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Caries Through Time: An Anthropological Overview

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1. Introduction

Bioanthropological[1] researches carried out in the last few decades have given special emphasis to the study of the relation between disease, as well as social and environmental phenomena, enhancing the already strong connection between lifestyle and health conditions during history of humankind (Cohen & Armelagos, 1984; Katzenberg & Saunders, 2008; Larsen, 1997). Because infectious diseases result from the interaction between host and agent, modulated by ecological and cultural environments, the comparative study of the historic prevalence of diseases in past populations worldwide can provide important data about their related factors and etiology.

The study of dental diseases (such as caries) has been given special attention from Paleopathology[2]. The tooth, for its physical features tends to resist destruction and taphonomic conditions better than any other body tissue and therefore, is a valuable element for the study on individual's diet, and social and cultural factors related to it, from a population perspective.

Caries is one of the infectious diseases more easily observable in human remains retrieved from archaeological excavations. For their long time of development and non-lethal nature the lesions presented at the time of the death remain recognizable indefinitely, allowing to infer, along with other archaeological and ecological data, the types of food that a specific population consumed, the cooking technology they used, the relative frequency of consumption, and the way the food was shared among the group (Hillson, 2001 2008; Larsen, 1997; Rodríguez, 2003).

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[1] Formerly called Physical Anthropology, Bioanthropology is a discipline that provides integrated information about the lifestyle of past populations and their associations with the environment through the study of human remains. The North American school denominates it Bioarchaeology (Buikstra & Beck, 2006; Larsen, 1997; Roberts & Manchester, 2005).

[2] In general, diseases, signs and determining factors have been studied by Bioanthropology under the label of Paleopathology (the study of diseases in past societies through ancient texts, art and human remains). The specific study of the oral diseases during ancient times is named Oral or Dental paleopathology (Campillo, 2001; Waldron, 2009).

Considering the available data, we know that the highest caries rates[3], their distribution and severity profiles observed nowadays are the result of a complex process of slow dietary changes, directly linked to the development of Western civilization. Consequently, the current caries patterns are not observed in past populations, on the opposite, they show a high variability along time and space that corresponds to a wide range of subsistence strategies, specific cultural regulations, and particular historical processes.

2. The antiquity of caries: Evidences of caries in hominines and early humans

Caries is a very old disease and it is not exclusive of the human species. Evidences of dental lesions compatible with caries have been observed in creatures as old as Paleozoic fishes (570-250 million years), Mesozoic herbivores dinosaurs (245-65 million years), pre-hominines of the Eocene (60-25 million years), and Miocenic (25-5 million years), Pliocenic (5-1.6 million years), and Pleistocenic animals (1.6-0.01 million years – Clement, 1958; Kear, 2001; Kemp, 2003; Sala et al., 2004). Caries has also been detected in bears and other wild animals (Pinto & Exteberria, 2001; Palamra et al., 1981), and it is common in domestic animals (Gorrel, 2006; Shklair, 1981; Wiggs & Lobprise, 1997).

In humans, caries is one of the most widely spread diseases and its presence takes place into our species origins. Paleodietary reconstructions have provided a high amount of data on the presence of caries in ancestral lineages. An approximal groove located in the cementum-enamel junction (CEJ) of bicuspids and molars has been noticed in several lineages of fossil hominines like Paranthropus robustus, *Homo habilis*, *H. erectus*, *H. heidelbergensis* and *H. neanderthalensis* (Bermúdez de Castro et al., 1997; Frayer, 1991; Milner & Larsen, 1991; Ungar et al., 2001). Although some scholars have reported that lesion as caries (Clement, 1956; Grine et al., 1990; Robinson, 1952), more recent analyses done in an specimen of *Homo erectus* from Olduvai Gorge (1.84 million years BP[4]) suggest that it could be an erosion produced by the habitual (possibly therapeutic) use of tooth-picks (Ungar et al., 2001).

Also, the paleopathological record of the ATE9-1 jaw (*Homo sp.* - Sima del Elefante site, Sierra de Atapuerca, Spain), considered the oldest hominine fossil of Western Europe (1.3 million years BP), shows numerous maxillary lesions such as hypercementosis, calculus deposits, periodontal disease, cystic lesions and an anomalous wear facet compatible with tooth picking but no caries (Martinón et al., 2011).

Several authors have suggested that the discovery of fire by *Homo erectus*-like species, around 800 thousand years ago, was a biologically significant step. Meanwhile cooked food replaced a

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[3] Some prompts are used for the recording of caries experience. Caries prevalence, defined as the number of individuals in a population affected by caries in a specific time span. Caries frequency, defined as the number of teeth affected for caries divided by the total number of sockets observed (tooth/tooth socket) in a individual or population; and caries index as the Decay Missing Filling Index adapted to fragmentary samples (Duyar & Erdal, 2003; Lukacs, 1992; Medronho et al., 2009; Pezo, 2010; Saunders et al., 1997).

[4] The chronological dating methods use some conventional parameters. BP (before present) refers to a non- calibrated C14 date, calculated since 1950 as year zero. BC and AD (before Christ and *Anno Domini* respectively) refers to a calibrated C14 date (calculated from accurate historical or geological data) in calendar years since the year one of our era (Taylor, 1987).

diet entirely based on raw meat and vegetables, the patterns of chewing, digestion and nutrition changed accordingly. The process of cooking using fire turned the food safer, juicer, and easier to digest, promoting a higher intake of energy that, in evolutionary terms, had a sequence of favorable physiological effects. The easy digestion of cooked food would have favored the reduction of the digestive system, facilitating metabolic energy savings that were used to develop the brain (Aiello & Wheeler, 1995; Cartmill, 1993; Wrangham, 2009). Nevertheless, it is supposed that *H. erectus*, a hunter-gatherer, obtained approximately 50% of its calories from carbohydrates (Wrangham, 2009) and under the hypothesis of cooking (that obviously included meat and vegetables), caries should have been present much earlier in the fossil record. However, caries appears clearly much later. So, the data on oral does not support the idea of a cariogenic diet based on cooked vegetables from the earliest periods. Maybe, in the beginning, fire was employed only for cooking meat.

The unquestionable oldest evidence of caries comes from a fossil found in 1921 in Broken Hill, Northern Rhodesia (Zambia) during the exploration of a zinc mine. The specimen denominated Broken Hill 1, a *Homo rhodesiensis* cranium (African version of the *Homo heidelberguensis* 650,000-160,000 BP) shows extensive dental caries and coronal destruction. Except for five teeth, all the rest is affected by rampant caries and several crowns are almost completely destroyed. Caries seems to have its origin in the interdental spaces. Besides, Broken Hill man experienced alveolar recession and dental abscesses in many teeth (Fig. 1). Although lesions have been attributed to a diet rich in vegetables and/or poisoning by the existing metals in the region (Bartsiokas & Day, 1993), it seems that, given the interdental origin of the caries and the absence of tooth picks evidence, the Broken Hill 1 developed his lesions due to his ignorance in the use of tooth picks, which was known by other earlier hominines (Puech, 1978).

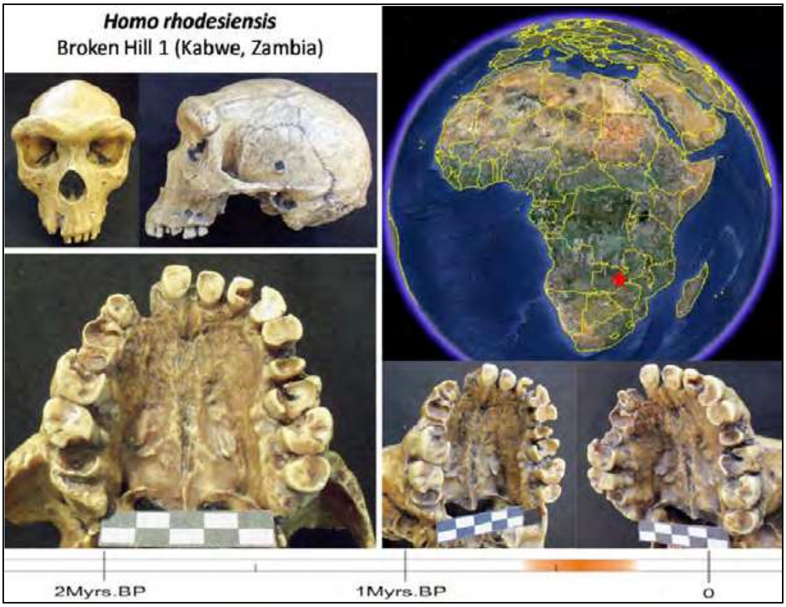

Fig. 1. **The unquestionable oldest evidence of caries in the human paleontological record.** Pictures of *H. rhodesiensis* skull cast. Map modified from Google Maps 2010.

In this sense, from the presence of caries in non-human primates one must consider that natural sources of carbohydrates can produce carious lesions. Caries have been reported in prime-age individuals of *Pongo pygmaeus* (4.1%), *Gorilla gorilla* (2.7%), *Hylobates* (0.9%) and *Pan troglodytes* (12.7% in juveniles versus 30.6% in older animals – Crovella & Ardito, 1994; Schultz, 1956). Thus, in modern apes, the disease exists despite them being mostly herbivorous with a raw diet based on only a few starchy tubers if any (Kilgore, 1995; Miles & Grigson, 1990).

The Neanderthals (230,000-30,000 BP) show a high prevalence of enamel hypoplasias, antemortem tooth loss, periodontal disease and abscesses but dental caries is very rare among them (Brennan, 1991; Brothwell, 1963; Grine et al., 1990; Ogilvie, 1989). Six cases (Table 1) of dental caries (0.48%) have been reported among the approximately 1250 known Neanderthal teeth (Lalueza et al., 1993; Lebel & Trinkaus, 2001; Tillier et al., 1995; Trinkaus et al., 2000; Walker et al., 2011). The presence of caries in Neanderthals suggests the existence of pathogenic dental plaque and dietary conditions compatible with the consumption of some cariogenic carbohydrates despite the hunter-gatherer lifestyle and cold climate existing during the Middle Paleolithic[5] (Trinkaus et al., 2000).

Specimen	Tooth	Description
Banyoles 1 France (Lalueza et al., 1993).	Mandibular M3	Two small pits with irregular shapes in occlusal fissures, penetration beyond the dento-enamel junctions.
Kebara 27 Israel (Tillier et al., 1995)	Maxillary I2	A cavity in the central pit of a strongly shoveled tooth, 2.6 mm diameter, extended through the dento-enamel junction.
Bau de l'Aubesier 5 France (Trinkaus et al., 2000)	Maxillary dm1	A mid-lingual pit lesion.
Bau de l'Aubesier 12 France (Lebel &Trinkaus, 2001)	Maxillary M1 or M2	A large hole across the disto-lingual corner of the cervical half of the roots, 7.2 mm high, 6.3 mm wide, 3.5 mm depth.
Sima de Palomas 25 Spain (Walker et al., 2011)	Mandibular dm1	An occlusal cavity, 1.2 mm diameter, extended through the exposed dentin.
Sima de Palomas 59 Spain (Walker et al., 2011)	MandibularM2	A small interproximal notch.

Table 1. Carious lesions among Neanderthals

[5] The Paleolithic or Antique Stone Age was the longest period of human prehistory (99% of it), ranging from 2.8 millions of years (in Africa) to 10,000 BP. The Paleolithic is divided in three periods: Lower Paleolithic (2.8 million years to 200,000 years: the epoch of the hominines and our first ancestors), Middle Paleolithic (the epoch of Neanderthals, from approximately 200,000 to 30,000 BP), and Upper Paleolithic (30,000 BP- 10,000 BP – the epoch of the earliest modern humans). The Neolithic or New Stone Age was defined considering the new way of life based on the production of food from domesticated species. It appears at different times and regions around the world during the Holocene (starts 10,000 BP). The phase of transition between the Paleolithic and Neolithic is known as Mesolithic (Carbonell, 2005).

Dental caries are present but still rare among early modern humans (European and Near Eastern *Homo sapiens*) during the Upper Paleolithic. Caries have been identified in Qafzeh 3 and Skhul 2 in Israel (Fryer, 1976; Boydstun et al., 1988), and only Cro-Magnon 4, Les Rois R50-4 and Les Rois R51-15 have been indentified with caries in Europe (Brennan, 1991; Trikanus et al., 2000). Caries are more widely found among more recent Eurasian foraging peoples, but caries frequencies remain below 10% (Brothwell, 1963; Caselitz, 1998).

3. Caries and lifestyle

3.1 Dietary changes and the raise of caries experience in past human societies

In fact, the history of dental caries is associated with the rise of civilization, and more recently with dietary changes that occurred since the Mercantilism and Industrial Revolution. Several archaeological and historical works have confirmed the relationship between high caries frequencies and prevalences and the increase of carbohydrates intake in human populations from the advent of agriculture[6] (Larsen, 1997; Saunders et al., 1997; Turner, 1979). Generally hunter-gatherers show low caries frequencies whereas peoples based on mixed economies, gardening, and farming, show increasingly higher caries rates (Hillson, 2001; Lukacs, 1992; Powell, 1985; Turner, 1979).

For instance, in the North American Southeast the number of carious teeth in farmers is three times the number of carious teeth in foragers of prior epochs (Powell, 1985). In several populations from Eastern Woodlands of North America the changes are also observed along the time, with frequencies below 7% in Archaic foragers and frequencies over 15% in farmer's phases contemporary to the first contact with Europeans (Larsen, 1997). In prehistoric peoples from Colombia, the prevalence of caries is close to zero in hunter-gatherers that used lithic technology, appears in early farmers and increases in pottery-makers, reaching frequencies of up to 76% (Rodríguez, 2003). These same tendencies have been observed in native modern peoples that had their traditional diets replaced by western ones, during the process of global colonization (Holloway et al., 1963; Mayhall, 1970).

Caselitz (1998) analyzed the historical evolution of caries in 518 human populations of Europe, Asia and America in a wide timeline from the Paleolithic to the present, confirming that during Paleolithic and Mesolithic periods, the hunter-gatherers had less caries and lesions progressed more slowly. Caries indices have increased gradually from Neolithic times, until they reach the high rates observed at the present. Considering only the Holocene (the last 10,000 BC) in the Old World, he observed that the low indices[7] of Mesolithic times remain relatively constant during the Early Neolithic (between the 9th and 5th millennium

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[6] Agriculture is a set of knowledge and techniques aimed to control the natural environment for production of crops. The transition from the hunting-gathering economy to self-sufficient food production changed radically the human history, promoting a high population growth for food availability, sedentary settlements, new labor division, and changes in the rights of land property that led to a more complex society, with specialists, social classes and centralized government systems.

[7] For his comparisons, Caselitz used a reduced variant of the DMF Index (Decayed Missing Filling Index) applied to archaeological samples, the I-CE (Index of carie-extractio) or DMI (Decay Missing Index – Lukacs, 1996; Pezo & Eggers, 2010; Saunders et al., 1997), calculated as the number of carious teeth added to the number of antemortem toot loss (AMTL) divided by the sum of teeth and sockets observed.

BC), but suffered a dramatic increase of 75% in a short time span of few centuries around 4500 BC. This phenomenon, observed in North Africa, Near East, China and Europe has been attributed to the drastic change in the diet that means the introduction and spread of cereals in the entire antique world (Caselitz, 1998).

In the Mediterranean region, Arabia and India the increase of caries began early between the 7th and 5th millennium BC. In Natufians from the Levant region, the phase of hunter-gatherers (10,500-8300 BC) shows 6.4% of caries frequency whereas Neolithic populations (8300-5500 BC) show 6.7% (Eshed et al., 2006). In the Indo region the caries frequencies range between 1.4-1.8% in the earliest populations, but in the site of Harappa (5000 BP, Pakistan) from the Early Bronze Age[8] the caries frequency is 12% (Lukacs, 1992, 1996) whereas an Iron Age skeletal sample from Oman shows 32.4% (Nelson & Lukacs, 1994) analyzed under the same methods (Fig. 2a). During the Chinese Neolithic, the initial phase Yangshao (7000 – 5000 BP) shows rare evidence of caries (0.04%) and all of them occur in the posterior sector of the mouth. The Longshan period (4500 – 4000 BP) presents caries frequencies of 0.30% and besides, showing caries located in the anterior teeth. The Chinese farming in this epoch was based on domesticated species of millet (*Setaria italica*), broomcorn millet (*Panicum miliaceum*) and rice (*Oryza sativa* – Pechenkina et al., 2002).

The most antique written reference of oral diseases in this region comes from a tablet of clay with cuneiform inscriptions from the lower valley of the Euphrates dated at 5000 BC. The tablet refers to the existence of a "worm" responsible for tooth pain and a recipe for spelling it. More than 3000 years later, in Egypt, the Eber's papyrus, a kind of medical tractate dated around 1550 BC, refers to the existence of gingivitis, pulpitis and dental pain and their treatment using dressings, mouth washers and enchantments (Nikiforouk, 1985). In antique civilizations caries and antemortem teeth loss seemed to be a permanent scourge that obviously must have caused the same physical and psychological suffering it causes nowadays. The first attempts of restorative dentistry have been recorded in Egyptians, Phoenicians, Etruscans and Romans (Asbell, 1948; Harris et al., 1975; Jackson, 1988; Puech, 1995; Teschler-Nichola et al., 1998).

In Europe caries rates are almost stable during the Middle Bronze Age (1600-1200 BC) and increase continuously between 1200 BC and 500 AD. It could mean that the spread of agriculture occurred at least one millennium later than in other Old World regions. A little peak is observed around 750 AD followed by a phase relatively stable during the Middle Age and a second increase, much more dramatic, is observed since the 16th century, and it has reached the highest records in our times (Caselitz, 1998). Examining the proportion of affected individuals per population, Caselitz (1998) observed that during the fifth millennium BC, around one third of individuals were affected with caries. In the Middle and Late Bronze Age (1500-300 BC) the affected proportion of individuals decreases relatively and then rose dramatically to 56% in the 7th century AD. This condition of deterioration remains constant until around 1300 AD when it reaches a new peak. In more

[8] In 1820, Christian Thomsen classified the prehistory of Europe in three ages (Cooper Age or Chalcolithic, Bronze Age and Iron Age) based on the analysis of metallic artifacts. Bronze Age was divided into Antique, Middle and Final Bronze Age but dates are different according to the region analyzed. In the Near East bronze appears at the final of the 4th millennium BC, in Greece around 2500 BC, in Persia in 2000 BC, and only about 1800 BC in China (Lull et al., 1991).

recent periods of Modern Age, almost 60% of individuals were affected, and in contemporary times the observations denote global values surpass 95% (Nikiforouk, 1985; Rugg-Gunn & Hackett, 1993; Shafer et al., 1983). These trends have been pointed out in other studies (Moore & Corbet, 1971, 1973, 1975; Roberts & Cox, 2007 – Fig. 2b).

In the American continent caries has been recorded since approximately 7000 BC with relatively high indices that decrease around 5000 BC (Bernal et al., 2007; Caselitz, 1998). A dramatic increase was noticed since 2300 BC. Although we do not have complete dietary inventories for each different period, the high caries rates of the oldest Americans could be related to the consumption of endemic fruits rich in maltodextrines and sugar, such as carob (*Prossopis sp.*) and acacia (*Acacia sp.*). This decrease could be explained by a reorientation in the subsistence activities that turned to marine foraging during the Middle Holocene (around 6000 BP), whereas the highest peak can be clearly related with the summit of agricultural production.

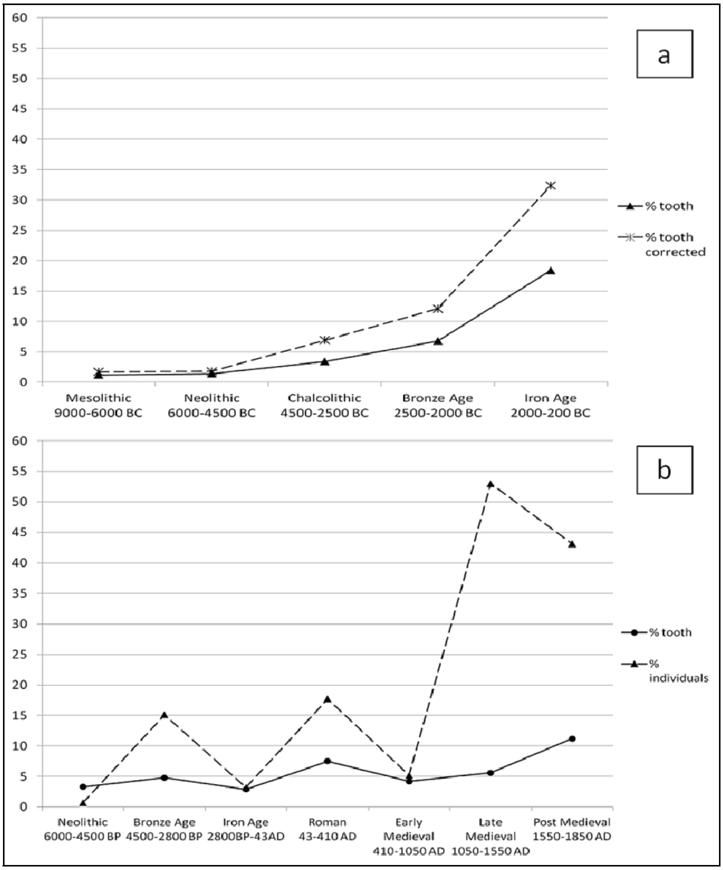

Fig. 2. **Caries trends in the Old World across time.** a) Indus valley civilization sequence, caries frequency versus corrected frequency (Lukacs, 1996). b) Britain sequence, caries frequency versus prevalence (Roberts & Cox, 2007).

In pre-contact America, the consumption of starchy seed-bearing plants like chenopodiaceous, cucurbitaceous, fabaceous, asteraceous (sunflower) has been suggested as the first stage of farming (between 8000-5000 BP) and is related to the first changes in the oral pathological profiles (Bernal et al., 2007; Pezo, 2010; Piperno, 2011). The increase of caries frequency has been attributed mainly (but not exclusively) to maize consumption[9] (*Zea mays* - Larsen et al., 1991; White, 1994) and more specifically to a gradual replacement of popcorn (*indurata* variety), consumed in the earliest periods, for a softer, sweeter and thus more cariogenic, amylaceous maize (*amylacea* or *saccharata* variety) during the second millennium BC (Pezo, 2010; Rodríguez, 2003). However, it is possible that due to the enormous dietary variety derivate from a multiplicity of ecological niches, there are other potentially cariogenic products such as tubercles (wild and cultivated), as well as sweet and sticky fruits (Bernal et al., 2007; Neves & Cornero, 1997; Pezo, 2010).

3.2 Caries: Frequencies and profiles in the last 2000 years

Comparative analyses between Late Antique and Early Medieval populations in Europe show a clear oral health deterioration pattern with high frequencies of caries, abscesses, antemortem tooth loss, alveolar resorption and more severe dental wear in the medieval epochs due to an impoverishment in life conditions after the down of the Western Roman Empire (Belcastro et al., 2007; Manzi et al., 1999; Slaus et al., 2011).

During the Roman Imperial Age (1st–4th centuries AD) caries affects 71.6% of the individuals and 15% of the teeth from Quadrella necropolis (Isernia, Italy). Lesions are more frequent in the posterior teeth and cervical caries are more frequent than occlusal ones. Moreover, occlusal caries decrease with age while cervical ones increase (Bonfiglioli et al., 2003). In general, caries frequencies of Late Antique populations range between 4-15%, whereas in the Early Medieval sites they range between 11.7-17.5% (Slaus et al., 2011). These noticeable differences suggest a drastic change in the dietary habits with a significant increase of carbohydrates in the Early Medieval times.

Historical records state that the typical diet of the middle and low classes in the Western Roman Empire was based on: bread (rich in impurities), porridge of cereals, some pulses, vegetables, olives, some fruits and wine, as well as goats and sheeps. Throughout the Empire diet was quiet homogeneous (Dosi & Schnell., 1990). In the medieval Europe low-class subsistence was based essentially on cereals (the bread represents the 70% of their intake) whereas the protein consumption (meat from hunting or shepherded animals and fresh fish) was low and uncommon (Mazzi, 1981).

The medieval diet of Mediterranean peasants was composed mainly by cereals, specially bread, wheat and barley, pulses (broad beans, peas, lentils, chickpeas), and fruits such as figs, olives, plums, peaches, pine kernels, almonds and grapes (Eclassan et al., 2009). In Britain the most common products were wheat, barley, oats, rye, beans, milk, cheese, eggs, bacon and fowl and the diet of the poor classes was probably restricted to coarse black bread

[9] Undoubtedly, corn was one of the most valuable products in the ritual and daily life within Americas. Whereas in Mesoamerica it seems that it has been cultivated almost exclusively (monoculture), in the Andes was only one of the most important crops, consumed in several ways and used to prepare "*chicha*" (maize beer) (Antúnez de Mayolo, 1981; Bonavia, 2008).

(Moore & Corbett, 1973). In Scandinavia, the medieval diet was basically composed of high amounts of salted herring and dried fish, but also barley porridge, turnips, cabbages, dried sour rye bread, sour milk products, some meat, and beer (Varrela, 1991). Only in Spain there was a higher consumption of sugar cane[10] and rice, introduced by the Muslims during almost eight centuries of Iberia occupation (López et al., 2010). In that epoch food was much more abrasive because the flour (milled by millstones) kept some grid that was incorporated to the bread. The cooking or storage techniques using ashes, or consumption of preparations made with unclean flour or non-dehusked grain of hulled cereals such as broomcorn (*Panicum miliaceum*) or barley (*Hordeum vulgare*) were common (Eclassan et al., 2009).

People from medieval French villages of Languedoc from the 13th-14th centuries show caries frequencies of 17.5%, with frequent occlusal and approximal caries (Eclassan et al., 2009). For medieval populations of England and Scotland from the 13th -15th centuries the caries frequency vary between 6.0-7.4% (Kerr et al., 1990; Watt et al., 1997), whereas in medieval sites in Croatia from the 11th-12th centuries the prevalence of caries is 45%, with frequencies or 9.5%, identical to the reported for later sites from the 14th-15th centuries of the same region (Slaus et al., 1997; Vodanovic et al., 2005). In general, Late Medieval populations do not present frequencies significantly higher than Early Medieval populations. It suggests that in a time span of eight centuries, no significant changes in diet occurred (Vodanovic et al., 2005).

Several studies have concluded that the most common locations of caries during the medieval epoch were occlusal and cervical approximal caries, whereas interproximal ones appear rarely (Eclassan et al., 2009; Kerr et al., 1990; Vodanovic et al., 2005; Varrela, 1991; Watt et al., 1997). Meanwhile, around the 10th-11th century, some changes in the location patterns of caries in populations in Continental and Islander Europe are evident. There is a gradual reduction in cervical-approximal caries (CEJ caries[11]) that was more common during the Antique Age, and an increase of occlusal, buccal, and lingual lesions, that have occurred since earlier ages. These data suggest that infantile diet became softer until the final of Middle Age (Lingström & Borrman, 1999; Moore, 1993; Moore & Corbett, 1975; Varrela, 1991; Vodanovic et al., 2005; Watt et al., 1997).

The transition from Middle to Modern Age in Europe was characterized by a remarked increase of flour for bread fabrication and consumption of sugar cane. The possibility of purchasing vegetables and grains in open markets seems to have contributed to the raise of

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[10] The earliest evidence of domestic sugar cane (8000 BC) comes from New Guinea, Southeast Asia (Sharpe, 1998). After domestication, it spreaded rapidly to southern China, Indochina and India. Sugar cane was taken to Persia during Dario's epoch, where it was discovered by the Macedonian armies in the 4th century BC. Greeks and Romans know it as a "salt from India" and imported it only for medicinal purposes due to its high cost. The crystallized sugar was discovered in India during the Gupta dynasty, around 350 AD. Muslims discovered the sugar when they invaded Persia in 642 AD and spreaded its consumption in Western Europe after they conquered Iberia in the eighth century AD. The first reference about sugar in England, where it was considered a "fine spice", dates from the Crusades epoch in 11th century. In the 12th century, Venice built some colonies near Tyre (modern Lebanon) and began to exports sugar to Europe. Sugar was taken to America in the second trip of Columbus in 1493 (Bernstein, 2009; Parker, 2011).

[11] These lesions have been attributed to physiological compensatory super-eruption of roots subsequent to severe occlusal wear produced by abrasive diets (Eclassan et al., 2009). However, the possible origin related to sweet beverages must be considered (Pezo, 2010; Pezo & Eggers, 2010).

caries and other oral diseases during that time (Bibby, 1990; López et al., 2011). In the first half of the 17th century, Scandinavian populations, with a diet based on marine products show a caries prevalence of about 60% and frequencies of approximately 13% with increases in antemortem tooth loss among the oldest individuals. Carious lesions were most common in the occlusal area, CEJ and interproximal surfaces predominantly in lower molars. In these populations, lesions are uncommon in children but appear earlier in young adults (Lingstrom & Borrman, 1999; Mellquist & Sandberg, 1939; Varrela, 1991).

Since the 17th century, and especially during 18th century, many kinds of foods were brought from America to Europe. Among them are: maize, beans, potatoes, tomatoes, cocoa, coffee and sugar (Prats & Rey, 2003). Although sugar and sugar cane came to the West from India carried by the army of Alexander the Great in 327 BC, the "white sugar" had not became a commercial product until the 7th century. It was largely distributed until the final of 12th century(Bernstein, 2009), but it has only been imported in large scales from America to Europe since 1550 AD when sugar cane plantations increased in Brazil and in the Caribbean islands (Saunders et al., 1997; Parker, 2011). The effect of refined food on caries trends can be observed clearly in Europe during the 18th century and coincides with the increase in the production of refined sugar and the introduction of flour mills.

Populations from the 11th century cemeteries, that were excavated in Britain, Canada and USA show caries frequencies over 35% and a high number of antemortem tooth loss due to caries mostly on inferior molars. For that epoch, changes follow the same trend: cervical lesions (CEJ caries) are less common and more lesions appear in the occlusal surfaces and interproximal contact areas (Moore, 1993; Moore & Corbett, 1975; Saunders et al., 1997).

In the North American colonial diet, meat (pork, beef, and mutton), bread, and vegetables were the staples, and sweet-baked goods were also popular. Maple sugar, maize (used as corn meal flour), pumpkins, and wild fruits were harvested as well. The recipes were all almost the same, and people consumed three meals a day. The use of refined flour for the production of bread and pastries seems to have been very important and bread is still one of the most important items. In addition, the use of corn meal porridge, cooked, sweetened flour mixtures and stewed, sweetened fruits probably contributed to the cariogenicity[12] of the diet (Boyce, 1972; Moore, 1993; Saunders et al., 1997).

However, those remarkable caries increments, occurred during the second half of the 19th century, have been attributed to dramatic increases in the intake of sugar and refined carbohydrates between 1830 and 1880 (Corbett & Moore, 1975; Moore, 1993). Since 1860 the importation of cane caused impressive improvements in per-capita consumption (Saunders et al., 1997). In the 1840 decade England, USA and Canada had an approximate consumption of 30 lb/person. At the end of the century those amounts raised to around 80 lb in England, 60 lb in USA and 50 lbs. in Canada (Boyce, 1972; Saunders et al., 1997). Besides, the introduction of ceramic mills in North America in 1875 (Leung, 1981), produced flours of better quality that favored its industrialization and massive consumption (Boyce, 1972).

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[12] A cariogenic diet has been defined by the following features: frequent intake of meals with a high content of carbohydrates quickly fermentable (mainly sucrose) with retentive and sticky consistence that produces repetitive lowering of pH values and changes in the ecology of dental plaque. The cariogenic diet produces increase and quicker development of lesions, and location in non-retentive surfaces (Nikiforouk, 1985; Rugg-Gunn & Hackett, 1993).

Caries increase tendency seems to have been constant during the second half of the 19th century and the first half of the 20th century, worldwide. On the other hand, preventive policies against caries did not have considerable effects until the second half of 20th century. France and England were major manufacturers of toothbrushes in 19th century, but they were considered luxury articles and regular tooth brushing was not a widespread practice until after the second half of 19th century (Asbell, 1992).

Since the 1970s a striking decline in caries experiences has been observed throughout industrialized countries (Brunelle & Carlos, 1990; Shafer et al., 1983). This seems to be related to dental treatment and the introduction of fluoride[13] water and toothpaste. Also, the decline in dental caries rates was due to a range of changing social factors that seem to be linked to improvements in general health indicators (**Haugejorden, 1996;** Nikiforouk, 1985; Shaw, 1985). But in emerging countries the situation is the opposite and high caries rates are associated with malnutrition, absence of health services and poor quality of life (Alvarez, 1988; Campodónico et al., 2001; Heredia & Alva, 2005).

3.3 Diet and the "main villain" in the raise of caries throughout human history

The available data indicates that the modern trends on caries increases start simultaneously with permanent growth intake of sucrose during the last two centuries. The hypotheses of an increase in the susceptibility or resistance diminishment by genetic reasons or the installation of a particularly cariogenic flora have not been sufficiently corroborated (De Soet & Laine, 2008; Hassell & Harris, 1995; Shuler, 2001; van Palenstein et al., 1996) while dietary changes seem to be the most reasonable answer. In the modern western world and increasingly in other regions of the globe approximately half of consumed calories comes from carbohydrates and almost half of it is sucrose.

Until recently, several populations living in isolated areas of the world kept their ancestral ways of life (for instance, many African tribes, Inuits, South American Indians, Melanesian, Polynesian) under conditions of perfect adaptation to their environments and diets (Donnelly et al., 1977; Mayhall, 1977; Pedersen, 1971; Schamschula et al., 1980; Walker & Hewlett, 1990). Bacteriologic analyses of their dental plaques, although not extensive, show cariogenic species, but those individuals are still developing few or no caries. Otherwise, when those populations were acculturated or simply replaced their traditional diet for an "occidental refined diet", they started to develop progressively destructive caries patterns.

The case of the British colony of Tristan da Cunha, a volcanic island in the South Atlantic, described several times since 1817, is famous. Until the Second World War their diet was based on fish and potatoes (from their own production) and they were visited by a ship once or twice a year. Despite their poor hygiene, the majority of them were free of caries. When the war started many factories and military stations were built on the island deeply changing the lifestyle of the population and facilitating the importation of other foodstuff.

[13] The fluoride contained in water has been recognized as a control factor of caries but high amounts of fluoride can produce recognizable enamel defects that usually involve a pattern of opacity named fluorosis (Fejerskov et al., 1994). Fluorosis has been reported in archaeological series related to consumption of phreatic waters from wells (Pezo, 2010; Valdivia, 1980).

The deterioration of their oral conditions was evident in the beginning of the 1950's. In 1962, when the volcanic activity obliged inhabitants to evacuate towards England, more than 40 % of their teeth were affected by caries or had been destroyed. The most notable change in life conditions of those individuals was diet, with a decrease in the consumption of potatoes and a compensatory consumption of sugar. It is estimated that the daily consumption of sugar rose from 1.8 g. in 1938 to 150 g. in 1966, three years after their return from England. On the other hand, under equivalent conditions, older people did not seem to be as resistant as their descendents (Holloway et al., 1963). Data that confirms this tendency have also been reported for populations from developing countries (Corraini et al., 2009; Ismail et al., 1997; Petersen & Kaka, 1999; Petersen & Razanamihaja, 1996).

Whereas the role of sugar as the main "villain" in the caries etiology seems to be evident, it is disputable if starches play a similar role (Tayles et al., 2000, 2009). By their slow accumulation in dental plaque and slower oral digestion, starch could have a relative low cariogenicity and its importance as a factor of caries depends on the simultaneous intake with sucrose as well as the frequency of its consumption (Frostell et al., 1967). Thus, starch has been defined as "co-cariogenic", especially when it is gelatinized by thermal effect (Grenby, 1997). The gelatinization of starch[14] seems to be the determining factor of its cariogenicity, because in general, only gelatinized starches are susceptible to enzymatic breakage (through salivary or bacterial pocesses) to produce highly cariogenic molecules (Grenby, 1997; Lingström et al., 2000). Nevertheless, the necessary temperature for starch gelatinization surpasses 80ºC in most of the cases.

In this sense, the invention of pottery (the earliest pottery appeared in the Samara region of South-Eastern Russia about 7000 BC – Anthony, 2007), its spread and common use for storage and cooking could have been a significant trigger for the raise of caries markers before the popularization of refined sucrose consumption. Until the introduction of pottery, other cooking methods were employed around the world, but those methods would hardly result in gelatinization of starche[15] (Antúnez de Mayolo, 1981; Pezo, 2010; Wrangham, 2009). The refinement and cooking of carbohydrates produce an increase in their retentive and sticky capacity the tooth surface leading to slower clearance times. For instance, bread starch shows higher clearance times than starches from potatoes or rice (Grenby, 1997; Lingström et al., 2000).

According to some authors, cooking can eliminate some protective agents (against the caries) of certain foodstuff. The Bantu of Africa show an increase in caries frequency after the adoption of a colonial diet. The amount of cereals and sugar were the same, but they

[14] During the process of cooking food, the starch granules are disintegrated by heat and mechanical forces. Eventually the liberation of the molecules in a process named gelatinization occurs. The temperature and water-starch proportion necessary to gelatinization are very variable in accordance to each distinct starches. For instance, the temperature for rice gelatinization ranges between 85-111°C with a proportion water-starch of 2.0-0.75 and ranges between 65-90ºC for maize starch (Lingström et al., 2000; Donald, 2004).

[15] These traditional methods include: a) the use of heated stones for boiling liquids within pumpkins and squashes; they were also used to roast meat and vegetables by direct contact or placed along with the food into the underground ovens covered with earth; b) roasting by direct contact with fire (as for mollusks or turtles); c) roasting of meat and vegetables wrapped in leaves or packed in bamboo canes over wood grills, among others.

were refined for cooking. In this case, by *in vitro* studies, caries increase was attributed to the absence of phytate, an organic phosphate contained in cereals that can be extracted easily by boyling (Bowen, 1994; Osborn & Noriskin, 1937). Thus, the softer texture and the elimination of "protective factors" through cooking increase cariogenicity.

On the other hand, there are some foods that inhibit the formation of caries. Diets rich in meat lead to low caries frequencies due to the fatty acids' antibacterial power and their capacity to reduce the adherence of plaque on dental surfaces. The intake of dairy products and fish (foods rich in calcium and casein that can increase urea concentration) modifies pH values and the quantity of salivary production, inhibiting the formation of dental plaque. Finally, a food rich in polyphenols (such as cacao, coffee and tea) inhibits the bacterial metabolism and stimulates the salivary secretion representing, thus, another mechanism of caries prevention (Bowen, 1994; Touger-Decker & Loveren, 2003).

Caries frequencies of only 0.3% - 0.6%, with prevalence of around 4% have been reported for the Inuit from Angmagssalik (East Greenland), isolated until 1884 and with a diet based on meat and fish, almost without carbohydrates. These observations are in accordance with prevalences of 0.4% - 2.5% and frequencies of 0.08% - 0.35% (mainly little carious lesions in molar fissures) in craniums of ancient Inuits and are strikingly different from that observed in neighboring populations with access to sugar and cereals (Mayhall, 1977; Pedersen 1947, 1952).

Little changes in the type of carbohydrate, texture, mode of conservation and preparing of meals can produce utterly different caries experiences (Molnar, 1972; Rodríguez, 2003; Turner, 1979). In Paleolithic and Mesolithic populations it is common to observe the effects of an abrasive and non-refined diet. The ancient people show an aggressive dental wear that frequently surpasses the speed of development of little aggressive carious lesion, producing an exposure of the pulp chamber with abscesses formation and consequent tooth loss (Fig. 3). In Neolithic populations the change to better processed diets gradually leads to a low wear of masticatory surfaces that is another factor why the occlusal caries could have developed earlier. This competitive relation between dental wear[16] and caries has been also observed in fishermen from the South American Pacific coast, Dutch sailors from 18th -19th centuries and in other populations with marine subsistence (Milner, 1984; Maat & Van der Velde, 1987; Pezo & Eggers, 2010). Finally, dental wear is a factor that can distort the real perception of caries experience in several populations with abrasive diet.

However, there are also some cases that have reported a positive correlation between caries and dental wear, as observed in Mesolithic populations from Portugal and Sicily (Meiklejhon et al., 1988; Lubell et al., 1994) where the consumption of honey, figs and sweet fruits accelerates the installation of caries in attrition surfaces. This phenomenon has also been noticed for the Pecos from South West -USA during the Archaic Period (4000-1000 BC) with caries prevalence of 14% and pulp chamber exposure as the main cause of tooth loss (Larsen, 1997). Thus, the cariogenic capacity of natural sugars contained in honey and sweet

[16] Dental wear is related to the physical consistence of food, the storage ways and the technology used in their processing. Analyses of coprolites (fossilized faeces) have shown some abrasive material such as phytolithes (microscopic silica structures contained in certain plant organs), seeds, little bone fragments and oxalate calcium crystals from some species (Larsen, 1997; Pearsall, 2000). Besides, historical and ethnographical data from several regions of the world describe the ingestion of abrasives such as ashes and clays as part of the meals (Antúnez de Mayolo, 1981; Indriati & Buikstra, 2001; Rodríguez, 2003).

fruits such as carob, figs, and prickly pear might not be understated because they have been noticed as responsible for the high caries prevalence in some populations (Bernal et al., 2007; Nelson et al., 1999; Neves & Cornero, 1997; Pezo, 2010).

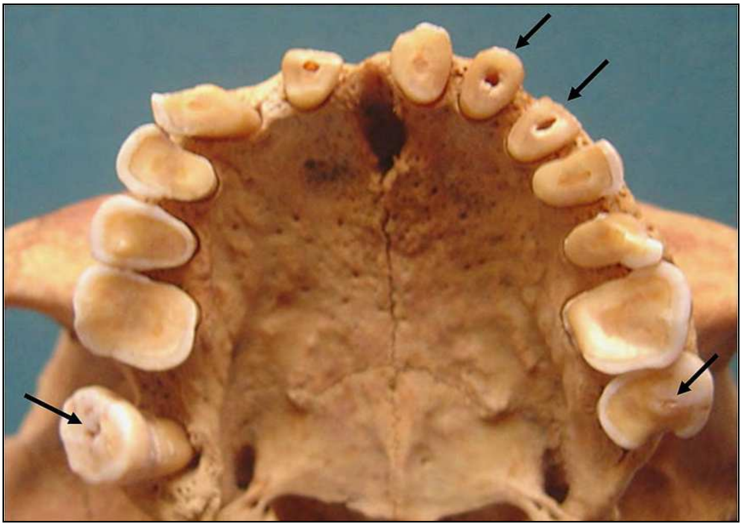

Fig. 3. **Competitive relation between caries and dental wear in an individual with abrasive diet.** Carious lesions almost eliminated through dental wear in molars, and pulp chamber exposure due to severe wear in anterior teeth.

Finally, drastic climatic changes, complex social processes, and wars can lead to resource searching by strategies considered "regressive", as well as technological innovations (Hillson, 2001; Molnar, 1972). Walker & Erlandson (1986) studied caries and dietary changes in Santa Rosa Island (Santa Barbara Channel, South California), during a time span from 4000 to 400 BP, observing that in the first 1500 years predominantly terrestrial products such as starchy roots and tubers were exploited, and later they readapted their subsistence strategies to marine sources dropped from 13.3 to 6.3% in the caries frequencies, following the reduction in carbohydrates intake.

On the other hand, there are some exceptions about the correspondence between agriculture and caries. Several groups of modern farmers with a diet based almost exclusively on starch rich foods such as taro, sweet potato, and manioc, show low caries frequencies (Barmes et al., 1970; Baume 1969). In populations from Eastern Asia, the consumption of rice, despite their frequency, has produced low caries experiences (Tayles et al., 2000). Other especially high values of caries in populations with hunter-gatherers technology have been attributed to the consumption of cariogenic species traded with neighbor farmers[17] (Lukacs, 1990; Walker & Hewlett, 1990).

[17] African pigmies (Aka, Mbuti, Efe) traded meat and honey with the Bantu, who provided back manioc, maize, nuts, rice and plantains. In these hunter-gatherers honey is an important dietary source during great part of the year (Walker & Hewlett, 1990).

As we can see, the historical evaluation of caries allows us to recognize some trends and recurrences in prevalences, frequencies and patterns. Although in general it is possible to identify some critical variables such as the excessive consumption of refined sucrose or gelatinized starches as etiological agents, there are many other socio-historical factors, specific for each population, that must be considered before generalizing about the complex relationship between caries and subsistence pattern.

4. Key factors related to caries prevalence in human populations: Physiological or cultural factors?

Much of the studies carried out in hunter-gatherers and farmers from different latitudes and temporal periods have stated a particular trend: women show higher caries prevalences than men (Larsen et al., 1991; Lukacs, 1992, 1996, 2008, 2011; Luckacs & Largaespada, 2006; Milner, 1984; Rodríguez, 2003; Walker & Hewlett, 1990). This phenomenon suggests two possible, not necessarily excluding, explanations: a) there is a major constitutional predisposition in females to caries; b) the differences are culturally regulated.

Clinical researches of the last decades have revealed that physiological differences between sexes have an important indirect impact on oral ecology. The saliva's chemical composition and flow are modified in various manners according to hormonal fluctuations associated with puberty, menstruation, and pregnancy. These processes lead to a much more cariogenic oral environment in females than in males. Estrogen levels are positively correlated with caries rates whereas androgens do not affect them (Lukacs & Largaespada, 2006). Experimental and clinical studies show that pregnancy reduces the buffer capacity of saliva and produces xerostomy that promotes bacterial growth, increasing the susceptibility to caries (Bergdahl, 2000; Dowd, 1999; Lukacs & Largaespada, 2006; Salvolini et al., 1998; Valdéz et al., 1993).

From an evolutionary perspective, it has been suggested that the increase of fertility that accompanied the sedentary lifestyle and the adoption of agriculture had a significant effect on the increase in caries rates worldwide (Lukacs, 2008). The classic proverb "a tooth per child" expresses the traditional idea that pregnancy results in a deterioration of oral health along with a weakening in the tooth structure and subsequent caries development and tooth loss (Lukacs, 2011; Lukacs & Largaespada, 2006). However, although there is evidence of increased periodontal inflammation in women during pregnancy, tooth loss due to pregnancy is more controversial (Larsen et al., 1991; Lukacs, 2011).

From the same point of view, the fact that much more males than females show high caries frequencies have been interpreted as a cultural mechanism of adaptation, in which young men are selectively buffered from malnutrition, through the exposition to higher amounts of cariogenic foods (Slaus et al. 1997). However, women usually show more severe nutritional stress markers, such as frequent enamel hypoplasias, less intervals between defects and more frequent tooth growth disruptions (King et al., 2005).

Among other "constitutional" reasons argued for this repetitive higher prevalence of caries in women, the earlier eruption of the female dentition (that exposes the teeth for longer time), has been also mentioned. This assertion, however, has not demonstrated strong correlation with caries prevalence (Larsen, 1997). On the other hand, if the reasons were strictly physiological, then differences between men and women should be universal, but in general there are many clinical and archaeological examples that suggest the existence of other factors involved (Powell, 1988; White, 1994). So, despite the plausible possibility that women show a higher intrinsic physiologic susceptibility towards caries than man, the caries experience is behaviorally mediated.

It has been observed that in populations where caries are higher in women, there is usually a differentiated consumption of foods: men consuming more meat and women consuming more carbohydrates. Contemporary foragers populations show that men, responsible for getting the protein, consumes more amounts from the meat that they hunted, whereas women, responsible for vegetables gathering, and food preparation, consume more carbohydrates during their activities (Walker & Erlandson, 1986; Walker & Hewlett, 1990). Furthermore, men eat some few "big" meals along the journey, whereas women eat several "little" ones, causing more exposition to caries (Gustafsson et al., 1953; Rugg-Gunn & Edgar, 1984; Wrangham, 2009).

Interestingly, the differences between men and women are much more subtle among farmers. However, these slight differences also seem to be related more to cultural than constitutional factors. The Bantu show high caries prevalence in accordance to their considerable intake of carbohydrates and men have higher frequencies than women (9.1% versus 7.1% - Walker & Hewlett, 1990). The same happens in some populations from South American Andes where the carious lesions (mainly cervical ones) are much more frequent in males that preserve the ancestral habit of coca leaf chewing (Pando, 1988). This pattern has also been observed in archaeological samples (Indriati & Buikstra, 2001; Langsjöen, 1996; Pezo & Eggers, 2010; Valdivia, 1980). In Andean and Amazonian populations, it was observed higher prevalence in women who are responsible for chewing maize and manioc as a part of preparing fermentable beverages (*chicha, masato, kiki* - Larsen, 1997; Pezo & Eggers, 2010).

On the other hand, we must consider the effect of social differences in the patterns of food consumption in stratified societies (Cucina & Tiesler, 2003; Gagnon, 2004; Sakashita et al., 1997). There is growing evidence suggesting that members from different social classes, consuming different foods, tend to have different patterns of dental disease. In Copán (Honduras) and Lamanai (Belize), during the Classic Maya Period, elites show lower prevalence of caries than ordinary people. Among low-status burials, there are significantly more caries than in high-status individuals. It was also observed, through an isotopic study, that low-status individuals eat mainly carbohydrates (maize). Stable isotopes studies confirmed that low-status individuals eat mainly carbohydrates (maize), whereas elite individuals consumed much less maize and had easy access to animal protein, and in general, a much varied and cariostatic diet (Reed, 1994). Contrarily, among citizens and slaves from Yin-Shang period (Anyang, China) oral diseases were significantly higher in citizens' samples (Sakashita et al., 1997). High-status individuals from the Peruvian North Coast (Late Formative, 400-1 BC) do not show more caries than their low-status contemporary ones (Gagnon, 2004).

Comparisons between social classes show contradictory results in medieval Europe. Individuals from all social classes, buried around the Westerhuss church (Sweden), do not show differences in caries prevalence that suggest similar diets independently of social status (Swardstedt, 1966). In Zalavár (Hungary), however, high class individuals linked to the castle show significantly lower caries frequencies (6.4%) than ordinary village people (12.1% - Fryer, 1984). In post-medieval Europe caries tends to affect more the opulent class than the poor class due to the regular consumption of sweet foods. Since that epoch caries has been perceived as an occupational disease among bakers and confectioners (Götze et al., 1986; Kainz & Sonnabend, 1983). Historical records of the meals served for the Spanish royalty of the 18th century included meat broths and stews from hunted and breeding animals that contained wine, sugar and cinnamon, while bread was the usual side order. The last part of each main meal was the sweet dessert that included cakes, creams, sugar coated donuts, fruit tartlets, cookies, jelly, fruits with syrup, dates, pomegranates, nuts, hazelnuts, and figs. The Spanish royalty usually consumed chocolate that was the unique food permitted during the penitence days (Pérez Samper, 2003).

From these information we can infer that, although it is true that high caries frequencies are associated to poverty and a restrict diet (rich in carbohydrates and poor in animal protein), it is also true that in some periods better economic conditions facilitated a more frequent intake of food, increasing also the amount of cariogenic substratum for certain sub-groups of the population. Other socio-economical factors must be carefully considered; among them, the unfavorable conditions of dental structure development due to malnutrition and hypocalcification that turns tooth much more vulnerable to caries attack (Alvarez, 1988; Campodónico et al., 2001; Heredia & Alva, 2005; Hollister & Weintraub, 1993). Finally, enamel defects, more common in emerging countries due to nutritional stress, can facilitate the development of carious lesions under the presence of cariogenic diets (Nikiforou & Fraser, 1981).

5. The new research agenda on the historical relation between caries and food

The main objective of the study of caries and other dental diseases from the anthropological point of view is to recognize long term dietary changes related to historical events, with the purpose of understanding the rise of civilization as an integrated process that articulates not only new subsistence patterns and technologies but also new forms of relationship among human beings.

Bioanthropological literature offers several comparative studies of caries among groups with known subsistence patterns and social organization that indicates that dental diseases are less frequent or do not appear in hunter-gatherers, whereas they are more frequent and variable in farmers (Table 2). However, there is not simple or universal explanation for patterns of changes in caries frequencies during human history (Tayles et al., 2000, 2009).

The relationship between caries and agriculture is based on the assumption of an increase of carbohydrate in the diet and the supposition that all these carbohydrates are cariogenic. This assumption has led many scholars to infer, solely based on the increase of caries rates, the adoption of agriculture. However, the lower caries rates observed in Asiatic rice-eating farmers contradicts this assertion (Tayles et al., 2009). On the other hand, there are ethnographic records of a great variety of groups that took advantage of diverse subsistence strategies combining foods from hunting and gathering (terrestrial and/or marine), with vegetables from gathering and farming in different proportions (Hillson, 2001). These groups can not be classified into those two "hermetic" categories (hunter-gatherers and farmers). During the human history many societies show different civilizatory trajectories and "wide spectrum" diets.

Despite, the "typical" frequencies for each type of diet have been used in bioanthropology to infer subsistence and social organization in groups with unknown dietary record[18] (Lukacs, 1992, 1996; Turner, 1978, 1979; Ubelaker, 2000), the use of "simple" caries indices and frequencies have showed limitations. These difficulties arise because of the superposition and non-specificity of the "typical" ranges and the consequent problem of classifying populations with mixed subsistence strategies or developing stages of agricultural subsistence (Godoy,2005; Hillson, 2001; Lukacs, 1992, 1996). In addition, there is a clear association between age and caries experience that is difficult to evaluate in archaeological populations. In living peoples caries progress with the age, and the proportion of teeth affected by coronal or root caries increase with age (Luan et al., 1989; Matthesen et al., 1990). In general, caries experience can be very variable among individuals, with many or few caries per individual, a situation that can obscure the perception of caries frequencies in whole populations.

Because of the fragmentary nature of the archaeological material the loss of information regarding the number of individuals affected in the population and the number of lesions in lost teeth (*antemortem* and *postmortem*[19]) is inevitable. Thus, since it is likely that some teeth lost antemortem should have been lost due to carious lesions, the resultant rate can be produce an under-estimative of the real caries experience of an individual or group. On the other hand, we do not know how many teeth were lost due to caries or other conditions such as trauma and periodontal disease (Carranza, 1986; Lukacs, 2007). Besides that, it is difficult to know how many teeth were present in the lost maxillary segments. For those reasons, modern caries indices such as DMFT or DMFS are unsuitable for bioarchaeological research. Also, diagenetic changes and variable preservation of skeletal series can obscure genuine differences or similarities between sites, making problematic any inter-observer comparisons (Hillson, 2001; Wesolowski, 2006).

The caries rates regularly used in bioanthropology (Duyar & Erdal, 2003; Hillson, 2001; Moore y Corbett, 1971; Lukacs, 1992, 2007; Powell, 1985; Saunders et al., 1997; Watt et al., 1997;) for being numeric, basically count the number of lesions creating a false perception that high frequencies, prevalences or caries indices, correspond to an increase of agricultural development. Furthermore, these rates do not discriminate between the type, severity or exact location of the lesions, which can be much more informative about a diet's cariogenicity. Individuals with carious lesions of different depth and location can have similar caries rates. This fact can obscure the interpretation of caries experience among populations. For instance, a young adult from a group A with two occlusal lesions that affects only enamel has the same numeric index as another young adult from a group B that

[18] Evaluating populations with known diets, Turner (1979) defined ranges of characteristics frequencies for each type of subsistence: 0%-5.3% for hunter-gatherers, 0.44% - 10.3% for mixed economies, and 2.2% - 26.9% for farmers.

[19] Approximately 15% of teeth are lost during the process of human remains recovery. These sockets are difficult to be considered for caries indexes because lost teeth could, or could not, have been affected by caries (Larsen, 1997; Pezo, 2010; Saunders et al., 1997).

suffers from two interproximal lesions that affect dentin and pulp. Although they have the same caries frequency and/or index it is possible that their diets are quite different (Fig. 4).

Pezo & Eggers (2010) employed several dental paleopathology markers to infer past diets in four groups with different stages of agricultural development inhabiting the Peruvian North Coast and observed a paradox overlap of the simple caries frequencies and DMI that did not correspond to technological and social changes of the different epochs. In a more detailed analysis it was observed an increase in the "speed of development" of caries and a gradual change in the caries location from occlusal to extra-occlusal caries, in accordance to the expected for more cariogenic diets associated with the adoption of new vegetal products and new processing technologies that accompanied the agricultural intensification. Sweet fruits and two maize types introduced in different epochs produced totally different caries patterns. In the later period, near to the European contact, when farming technologies reached their maximum apogee, besides carious lesions and other conditions inherent of an agricultural diet, typical culturally inflicted lesions appear: those produced by coca leaf chewing and maize beer or "*chicha*" beverage.

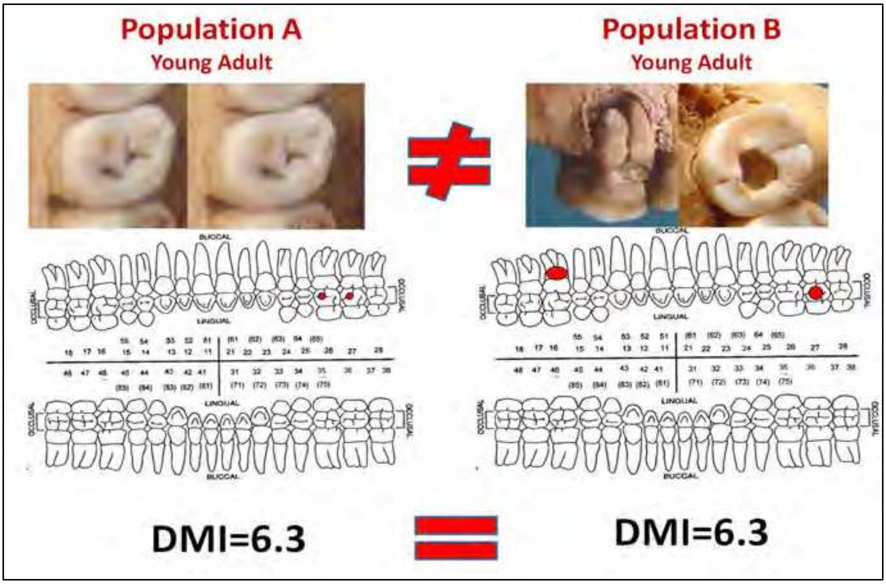

Fig. 4. **The problem of "simple" caries frequencies and indices in Bioanthropology.** In archaeological samples similar indices do not necessarily correspond to similar dietary conditions and comparable caries patterns.

These results, lead us to conclude that the use of caries indices like DMI or the record of simple caries frequencies are insufficient in reflecting known differences in agricultural development because they do not allow one to discriminate between different degrees of cariogenicity of a diet (Fig. 5). Caries depth and location are better markers to evaluate cariogenicity in past populations. The most accurate indicators are dentine caries and extra-occlusal lesions. Occlusal caries are informative, but can be eliminated by intense dental wear (pulp exposures due to dental wear must then be subtracted from the total number of carious lesions). Other comparisons along the time have confirmed an increase of the depth of lesions and more affected dental surfaces, related to the introduction of more cariogenic foods (Bonfiglioli et al., 2003; Hillson, 2001, Godoy, 2005; Pechenkina et al., 2002; Sakashita et al., 1997).

Then, the new challenge of oral paleopathology is to determine the impact of farming of different kinds of crops in different parts of the world by the observation of caries depth and location patterns associated with different diets. Rather than a particular indicator, the "ideal method" for paleodietary reconstruction with oral pathology is the characterization of specific "paleopathological models" produced by the integration of caries, periodontal disease and dental wear patterns obtained through the maximum possible number of markers. Caries depth and location as well as other oral conditions need to be considered in the context of oral ecology. Only an integrative analysis, relying also on as much archaeological data[20] (concerning the contextual social conditions) and bioanthropological evidence as possible can result in more reliable reconstructions of ancient diet.

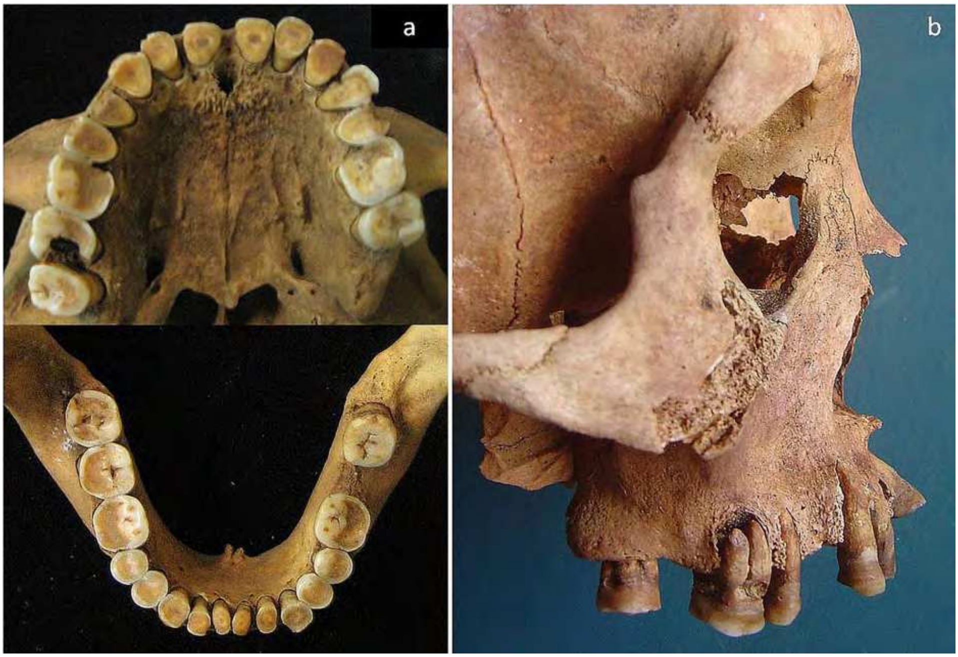

Fig. 5. **Pathological profiles in archaeological samples from the Central Andean Coast.** a) Fisherman with incipient agriculture (around 2400 BC). b) Fully developed farmer with coca leaf chewing habit (around 1300 AD).

[20] The methods commonly used for paleodietary reconstruction are: a) the identification of botanical and zoological macro-remains from excavations; b) the physico-chemical analyses (stable isotopes and traces) in bones; c) the identification of botanical micro-remains (phytoliths and starch granules) from dental calculus, coprolites and artifacts (Fry, 2006; Pearsall, 2000).

Population	Frequency (%)	Subsistence pattern
Hunter-gatherers (Turner, 1979)	**0 – 5.3**	
Oklahoma-USA, Fourche Maline, Archaic (Powell, 1985)	0.07	
Cis-Baikal-Siberia, Neolithic Kitoy (Lieverse et al., 2007)	0.23	
Patagonia, NW-MZ Final Late Holocene (Bernal et al., 2007)	3.30	Hunter-gatherers
Patagonia, NW-MZ Early Late Holocene (Bernal et al., 2007)	5.19	
Central Brazil, Paleoindian (Neves & Cornero, 1997)	9.00	
Portugal, Mesolithic (Lubell et al., 1994)	14.30	
Mixed diet (Turner, 1979)	**0.4 – 10.3**	
Alaska, Esquimos pre-contact (Keenleyside, 1998)	<0.05	
Brazilian Shellmound, Middle Holocene (Okumura & Eggers, 2005)	0.40	Fishermen
Northern Chile (3500–2000 BC) (Kelley et al., 1991)	0.60	
Patagonia, NE-RN Middle Late Holocene (Bernal et al., 2007)	0.95	
Alaska, Ipiutak pre-contact (Costa, 1980)	14.40	
Gran Canaria, coastal mounds (Delgado et al., 2006)	6.20	
Early Hawaians (Keene, 1986)	9.80	Fisher-gardeners
Peruvian Coast, Early Formative (Pezo & Eggers, 2010)	21.60	
Farmers (Turner, 1979)	**2.2 – 26.9**	
Portugal, Neolithic (Lubell et al., 1994)	3.10	
China, Ying Shang period (Sakashita et al., 1997)	3.45	
Pakistan, Harappa-Bronze Age (Lukacs, 1992)	6.80	
Turkey, Bizantines 13 th century (Caglar et al., 2007)	6.80	
Florida-USA, Early Mission 1600-1680 (Larsen et al., 2007)	7.40	
Georgia-USA, Early Mission 1600-1680 (Larsen et al., 2007)	7.60	
England, Roman 43-410 AD (Roberts & Cox, 2007)	7.50	
Patagonia, CW-SJFLH Late Holocene (Bernal et al., 2007)	10.17	
Sweden, 17 th century (Lingström & Borrman, 1999)	12.00	
Northern Chile, Maitas (Kelley et al., 1991)	14.40	Farmers
Gran Canaria-inland caves (Delgado et al., 2006)	15.70	
Oman, Iron Age (Nelson & Lukacs, 1994)	18.00	
Peruvian Coast, Middle Formative (Pezo & Eggers, 2010)	21.73	
Peruvian Coast, Epiformative (Pezo & Eggers, 2010)	20.67	
Peruvian Coast, Late Intermediate Period (Pezo & Eggers, 2010)	22.07	
Florida-USA, Late Mission 1680-1700 (Larsen et al., 2007)	24.40	
Texas-USA, Confederate Veterans (Denseizer & Baker, 2004)	24.40	
High Canada, 19th century (Saunders et al., 1997)	35.95	
Northern Chile, Quitor-5 (Kelley et al., 1991)	48.10	

Table 2. Caries frequencies and subsistence patterns among past populations

Comparing peoples living in the same place at different times or groups living in different sites at the same time is more useful and informative than studying an isolated site or population. Statistical analyses, although necessary for the depuration of more important information, must not disregard qualitative analyses. A permanently pending agenda is the refinement of methods and the increase of epidemiological studies in traditional non-Occidentalized groups that can be useful for a better contextualization of future bioarchaeological studies. These research avenues would allow a much better contextualization of future bioarchaeological work. Last but not least, the better knowledge of our past diets will certainly make us better cope with the future of food production and its ecological and health consequences.

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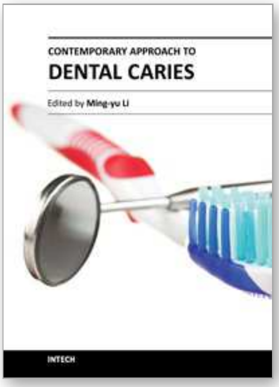

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With an update of the recent progress in etiology, pathogenesis, diagnosis, and treatment of caries, it may be said that the final defeat of dental caries is becoming possible soon. Based on the research in this area in recent decades, "Contemporary Approach to Dental Caries" contained the caries in general, the diagnosis of caries, caries control and prevention, the medical treatment of caries, dental caries in children and others such as secondary caries. This book provides the reader with a guide of progress on the study of dental caries. The book will appeal to dental students, educators, hygienists, therapists and dentists who wish to update their knowledge. It will make you feel reading is profitable and useful for your practice.