around 30 % of teeth were lost *ante-mortem* (Table 4) and most adult individuals are concerned by this pathology (Figure 3). A very high presence of dental caries was recorded. Between 13 % and 23 % of teeth are affected (Table 4). Carious lesions develop early in life (from 1-4 years old in LC HOP, and before the end of the first year of life in MPC) and, when reaching adulthood, most individuals exhibit at least one dental caries (Figure 3). Paradoxically, dental abscesses are quite rare, considering the high rate of dental decay (Table 4), but they are well distributed among the adults. Thirty percent show at least one periapical lesion (Table 4). Calculus deposits and periodontal disease are frequent and age correlated, but no actual changes between early and late modern periods was observed (Table 4; Figure 3). Finally, LEH are very frequent: more than half of both groups are affected by this general stress marker (Figure 3).

4.2. Differences between the early and the late modern samples

Despite many common characteristics, significant differences were observed for three indicators in both analyses (per tooth and per individual).

4.2.1. Dental caries and dental wear

Results emphasize a significant increase in dental caries frequencies and prevalence (Table 4; Figure 3), associated with a decrease in the rate of dental wear (Table 4; Figure 3). A closer look at these two parameters shows how they changed over time.

When considering the distinct burial chronological phases, results show the constant rise of dental decay from the end of 16th century to the beginning of the 20th century (Figure 4). Meanwhile, a decrease in the severity of carious lesions simultaneously occurred. The mean score of severity, related to the extent of the lesion, declined and the proportion of cavities located on the dental crown tended to rise at the expense of those caries developing around the cervix (Figure 4). Finally, these shifts in the severity and location of dental caries are combined with a progressive reduction of dental wear (Figure 4). Moreover, these changes appear to have occurred simultaneously: they took place or intensified during the second phase of *Le Cimetière des Crottes* in Marseille, around the 1830-1850.

4.2.2. Linear enamel hypoplasia

The high frequencies and prevalence of LEH in both sites highlights the omnipresence of biological stressors, which increase even further during the 19th century (Table 4; Figure 3). It may indicate the upsurge of stressful events during that period. Moreover, individuals from the 19th century in the *Cimetière des Crottes* in Marseille, tend to have survived more stress episodes than those from the early modern period in La Ciotat (Figure 5b). When taking age at death into account, two differences stand out. Prevalence among adults tends to decrease with ageing in La Ciotat but remains stable in Marseille (Figure 5a). Considering juveniles, prevalence is higher for the youngest children (under 5 years old at death) in La Ciotat (Figure 5a). These differences may indicate a change in mortality patterns as a consequence of stressful events. Finally, the age of formation of LEH show that the earliest stress periods (before 3 years old) are significantly more frequent during the 19th century.

5. DISCUSSION

Results mostly show similarities between both samples, which highlight common features in health status during the early and late modern periods in southeastern France. Hence, both populations' health was characterized by limited dental wear, many dental caries and LEH, high rates of AMTL, few abscesses and moderate levels of calculus and periodontitis. A few differences were also observed for dental wear, caries and LEH, revealing changes over time. However, these changes are evident on traits already documented for earlier periods and further accentuate some trends. Considering the etiologies of these dental indicators and including archaeological and historical data available, a number of assumptions can be discussed in terms of diet, dental care and the infectious environment. Cross-referencing these different kinds of data allows the construction of a precise framework to interpret the biological characteristics of health status at the time.

5.1. Everyday diet during the early and late modern periods

5.1.1. Ubiquitous cereal consumption

The high level of dental decay in both samples (Table 4; Figure 3) suggests that daily diet heavily depended on carbohydrates. Indeed, diet is a key factor in the development of carious lesions and carbohydrates are known to be particularly cariogenic (Powel, 1985; Lukacs, 2008; Hillson, 1996; 2001; 2019).

From modern times onward, subsistence has massively relied on a single type of resource: cereals, consumed mainly as bread, gruels or porridge (Flandrin, 1996a; Lachiver, 1991; Morineau, 1996). This prominence reflected new feeding strategies, in relation to the European demographic expansion of the end of the Middle Ages (Morineau, 1996). Agriculture mostly turned to cereal production because it provided more calories per equal surface of allocated land than did animal husbandry, hunting or gathering (Flandrin, 1996a).

During the 19th century, cereals were still essential in everyday diet. While the structure of the food portion underwent some modifications, the caloric intake first increased only through the consumption of cereals and other starchy foods (Flandrin, 1996b and c). Hence, the highest cereal consumption in France was reached between 1885 and 1894 (Flandrin, 1996c).

5.1.2. Paradoxical subsistence strategies: diet and stress episodes

Such a diet, mainly based on one type of nutrient, could have noxious consequences both from a qualitative and quantitative perspective. Poor diet, one of the main etiologies for the formation of LEH, could explain the widespread occurrence of stress periods in the populations under study, illustrated by the high frequencies of these linear defects (Table 4; Figure 3).

Under normal circumstances, food should have been sufficient thanks to new feeding strategies and the progress in agricultural practices. Nevertheless, the popular diet remained little diversified for both the early and late modern periods, which were still marked by monotonous meals. This kind of diet would not have met sufficiently the body's needs (Lachiver, 1991; Flandrin, 1996 b and c) and this widespread phenomenon of malnutrition could explain the high prevalence of LEH (Goodman et al., 1991).

The high consumption of cereals in everyday diet can have dramatic effects, leading to periods of food shortages when harvests were poor. During the early modern period, food crises reached an unprecedented scale (Lachiver, 1991; Flandrin, 1996a and b). The subsistence economy of the *Ancien Régime*, influenced by inefficient agronomic techniques and founded on self-based consumption, prevented long-term storage (Lachiver, 1991). Inadequate means of transport complicated the supply chains during shortage events. The end of the 17th and beginning of the 18th centuries were periodically marked by several episodes of drought, heavy rains, late frosts, etc. For instance, the severe winters of 1680 and 1709, directly mentioned in the archives of La Ciotat (Reboul, 1934), had a serious impact on harvests, causing periods of famine, which in turn caused terrible epidemics. These food crises, followed by epidemic outbreaks, had a strong effect on morbidity and mortality (Lachiver, 1991; Flandrin, 1996a and b). They could explain the recurrence of stress episodes experienced by the inhabitants of La Ciotat and materialized in LEH. More than 60% of the people buried in the Saint-Jacques cemetery display these defects (Figure 3).

However, by the 19th century, the subsistence economy gradually disappeared in favor of a market economy. With the onset of global commerce, promoted by the transport revolution (steam navigation, extensive railway networks) and agricultural advances, these periods of shortage tended to end (Flandrin, 1996c; Daumalin and Raveux, 2001; Bertrand, 2012). Other factors may explain the predominance of LEH and their increasing frequencies. Among them, the social and financial status of the population must certainly be taken into account. Despite the shift towards a market economy, both populations under study mostly came from the lowest or modest classes, who may have not had the financial means to flourish yet and did not benefit from the positive effects of the growing economy.

5.2. The Industrial Revolution and technical progress

5.2.1. Introduction and consumption of new products

The synchronized changes in dental caries and dental wear chronologically coincide with the early to mid-19th century, the take-off of the Industrial Revolution in Marseille. This period was marked by important changes in everyday diet (Figure 4). With the development of more modern transports and world trade, new foodstuffs were introduced and distributed on a large scale, especially overseas products rich in carbohydrates, such as potatoes or refined sugar (Flandrin, 1996c). While potatoes would only become popular in central and northern Europe (Flandrin, 1996c), refined sugar had a different fate worldwide and particularly in southeastern France. Sugar derived from the transformation of sugar cane, imported from the West Indies, appeared in France during the 17th century, but remained an expensive commodity, reserved for the highest spheres (Flandrin, 1996b). Until the 1830s, its consumption remained quite limited (Huetz de Lemps, 1996; Daumalin and Raveux, 2001). However, thanks to the transformation of beetroots, progressively produced in greater amounts and increasingly popular in northern France, the price of refined sugar decreased drastically. Marseille became the largest sugar cane warehouse and refineries multiplied: sugar was no longer a luxury product, progressively freeing the offer and demand (Daumalin and Raveux, 2001). In France, in only 70 years, sugar consumption exploded: from 1.2 kg per individual in 1815 to 12 kg in 1894 (Flandrin, 1996c).

Over the long term, starch slightly decreases buccal acidity. Its regular consumption favors the development of carious lesions, leading to moderate prevalence (Hillson, 1996), as obtained at La Ciotat. However, sugar leads to a dramatic drop of the oral pH, but not necessarily over a long time. Hence, the combination of both types of food (starch and sugar), could explain the considerable rise in the prevalence of caries (Hillson, 1996) observed in the Marseille sample. Such an increase in caries from the 18th century has been documented across all of Europe and is associated with the advent of sugar (Müller and Hussein 2017).

Finally, one last overseas product must have had great consequences on dental health: tobacco. At first, the prerogative of men, it was consumed in particular through the pipe. Its success, from the second half of the 19th century onwards, was due to a new medium: the cigarette, dating back to 1830 and gradually spreading to all levels of society including women (Nourrisson, 1988; 2010). Throughout the 19th century, tobacco consumption exploded, rising from 9000 tons in 1815 to 48000 tons in 1914 (Nourrisson, 1988). Smoking increases the risk of certain oral pathologies, particularly caries, periodontitis and abscesses (de Araùjo Nobre and Malo, 2017). The increase of tooth decay and to a lesser extent of periodontitis coincided with the expansion of cigarette smoking and, more generally, with tobacco consumption in France (Figure 4; Table 4).

5.2.2. New production techniques

Alongside the introduction of new dietary products, industrialization innovated with new techniques for food production, especially in refineries and flour mills. As a result, food and more specifically flour were more refined, producing a less abrasive food and influencing the rate of dental wear. In Marseille, the technological modernization of grain milling occurred between 1830 and 1848 (Daumalin and Raveux, 2004). This period seems to match the decrease of dental wear documented in the studied samples (Figure 4). These new food processing techniques marked the end of the regularly observed competition between

dental wear and caries (Hillson, 2001). Indeed, heavy wear obliterates morphological irregularities on posterior teeth and erases early lesions as the tooth crown is progressively destroyed. Moreover, hard food is a protective and cleansing asset through attrition and the stimulation of saliva production (Corbett and Moore, 1976). In Provençal samples, the progressive decrease of dental wear may have played a part in the gradually rising prevalence of dental caries, in the decreasing severity of these lesions and also in the type of lesion itself (Figure 4). Indeed, data show a shift in the initiation site: a relative regression of lesions located around the tooth cervix, in favor of those developing on the crown. This gradual change over time has already been observed elsewhere (Corbett and Moore, 1976; Hillson, 2001; Müller and Hussein, 2017). Cervix area lesions are mainly characteristic of older periods, when tooth wear was still high. In populations where wear is less intense, caries more likely initiate in occlusal fissures and in interproximal contact areas (Figure 4).

Such patterns of caries and dental wear have already been identified in England in a similar time frame (Corbett et Moore, 1976), where this transition was initiated at the end of Middle Ages, asserted during the 17th century and intensified during the 19th century.

5.3. Industrial Revolution: evolution of curative and social practices

5.3.1. Dental health and hygiene practices

From the 18th century, dentistry witnessed many medical improvements (David, 2010). However, the high rate of carious lesions may also indicate limited dental hygiene. Furthermore, no evidence of dental treatment was found in both sites, in contrast to other contemporary contexts (Valentin and Granat, 1997; Molleson and Cox, 1993; Cox, 1996; Miles et al., 2008). In those cemeteries, prostheses, dentures, or fillings sometimes made of expensive materials have been discovered. The social composition of samples under study may likely explain this absence: the relatively modest populations buried in the Saint-Jacques and Les Crottes cemeteries had probably little access to this type of sophisticated care.

In both series, AMTL are the only element suggesting dental care. In ancient populations, caries and wear were the major causes for tooth loss (Lukacs, 1995). Considering the high prevalence of caries and the low wear rate observed in the studied samples, tooth loss might be mainly related to carious lesions. Besides, severe caries are rare and AMTL were also observed on young individuals (Figure 3). Most serious lesions could have led to tooth extractions for therapeutic purposes given that caries unlikely cause a spontaneous tooth loss (Hillson, 2019). Tooth removal could therefore have been seen as the only effective and affordable dental pathology treatment.

5.3.2. New feeding practices for young infants

During the 19th century, women started to work outside the domestic sphere more often and this called for new arrangements, such as the increased need of nurses for the youngest children and babies. Initially reserved for the elites of the 17th and 18th centuries, the employment of child nurses became a common practice and gradually spread to the lowest social categories (Rollet, 1978; Gaillard, 1981; Fildes, 1987; Cox, 1996). Wet nurses were quite expensive and it is more likely that in the working-class environment of Provence, dry nurses were privileged (Gaillard, 1981). Moreover, breastfeeding declined across Europe either as a fad or out of necessity (Riordan and Countryman, 1980). This phenomenon could generate a new kind of systemic stress as it would demand artificial feeding and early weaning.

Artificial breastfeeding was being developed and recipes varied from one mother/nurse to another. They may have been largely unsuitable for infant feeding: often a mixture of groats and animal milk (Rollet, 1978; Riordan and Countryman, 1980; Cox, 1996). In Marseille, sweet bread soup seems to be preferred, replacing milk, often adulterated in this region where it is not produced (Gaillard, 1981).

Those practices might have created early biological stress as the artificial “milk” or weaning food (that is mainly water and flour) did not meet the nutritional needs of infants. This could be one of the recurrent childhood stressors during the 19th century, illustrated by the increase of both frequencies in LEH and in individually-experienced stress episodes (Figure 5). Starch-rich weaning food and artificial “milk” (Cox, 1996; Sorcinelli, 1996) provide many calories, but few of the essential elements for infant survival (proteins, vitamins, calcium, minerals) and therefore would cause nutritional defects. Moreover, hand feeding was spreading while at the same time sterilization and pasteurization, supposed to eliminate the pathogens responsible for many deaths, were neither mastered nor generalized and caused serious health issues (Rollet, 1978; Riordan and Countryman, 1980; Cox, 1996).

Moreover, the mean age at weaning seemed to decrease in Provence and generally across Europe (Rollet, 1978; Gaillard, 1981). The development of LEH has often been related to stress occurring during the weaning process (Moggi-Cecchi et al., 1994). In the Provençal assemblages, early weaning or artificial breastfeeding could partly explain the shift seen in the age at which episodic stress events appear (Lewis, 2002a). Indeed, LEH formed between 6 months and 3 years were more frequent in the 19th century assemblage (24 %) compared to the *Ancien Régime* one (18.7%; Figure 5).

Furthermore, an early introduction of carbohydrate-rich cereals or starchy food easily explains the high prevalence of caries on deciduous teeth and the increasing prevalence among the youngest children in the population of the *Cimetière des Crottes* (Table 4; Figure 3).

Finally, artificial breastfeeding could deprive the newborn of colostrum, rich in vitamin A and important for developing immune protection especially against infectious diseases (Rollet, 1978; Cox, 1996; Sorcinelli, 1996).

5.4.Industrial Revolution: evolution of the infectious environment

In this general context of malnutrition, which seems to initiate early in the studied population (from early childhood), metabolic /deficiency or infectious diseases could easily spread (Sorcinelli, 1996). Infectious diseases and epidemic outbreaks, particularly prevalent in the modern periods, are a main cause of death (Harrison, 2004). Until the mid-19th century, Marseille was still marked by a high infant mortality rate and infectious diseases accounted for at least 30 % of the deaths of the entire population (Aubert, 1993; Mafart and Morillon, 1998). Children are especially vulnerable to this infectious context. The high prevalence of hypoplasia could be indirect evidence for systemic stress caused by infectious diseases. Indeed, infections remain a key factor for the development of LEH (Goodman and Rose, 1990; Hillson, 1996; 2019; Lewis, 2017) and the general environment, witnessing massive urban and commercial growth, could have favored their development and spread.

5.4.1. Urbanization

Both populations come from urban contexts. In La Ciotat, urban development appeared quite rapidly at the beginning of the 16th century, but before the end of the 18th century the city declined soon after its apogee,

and the population fell drastically (Reboul, 1934; Deidier and Susini, 1957; Deidier, 1965) (Reboul, 1934; Deidier and Susini, 1957; Deidier, 1965; Castrucci, 2017). In this context, urbanization could then have had a limited or short-term effect on morbidity or mortality. Moreover, studies by Lewis (2002a and b) tend to minimize the influence of urbanization on health before the industrial period in England.

However, the development of cities and their transformation during the Industrial Revolution could have had a huge impact on the infectious environment, through an immense and unprecedented concentration of people in urban centers. Such a situation would favor the transmission and spread of pathogens. The city of Marseille experienced significant demographic growth, due to rural exodus and immigration (Gaillard, 1981; Temime, 1999; Dell'Umbria, 2006; Daumalin and Guillon, 2012). Although rapid, urban development was slower than the pace of the massive influx of new people, leading to overcrowded houses in the old town and to the hasty creation of new districts on the outskirts, built without any consideration for hygiene (Gaillard, 1981). The infrastructure, especially for the water supply and drainage, could barely cope with such an expansion (Gaillard, 1981; Mafart and Morillon, 1998). This urbanization, of an unprecedented scale in History, certainly played a role in the frequency of epidemics (Mafart and Morillon, 1998) and in the increased prevalence of LEH.

5.4.2. Globalization

In urban centers international trade expanded exponentially with the Industrial Revolution. While the success of La Ciotat, during the 17th century relied on its commercial exchanges with other Mediterranean cities (Reboul, 1934; Deidier and Susini, 1957; Deidier, 1965), the expansion of colonial empires and the development of means of transport, during the 19th century, opened a new and significant perspective for a globalized and massive trade. National and international exchanges intensified in Marseille (Daumalin and Raveux, 2004) : the flow of goods, but also of people, carriers of diseases, was more fluid, therefore stimulating the spread of pathogens.

The city faced the arrival of new diseases, such as cholera, which broke out in 1834 and became almost endemic in between periodical and regular massive epidemics (Mafart and Morillon, 1998). However, cholera was not the only epidemic disease present: there were also smallpox (which was also endemic), typhus, typhoid fever, influenza, diphtheria and measles (Mafart and Morillon, 1998), as well as residual diseases such as tuberculosis.

This specific context would promote both the apparition of new pathogens and their transmission, which could explain the rising frequencies of LEH, revealing increased childhood stress. It could also account for the increased number of periods of biological stress experienced during the industrial transition for those individuals who had reached adulthood. Finally, the virulence of these epidemic diseases could also explain the lower survival rate of children under 4 years old in *Les Crottes*, who died before hypoplastic lines formed (Figure 5). Even though the first campaigns of vaccination against smallpox took place in Marseille in 1801, it was incomplete and would have had very little effect on morbidity and mortality (Aubert, 1993; Mafart and Morillon, 1998).

6. CONCLUSION

This study presents a first set of references to characterize the post-medieval health status of French populations. Large and significant differences between the early and late modern samples were expected

and were supposed to highlight the changes occurring during the Industrial transition. However, health was also characterized by common features in both populations. The observed differences were less obvious than originally presumed and concerned mostly dental decay, dental wear and hypoplasia. Results rather display a continuity of dental health features than a sharp break. Moreover, the specific characteristics of the health status observed were first established during the early modern period and only exacerbated during late modern times. In the light of these new results and concerning the secular changes of health in Provence, it would seem more relevant to refer to an industrial transition, rather than an Industrial Revolution.

Technical and medical progress, social changes, public and sanitation policies set during the 19th century are often considered one of the main factors improving living conditions. However, this study shows that far from improving, health seemed to deteriorate in southeastern France. Indeed, large hygienist investment might first benefit to the upper classes of the society. Moreover, long debated, health and hygiene measures would effectively be introduced and enforced only at the end of the 19th century, having real and large consequences only from the beginning of the 20th century onwards.

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References

Adalian, P., Piercecchi-Marti, M.-D., Bourliere-Najean, B., Panuel, M., Leonetti, G., Dutour, O., 2002. Nouvelle formule de détermination de l'âge d'un fœtus. *CR Biol.* 325(3), 261-269.

de Araújo Nobre, M., Malo P., 2017. Prevalence of periodontitis, dental caries, and peri-implant pathology and their relation with systemic status and smoking habits: Results of an open-cohort study with 22009 patients in a private rehabilitation center. *J Dent.* 67, 36-42.

Aubert, M., 1993. La médecine à Marseille au XIX^e siècle. *Provence Historique.* 172, 185-206.

Bertrand, R., 2012. Histoire d'une ville : Marseille. CNDP-CRDP, Marseille.

Bocquentin, F., 2003. Pratiques funéraires, paramètres biologiques et identités culturelles au Natoufien : une analyse archéo-anthropologique. Doctoral dissertation. Université de Bordeaux 1.

Brothwell, D.R., 1981. *Digging up Bones: The excavation, treatment, and study of human skeletal remains.* Cornell University Press, New York.

Bruzek, J., 2002. A method for visual determination of sex, using the human hip bone. *Am J Phys Anthropol.* 117(2), 157-168.

Castrucci, C., 2017. Les habitats du faubourg et les maisons à double affectation. In: VASSELIN, B. (Ed.). La Ciotat, de Citharista aux chantiers navals. Histoire et archéologie. Aurorae Libri, Valensole, pp.111-115.

Corbett, M.E., Moore, W.J., 1976. Distribution of dental caries in ancient British populations. IV- The 19th century. Caries Res. 10(6), 401-414.

Cox, M., 1996. Life and death at Spitalfields, 1700-1850. Council for British Archaeology, York.

Daumalin, X., Guillon, J.-M., 2012. La grande mutation 1815-1870. In: Bertrand, R. (Ed.). Histoire d'une ville : Marseille. CNDP-CRDP, Marseille, pp.155-181.

Daumalin, X., Raveux, O., 2001. Marseille (1831-1865). Une révolution industrielle entre Europe du Nord et Méditerranée. Annales. Histoire, Sciences Sociales. 56(1), 153-176.

Daumalin, X., Raveux, O., 2004. Les difficiles débuts de la minoterie à vapeur à Marseille (1779-1835) : Blocage technologique ou problème de marché ? In: Autour de l'industrie. Histoire et patrimoine. Mélanges offerts à Denis Woronoff. Comité pour l'histoire économique et financière de la France, Paris, pp.473-488.

David, C., 2010. Hygiène bucco-dentaire du XVII^e au XIX^e siècle en France. L'Harmattan, Paris.

Deidier, M., 1965. Histoire de La Ciotat : Des origines à nos jours. Imprimerie du Vieux Moulin, La Ciotat.

Deidier, M., Susini, L. 1957. Le terroir de La Ciotat. Sa géographie et son histoire. Imprimerie Nouvelle Aubagne, Aubagne.

Dell'Umbria, A., 2006. Histoire universelle de Marseille: De l'an mil à l'an deux mille. Agone, Marseille.

Dias, G., Tayles, N., 1997. 'Abscess cavity'-a misnomer. Int J Osteoarchaeol. 7(5), 548-554.

Fildes, V., 1987. Breasts, bottles and babies: A history of infant feeding. Edinburgh University Press, Edinburgh.

Flandrin, J.-L., 1996a. L'alimentation paysanne en économie de subsistance In: Flandrin, J.-L., Montanari, M. (Eds.). Histoire de l'alimentation. Fayard, Paris, pp.597-627.

Flandrin, J.-L., 1996b. Les temps modernes. In: Flandrin, J.-L., Montanari, M. (Eds.). Histoire de l'alimentation. Fayard, Paris, pp.549-575.

Flandrin, J.-L., 1996c. Les XIX^e et XX^e siècles. In: Flandrin, J.-L., Montanari, M. (Eds.). Histoire de l'alimentation. Fayard, Paris, pp.717-723.

Gaillard, L., 1981. La Vie quotidienne des ouvriers provençaux au XIX^e siècle. Hachette, Paris.

Goodman, A.H., Rose, J.C., 1990. Assessment of systemic physiological perturbations from dental enamel hypoplasias and associated histological structures. Am J Phys Anthropol. 33(11), 59-110.

Goodman, A.H., Armelagos, G.J., Rose, J.C., 1984. The chronological distribution of enamel hypoplasias from prehistoric Dickson Mounds populations. *Am J Phys Anthropol.* 65(3), 259-266.

Goodman, A.H., Brooke-Thomas, R., Swedlund, A.C., Armelagos, G.J., 1988. Biocultural perspectives on stress in prehistoric, historical, and contemporary population research. *Am J Phys Anthropol.* 31(9), 169-202.

Goodman, A.H., Martinez, C., Chavez, A., 1991. Nutritional supplementation and the development of linear enamel hypoplasias in children from Tezonteopan, Mexico. *Am J Clin Nutr.* 53, 773-781.

Harrison, M., 2004. *Disease and the Modern World: 1500 to the Present Day.* Polity Press, Cambridge.

Hillson, S., 1996. *Dental Anthropology.* University Press of Cambridge, Cambridge.

Hillson, S., 2001. Recording dental caries in archaeological human remains. *Int J Osteoarcheol,* 11(4), 249-289.

Hillson, S., 2019. *Dental Pathology.* In: Katzenberg, M.A., Grauer, A. L. (Eds.). *Biological anthropology of the human skeleton*, third edition. Wiley Blackwell, Hoboken.

Huetz De Lempis, A., 1996. Boissons coloniales et essor du sucre. In: Flandrin, J.-L., Montanari, M. (Eds.). *Histoire de l'alimentation.* Fayard, Paris, pp.629-641.

Irish, J.D., Scott, G.R., 2016. *A Companion to dental anthropology.* Wiley Blackwell, Chichester.

Lachiver, M., 1991. *Les années de misère: La famine au temps du Grand Roi.* Fayard, Paris.

Lewis, M.E., 2002a. Impact of industrialization: Comparative study of child health in four sites from Medieval and Postmedieval England (A.D. 850-1859). *Am J Phys Anthropol.* 119(3), 211-223.

Lewis, M.E., 2002b. Urbanisation and child health in medieval and post-medieval England an assessment of the morbidity and mortality of non-adult skeletons from the cemeteries of two urban and two rural sites in England (AD 850-1859). *BAR,* Oxford.

Lewis, M.E., 2017. *Paleopathology of children.* Academic Press, London.

Lovejoy, C.O., Meindl, R.S., Pryzbeck, T.R., Mensforth, R.P., 1985. Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age at death. *Am J Phys Anthropol.* 68(1), 15-28.

Lukacs, J.R., 1995. The 'caries correction factor': A new method of calibrating dental caries rates to compensate for antemortem loss of teeth. *Int J Osteoarcheol.* 5(2), 151-156.

Lukacs, J.R., 2008. Fertility and Agriculture Accentuate Sex Differences in Dental Caries Rates. *Curr Anthropol.* 45(5), 901-914.

Mafart, B., Morillon, M., 1998. Les épidémies à Marseille au XIX^e siècle. *BMSAP.* 10(1), 81-98.

Maresh, M.M., 1970. Measurements from roentgenograms, heart size, long bone lengths, bone, muscles and fat widths, skeletal maturation. In: MCCAMMON, R. (Ed.). Human growth and development. Charles C. Thomas Publisher, Springfield, pp.155-200.

Miles, A., Powers, N., Wroe-Brown, R., Walker, D., Roberts, C., 2008. St Marylebone Church and Burial Ground in the 18th to 19th centuries: Excavations at St Marylebone School 1992 and 2004-6. MoLAS Monograph, London.

Molleson, T., Cox, M., 1993. The Spitalfields Project. Volume 2, The anthropology. The middling sort. CBA, London.

Moggi-Cecchi, J., Pacciani, E., Pinto-Cisternas, J., 1994. Enamel hypoplasia and age at weaning in 19th century Florence, Italy. *Am J Phys Anthropol.* 93(3), 299-306.

Morineau, M., 1996. Croître sans savoir pourquoi: structures de production, démographie et rations alimentaires. In: Flandrin, J.-L., Montanari, M. (Eds.). Histoire de l'alimentation. Fayard, Paris, pp.577-595.

Moorrees, C.F.A., Fanning, E.A., Hunt E.E., 1963a. Formation and resorption of three deciduous teeth in children. *Am J Phys Anthropol.* 21(2), 205-213.

Moorrees, C.F.A., Fanning, E.A., Hunt E.E., 1963b. Age variation of formation stages for ten permanent teeth. *J Dent Res.* 42(6), 1490-1502.

Müller, A., Hussein, K., 2017. Meta-analysis of teeth from European populations before and after the 18th century reveals a shift towards increased prevalence of caries and tooth loss. *Arch Oral Biol.* 73, 7-15.

Murail, P., Bruzek, J., Braga, J., 1999. A new approach to sexual diagnosis in past populations. Practical adjustments from Van Vark's procedure. *Int J Osteoarchaeol*, 9(1), 39-53.

Murail, P., Bruzek, J., Houët, F., Cunha, E., 2005. DSP: A tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. *BMSAP.* 17(3-4), 167-176.

Nourrisson, D., 1988. Tabagisme et antitabagisme en France au XIX^e siècle. *Histoire, Économie et Société.* 7(4), 535-547.

Nourrisson, D., 2010. Cigarette: histoire d'une allumeuse. Payot, Paris.

Perrin, M., 2019. État sanitaire entre Ancien Régime et révolution industrielle: Étude paléoépidémiologique de deux populations provençales, interactions bio-culturelles. Doctoral dissertation. Université Aix-Marseille.

Perrin, M., 2021. État sanitaire entre Ancien Régime et révolution industrielle: Étude paléoépidémiologique de deux populations provençales. BAR International Series, Oxford.

Powell, M.L., 1985. The analysis of dental wear and caries for dietary reconstruction. In: Gilbert, R.I., Mielke, J.H. (Eds.). The analysis of prehistoric diet. Academic Press, Orlando.

Reboul, C., 1934. La Ciotat: Essai de géographie urbaine. Mémoire de diplôme d'étude supérieure d'Histoire et Géographie. Université d'Aix-en-Provence.

Richier, A., 2011. Bouches-du-Rhône, La Ciotat. Carré Saint-Jacques: L'îlot Saint-Jacques, du vignoble champêtre au cimetière paroissial. Rapport final d'opération préventive. Inrap Méditerranée, SRA PACA.

Richier, A., Weydert, N., 2016. Bouches-du-Rhône, Marseille, prolongement de la ligne 2 du métro de Bougainville vers Capitaine Gèze - 72 avenue Félix Zoccola. Ancien cimetière des Crottes. Rapport final d'opération préventive. Inrap Méditerranée, SRA PACA, Nîmes.

Riordan, J., Countryman, B.A., 1980. Basics of breastfeeding. Part I: Infant feeding patterns past and present. *JOGN Nurs.* 9(4), 207-210.

Rollet, C., 1978. Allaitement, mise en nourrice et mortalité infantile en France à la fin du XIX^e siècle. *Population.* 33(6), 1186-1203.

Rose, J.C., Armelagos, G.J., Lallo, J.W., 1978. Histological enamel indicators of childhood stress in prehistoric skeletal samples. *Am J Phys Anthropol.* 49(4), 511-516.

Scheuer, L., Black, S., 2000. *Developmental juvenile osteology.* Academic Press, New York.

Schmitt, A., 2005. Une nouvelle méthode pour estimer l'âge au décès des adultes à partir de la surface sacro-pelvienne iliaque. *BMSAP.* 17(1-2), 89-101.

Schmitt, A., 2008. Une nouvelle méthode pour discriminer les individus décédés avant ou après 40 ans à partir de la symphyse pubienne. *Journal de La Médecine Légale, Droit Médical.* 51(1), 15-24.

Smith, B.H., 1984. Patterns of molar wear in hunger-gatherers and agriculturalists. *Am J Phys Anthropol.* 63(1), 39-56.

Sorcinelli, P., 1996. L'alimentation et la santé. In: Flandrin, J.-L., Montanari, M. (Eds.). *Histoire de l'alimentation.* Fayard, Paris, pp.809-822.

Temime, E., 1999. *Histoire de Marseille de la révolution à nos jours.* Perrin, Paris.

Ubelaker, D.H., 1987. Estimating age at death from immature human skeletons: An overview. *J Forensic Sci.* 32(5), 1254-1263.

Valentin, F., Granat, J., 1997. Anthropologie, pathologie et soins dentaires au XVIII^e siècle: Découverte exceptionnelle à Saint-Martin-des-Champs de Paris. *BMSAP.* 9(3), 305-318.

Veschi, S., Facchini, F., 2002. Recherches sur la collection d'enfants et d'adolescents d'âge et de sexe connus de Bologne (Italie): Diagnose de l'âge sur la base du degré de maturation osseuse. *BMSAP.* 14(3-4), 263-294.

Waldron, T., 1994. *Counting the dead, the epidemiology of skeletal populations.* Jon Wiley & Sons, Chichester.

Waldron, T., 2007. Palaeoepidemiology: The measure of disease in the human past. Left Coast Press, Walnut Creek.