Lifestyle on the south coast of Brazil: considerations about shell mound (*sambaqui*) builders through bone and dental analysis

Estilo de vida no litoral sul do Brasil: considerações sobre os construtores de sambaquis por meio das análises ósseas e dentárias

Marina Di Giusto

Universidade de São Paulo. Museu de Arqueologia e Etnologia. São Paulo, São Paulo, Brasil

Abstract: *Sambaquis* are a specific type of archaeological site found on the Brazilian coast that contain a large number of human burials and were constructed by progressively and intentionally accumulating shells and fish bones. Brazilian archaeologists have suggested that these groups comprised a stable system during their occupation of the coast, especially on the southern coast of Santa Catarina state. This study investigates whether the cultural continuity and stability in this region are also reflected in markers of physiological stress visible in bones and teeth, looking for three non-specific stress markers (porotic hyperostosis, cribra orbitalia, and linear enamel hypoplasia) in human skeletal remains from two *sambaquis* (Cabeçuda, n = 77 and Jabuticabeira II, n = 55, c. 3,200-1,500 years BP). The resulting data indicate that the individuals buried in these *sambaquis* were constantly exposed to stressful events during childhood, but physiological stress patterns changed over time, signaling biocultural variability among the groups despite similar material cultures and constructive aspects.

Keywords: Shell mounds. Bioarchaeology. Lifestyle. Non-specific stress markers.

Resumo: Sambaqui é um tipo particular de sítio arqueológico encontrado na costa brasileira que contém um grande número de sepultamentos humanos, construídos através do acúmulo progressivo e intencional de conchas e ossos de peixes. Pesquisas arqueológicas sugeriram que esses grupos constituíram um sistema estável durante a ocupação do litoral, especialmente no litoral sul do estado de Santa Catarina, Brasil. O objetivo deste estudo é testar a hipótese de que a continuidade e a estabilidade cultural nessa região também se refletiriam no estresse fisiológico dos ossos e dentes. A autora analisou três marcadores de estresse não específicos, hiperostose porótica (HP), cribra orbitalia (CO) e hipoplasia linear do esmalte (HLE) em remanescentes esqueléticos humanos de dois sambaquis, Cabeçuda (n = 77) e Jabuticabeira II (n = 55) (c. 3.200-1.500 anos AP). Os dados apontam que os indivíduos de Cabeçuda e Jabuticabeira II estavam constantemente expostos a eventos de estresse durante a infância, porém com mudanças nos padrões de estresse fisiológico ao longo do tempo, sinalizando variabilidade biocultural entre os grupos, ainda que sua cultura material e aspectos construtivos sejam semelhantes.

Palavras-chave: Sambaqui. Bioarqueologia. Estilo de vida. Marcadores de estresse não específicos.

Di Giusto, M. (2023). Lifestyle on the south coast of Brazil: considerations about shell mound (*sambaqui*) builders through bone and dental analysis.. *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas, 18*(1), e20210064. doi: 10.1590/2178-2547-BGOELDI-2021-0064
Autora para correspondência: Marina Di Giusto. Universidade de São Paulo. Museu de Arqueologia e Etnologia. Av. Prof. Almeida Prado, 1466. São Paulo, SP, Brasil. CEP 05508-070 (marina.giusto@yahoo.com.br).
Recebido em 26/06/2021
Aprovado em 19/01/2022
Responsabilidade editorial: Cristiana Barreto

Sambaquis are shellmounds situated along the Brazilian coast, intentionally constructed by fisher-hunter-gatherer groups through the long-term accumulation of shells, fish bones and sediments, interspersed in a complex stratigraphy, with a material culture that includes burials, lithic and bone artifacts, hearths, and food waste. They are one of the most numerous and well-documented Brazilian sites, with a great density of archaeological datas that allow important inferences about the lifestyle of their builders. There exists substantial variability in the dimension of sambaquis, with some of them reaching impressive proportions of more than 30 m in height. These are located mainly in the state of Santa Catarina (southern Brazil) and appear to have functioned exclusively as cemeteries, without evidence of daily activities (DeBlasis et al., 2007; Fish et al., 2013; Gaspar et al., 2014).

Most coastal sambaquis are located in bays, estuaries, lagoons, and mangroves, that constitute a range of environments or ecological zones with high and diverse biotic productivity (Lima, 1999-2000; Gaspar et al., 2008, 2014). The southern coast of the state of Santa Catarina is an ecotonal zone characterized by the meeting of Atlantic Forest, restinga vegetation, mangroves, lagoons, and Atlantic Ocean marine environments. It is thus a region with a vast and varied availability of resources (Scheel-Ybert et al., 2003; Kneip, 2004) that perhaps facilitated human settlement. Currently, it is known that sambaqui people had a broad dietary spectrum, based on marine protein, but which also incorporated terrestrial protein and a diversity of plants (Figuti, 1993; Masi, 2001; Wesolowski et al., 2007; Scheel-Ybert, 2013; Boyadjian et al., 2016; Pezo-Lanfranco, 2018).

The high concentration of sambaquis on the southern coast of Santa Catarina state, active for thousands of years, with large dimensions, high burial density, similar building patterns, and similar bone and lithic industries, suggest that these people would constitute a complex and long-lasting social system, with an economic, social, and political stability over these years of permanence in the coast (DeBlasis & Gaspar, 2009; Fish et al., 2013; Kneip et al., 2018; DeBlasis et al., 2021). Taking as a case study this region of interest, the present research studied the human remains from two large and important sambaquis in the region: Cabeçuda and Jabuticabeira II.

Sambaqui Cabeçuda (UTM 712601-6852170) is located in the town of Laguna, Santa Catarina State (Figure 1) and is dated between 3,235 and 1,510 cal. years before present (BP) (Saladino, 2016). The site is reputed one of the largest sambaquis in Brazil, and measured 100 m in diameter and 20 m in height before its partial destruction during the 19th and 20th centuries (Rohr, 1984; Saladino, 2016). The first excavations in Cabeçuda were in 1950/1951 and more than 200 individuals were exhumed (Souza, 1995; Klökler, 2014), which constituted one of the largest and most important human skeletal archaeological collections in Brazil, and were housed in the National Museum of the Federal University of Rio de Janeiro (MN/UFRJ). The last archaeological excavation in Cabeçuda was in 2012, and the 20 individuals exhumed then are housed at Universidade do Sul de Santa Catarina (UNISUL) (Farias & Deblasis, 2014; Silva, 2020), in Tubarão, Santa Catarina State.

Sambaqui Jabuticabeira II (UTM 699489-6835694), Santa Catarina State, is located in the town of Jaguaruna (Figure 1) and dates between 2,851 and 1,534 cal. years BP (Klökler, 2008). It is considered a medium-sized sambaqui, measuring 200 m wide and 6 m high (Fish et al., 2000). It is one of the most-studied sambaquis in Brazil, with its first archaeological excavation taking place in the late 1990s. There are currently at least 90 individuals housed in the Museum of Archaeology and Ethnology at the University of São Paulo (MAE/USP).

Research at Jabuticabeira II was essential for reformulating the meaning of the largest sambaquis of the southern coast of Santa Catarina. Its construction continued uninterrupted for hundreds of years and its function was strictly oriented to funeral activities (DeBlasis & Gaspar, 2009). Klökler (2008) points out that faunal remains, especially fish, played an integral role in feasts performed to honor the dead.

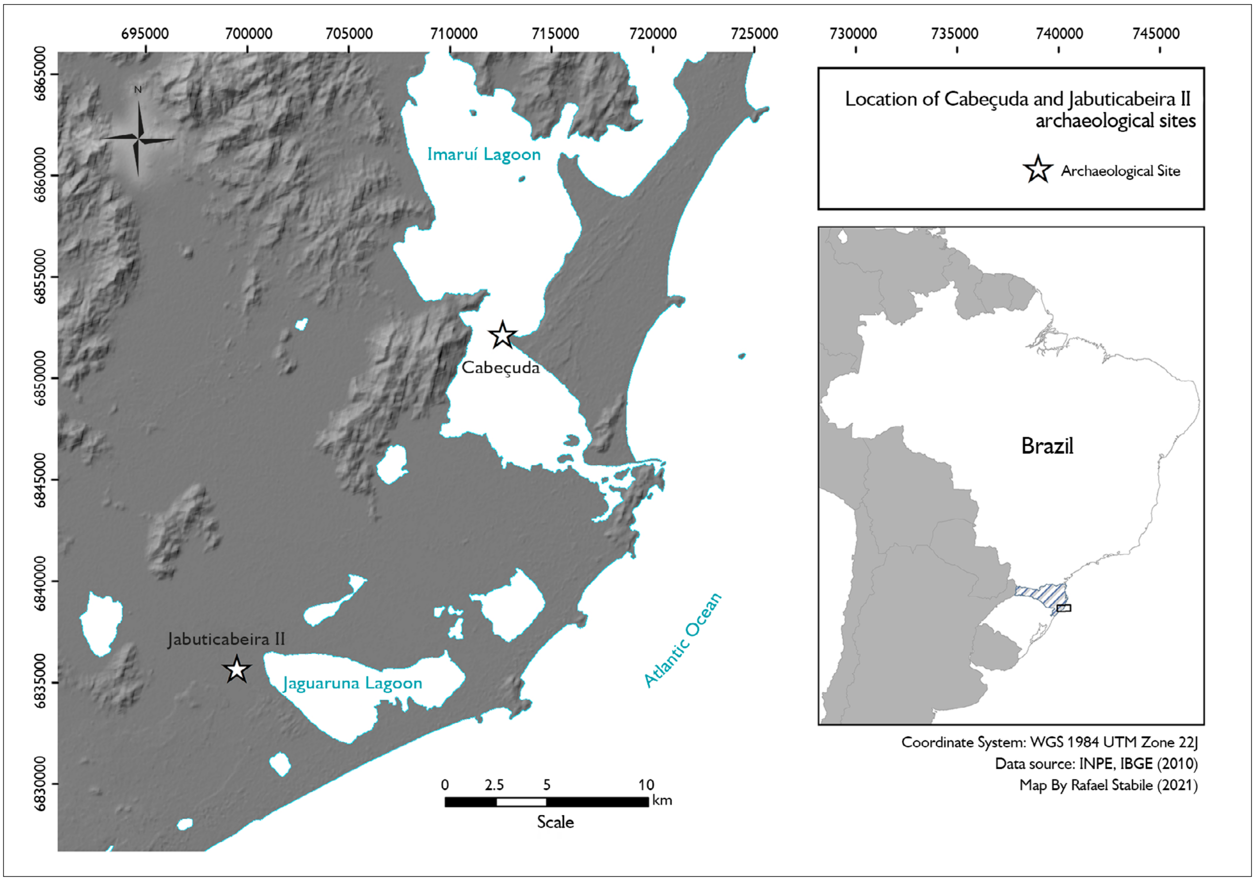

Figure 1. Location of the sambaquis Cabeçuda and Jabuticabeira II. Map: Rafael Stabile (2021).

An important feature of Jabuticabeira II is the presence of a dark sediment layer covering the conchiferous layers across the whole site. This dark layer, also described as *fishmound* (Villagran, 2013), is composed primarily of fish bones and sediments rich in charcoal and organic materials (DeBlasis et al., 2007; Villagran, 2013).

Both Jabuticabeira II and Cabeçuda are cemeteries, and systematic archaeological excavations observed variability in relation to burial practices that could indicate different moments of occupation. In Jabuticabeira II, there are visible changes in the site construction layers (shellmound vs. fishmound), with the presence of pottery in the latest one. During excavations of Cabeçuda during the 1950's, were identified two distinct contexts with higher burial density and different funerary characteristics: one group of burials located between 2 and 3 meters deep and another group between 6 and 8 meters deep, which could indicate different moments of occupation with potentially different morbidity and mortality realities (Souza, 1995). During the last archaeological excavation (carried out in 2012) human skeletal remains were exhumed in an area of the site with older dates (between 3,235 and 2,925 cal. BP) that could also be related to another moment of occupation. As Saladino (2016) and Silva (2020) point out, changes related to funerary rituals occurred throughout the construction of Cabeçuda.

Archaeologists usualy argued for the continuity and stability in the lifestyles of the sambaqui builders, as reflected in the homogeneity of various aspects of material culture. According to these studies, these groups could have an egalitarian political organization, sharing the same environment and resources, and recognizing themselves as belonging to the same identitary group (DeBlasis & Gaspar, 2009; Fish et al., 2013; DeBlasis et al., 2021). This paper aims to discuss this hypothesis for the study area through the analysis of physical stress markers (Porotic Hyperostosis, Cribra orbitalia, and Linear Enamel Hypoplasia) in individuals buried in the Cabeçuda and Jabuticabeira II sambaquis.

Applying a biocultural perspective, the research sought to understand the temporal variation of the stress pattern, considering that these are closely related to the lifestyle, culture and environment, as pointed out by Souza (1995) to Cabeçuda sambaqui and Wesolowski (2000) to Rio Comprido and Morro do Ouro sambaquis (northern coast of Santa Catarina).

BIOARCHAEOLOGY AND PHYSIOLOGICAL STRESS MARKERS

Bones and teeth are tissues that responds to chronic physical stress, which allows us to uncover important information about lifestyle and behavior of individuals or populations. Skeletal series from sambaquis have been widely used to investigate various aspects of the lifestyle of these groups, such as physical and labor activities, diet, pathologies, violence, mobility, among others (e.g. Alvim & Gomes, 1989; Souza et al., 2009; Petronilho, 2005; Lessa & Scherer, 2008; Bastos et al., 2014; Colonese et al., 2014, 2015; Boyadjian et al., 2016; Stabile, 2017; Filippini et al., 2019; Pezo-Lanfranco et al., 2020). The use of non-specific stress markers has been a common strategy in Brazilian bioarchaeology and there is important information for several areas of the Brazilian coast that suggests patterns with slight regional variations (e.g., Wesolowski, 2000; Fischer, 2012; DiGiusto, 2017).

Physiological stress markers are observed in bones and teeth and occur when there is an imbalance of the organism resulting from environmental and/or cultural circumstances (Martin et al., 1985; Larsen, 1997). The nonspecific stress markers analyzed in this study are Porotic Hyperostosis (PH), Cribra orbitalia (CO), and Linear Enamel Hypoplasia (LEH).

PH and CO are nonspecific stress markers characterized by macroscopic porous lesions on the outer part of the cranial vault and orbital roof, respectively (Moseley, 1965; El-Najjar et al., 1975; Oxenham & Cavill, 2010). These lesions are formed as a result of bone marrow hypertrophy and the consequent expansion of the trabecular bone of the skull (*diploe*), with thinning of the external cortex (Ortner, 2003).

The pathological process that generates the expansion of the diploe and the porosities was and still is the subject of discussion. Traditionally, PH and CO are related to anemic conditions, whether due to genetic anemias (sickle-cell and thalassemia) or acquired anemias (Moseley, 1965; Angel, 1966; Carlson et al., 1974; El-Najjar et al., 1975), although some studies point out other causes, such as inflammatory processes, subperiosteal hematomas, tumors, nutritional problems or meningitis (Schultz, 2001; Walker et al., 2009).

In general, the bioaqueological literature identifies multiple causes for these conditions (e.g. Wapler et al., 2004; Walker et al., 2009; McIlvaine, 2013), but points to nutritional anemia, such as iron deficiency, as the most likely factor for both PH and CO (El-Najjar et al., 1975; Fairgrieve & Molto, 2000; Steckel et al., 2002; Walker et al., 2009; McIlvaine, 2013).

According to the World Health Organization (WHO), anemia is not a pathology, but a physiological condition that occurs when there is a low amount of red blood cells or a drop in the ability to carry oxygen through the blood (WHO, 2019). Adequate oxygen transportation depends on serum hemoglobin levels in blood which can drop in response to a lack of essential micronutrients (e.g., vitamins B6, B12, and iron) resulting in anemia (Isselbacher, 1994). The hypoxia resulting from low serum hemoglobin levels triggers the release of the erythropoietin hormone that, in a compensatory process, accelerates the production and maturation of red blood cells by the hematopoietic marrow (Isselbacher, 1994; Walker et al., 2009), resulting in the expansion of the diploe. Once the anemic condition is overcome, the diploe returns to its normal state and the porosities heal (Figure 2).

Researchers have excluded the possibility that genetic anemia was present in the American continent before European colonization; therefore, the presence of PH and CO in precolonial skeletal series in America has been interpreted as indicative of anemia by nutritional or infectious processes (Carlson et al., 1974; El-Najjar & Robertson, 1976; Mensforth et al., 1978; Stuart-Macadam, 1985, 1992; Walker, 1986; Blom et al., 2005). Studies with American coastal groups with diets rich in protein and iron, such as sambaqui groups from the Brazilian coast, propose that infections and parasites would be more plausible hypotheses for these conditions (Walker, 1986; Alvim & Gomes, 1989; Alvim et al., 1991; Souza, 1999; Blom et al., 2005; Suby, 2014).

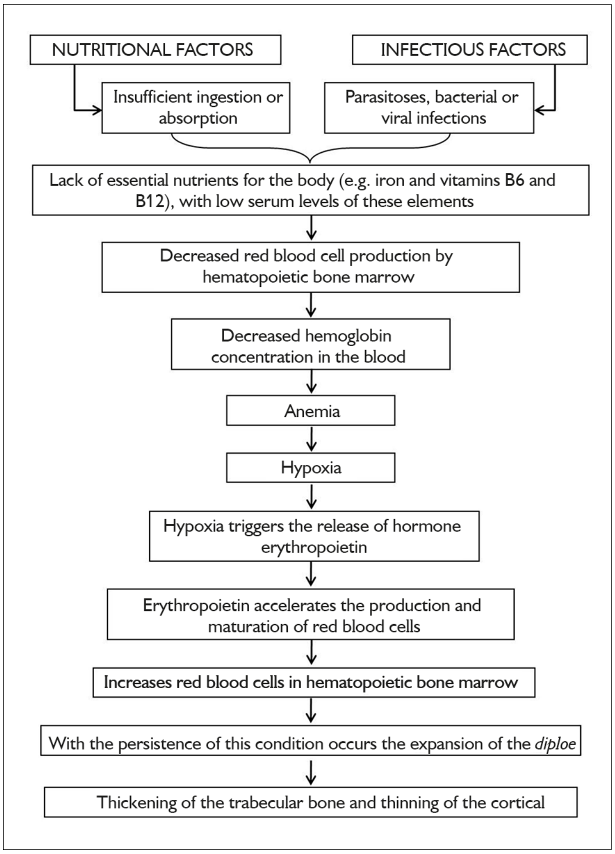

Figure 2. PH and CO development. The figure shows the factors and the organism physiological response that leads to the appearance of the bone characteristics associated with PH and CO.

Enamel hypoplasia is defined as the reduction of enamel thickness and can be caused by the cessation or diminution of ameloblast function during the secretory stage of enamel formation in early life (Goodman et al., 1980; Bocaege & Hillson, 2016; Towle & Irish, 2020). Although there is more than one type of hypoplasia, the focus of this study is on the most studied, linear enamel hypoplasia (LEH). LEH forms when an individual is exposed to physiological stress while tooth crowns are developing and provides a relatively permanent record of the past health of an individual (Goodman et al., 1980) (Figure 3). It is an important indicator of stress because it is possible to establish the chronology or estimate the approximate age of the individual at the time of LEH formation.

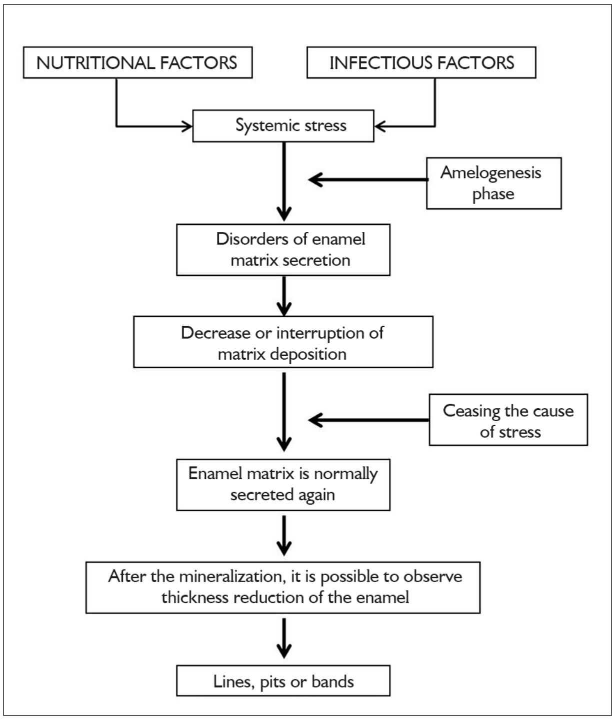

Figure 3. LEH development. The figure shows the factors and the organism physiological response that leads to the appearance of the teeth characteristics associated with LEH.

LEH is a non-specific indicator of stress and can result from dietary deficiencies, metabolic disorders, infectious disease or even intoxication (El-Najjar et al., 1978; Cook & Buikstra, 1979; Larsen & Hutchinson, 1992; Ubelaker, 1992; Primeau et al., 2015). Recent studies seek to better understand possible etiologies for the formation of hypoplasia, including genetic factors (Towle & Irish 2019, 2020). Some paleopathological studies associate the occurrence of systemic LEH with weaning age (Ubelaker, 1992; Wright, 1997).

MATERIAL AND METHODS

Individuals who had retained at least 50% of the right and/or left parietal bones and/or frontal bones were selected for PH analysis. For CO analysis, were selected individuals who had at least 50% of the right and/or left orbitals. When only one orbit was present (left or right), the individual was not considered analyzable if the result for CO was negative, since CO lesions can be unilateral, although often described as bilateral (Ortner, 2003). For LEH analysis, were included individuals who had at least two anterior teeth present (upper and/or lower), with at least 1/3 of the crown fully formed, and with systemic LEH, that is, present in at least two teeth in the same age range. Both adult and subadult individuals were included for all analysis.

Seventy-seven individuals (of a total of 134) were analyzed from Cabeçuda, of whom 56 were analyzed for PH, 29 for CO, 44 for LEH in permanent teeth and 5 for LEH in deciduous teeth. In Jabuticabeira II, 55 individuals were analyzed (of a total of 93), of whom 46 individuals were analyzed for PH, 27 for CO, 32 for LEH in permanent teeth and 11 for LEH in deciduous teeth. Parameters described in Buikstra and Ubelaker (1994) and Schaefer et al. (2009) were used to estimate sex (e.g. cranial and pelvic morphology) and age (e.g. cranial and pelvic morphological changes and dental development). Sex estimative for subadults was undetermined for all of them.

The skeletal series of each site was subdivided according to chronological, stratigraphic and contextual information (for details see DiGiusto, 2017). In this way, the series of Cabeçuda could be reconfigured in three sub-series and the Jabuticabeira II in 2 sub-series (Table 1).

For the physical stress marker, PH and CO were identified by macroscopic observation on the external surface of the parietal bones and the orbit roof, with a 10x magnifying glass. The porosities were classified as active, healed, or healing (Stuart-Macadam, 1985). For LEH analysis, as proposed by Fischer (2012), the teeth were divided in three parts according to dental anatomy and into age groups (based in dental growth published by Primeau et al., 2015) (Figure 4). The division in three parts guided the division between age groups, since the teeth have similar anatomies between individuals. This was important in view of the presence of tooth occlusal wear in sambaquis groups, which makes it difficult (and in some cases, impossible) to locate hypoplasias based on the total size of the crown. For each individual, a schematic drawing was made noting the presence/

Table 1. Skeletal series division and nomenclature, according to chronological, stratigraphic and contextual information. Legends: * = calibrated dates [for Cabeçuda, published in Farias and Deblasis (2014) and Saladino (2016); for Jabuticabeira II, published in Klökler (2008) and Posth et al. (2018)]; ** = number of individuals analyzed in this study.

Sambaqui	Years B.P.*	Number of individuals**	Serie nomenclature for this study
Cabeçuda	1987-1519	57	CB-late
Cabeçuda	2308-2108	11	CB-intermediate
Cabeçuda	3235-2925	9	CB-early
Jabuticabeira II (fishmound)	1864-1080	19	JAB II-late
Jabuticabeira II (shellmound)	2851-1992	36	JAB II-early

absence of each anterior tooth, as well as the presence of dental wear, calculus, and any other element that could interfere with the analysis, making it possible to later calculate LEH prevalence for each age range. LEH was identified by macroscopic observation and tangential illumination with the aid of a small flashlight. The stress marker studied per individual, with their respective sex and age estimates are in the Table 2.

Subsequently, the prevalence of PH, CO, and LEH were submitted to a statistical test (Fischer's Exact Test).

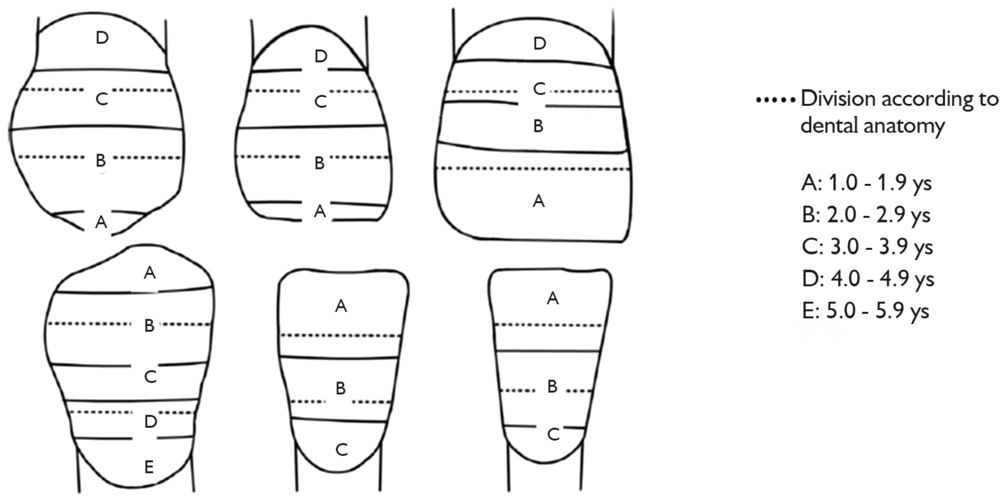

Figure 4. Permanent anterior teeth divided into age groups. Image credit: M. Di Giusto.

Table 2. Individuals analyzed in this study, divided among the series with indication of sex, age and stress markers observed (signalized with X). Legends: M = male; F = female; Und. = undetermined; Y.A. = young adult (19-25 years); adult (26-34 years); M.A. = middle adult (35-49 years); O.A. = old adult (+ 50 years); Und. Ad. (adult with no specified age range); ys = years; ms = months; CB = Cabeçuda; JAB II = Jabuticabeira II.

(Continue)

Serie	Burial	Sex	Age	PH	CO	LEH
CB-late	I.A - 1.25 - 1.50	M	M.A.	X	-	-
CB-late	V - A - 1.50 - 1.75	F	M.A.	X	X	-
CB-late	I II - B B - 0.50	Und.	6 ys (± 24 ms)	X	X	X
CB-late	6 - I - C - 0.75 - 1.00	Und.	12 ys (± 36 ms)	-	-	X
CB-late	8 - III - C - 0.75	Und.	Und. Ad.	-	-	X
CB-late	11 - I - B - 0.50 - 0.75	Und.	15 ys (± 30 ms)	-	-	X
CB-late	12 - IV - C - 1.00 - 1.25	M	M.A.	X	-	-
CB-late	13 - V - C - 1.00 - 1.25	Und.	M.A.	-	X	X
CB-late	14 - VI - C - 1.50 - 1.75	Und.	6 ys (± 24 ms)	X	X	X
CB-late	15 - VI - C - 1.75 - 2.00	F	Y.A.	X	X	X
CB-late	16B - VI - D - 1.75 - 2.00	Und.	4-6 ys	X	-	-
CB-late	I (II) A.2.50 - 2.75	Und.	M.A.	X	-	-
CB-late	II A 2.50 - 2.75 2/VIII/50	M	O.A.	X	-	-
CB-late	II B (A) 2.50 - 2.75	M	Y.A.	X	-	X
CB-late	II B-C - 2.50 - 2.75	F	M.A.	X	X	-

Table 2. (Continue)

Serie	Burial	Sex	Age	PH	CO	LEH
CB-late	III A.2.00 - 2.25	Und.	17-19 ys	X	X	X
CB-late	III A - 2.25 - 2.50	M	M.A.	X	X	X
CB-late	III A - 2.50 - 2.75	M	Y.A.	X	X	X
CB-late	II B - 2.50 - 2.75	F	M.A.	X	-	X
CB-late	III B - 2.50 - 2.75	Und.	10 ys (± 30 ms)	X	X	-
CB-late	III D - 2.50 - 2.75	F	Y.A.	X	-	X
CB-late	III D - 2.50 - 2.75	Und.	Und. Ad.	X	-	X
CB-late	III E - 2.25 - 2.50	F	Y.A.		-	X
CB-late	III E - 2.75 - 3.00	F	M.A.	X	-	-
CB-late	III F - 3.25 - 3.50	M	Y.A.	X	X	X
CB-late	IV D - 2.25 - 2.50	F	M.A.	-	-	X
CB-late	IV B - 2.25	M	M.A.	X	X	-
CB-late	IV B - 2.50 - 2.75	F	M.A.	X	X	X
CB-late	IV D - 2.50 - 2.75	M	M.A.	-	-	X
CB-late	IV D - 2.50 - 2.75	F	M.A.	X	X	X
CB-late	IV D - 2.75 - 3.00	M	Y.A.	X	-	X
CB-late	IV E - 2.25 - 2.50	M	O.A.	X	X	-
CB-late	IV E - 2.25 - 2.50	Und.	15-18 ys	X	X	X
CB-late	IV E - 2.50 - 2.75	Und.	18-20 ys	X	-	X
CB-late	IV E - 2.50 - 2.75	M	Y.A.	X	X	X
CB-late	IV H - 3.75 - 4.00	Und.	18-20 ys	-	-	X
CB-late	IV A - 2.25 - 2.50	F	Adult	X	-	X
CB-late	IV (A) - G - 2.25 - 2.50	M	Und. Ad.	-	-	X
CB-late	IV (A) - D - 2.25	M	M.A.	X	-	X
CB-late	IV (A) - D - 2.50	M	M.A.	X	X	-
CB-late	IV (A) - D - 2.50 - 2.75	M	M.A.	-	X	X
CB-late	IV (A) - D - 2.50 - 2.75	Und.	10 ys (± 30 ms)	X	-	X
CB-late	IV (A) - E - 2.25	Und.	3 ys (± 12 ms)	-	-	X
CB-late	IV (A) - E - 2.25	M	M.A.	X	-	-
CB-late	IV (A) - F - 2.50	F	M.A.	X	X	-
CB-late	V - A - 2.25 - 2.50	Und.	12 ys (± 36 ms)	X	X	X
CB-late	VII - A - 2.00 - 2.25	M	M.A.	X	X	-
CB-late	VII - A - 2.25 - 2.50	F	M.A.	X	X	-
CB-late	IV (A) F - 2.70	Und.	4 ys (± 12 ms)	-	-	X
CB-late	IV - E - 2.75 - 3.00	M	M.A.	X	-	-
CB-late	I (V) A.2.25-2.50	M	O.A.	X	-	-
CB-late	IV (A) C D 2.25	F	Y.A.	X	-	-
CB-late	V - B - 2.25	M	O.A.	X	-	-
CB-late	VI - A - 2.00-2.25	M	M.A.	X	X	-

Table 2. (Continue)

Serie	Burial	Sex	Age	PH	CO	LEH
CB-late	IV (A) E-2.25	F	M.A.	X	X	-
CB-late	IV - B - 2.50-2.75	M	M.A.	X	X	-
CB-late	IV - 2.75-3.00	M	M.A.	X	-	X
CB-intermediate	III F - 4.00 - 4.25	F	M.A.	X	-	-
CB-intermediate	III F - 4.00 - 4.25	M	M.A.	X	-	X
CB-intermediate	VI - C - D - 5.20	Und.	5 ys (± 16 ms)	X	-	-
CB-intermediate	17 - VI - C - 5.20	M	Y.A.	X	X	X
CB-intermediate	18 - V - D - 5.25 - 5.50	Und.	12 ys (± 36 ms)	-	-	X
CB-intermediate	23-Cr2-VII-H-6.00-6.25	Und.	M.A.	X	-	X
CB-intermediate	24 - VII - H - 6.25 - 6.50	M	Y.A.	-	-	X
CB-intermediate	24 - VII - H - 6.25 - 6.50	F	M.A.	X	-	-
CB-intermediate	39 - VII - H - 7.50	Und.	Und. Ad.	-	-	X
CB-intermediate	42 - VII - I - 7.50	M	Und. Ad.	X	-	-
CB-intermediate	VI - C - D - 5.20	Und.	12 ys (± 36 ms)	-	-	X
CB-early	1	Und.	12 ys (± 36 ms)	-	-	X
CB-early	3	Und.	10 ys (± 30 ms)	-	-	X
CB-early	5	Und.	17–20 ys	-	-	X
CB-early	9	Und.	8 ys (± 24 ms)	-	-	X
CB-early	11	Und.	14-16 ys	-	-	X
CB-early	12	F	M.A.	X	X	X
CB-early	13	Und.	12 ys (± 36 ms)	X	-	X
CB-early	15	M	M.A.	X	X	-
CB-early	16	M	M.A.	X	-	X
JAB II-late	3A - L1.05	Und.	Und. Ad.	-	-	X
JAB II-late	3B1 - L1.05	M	Und. Ad.	X	-	-
JAB II-late	3B2 - L1.05	M	M.A.	X	-	-
JAB II-late	6 - L1.10	M	O.A.	X	-	-
JAB II-late	10A - L1.25	Und.	6 ys (± 24 ms)	X	-	X
JAB II-late	10B - L1.25	F	M.A.	X	-	X
JAB II-late	11 - L1.25	M	Und. Ad.	X	-	X
JAB II-late	12A - L1.25	F	O.A.	X	-	-
JAB II-late	12B - L1.25	F	Y.A.	X	-	X
JAB II-late	12C - L1.25	M	O.A.	X	-	X
JAB II-late	17A - L1.05	M	M.A.	X	-	X
JAB II-late	20 - L1.20	Und.	15 ys (± 36 ms)	X	-	X
JAB II-late	24 - L1.20	M	Und. Ad.	X	-	-
JAB II-late	106 - L1.90	Und.	Und. Ad.	X	-	X
JAB II-late	107 - L1 - T18	M	O.A.	X	X	-
JAB II-late	Prep. Antraco - L1	Und.	Und. Ad.	-	-	X

Table 2. (Conclusion)

Serie	Burial	Sex	Age	PH	CO	LEH
JAB II-late	FS46A - L1.05	Und.	Adult	X	-	-
JAB II-late	17A - L2.05	M	O.A.	X	-	X
JAB II-late	25A - L2.65	F	M.A.	X	-	X
JAB II-late	26 - L2.05	Und.	6 ys (± 24 ms)	-	-	X
JAB II-late	27 - L2 – T15	Und.	Und. Ad.	X	-	X
JAB II-late	34 - L2.05	F	Adult	X	X	X
JAB II-late	35A - L2.05	Und.	6 ms (± 3 ms)	-	-	X
JAB II-late	35B - L2.05	Und.	3 ys (± 12 ms)	X	X	X
JAB II-late	36A - L2.05	M	M.A.	X	-	X
JAB II-late	37 - L2.05	M	O.A.	X	X	X
JAB II-late	38 - L2.05	Und.	5 ys (± 16 ms)	X	X	X
JAB II-late	40 - L2.05	F	Und. Ad.	X	X	X
JAB II-late	41A - L2.05	M	Und. Ad.	X	X	X
JAB II-late	108 - L2.05	F	M.A.	X	-	X
JAB II-late	110 - Perfil - L2	M	Adult	X	-	X
JAB II-late	111/112A -TL1 - L2	F	Adult	X	-	-
JAB II-late	111/112B - TL1 - L2	F	Adult	X	-	X
JAB II-late	120 - L2	Und.	6 ys (± 24 ms)	-	X	X
JAB II-late	Bebê - L1/2	Und.	9 ms (± 3 ms)	-	X	X
JAB II-late	BASE 1.25	F	Und. Ad.	X	X	X
JAB II-early	14 - L1.05	Und.	Y.A.	X	-	-
JAB II-early	15 - L1.05	M	M.A.	X	-	X
JAB II-early	104A - L1.85	Und.	12 ys (± 36 ms)	X	X	X
JAB II-early	101 - L2.05	Und.	5 ys (± 16 ms)	X	X	X
JAB II-early	1B - L6C	F	M.A.	X	X	X
JAB II-early	2A - L6	F	M.A.	X	X	X
JAB II-early	3B - L6	F	Und. Ad.	X	-	X
JAB II-early	3C - L6	Und.	8 ys (± 24 ms)	X	X	-
JAB II-early	3F - L6	Und.	6 ms (± 3 ms)	-	X	X
JAB II-early	3B - L6 - QB3	Und.	15 ys (± 36 ms)	X	-	X
JAB II-early	3C - L6 - QB8	Und.	5 ys (± 16 ms)	-	-	X
JAB II-early	114 - L6	Und.	O.A.	X	-	-
JAB II-early	115A - L6	Und.	9 ms (± 3 ms)	X	X	X
JAB II-early	115B - L6	M	O.A.	X	-	-
JAB II-early	118 - L6	M	Adult	X	X	X
JAB II-early	119A - L6	Und.	3 ys (± 12 ms)	X	-	X
JAB II-early	121 - L6	M	M.A.	X	-	-
JAB II-early	102 - L1.75	F	Und. Ad.	X	X	-
JAB II-early	43 - L1.77	M	M.A.	X	X	X

RESULTS

The combined prevalence of PH and CO is greater than 50% for all the series. When separated by sex, both female and male individuals have PH prevalence above 90% and CO prevalence above 40%. In CB-late there were no females with CO; in CB-intermediate and CB-early there were no analyzable females for CO. When the lesions are observed according to their condition (active, healed, or healing), CB-early is unique because it presented only healed PH/CO. There were no significant statistical differences between all the prevalences tested for all the series ($p > 0.5$). Table 3 shows the individuals with active and/or healing PH/CO, illustrated in Figure 5.

For LEH, all series have prevalence above 70%. When separated by sex, both female and male individuals

Figure 5. Healing PH in parietals. Burial IV E-2.50-2.75 (CB-late). Photo: M. Di Giusto.

Table 3. Individuals with active or healing PH/CO, indicated with X.

Serie	Burial	Active PH/CO	Healing PH/CO
CB-late	I II-B B-0.50	X	-
CB-late	14-VI-C-1.50- 1.75	X	-
CB-late	III-B-2.50-2.75	X	-
CB-late	V-A-2.25-2.50	X	X
CB-late	III-A-2.00-2.25	-	X
CB-late	IV-E-2.50-2.75	-	X
CB-late	III-F-3.25-3.50	-	X
CB-late	IV-E-2.50-2.75	-	X
CB-late	VII-A-2.00-2.25	-	X
CB-intermediate	VI-C-D-5.20	X	-
CB-intermediate	17-VI-C-5.20	-	X
JAB II-late	3F - L6	X	-
JAB II-late	115A - L6	X	-
JAB II-late	101 - L2.05	X	-
JAB II-late	104A - L1.85	-	X
JAB II-late	102 - L1.75	X	-
JAB II-late	1B - L6C	-	X
JAB II-late	43 - L1.77	-	X
JAB II-early	Bebê - L1/2	X	-
JAB II-early	120 - L2	X	-
JAB II-early	40 - L2.05	-	X

have LEH prevalence above 70%, without significant statistical differences between them (p > 0.5). Systemic LEH was absent in deciduous teeth. The presence of dental wear in all series decreased the number of analyzable teeth in the age groups between 0-1 year old and 1-2 years old, and the presence of calculus decreased analyzable teeth in the age group between 5-6 years old. In some teeth from Jabuticabeira II, a technique called 'dental wash' was applied for the visualization of microscopic calculus (Boyadjian et al., 2007) which resulted in excessive enamel whitening, making difficult, and in some cases impossible, to observe LEH in those teeth. A total of 539 teeth were analyzed (185 teeth for CB-late, 30 for CB-intermediate, 47 for CB-early, 85 for JAB II-late and 192 for JAB II-early).

Regarding the age ranges most affected by LEH (Figure 6), both JAB II-late and JAB II-early people had a similar prevalence across all age ranges, except for a higher prevalence among 5-6 years old in JAB II-late. At Cabeçuda, there is a change in LEH prevalence through time. In the CB-late series, the highest prevalence is in individuals between 3-4 years old, while in CB-early it is in the 4-5 year-old age range. In CB-intermediate, there is a stability in prevalence between 2-3, 3-4 and 4-5 years old, with the highest prevalence in the 5-6 year-old age range. There was significant statistical difference in the 4-5 year-old age range between the series CB-early and CB-late (p = 0.03), CB-early and CB-intermediate (p = 0.007) and CB-early and JAB II-early (p = 0.02) and among 5-6 year-olds between the series JAB II-late and JAB II-early (p = 0.04). The age range for each individual with LEH is in Table 4.

Regarding the number of age groups with systemic LEH (Figure 7), in JAB II-late, most of the individuals have equally systemic LEH in 1, 2 or 3 age ranges, while 10% of the individuals have LEH in 4 or more age ranges. In JAB II-early, one third of the individuals are affected in 3 age ranges, followed by 1 and 2 age range. In CB-late and CB-intermediate, almost half of the individuals are affected in 1 age range, while in CB-early, 50% of individuals express LEH in 2 age ranges. In JAB II-early, CB-intermediate and CB-early there were no observable individuals affected in 4 or more age ranges. Such cases only occurred during the latest period of occupation of Jabuticabeira II and Cabeçuda. There were no significant statistical differences between all the prevalence tested for all the series (p > 0.5).

Regarding the maximum number of systemic lines for the same individual (Figure 8), in JAB II-late, most of the individuals are equally affected by 1 and 2 lines, followed

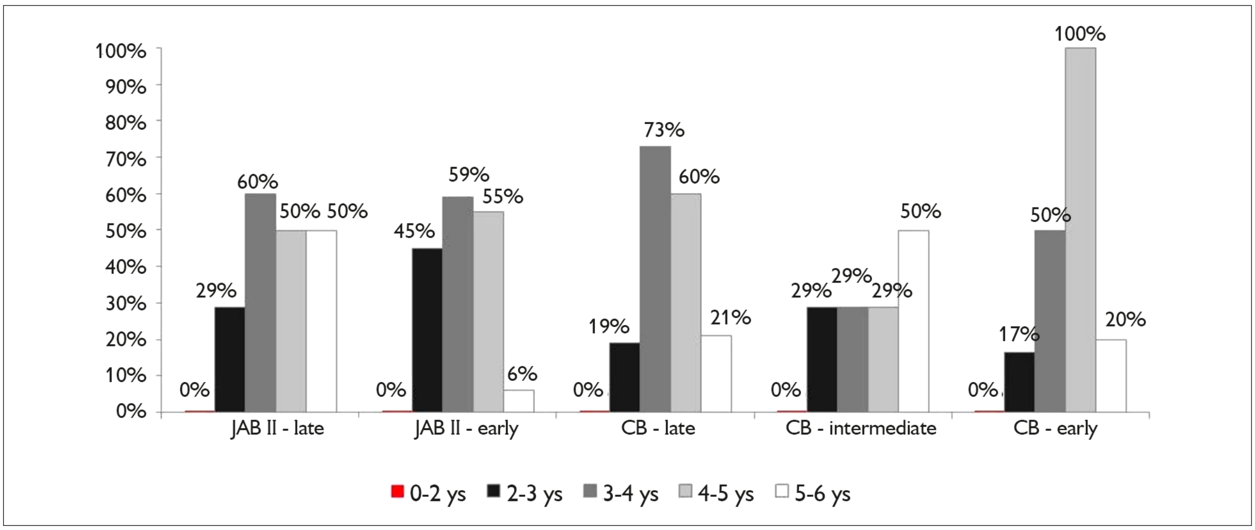

Figure 6. Age ranges most affected by LEH, divided between 0-2 years, 2-3 years, 3-4 years, 4-5 years, and 5-6 years.

Table 4. Age range affected by LEH for each analysed individual. (Continue)

Serie	Burial	Age range with LEH (permanent teeth)					
		0-1 yr	1-2 yrs	2-3 yrs	3-4 yrs	4-5 yrs	5-6 yrs
CB-late	6-I-C-0.75-1.00	-	-	-	-	X	-
CB-late	8-III-C-0.75	-	-	-	X	X	-
CB-late	11-I-B-0.50-0.75	-	-	X	X	X	-
CB-late	13-V-C-1.00-1.25	-	-	-	X	-	-
CB-late	15-VI-C-1.75-2.00	-	-	-	-	X	-
CB-late	IIB(A)2.50-2.75	-	-	X	X	X	-
CB-late	III A.2.00-2.25	-	-	-	X	X	-
CB-late	III A-2.25-2.50	-	-	-	X	-	-
CB-late	III A-2.50-2.75	-	-	-	X	-	-
CB-late	III D-2.50-2.75	-	-	-	X	-	-
CB-late	III D-2.50-2.75	-	-	-	X	X	-
CB-late	III E-2.25-2.50	-	-	-	X	-	-
CB-late	III F-3.25-3.50	-	-	-	X	X	X
CB-late	IV D-2.25-2.50	-	-	-	X	-	-
CB-late	IV D-2.50-2.75	-	-	-	X	-	-
CB-late	IV D-2.50-2.75	-	-	-	X	X	-
CB-late	IV D-2.75-3.00	-	-	-	X	X	-
CB-late	IV E-2.25-2.50	-	-	-	X	-	-
CB-late	IV E-2.50-2.75	-	-	X	-	X	-
CB-late	IV E-2.50-2.75	-	-	-	X	X	X
CB-late	IV H-3.75-4.00	-	-	X	X	X	-
CB-late	IV A-2.25-2.50	-	-	X	X	X	X
CB-late	IV(A)-G-2.25-2.50	-	-	-	-	X	-
CB-late	IV(A)-D-2.50-2.75	-	-	-	X	X	-
CB-late	IV(A)-D-2.50-2.75	-	-	-	X	X	-
CB-late	V-A-2.25-2.50	-	-	-	-	X	-
CB-late	IV-2.75-3.00	-	-	-	X	-	-
CB-intermediate	III F-4.00-4.25	-	-	-	-	X	-
CB-intermediate	18-V-D-5.25-5.50	-	-	-	-	-	X
CB-intermediate	23–VII–H-6.00-6.25	-	-	X	-	-	-
CB-intermediate	24-VII-H-6.25-6.50	-	-	X	X	-	-
CB-intermediate	39-VII-H -7.50	-	-	-	X	X	X
CB-early	1	-	-	-	X	X	-
CB-early	3	-	-	-	X	X	-
CB-early	5	-	-	-	-	X	-
CB-early	9	-	-	-	X	X	-
CB-early	11	-	-	-	X	X	-
CB-early	12	-	-	-	-	X	-

Table 4. Age range affected by LEH for each analysed individual. (Conclusion)

Serie	Burial	Age range with LEH (permanent teeth)					
		0-1 yr	1-2 yrs	2-3 yrs	3-4 yrs	4-5 yrs	5-6 yrs
CB-early	13	-	-	X	-	X	X
CB-early	16	-	-	-	-	X	-
JAB II-early	10A-L1.25-E1	-	-	X	-	-	-
JAB II-early	10B-L1.25-E1	-	-	X	X	X	-
JAB II-early	11-L1.25-E1	-	-	-	X	-	-
JAB II-early	12C-L1.25-E1	-	-	X	X	-	-
JAB II-early	17A-L1.05-E1	-	-	-	-	X	-
JAB II-early	20-L1.20-E1	-	-	-	-	X	-
JAB II-early	25A-L2.65-E3	-	-	-	X	-	-
JAB II-early	27-L2–T15–E3	-	-	-	X	X	X
JAB II-early	34-L2.05–E4	-	-	X	X	X	-
JAB II-early	36A-L2.05–E4	-	-	X	X	X	-
JAB II-early	37-L2.05–E4	-	-	X	X	X	-
JAB II-early	40-L2.05–E4	-	-	X	X	X	-
JAB II-early	106-L1.90-E5	-	-	X	X	X	-
JAB II-early	108-L2.05-E5	-	-	-	X	X	-
JAB II-early	110-Perfil-L2	-	-	X	-	-	-
JAB II-early	111/112B-TL1-L2	-	-	-	X	X	-
JAB II-early	BASE 1.25	-	-	-	X	X	-
JAB II-late	1B-L6C-E2	-	-	-	-	X	-
JAB II-late	3B-L6-E3	-	-	-	X	-	-
JAB II-late	3B-L6-QB3-JUVENIL	-	-	-	X	X	X
JAB II-late	15-L1.05-E1	-	-	X	X	-	-
JAB II-late	43-L1.77-E3	-	-	-	X	X	X
JAB II-late	104A-L1.85-E5	-	-	X	X	X	X
JAB II-late	118–L6	-	-	-	X	X	-

also equally by 3 and 4 or more lines. In JAB II-early, the individuals are equally affected by 1, 2 and 4 or more lines, with a slightly higher percentage of individuals affected by 3 lines. In CB-late, 37% of the individuals are affected by 1 line. In CB-intermediate, most of the individuals are affected equally by 1 and 2 lines, followed by 4 or more lines. In CB-early, half of the individuals are affected by 3 lines, followed equally by 1 and 2 lines. In CB-intermediate and in CB-early, no individuals were affected by 3 and 4 or more lines, respectively. There was significant statistical difference only amongst the series CB-early and CB-late ($p = 0.03$) for the presence of 3 lines.

The presence of LEH in different age ranges is illustrated in the right lower canine and left upper canine from burial 104-A-L1.85 (JAB II-late) (Figure 9). The presence of LEH in the same age range affecting all the anterior superior teeth are illustrate for the burial 6-I-C-0.75-1.00 (CB-late) (Figure 10).

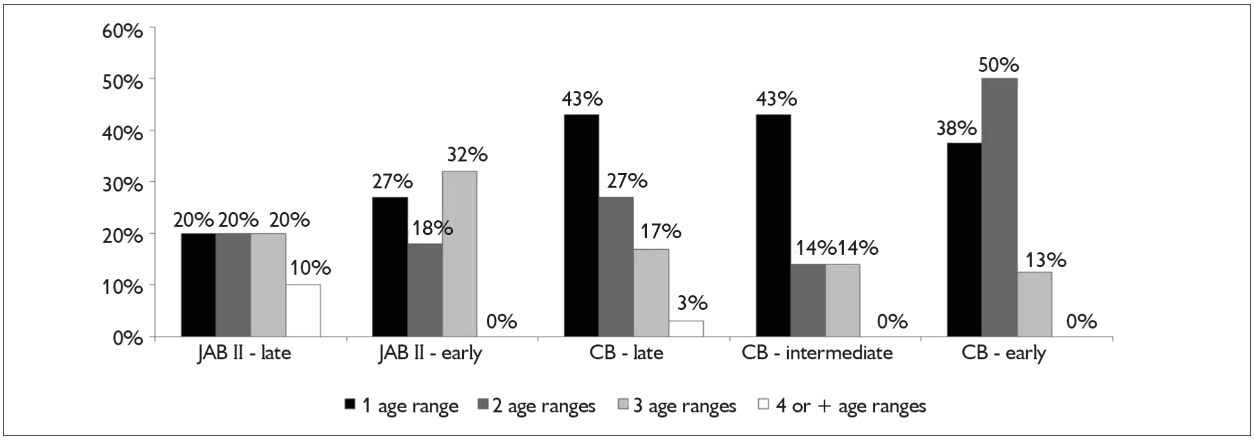

Figure 7. Number of age ranges with systemic LEH (1, 2, 3, 4 or more age groups).

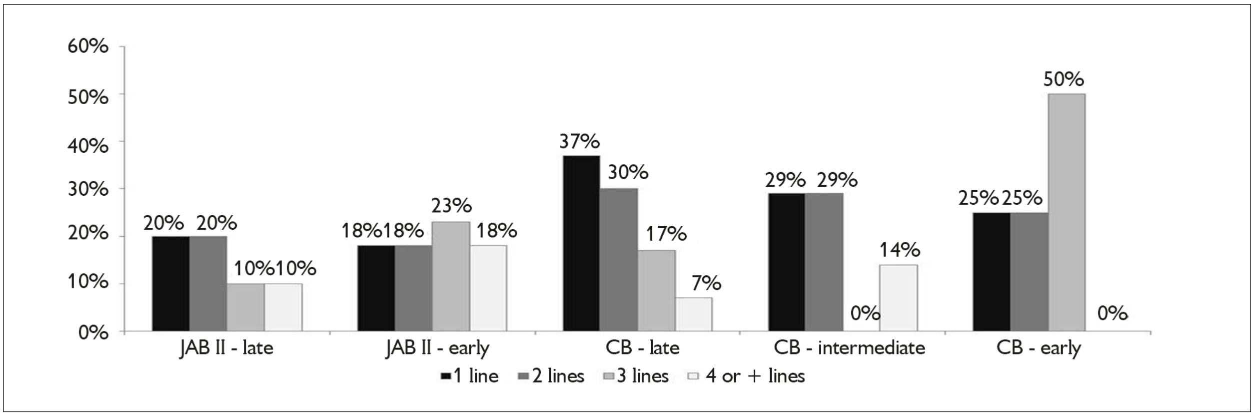

Figure 8. Maximum number of LEH (lines) per individual, with 1, 2, 3, 4, or more lines.

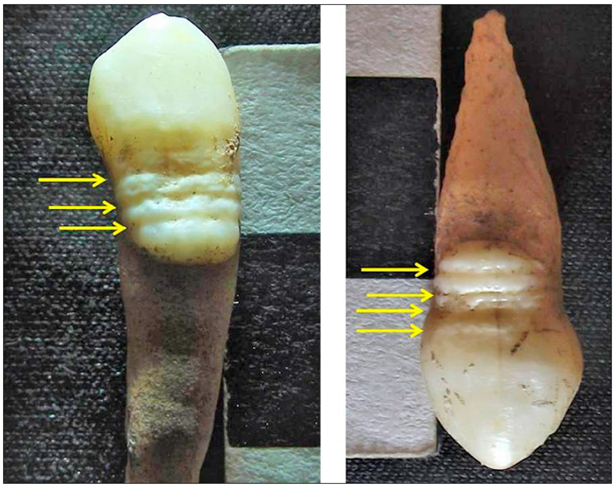

Figure 9. LEH in right lower canine and left upper canine, burial 104-A-L1.85 (Jab II-late). Photos: M. Di Giusto.

Figure 10. LEH in anterior superior teeth, burial 6-I-C-0.75-1.00 (Cb-late). Photo: M. Di Giusto.

DISCUSSION

The high PH/CO prevalences in this study are compatible with those formerly found for other sambaquis builders from the south and southeast coast of Brazil (Alvim & Gomes, 1989; Alvim et al., 1991; Souza, 1995; Wesolowski, 2000; Souza et al., 2009), and for several other coastal groups from the American continent (Walker, 1986; Blom et al., 2005; Suby, 2014).

Since (1) PH and CO could indicate the presence of chronic iron deficiency anemia in archaeological human groups (El-Najjar et al., 1975; Fairgrieve & Molto, 2000; Steckel et al., 2002; Walker et al., 2009; McIlvaine, 2013) and (2) anemic condition is also a consequence of infectious diseases (Carlson et al., 1974; El-Najjar & Robertson, 1976; Mensforth et al., 1978; Stuart-Macadam, 1985, 1992; Walker, 1986; Blom et al., 2005), the results suggest that, throughout the occupation of the Cabeçuda and Jabuticabeira II sambaquis, these population suffered iron deficiency anemia derived from endemic infectious disease since childhood.

Some studies have reported the presence of systemic infectious stress in some individuals from both sambaquis. For Jabuticabeira II, Okumura & Eggers (2005) observed periostitis in children and adults, which was considered by the authors as indicative of systemic infectious stress. Three individuals in Jabuticabeira II were also affected by treponematosis (Filippini et al., 2019), with two of these presenting healed HP (individuals 24A and 111/112 A). For Cabeçuda, Souza (1995) identified a high prevalence of symmetrical periostitis in adult lower limbs, considering it as a probable cause of non-specific infectious stress. Specific infections, such as osteomyelitis, were not identified in any individual excavated from this site.

An immunodiagnostic study reported the discovery of protozoan antibodies for *Cryptosporidium parvum* (the cause of cryptosporidiosis) and *Giardia lamblia* (the cause of giardiasis) in sediments of the Cabeçuda sambaqui (Camacho et al., 2015). Both may be transmitted by the ingestion of contaminated water or food, leading mainly to diarrhea in children. This evidence strengthens the hypothesis that the anemic condition that caused PH/CO lesions in coastal groups in Brazil could be from parasitic infections.

It is also suggested here that the presence of active PH/CO already in infancy in human groups from Jabuticabeira II and Cabeçuda is probably due to higher sensitivity to parasites during childhood (Stuart-Macadam, 1985) and the increased contact with parasites during the weaning period (Katzenberg et al., 1996). The weaning period exposes the child to food and water that may be contaminated by microorganisms, increasing the risk to diarrhea. Recurrent diarrheal episodes, even with a sufficient intake of iron and essential nutrients, can lead to the development of anemia (Walker, 1986; Sandberg & van Gerven, 2016).

From all the studied groups, both females and males were similarly affected by a high prevalence of PH. Considering that PH represents previous chronic anemic conditions, usually in childhood, the results suggest that children of both sexes were similarly exposed to risk factors that could lead to the development of anemia. This similar exposition indicates practices in early childhood that did not distinguish between females and males or put individuals differentially at risk according to sex. If there were distinct cultural practices for girls and boys, such practices did not affect health regarding infections and parasites.

Regarding LEH, the high prevalence found in the individuals from Jabuticabeira II and Cabeçuda is also compatible with those formerly found for other sambaquis builders from the south and southeast coast of Brazil (Souza, 1995; Wesolowski, 2000; Fischer, 2012), as well as coastal groups from other parts of the American continent (Ubelaker, 1992). This could also reinforce that individuals in both sites are routinely exposed to physiological stress during childhood.

Systemic LEH was not observed in any individuals from any of the series between 0-2 years, but this could be the result of the low number of observable teeth, given the occlusal wear in this age range. There was no systemic LEH on deciduous anterior teeth, for which most of the enamel development period is intrauterine (Buikstra & Ubelaker, 1994). In this case, if health instability (e.g., malnutrition) occured to mothers during the gestational period, it would not influence the baby's osteological and dental growth, but rather would alter the amount of accumulated fat presented by low birth weight (Kennedy, 2005).

According to the data for LEH prevalence by age range, number of age ranges and number of lines per individual, it is possible to see variability in stress episodes during childhood throughout the occupations of both Jabuticabeira II and Cabeçuda. One of these stress episodes is the weaning period, traditionally understood as coinciding with the age most affected by LEH (Cook, 1979; Cook & Buikstra, 1979; Katzenberg et al., 1996; Sandberg & van Gerven, 2016), due to the contact with pathogens present in the environment (transmitted by contaminated water and/or food) and by the nutritional stress that occur during this process (Buikstra & Cook, 1980). Concomitant with this transition, there are also other psychological factors that could be intrinsic in this process that cannot be excluded, such as greater autonomy for the mother to continue with her daily activities or the birth of a new child, which both generate less attention and greater autonomy to the older child.

In the Jabuticabeira II skeletal series, the LEH peak is between 3-4 years throughout the site occupation period. According to isotopic analysis performed by Pezo-Lanfranco et al. (2018), the weaning age at Jabuticabeira II was between 2-3 years old. Thus, the LEH data reveal that the peak of stress occurred during or soon after weaning. At Cabeçuda, the LEH peak occurs during older ages in earlier occupations (4-5 years old in CB-early) and during younger ages in the later occupations (3-4 years old in CB-late). Thus, there seems to have been a change in the way that the Cabeçuda sambaqui builders dealt with breastfeeding, choosing to wean earlier in later phases of occupation.

In CB-early, half of the analyzed individuals presented 3 systemic lines in up to 2 age ranges, that is, they suffered 3 alterations to enamel growth in two different age ranges. In CB-intermediate, most of the individuals had 1 or 2 systemic lines and were affected in only 1 age range, that is, they suffered alteration in enamel growth up to 2 times in the same age range. In CB-late, most of the individuals had just 1 systemic line within 1 age range.

Based on these data, I suggest that the group occupying Cabeçuda during its initial and earlier occupation phases were more prone to environmental stressful events than the group of the final and latest phase of occupation, since individuals of the earliest series suffered more interference in enamel growth in prolonged periods throughout childhood. It is possible to suggest that people in CB-late were better adapted to the coastal lifestyle, with stress perhaps only increasing during the weaning period.

In JAB II-early, most individuals were affected by LEH in 3 age ranges and had a maximum of 4 systemic lines per individual. However, in JAB II-late, children were similarly affected in 1, 2, and 3 age groups, with 1 or 2 lines. In JAB II-late, although individuals experienced less LEH, stressful events occurred for more extended periods during childhood, and in older age ranges generally considered at low risk for stress susceptibility from infections and malnutrition (WHO, 2019).

In JAB II-late*,* the different groups of individuals that respond to risk factors in different age ranges are more heterogeneous, indicated by equal prevalence of affected age ranges. There are at least three distinct risk groups for children: a group at risk in just 1 age range, a group at risk in 2 age ranges, and a group at risk in 3 age ranges. Two different hypotheses are proposed here to explain these data. On the one hand, there may be more significant variability in biological adjustments during childhood, which would be consistent with a higher number of less related domestic groups or totally unrelated groups (eg. sambaqui and non-sambaqui groups) using the same funerary space. On the other hand, these data could signalize social differentiation between groups of children, consistent with the notion of inherited status, which would imply different risks of stress exposure among individuals during childhood.

Although the proposed model for sambaqui communities on the southern coast of Santa Catarina is that they belonged to a singular sociological unit, with human groups living stably together for hundreds of years (Kneip et al., 2018; DeBlasis et al., 2021), the stress profiles in Cabeçuda and Jabuticabeira II point to some changes with biological adjustments identified in paleopathological analyzes. These biological adjustments could be related (however, not exclusively) to the environmental changes that occurred between 3,200-1,700 years AP, when the region of the Cabeçuda sambaqui became progressively drier (Kneip, 2004). Although gradual, these changes may have led to small changes in the epidemiological dynamics and altered the circulation of pathogens. In the case of Jabuticabeira II, the change could be related with an intensification of contact with people from the highlands or with a decrease in egalitarity that was manifested since childhood.

In addition, the results presented here show the importance of segmenting the analyzed osteological series. In a pathocenotic perspective, as proposed by Grmek (1989), and adopted by Souza (1995) in Brazilian sites, diseases and stress patterns present within a particular group have a strict relationship with the lifestyle adopted by those individuals at that specific time, and within their specific cultural and geographical context. Thus, in order to understand the health/disease process of a group with a long chronology, even if their individuals are buried in the same place, it is not possible to analyze them as just one large group, since cultural and/or environmental and/or behavioral changes constitute completely different conditions in terms of the development of diseases and, consequently, stress patterns.

CONCLUSION

Previous studies of sambaqui groups from Santa Catarina suggest that they constituted a complex and long-lasting social system, with economic, social, and political stability over the thousands of years of permanence on the coast. However, the results presented here identified changes among systemic physiological stress patterns, suggesting that lifestyle changes did occur during their permanence in the southern coast of the state.

The high prevalences of PH, CO, and LEH in the Cabeçuda and Jabuticabeira II sambaqui groups could be related to a constant exposure to stressful events during childhood, aggravated during the weaning period, that decrease the passive immunization provided to the child by the antibodies present in breast milk and increase the consumption of liquids and solid foods that can be a source of infections and parasites. However, individuals were differentially subjected to environmental stressors as indicated by the differences in the age-rages most affected by LEH over the periods of occupation in the two sites. In the Cabeçuda sambaqui, children were more subject to stressful events during the earlier than later occupation, probably due to environmental changes that led to changes in epidemiological dynamics and altered pathogen circulation. In Jabuticabeira II, stressful events affected children for more extended periods, mainly during the later period of occupation, probably due either to a higher number of less related domestic groups or totally unrelated groups using the same funerary space, or a decrease in egalitarian aspects of the society and an increase in inherited status.

The results also show the importance of segmenting osteological series chronologically, whenever possible, since the lifestyles adopted by individuals are related to a specific time, within a specific cultural and geographical context.

ACKNOWLEDGEMENTS

The author thanks the supervision of Prof. Dr. Veronica Wesolowski (*Museu de Arqueologia e Etnologia/Universidade de São Paulo* - MAE/USP) during this research and Prof. Dr. Claudia Rodrigues-Carvalho (*Museu Nacional/Universidade Federal do Rio de Janeiro* – MN/UFRJ) and Sabine Eggers for the authorization to access the osteological collection of Cabeçuda and Jabuticabeira II, respectively, at the time. Thanks are also extended to Prof. Dr. Maria Dulce Gaspar (MN/UFRJ), to Prof. Dr. Paulo De Blasis (MAE/USP) and once more to Claudia Rodrigues-Carvalho for the suggestions during the defense of this work. This research was financially supported by *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), to whom the author is thanks.

REFERENCES

Alvim, M. M., & Gomes, J. (1989). Análise e interpretação da hiperostose porótica em crânios humanos do sambaqui de Cabeçuda (SC-Brasil). *Revista de Pré-História*, *7*, 127-145.

Alvim, M. M., Gomes, J. C. O., & Uchôa, D. P. (1991). Cribra orbitalia e lesões cranianas congêneres em populações pré-históricas da costa meridional do Brasil. *Revista do Museu de Arqueologia e Etnologia*, (1), 21-53. https://doi.org/10.11606/issn.2448-1750.revmae.1991.107914

Angel, J. L. (1966). Porotic hyperostosis, anemias, malarias and marshes in the prehistoric eastern mediterranean, *Science*, *153*(3737), 760-763. https://doi.org/10.1126/science.153.3737.760

Bastos, M. Q. R., Lessa, A., Rodrigues-Carvalho, C., Tykot, R. H., & Santos, R. V. (2014). Análise de isótopos de carbono e nitrogênio: a dieta antes e após a presença de cerâmica no sítio Forte Marechal Luz. *Revista do Museu de Arqueologia e Etnologia*, (24), 137-151. https://doi.org/10.11606/issn.2448-1750.revmae.2014.109329

Blom, D. E., Buikstra, J. E., Keng, L., Tomczak, P. D., Shoreman, E., & Stevens-Tuttle, D. (2005). Anemia and childhood mortality: latitudinal patterning along the coast of pre-Columbian Peru. *American Journal of Physical Anthropology*, *127*(2), 152-169. https://doi.org/10.1002/ajpa.10431

Bocaege, E., & Hillson, S. (2016). Disturbances and noise: defining furrow-form enamel hypoplasia. *American Journal of Physical Anthropology*, *161*(4), 744-751. https://doi.org/10.1002/ajpa.23070

Boyadjian, C. H. C., Eggers, S., & Reinhard, K. J. (2007). Dental wash: a problematic method for extracting microfossils from teeth (galley proofs). *Journal of Archaeological Science*, *34*(10), 1622-1628. http://doi.org/10.1016/j.jas.2006.12.012

Boyadjian, C. H. C., Eggers, S., Reinhard, K. J., & Scheel-Ybert, R. (2016). Dieta no sambaqui Jabuticabeira-II (SC): consumo de plantas revelado por microvestígios provenientes de cálculo dentário. *Cadernos do LEPAARQ*, *13*(25), 132-161. https://periodicos.ufpel.edu.br/ojs2/index.php/lepaarq/article/view/7395

Buikstra, J. E., & Cook, D. E. (1980). Paleopathology: an american account. *Annual Review of Anthropology*, *9*, 433-470. https://doi.org/10.1146/annurev.an.09.100180.002245

Buikstra, J. E., & Ubelaker, D. H. (1994). *Standards for data collection from human skeletal remains* (Research Series, 44). Arkansas Archeological Survey.

Camacho, M., Cruz, P., Silva, V., Mendonça De Souza, S., & Araújo, A. (2015). Use of the parasitological technique of 10% hydrochoridric and immunoassay methods for recovery of parasites remains from sambaqui (shell mound) sediments. In *Anais do VI Paleopathology Association Meeting In South America*, Buenos Aires.

Carlson, D. S., Armelagos, G. J., & Gerven, D. P. (1974). Factors influencing the etiology of cribra orbitalia in prehistoric Nubia. *Journal of Human Evolution*, *3*(5), 405-410. https://doi.org/10.1016/0047-2484(74)90203-6

Colonese, A. C., Collins, M., Lucquin, A., Eustace, M., Hancock, Y., Ponzoni, R. A. R., . . . Craig, O. E. (2014). Long-term resilience of late holocene coastal subsistence system in southeastern south America. *PLOS ONE*, *9*(8), 1-13 https://doi.org/10.1371/journal.pone.0093854

Colonese, A. C., Farrell, T., Lucquin, A., Firth, D., Charlton, S., Robson, H. K., Alexander, M., & Craig, O. E. (2015). Archaeological bone lipids as palaeodietary markers. *Rapid Communications in Mass Spectrometry*, *29*(7), 611-618. https://doi.org/10.1002/rcm.7144

Cook, D. C. (1979). Part four: Subsistence base and health in prehistoric Illinois valley: evidence from the human skeleton. *Medical Anthropology*, *3*(1), 109-124. https://doi.org/10.1080/01459740.1979.9965835

Cook, D. C., & Buikstra, J. E. (1979). Health and differential survivor in prehistoric populations: prenatal dental defects. *American Journal of Physical Anthropology*, *51*(4), 649-664. https://doi.org/10.1002/ajpa.1330510415

DeBlasis, P., Kneip, A., Scheel-Ybert, R., Giannini, P., & Gaspar, M. D. (2007). Sambaquis e paisagem: Dinâmica natural e arqueologia regional no litoral do sul do Brasil. *Arqueologia Sul-Americana*, *3*(1), 29-61. https://repositorio.usp.br/directbitstream/b60a80ea-7720-4f4a-ad58-bb5a9533f7a7/1651410.pdf

DeBlasis, P., & Gaspar, M. D. (2009). Sambaquis do sul catarinense: retrospectiva e perspectivas de dez anos de pesquisas. *Especiaria: Caderno de Ciências Humanas (UESC), 11*(20-21), 20-30. https://periodicos.uesc.br/index.php/especiaria/article/view/693

DeBlasis, P., Gaspar, M. D., & Kneip, A. (2021). Sambaquis from the Southern Brazilian coast: landscape building and enduring heterarchical societies throughout the holocene. *Land*, *10*(7), 757. https://doi.org/10.3390/land10070757

DiGiusto, M. (2017). *Os sambaquieiros e os outros: estresse e estilo de vida na perspectiva da longa duração - O caso do litoral sul de Santa Catarina* [Dissertação de mestrado, Universidade de São Paulo].

El-Najjar, M. Y., Lozoff, B., & Ryan, D. J. (1975). The paleoepidemiology of porotic hyperostosis in the American southwest: radiological and ecological considerations. *American Journal of Roentgenology*, *125*(4), 918-924. https://doi.org/10.2214/ajr.125.4.918

El-Najjar, M. Y., & Robertson, A. L. (1976). Spongy bones in prehistoric America. *Science*, *193*(4248), 141-143. https://doi.org/10.1126/science.779029

El-Najjar, M. Y., DeSanti, M. V., & Ozebek, L. (1978). Prevalence and possible etiology of dental enamel hypoplasia. *American Journal of Physical Anthropology*, *48*(2), 185-192. https://doi.org/10.1002/ajpa.1330480210

Fairgrieve, S. I., & Molto, J. E. (2000). Cribra orbitalia in two temporally disjunct population samples from the Dakhleh Oasis, Egypt. *American Journal of Physical Anthropology*, *111*(3), 319-331. https://doi.org/10.1002/(sici)1096-8644(200003)111:3%3C319::aid-ajpa3%3E3.0.co;2-n

Farias, D., & Deblasis, P. (2014). *Programa de salvamento arqueológico e educação patrimonial na área de duplicação da BR-101 trecho Ponte de Cabeçuda/SC – Relatório final*. Tubarão.

Figuti, L. (1993). O homem pré-histórico, o molusco e o sambaqui: considerações sobre a subsistência dos povos sambaquieiros. *Revista do Museu de Arqueologia e Etnologia*, (3), 67-80. https://doi.org/10.11606/issn.2448-1750.revmae.1993.109161

Filippini, J., Pezo-Lanfranco, L., & Eggers, S. (2019). Estudio regional sistemático de treponematosis en conchales (sambaquis) precolombinos de Brasil. *Chungara, Revista de Antropología Chilena*, *51*(3), 403-425. http://dx.doi.org/10.4067/S0717-73562019005000301

Fischer, P. F. (2012). *Os moleques do morro e os moleques da praia: estresse e mortalidade em um sambaqui fluvial (Moraes, Vale do Ribeira de Iguape, SP) e em um sambaqui litorâneo (Piaçaguera, Baixada Santista, SP)* [Dissertação de mestrado, Universidade de São Paulo]. http://www.teses.usp.br/teses/disponiveis/71/71131/tde-28082012-143626/

Fish, S. K., DeBlasis, P., Gaspar, M. D., & Fish, P. R. (2000). Eventos incrementais na construção de sambaquis, litoral sul do estado de Santa Catarina. *Revista do Museu de Arqueologia e Etnologia*, (10), 69-87. https://doi.org/10.11606/issn.2448-1750.revmae.2000.109378

Fish, P. R., Fish, S. K., DeBlasis, P., & Gaspar, M. D. (2013). Monumental shell mounds as persistent places in southern coastal Brazil. In V. Thompson & J. Waggoner (Orgs.), *The archaeology and historical ecology of small scale economies* (pp. 120-140). University Press of Florida.

Gaspar, M. D., DeBlasis, P., Fish, S., & Fish, P. (2008). Sambaqui (shell mound) societies of coastal Brazil. In H. Silverman & W. Isbell (Orgs.), *Handbook of South American Archaeology* (pp. 319-335). Springer.

Gaspar, M. D., Klökler, D., & DeBlasis, P. (2014). Were sambaqui people buried in the trash? Archaeology, physical anthropology, and the evolution of the interpretation of Brazilian shell mound. In M. Roksandic, S. M. Souza, S. Eggers, M. Burchell & D. Klokler (Orgs.), *The cultural dynamics of shell middens and shell mounds: a worldwide perspective for American archaeology* (pp. 91-100). University of New Mexico Press.

Goodman, A. H., Armelagos, G. J., & Rose, J. C. (1980). Enamel hypoplasias as indicators of stress in three prehistoric populations from Illinois. *Human Biology*, *52*(3), 515-528. http://www.jstor.org/stable/41464558

Grmek, M. (1989). *Diseases in the ancient Greek world*. Johns Hopkins University Press.

Isselbacher, K. (1994). *Harrison's principles of internal medicine*. McGraw Hill Editors.

Katzenberg, M. A., Herring, D. A., & Saunders, S. R. (1996). Weaning and infant mortality: evaluating the skeletal evidence. *Yearbook of Physical Anthropology*, *101*(S23), 177-199. https://doi.org/10.1002/(SICI)1096-8644(1996)23+%3C177::AID-AJPA7%3E3.0.CO;2-2

Kennedy, G. E. (2005). From the ape's dilemma to the weanling's dilemma: early weaning and its evolutionary context. *Journal of Human Evolution*, *48*(2), 123-145. https://doi.org/10.1016/j.jhevol.2004.09.005

Klökler, D. (2008). *Food for body and soul: mortuary ritual in shell mounds (Laguna – Brazil)* [Tese de doutorado, University of Arizona].

Klökler, D. (2014). Adornos em concha do sítio Cabeçuda. *Revista de Arqueologia*, *27*(2), 150-169. https://doi.org/10.24885/sab.v27i2.408

Kneip, A. (2004). *O povo da lagoa: uso de SIG para o modelamento e simulação na área arqueológica do Camacho* [Tese de doutorado, Universidade de São Paulo].

Kneip, A., Farias, D., & DeBlasis, P. (2018). Longa duração e territorialidade da ocupação sambaquieira na laguna de Santa Marta, Santa Catarina. *Revista de Arqueologia*, *31*(1), 25-51. http://dx.doi.org/10.24885/sab.v31i1.526

Larsen, C. (1997). *Bioarchaeology: interpreting behavior from the human skeleton*. Cambridge University Press.

Larsen, C. S., & Hutchinson, D. L. (1992). Dental evidence for physiological disruption: Biocultural interpretations from the eastern spanish borderlands, USA. *Journal of Paleopathology*, *Monographic Publications*, *2*, 151-169.

Lessa, A., & Scherer, L. Z. (2008). O outro lado do paraíso: novos dados e reflexões sobre violência entre pescadores-coletores pré-coloniais. *Revista do Museu de Arqueologia e Etnologia*, (18), 89-100. https://doi.org/10.11606/issn.2448-1750.revmae.2008.89830

Lima, T. A. (1999-2000). Em busca dos frutos do mar: os pescadores-coletores do litoral centro-sul do Brasil. *Revista do Museu de Arqueologia e Etnologia*, (44), 270-327. https://doi.org/10.11606/issn.2316-9036.v0i44p270-327

Martin, D., Goodman, A., & Armelagos, G. (1985). Skeletal pathologies as indicators of quality and quantity of diet. In R. Gilbert & J. H. Mielke (Orgs.), *The analysis of prehistoric diets* (pp. 227-279). Academic Press.

Masi, M. A. N. (2001). *Pescadores coletores da costa sul do Brasil*. Instituto Anchietano de Pesquisas.

McIlvaine, B. K. (2013). Implications of reappraising the iron-deficiency anemia hypothesis. *International Journal of Osteoarchaeology*, *25*(6), 997-1000. https://doi.org/10.1002/oa.2383

Mensforth, R. P., Lovejoy, C. O., Lallo, J. W., & Armelagos, G. J. (1978). The role of constitutional factors, diet and infectious disease in the etiology of porotic hyperostosis and periosteal reactions in prehistoric infants and children. *Medical Anthropology*, *2*(1), 1-59. https://doi.org/10.1080/01459740.1978.9986939

Moseley, J. E. (1965). The paleopathological riddle of symmetrical osteoporosis. *The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine*, *95*(1), 135-142. https://doi.org/10.2214/ajr.95.1.135

Okumura, M. M. M., & Eggers, S. (2005). The people of Jabuticabeira II: reconstruction of the way of life in a Brazilian shellmound. *Journal of Comparative Human Biology*, *55*(3), 263-281. https://doi.org/10.1016/j.jchb.2004.10.001

Ortner, D. (2003). *Identification of pathological conditions in human skeletal remains* (2. ed.). Academic Press.

Oxenham, M. F., & Cavill, I. (2010). Porotic hyperostosis and cribra orbitalia: the erythropoietic response to iron-deficiency anaemia. *Anthropological Science*, *118*(3), 199-200. https://doi.org/10.1537/ase.100302

Petronilho, C. (2005). *Comprometimento articular como um marcador de atividades em um grande sambaqui-cemitério* [Dissertação de mestrado, Universidade de São Paulo].

Pezo-Lanfranco, L. (2018). Evidence of variability in carbohydrate consumption in prehistoric fisher-hunter-gatherers of Southeastern Brazil: spatiotemporal trends of oral health markers. *American Journal of Physical Anthropology*, *167*(3), 507-523. https://doi.org/10.1002/ajpa.23681

Pezo-Lanfranco, L., DeBlasis, P., & Eggers, S. (2018). Weaning process and subadult diets in a monumental Brazilian shellmound*. Journal of Archaeological Science: Reports*, *22*, 452-469. https://doi.org/10.1016/j.jasrep.2018.04.025

Pezo-Lanfranco, L., Filippini, J., DiGiusto, M., Petronilho, C., Wesolowski, V., DeBlasis, P., & Eggers, S. (2020). Child development, physiological stress and survival expectancy in prehistoric fisher- hunter-gatherers from the Jabuticabeira II shell mound, South Coast of Brazil. *PLoS ONE*, *15*(3), e0229684. https://doi.org/10.1371/journal.pone.0229684

Posth, C., Nakatsuka, N., Lazaridis, L., Soglund, P., Mallick, S. Lamndis, T. C. . . . . & Reick, D. (2018). Reconstructing the deep population history of central and South America. *Cell*, *175*(5), 1185-1197. https://doi.org/10.1016/j.cell.2018.10.027

Primeau, C., Arge, S. O., Boyer, C. & Lynnerup, N. (2015). A test of inter – and intra – observer error for an atlas method of combined histological data for the evaluation of enamel hypoplasia. *Journal of Archaeological Science*: *Reports*, *2*, 384-388. https://doi.org/10.1016/j.jasrep.2015.03.007

Rohr, J. A. (1984). Sítios arqueológicos de Santa Catarina. In *Anais do Museu de Antropologia*, *16*, 77-168.

Saladino, A. (2016). *A morte enfeitada: um olhar sobre as práticas mortuárias dos construtores do sambaqui Cabeçuda a partir de um sepultamento infantil* [Dissertação de mestrado, Universidade Federal do Rio de Janeiro].

Sandberg, P., & van Gerven, D. (2016). Canaries in the mineshaft: the children of Kiribati. In M. K. Zuckerman & D. L. Martin (Orgs.), *New directions in biocultural anthropology* (pp. 159-180). John Wiley & Sons, Inc.

Schaefer, M., Black, S., & Scheuer, L. (2009). *Juvenile osteology: a laboratory and field manual*. Academic Press.

Scheel-Ybert, R., Eggers, S., Wesolowski, V., Petronilho, C., Boyadjian, C., DeBlasis, P. Barbosa-Guimarães, M., & Gaspar, M. D. (2003). Novas perspectivas na reconstituição do modo de vida dos sambaquieiros: uma abordagem multidisciplinar. *Revista de Arqueologia, 16*(1), 109-137. https://revista.sabnet.org/ojs/index.php/sab/article/view/182

Scheel-Ybert, R. (2013). Preliminary data on nonwood plant remains at sambaquis from the southern and southeastern Brazilian Coast: Considerations on diet, ritual, and site particularities. *Cuadernos del Instituo Nacional de Antropologia y Pensamento Latinoamericano - Series Especiales, 1*(1), 60-72.

Schultz, M. (2001). Paleohistopathology of bone: a new approach to the study of ancient diseases. *American Journal of Biological Anthropology*, *116*(533), 106-147. https://doi.org/10.1002/ajpa.10024

Silva, R. E. (2020). *(Re)Começando do princípio: o que a arqueografia de uma área funerária do Sambaqui de Cabeçuda pode nos ensinar sobre práticas funerárias sambaquieiras?* [Dissertação de mestrado, Universidade de São Paulo].

Souza, S. M (1995). *Estresse, doença e adaptabilidade: estudo comparativo de dois grupos pré-históricos em perspectiva biocultural* [Tese de doutorado, Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz].

Souza, S. M. (1999). Anemia e adaptabilidade em um grupo costeiro pré-histórico: uma hipótese patocenótica. In M. C. Tenório (Org.), *Pré-história da Terra Brasilis* (pp. 171-188). Ed. UFRJ.

Souza, S. M., Wesolowski, V., & Rodrigues-Carvalho, C. (2009). Teeth, nutrition, anemia, infection, mortality: costs of lifestyle at the coastal Brazilian sambaquis. In *Anais do XV Congresso da União Internacional de Ciências Pré-Históricas e Proto-Históricas (UISPP)*, 33-40.

Stabile, R. (2017). *Ossos do ofício: análise de marcadores de estresse ocupacional em séries esqueléticas de sambaquis da Baixada Santista-SP* [Dissertação de mestrado, Universidade de São Paulo].

Steckel, R., Sciulli, P., & Rose, J. (2002). A health index from skeletal remains. In R. H. Steckel & J. C. Rose (Orgs.), *The backbone of history: health and nutrition in the western hemisphere* (pp. 61-93). Cambridge University Press.

Stuart-Macadam, P. (1985). Porotic hyperostosis: representative of a childhood condition. *American Journal of Physical Anthropology*, *66*(4), 391-398. https://doi.org/10.1002/ajpa.1330660407

Stuart-Macadam, P. (1992). Porotic hyperostosis: a new perspective. *American Journal of Physical Anthropology*, *87*(1), 39-47. https://doi.org/10.1002/ajpa.1330870105

Suby, J. A. (2014). Porotic hyperostosis and cribra orbitalia in human remains from southern Patagonia. *Anthropological Science*, *122*(2), 69-79. https://doi.org/10.1537/ase.140430

Towle, I., & Irish, J. D. (2019). A probable genetic origin for pitting enamel hypoplasia on the molars of paranthropus robustus. *Journal of Human Evolution*, *129*, 54-61. https://doi.org/10.1016/j.jhevol.2019.01.002

Towle, I., & Irish, J. D. (2020). Recording and interpreting enamel hypoplasia in samples from archaeological and palaeoanthropological contexts. *Journal of Archaeological Science, 114*, 105077. https://doi.org/10.1016/j.jas.2020.105077

Ubelaker, D. (1992). Enamel hypoplasia in ancient Ecuador. *Journal of Paleopathology, Monographic Publications*, *2*, 207-217.

Villagran, X. S. (2013). O que sabemos dos grupos construtores de sambaquis? Breve revisão da arqueologia da costa sudeste do Brasil, dos primeiros sambaquis até a chegada da cerâmica Jê. *Revista do Museu de Arqueologia e Etnologia*, (23), 139-154. https://doi.org/10.11606/issn.2448-1750.revmae.2013.107182

Walker, P. L. (1986). Porotic hyperostosis in a marine-dependent California Indian population. *American Journal of Physical Anthropology*, *69*(3), 345-354. https://doi.org/10.1002/ajpa.1330690307

Walker, P. L., Bathurst, R. R., Richman, R., Gjerdrum, T., & Andrushko, V. A. (2009). The causes of porotic hyperostosis and cribra orbitalia: a reappraisal of the iron-deficiency-anemia hypothesis. *American Journal of Biolical Anthopology*, *139*(2), 109-125. https://doi.org/10.1002/ajpa.21031

Wapler, U., Crubézy, E., & Schultz, M. (2004). Is cribra orbitalia synonymous with anemia? Analysis and interpretation of cranial pathology in Sudan. *American Journal of Physical Anthropology*, *123*(4), 333-339. https://doi.org/10.1002/ajpa.10321

Wesolowski, V. (2000). *A prática da horticultura entre os construtores de sambaquis e acampamentos litorâneos da região da Baía de São Francisco: uma abordagem bio-antropológica* [Dissertação de mestrado, Universidade de São Paulo].

Wesolowski, V., Souza, S. M. F. M., Reinhard, K., & Ceccantini, G. (2007). Grânulos de amido e fitólitos em cálculos dentários humanos: contribuição ao estudo do modo de vida e subsistência de grupos sambaquianos do litoral sul do Brasil. *Revista do Museu de Arqueologia e Etnologia*, (17), 191-210. https://doi.org/10.11606/issn.2448-1750.revmae.2007.89773

World Health Organization (WHO). (2019). *Child mortality and causes of death*. https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/child-mortality-and-causes-of-death

Wright, L. E. (1997). Intertooth patterns of hypoplasia expression: implications for childhood health in the classic Maya collapse. *American Journal of Physical Anthropology*, *102*(2), 233-247. https://doi.org/10.1002/(sici)1096-8644(199702)102:2%3C233::aid-ajpa6%3E3.0.co;2-z