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Dental worm disease

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SUMMARY

During human evolution, the period in which groups of humans stopped harvesting fruits and seeds growing wild and introduced the cultivation of cereals as well as the domestication of animals represents a very important event. This circumstance had a considerable impact on human pathocenosis, increasing the risk of infectious diseases of animal origin.
The aim of this review was to summarise the archaeological and palaeo-pathological evidence in the literature concerning this topic. Starting from early prehistory (about 1.5 million years ago) up to the historical period, several authors have described the changes in human habits and the consequent changes in food supply, leading to the transition from a protein- to a carbohydrate-rich diet across a broad interval of time. This led to additional problems for human health. The increased accumulation of carbohydrate debris in the odonto-stomatological apparatus, without the appropriate use of hygiene in the oral cavity, increased the risk of infectious disease involving the mouth. Therefore, since the Neolithic period there has been a higher risk of tooth caries, abscesses, deep infection of the teeth roots, reaching also the mandibular and maxillary bone. Several hypotheses have been proposed by the distinct civilizations, which have alternated in the different ages, to explain the cause of these human health problems, including the idea that a "dental worm" could be involved in this process, such as in the Sumerian period. We describe and discuss further modifications of this theory, developed in Egypt, Assyria, Babylon, China, Greece, in Etruscan cities and in Rome in ancient times as well as in the Middle Ages, and the evolution of scientific thought on this topic in the past 300 years. In addition, the results of some palaeo-pathological studies, which were performed on human remains, such as the maxillary bone and teeth, mainly in different geographical areas in Italy, are examined and reported.

Keywords: caries, dentistry, gum disease, teeth remains.

ARCHAEOLOGICAL AND PALEO-PATHOLOGICAL NOTES

The first paleo anthropological evidence of infection, involving the oral cavity with a likely primary odonto-stomatological localization dates back to about 1.5 million years ago. In 1984 the remains of a young and male individual, originally classified as Homo erectus, but now attributed to the species Homo Ergaster, were discovered in Nariokoton field, near the shores of Lake Turkana (Kenya)[1]. Then, these remains were renamed Turkana Boy and their analysis revealed a visible lesion on the right side of the jaw. It has been hypothesized that the death of this individual has a relationship with this injury. In particular, an infection in the gums could have caused this damage, that occurred shortly before his death, when the "Turkana Boy" would have lost its second milk-molar tooth[2]. The gingival inflammation, induced by this event would have been infected, with the consequent septicaemic dissemination [1]. Investigations by the group at the University of Bologna - Institute of Paleo-Anthropology -

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1 The author of this important discovery is the researcher Kamoya Kimeu, member of paleo anthropologist Richard Leakey's team [1].
2 Two small signs indicate that parts of the roots remained inside the bone and that the underlying permanent premolar would have had a difficult eruption [1].

would have proved the absence of dental caries in Neanderthals, who lived about 130,000 years ago in Croatia, in the region of Krapina; this finding is typical of populations, in whom the diet is particularly low in carbohydrates. The Neanderthals were hunters and gatherers, therefore they had a mainly proteic diet [2].

The investigations, concerning the teeth in the group of Neanderthals of Krapina, have shown instead a significant presence of chipping, which involved the molar teeth. In some cases even fractures, generally detectable in individuals chewing a particularly hard and rough material, were observed. The presence of chipping and fractures observed on the front teeth suggests the use of the teeth to "jerk", therefore, for activities not properly directed to chewing. These extra-chewing activities would have been performed by these individuals since childhood. The authors of the research formulated the hypothesis that these individuals would have used their teeth as a "third hand" with the aim to hold inedible objects, whose handling was important for their survival [3].

In this necessarily incomplete excursus, whether we omit to consider a very long period of time and we take into account more recent prehistoric times, the findings of lesions in skeletal or in mummified tissues of odonto-stomatological district become relatively more frequent.

It is well-known that the introduction of a diet rich in carbohydrates, -this event emerged for the first time, during the Mesolithic age and in the Neolithic age had a more important impact- was associated with a significant contemporary modification in the human physical activity, that was typical in Palaeolithic hunter-gatherers[3]. This situation induced a series of health problems, which affected the human pathocenosis [4]. The increase of carbohydrates use in the diet and the progressive habit to a "sedentary life" in the populations of some regions worldwide led to the formation of the first cities. These events were favored in different geographical areas by climate, such as the Nile Valley, Mesopotamia and the valley of the Yellow River, where the abundance of water and alluvial soils allowed several harvests each year, as well as determined a significant increase in population. In these first cities the trade was stimulated and the first intellectual classes arose; the encouragement of individual abilities promoted the development of specializations among the craftsmen and the first "professions" as well as the first examples of human Economy flourished. The growth in numbers of people involved in specialized activities in the intellectual field created the conditions for the circulation of ideas and inventions. When the first writing systems appeared it was possible to "capitalize in cultural deposits" the acquired knowledge and to form the first groups of "libraries"[4]. In these geographic districts, which were privileged by nature, the nourishment conditions improved at the end of the Mesolithic about 8000-10,000 years ago, whereas proteic intake related to hunting drastically decreased, carbohydrate one proportionally increased. With the enhancement of carbohydrates use in diets, the conditions for the insulin resistance were fulfilled as well as for widespread among individuals who had access to a rich feeding, which was strongly oriented towards carbohydrates. Therefore, in a context where the microbiological pressure was high, the risk of infection increased strongly.

During the Mesolithic age - a period in which mankind stopped from the harvest of fruits and seeds growing spontaneously and introduced the cultivation of the cereals - the domestication of animals also took place and this event significantly increased the risk of infection with the introduction into the human pathocenosis of infectious diseases, having an animal origin, such as tuberculosis, smallpox, brucellosis and measles [5].

Again the transition from the highly-proteic diet of Palaeolithic hunters to the diet rich of carbohydrates, which was accomplished in the geographic districts of the so-called Fertile Crescent, where the first civilization flourished, the establishment of an additional problem for the human health was favored. The increased accumulation of residual carbohydrates in the odonto- stomatological apparatus, without the appropriate use of hygienic practices in the oral cavity, the risk of dental infections was increased and, more generally, of infectious diseases, involving the mouth. Therefore, in the Neolithic period a higher risk of tooth caries, abscesses, deep infection of the teeth roots, reaching

3 This sentence refers to the Neolithic development in the climatically-favored geographical areas, where the processes of human mankind growth were more advanced, clearly, these processes have not had an uniform growth in all the inhabited lands.

4 The royal archives of Ebla city, containing more than 17,000 tablets and fragments of clay tablet with cuneiform inscriptions in Eblaite, date back to a period ranging between 2500 and 2200 BC.

also the mandibular and maxillary bone was established. As a consequence of these life-style changes is not a coincidence that the first evidence of dentistry applications has been observed in Pakistan, in a burial area, where some teeth were detected. These remains, showing holes that were made by means of a drill, without, apparently, ritual purposes, dated back to a period ranging from 7000 to 5500 BC. Among a total of more than 4,000 teeth, which were found in 300 graves, at least 11 showed clear signs of the drill[5] [6]. Simultaneously, in a burial, different flint drill bits were found, and this finding led researchers to consider the possibility that these holes were the result of drilling for therapeutic purposes. The holes were subjected to more detailed analysis, including reflected light microscopy and microtomography, which have revealed traces of flint bits on the structure of the teeth.

In the southern Mesopotamian region, that was inhabited by Sumerians, in a cuneiform text of a few thousand years later, for the first time, the presence of "dental worms" is described as a cause of dental caries [7]. At the time of the Babylonians, when an individual suffered from toothache, a spell was said. According to a poetic language this spell told that, the evil was caused by a worm, looking for its food in the gums. By means of these rituals, the priests prayed that the worm returned to the gods and also during this rite, the magician-exorcist grabbed the worm by the tail and pulled out[6]. Since the Sumerian period, the so-called "theory of worms", that attributed the responsibility for the development of caries, to this cause, was considered right for a long time, albeit with revisions and changes. There are also indirect evidences that in Mesopotamia the problem of oral hygiene was considered; gold toothpicks were found in the ancient city of Ur in Mesopotamia and, according to archaeologists, the use of these artifacts dates back to around 1000 BC [8]. A further site of the early development of civilization was the Nile Valley. On the basis of hieroglyphic texts, we know that around 2600 BC the Egyptian scribe Hesy-Ra died. He is recognized as the "first dentist", an inscription in his tomb contains the following statement: "the greatest among all doctors and among those who took care of the teeth." This is considered as the first evidence that refers explicitly to an individual, working as a dentist [9]. Later, around 1750 BC, in an Egyptian text, the Eber papyrus[7], dental diseases and some remedies for dental pain are described [10-12][8]. However it should be underlined that, during this historical period and in this region, the low classes were lacking in a diet rich in carbohydrates and had to exert a strong physical activity. The individuals belonging to the aristocratic class only had the possibility to have this type of diet. Studies performed in Egyptian mummies of pharaohs and of courtiers have found, in a significant number of these, dental pathologies. It is interesting to note that subjects with a diet poor in carbohydrates, had a lower risk of dental diseases. It should also be considered that the mummies dating to pre-dynastic period have a lower incidence of infections, involving the teeth. However, only since the second part of the third millennium BC, the individuals of the Egyptian aristocracy began to suffer from dental caries in a significant proportion. On the other hand, in this period, the poorest social classes had not yet these problems. Paleo pathological remains, seem to confirm this assumption. The X-ray of Pharaoh Amenhotep III's (Amenophis) mummy (Figure 1) who reigned between 1378 and 1339 a. C., showed

Figure 1 - Pharaoh Amenhotep's mummified skull.

5 According to researchers who have made an important discovery these early dentists used drills similar to those, which are used today in India to drill beads [6].

6 In the tradition of the Near East there is the survival of the belief that the toothache is caused by a worm.

7 Dentists in ancient Egypt were already active in the third millennium BC In the Ebers Papyrus, the following sentences may be read: "Remedy to strengthen a tooth. Nubia powder and honey. Mix and fill the tooth. "

8 From another point of view around 1800 BC the Code of Hammurabi refers to dental extractions, which were imposed as punishment.

in his mouth dental infections, spreading to the maxillary bone. It has been suggested that these health problems caused Pharaoh's death, because of septicemia, when he was less than forty years old [13]. In the development of dental caries in the Egyptian world another pathogenic element has to be mentioned. The massive introduction of cereals in the diet and the need to grind them, through the use of the mill stones, inevitably, caused the introduction of abrasive sand [14-18]. It is clear that the persistence of abrasive action on teeth enamel during a long period of time, induced as a consequence, the weakening of their crown. In addition, the fermentation of carbohydrates, favored the development of an environment in the oral cavity, where the resident bacteria could grow [19]. Because of poor oral hygiene, it is evident that all these elements represented serious risk factors for disease. The association of abrasive action and of the caries, caused by a diet rich in carbohydrates, and the development of advanced gum diseases (periodontitis) in older age, induced pulp exposure, resulting in the formation of dental abscesses. Therefore, dental infections, in the absence of a surgical treatment as well as of antibiotics able to counteract the pathogens, could cause chronic and/or acute systemic infections. Another issue has to be considered. Egyptians, belonging to the wealthy classes, with the aim to make their teeth whiter and brighter used pastes based on scouring powders, which were obtained from stones like carnelian, coral, pumice and egg shells and which were mixed with fragrant liquid or urine. Such cosmetic practices caused enamel weakening and contributed the development of caries.

In more recent historical contexts, in Italy, Gino Fornaciari studied the skeletons of 35 individuals found in the Etruscan necropolis of Pontecagnano, (Archaic period, VII-VI centuries BC) and of 32 subjects in the Etruscan necropolis of Monterozzi, Tarquinia, (Hellenistic period, third century BC). He observed dental wear and tear in a significant percentage of cases (24%) at Tarquinia, while at Pontecagnano this evidence was less frequent (17.6%) (20). Presence of caries (Figure 2a and 2b) was very frequent in the necropolis of Pontecagnano (51.4%), mainly at the neck of the teeth, while it was relatively less frequent at Tarquinia (31.2%). The incidence of other paleo pathological alterations, such as abscesses and granulomas, was very low (0.8%) at Pontecagnano, but slightly higher (2.6%) at Tarquinia [20]. The enamel hypoplasia, which is considered the expression of nutritional stress or disease, according to Brothwell ([21], is observed at Pontecagnano in 45.7% of cases, while at Tarquinia in 28.1%. Fornaciari suggests that the different incidence of these distinct diseases depends on the dietary habits of the two groups of individuals. Paleo-nutritional investigations were carried out on the remains of individuals, who were found at Tarquinia, and helped to establish that this Etruscan population had, in the Hellenistic period, an agricultural economy, based on plant foods and cereals [22]. The higher consumption of mill-stone ground ce-

Figure 2a-2b - Caries penetrating the tooth collar with apical granulomas and severe periodontal disease in women of 35-40 years (Pontecagnano, VI century BC). Courtesy of Prof. Gino Fornasari, Paleo Pathologist at the University of Pisa.

Figure 3 - Julius Polybius' House.

reals, would have been the cause of the increased teeth wear and tear as well as of a lower incidence of caries [23-25] at Tarquinia in comparison with Pontecagnano. On the other hand, a greater percentage of caries was detected at the neck of the teeth in individuals found at Pontecagnan. This could be related to the consumption of foods with a high sugar content, particularly viscous products (honey, figs). Penetrating wear and tear could justify the higher incidence of apical granulomas and abscesses at Tarquinia [20]. In the Comacchio Valleys, near Spina, archaeological investigations were developed between 1922 and 1965. Several buried individuals were found in a sepulchral area. These people lived between the late sixth century and the middle of the third century BC [26]. In particular, 811 teeth were studied to determine the incidence of caries and indirect information about the type of nourishment of the Etruscans, who lived in these areas. Caries were detected in about 20% of the studied remains, mainly in 25-35 years old adult individuals and no differences between both sexes were observed. Caries, affected mainly the coronal surface of the molar teeth [27]. Other studies about Etruscans by Capasso found an incidence slightly higher (27%) [28]. It is indubitable that the introduction into the diet of high amount of carbohydrates and of monosaccharides has affected some social settings and favored the onset of major infectious risks in the odonto stomatological district. Probably, fluorine-rich water has had an important role. A very low presence of dental caries has been demonstrated in paleo pathological remains from the House of Julius Polybius (Pompei), dating back to the first century after Christ [29]. In particular, among 11 examined skulls, only 2 osteolytic lesions were found, one of these near a lost tooth, the other near a caries. In addition, only a residual dental root was observed, concerning a pathology, during the life. The percentage of caries on the examined dental elements is equal to 10/145 (6.89%) [29]. This sample has a relatively small percentage of paleo pathological remains indicative of dental infections, when compared with other populations of classical Magna Greece (8.5%) and of the ancient inhabitants of Britain, during Roman times (11.4%) [29]. A low incidence of caries was also observed in another series of remains, numerically more consistent (1275 teeth). They belonged to individuals, who were found at Ercolano and who were also victims of the Vesuvius eruption in 79 AD. The survey was carried out on 41 adults and 12 children and it allowed to detect a low incidence of caries (3.8%) [30]. The low rate of caries observed in the teeth of inhabitants of Polybius' House (Figure 3) would be linked to the significant presence of fluorine in the water sources, in the area of Vesuvius [29]. The assumption of adequate amounts of fluorine, during the phase of ontogenesis, would allow the formation of fluorapatite in teeth enamel, making

it particularly resistant to caries [29]. The excessive presence of lead in water caused a serious public health problem in the Roman Empire, it is now well-known that lead was largely used for the pipes (Figure 4). In chronic lead-poisoning, defined as saturnism, one of the early symptoms is represented by the so-called "rim gum", a bluish-gray coloration that appears on the gums only near the teeth. Starting from this injury, ulcerative lesions develop and the normal commensal flora, generally detectable in the mouth, may induce an over-infection. The lesions involving the gum mucosa, unlike caries, do not cause alterations, which are preserved in remains [31]. It is very likely that the chronic lead-poisoning, through the aforementioned localizations in the gums, especially in the imperial era, represented an important epidemiological problem in Rome, because it is probable that saturnism favored periodontal and, more generally, odonto-stomatological infections. Concerning the incidence of dental caries in Rome, during the imperial age, several skeletal remains were found in a large burial area, located along the Via Latina, near Rome. In this place, over 700 burials, dating back between the first and third centuries AD, were detected and studied. Among these individuals, subjects, aged over 16 years and with sufficiently preserved teeth and dental alveoli, were selected. According to the study in this population, living near Rome in imperial times, the rate of caries in comparison with the analyzed teeth was relatively low, while the percentage of those suffering from caries was high (70%). It is interesting to point out the percentage of subjects with tartar presence in the teeth. It reached about 80% in the studied sample. Abscesses localized at the apex of the alveoli were found in 26% of the studied subjects (32). In conclusion, this sample of Roman population, during imperial age, dental problems seem more related to poor oral hygiene, rather than a specific food imbalance, related to a food surplus with a particularly sugar rich diet [32].

Figure 4 - Lead pipes in the Roman era. Palermo. Archaeological Museum. Property photo: G. Dall'Orto, published with his permission.

THE THEORY OF THE DENTAL WORM AND ITS SUBSEQUENT EVOLUTION

In a previous section of our manuscript, we reported the "theory of the dental worm". The first written record, describing this theory dates back to the Assyrian-Babylonians, about 4,000 years ago. They believed that there was a worm, gnawing the teeth, as reported in a text engraved on a tablet in cuneiform characters. So the Babylonian text says: "... the worm ... went to the god of justice ... put me between the teeth of the man, give me a place in his jaw so that I may drink the blood of his teeth and feed on the roots of its jaws and ... so it was ... the worm slaughters, teeth ... but the dentist ... attacks it and kills it ..." [7]. The theory of the rodent worm is detectable not only in the Assyrian-Babylonian culture, but also it may be found in China in the "Chings" or Canons of Medicine, dating back to 2668 BC (33). Concerning the Western culture, in the ancient Hippocratic Corpus the theory of the rodent worm, went on throughout the centuries and it was enriched by further elements. According to Hippocrates (about 460 BC - 377 BC) the formation of caries depends not only on the attack of a parasite, but also on the existence of a suitable environment. These conditions facilitate its action. Therefore a favorable environment is need. Hippocrates thinks that the imbalance among the four basic humors (blood, phlegm, black bile, yellow bile) represent a promoting factor. Therefore, on the basis of this idea, the action of the parasite has to be counteracted not only by a local therapy, but also it has to be associated with a therapy able to restore the compromised

balance. According to Hippocratic Corpus the accumulation of phlegm would be responsible for this imbalance. After all, this event would facilitate the action of some foods that are defined as "corrosive". The Roman School, with its two members, Aulus Cornelius Celsus (I cent. AD) and Claudius Galen (131-201 AD) accepted the theory proposed in Hippocratic Corpus, but it suggested further explanations: acid and corrosive moods, which favor the action of the parasite, can be produced by the body as well as can come from the outside. With the advent of Hippocratic thought, medicine had reached a rather interesting maturation. According to this theory, the parasite is not the only agent causing the caries, but a cofactor also acts. It can be defined as "chemical" and it may be considered as equally responsible for this process. In our opinion, this Hippocratic idea represents an improvement in medical thought and precedes our modern conceptions. Later, in the Later Middle Ages, Paul of Aegina (625-690) suggested that the acids, secreted by the stomach, whether vomited or evaporated in the mouth, corrode teeth and promote their damage. According to this author, "small animals" would settle into this initial dental injury, promoting its further impairment.

A few centuries after the Arab physician Avicenna (980-1037), induced an arrest in the maturation of medical thought, as it had been obtained by Hippocraes, because he suggested that the "gnawing worms " were the only cause of caries [34]. With the advent of the first microscopes (Figure 5), in the late seventeenth century, it was not yet possible to correlate the formation of caries with those "small animals", having different shapes and sizes, elongated as rod, rounded, spherical and gathered in couples, which the Dutchman Antoni van Leeuwenhoek (1632-1723)[9] had seen and described in residual food, obtained from the teeth. The microbiological revolution that was triggered by Louis Pasteur had still to come and "the world of the very small" could not yet be understood by human intellect. At the end of eighteenth century, in 1778, the surgeon John Runter (1728-1793), a member of the "Vitalist School" suggested a hypothesis on the pathogenesis of dental caries that apparently induced confusion. According to Runter, everything would originate from an imbalance, arising in the oral cavity and following the development of changes in this district, in comparison to normal situation. Therefore, the body would react to these events by triggering processes, leading to necrosis and causing the caries. According to this pathogenic hypothesis, caries may develop not only on the outer teeth surface, but also inside of them. In the same historical period, the spread of empirical scientific doctrine led to different conclusions. In England also, the prestigious royal doctor Berdmore Thomas (1740-1785)[10] evaluated the effects produced on the teeth by nitric and sulfuric acids. His test was performed on extracted teeth, which were subjected to the action of these acids. At the end of this experiment, he observed characteristic abrasions on the teeth surface. According to Berdmore's hypothesis, in vivo these acids would have arisen from the secretions of gum or from the alterations of food debris [35]. It has to be considered that the proposed theories were influenced from cultural climates and scientific experiences of that time. The nineteenth century is the century of electricity discover and advances linked to the application of this revolutionary discovery. In 1863 two Englishmen, Bridgemann and Chese proposed a new theory (Electrolytic theory). They showed that the teeth can be de-

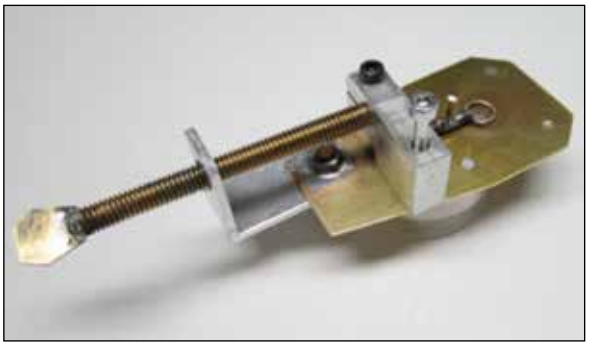

Figure 5 - First microscope by Antoni van Leeuwenhoek. Model reproduced by Mr Giorgio Carboni. Fun Science Gallery. Photo reproduced with Author's permission.

9 Despite Leeuwenhoek was devoid of a scientific background, with his microscopes (figure) he was able to make several and important observations in the field of microbiology, he sent these results to the Royal Society of London. The microscope of Leeuwenhoek included a single magnifying glass. Because of its small size, this lens was very powerful and allowed to reach 300 magnifications, about 1/3 of the magnification attainable with a modern microscope.

10 Berdmore was King George III's dentist.

stroyed by galvanic electricity. A few years later, J. Tomes proposed a theory on the basis of this assumption. In particular, he hypothesized that the onset of caries was caused by a loss of the dentine viability. The dentine was weakened and it could no longer withstand an unspecified action of the fluids detectable in the mouth. This hypothesis was a synthesis both of Berdmore's Chemical Theory and of Runter's Vitalist Theory. But an important progress was beginning. The microbiological revolution had just been triggered when T. Leber and JB Rottenstein in 1867, after coloration of dentin with iodine solution, observed granular particles in the tubules. They thought that these structures were "a parasitic plant", with a linear growing (filaments), that they named Leptotrix buccales. According to this "parasitic theory", caries would start after a chemical damage, producing an initial decalcification. This event would be followed by the colonization of Leptotrix that, penetrating into the dentin tubules, would have dilated them and favored the later invasion of the acids, originating from food products.

The action of acids, in turn, would enable a further progression of caries [35]. In the seventh decade of the nineteenth century the revolutionaries studies by Louis Pasteurs have ruled that the action of bacteria could transform sugars into lactic acid and those by French Emil Magitot have shown that it is possible dissolve the teeth in the laboratory, by use of fermenting sugars. These observations opened new possibilities for experiments and speculations. In this situation, the American researcher Willoughby D. Miller (1853-1907) carried out his studies (Figure 6). Miller obtained the degree in Medicine in 1879 in the United States, then he went to Berlin, where he studied initially in a dentist's room and then he devoted himself passionately in microbiology. To that time, it was the emerging science. In that period, he was working in the laboratory directed by Robert Koch and he was interested in investigating the biological events, inducing the development of caries [36]. In Berlin, the American scientist initially examined all previous theories and refuted them, by means of convincing experiments [37]. On the basis of the experiences of Magitot, he demonstrated the importance of the germs capable of producing lactic acid in the pathogenesis of dental caries.

Figure 6 - Willoughby D. Miller.

The following experiment was conclusive. He kept in an incubator a mush of bread and saliva, which he renewed every week. Then he included in this sludge wax-coated teeth, leaving them uncovered in only some points. He proved that the germs, detectable in saliva, caused a process of lactic fermentation and the produced amount of lactic acid was able to alter the enamel of the uncovered teeth. The consequence of this attack was the formation of lesions on the dentin [38]. Miller hypothesized that, in the mouth, acids derived from the fermentation of food scraps, and therefore, he postulated that the acids induced the enamel decalcification and destroyed it completely, while the dentin was reduced to a rough and spongy mass and it was subjected to the invasion of a large number of distinct bacteria [38]. According to Miller, all the bacteria were able to produce lactic acid, and therefore all were potentially able to induce caries. By the use of a litmus paper, he showed the presence of an acid reaction in more than 90% of carious cavity, while the lactic acid was detectable by means of the modified Ewald's reaction. Although, according his theory, all the bacteria in the oral cavity were able to produce lactic acid and therefore they were cariogenic, his attention was focused on two bacteria: Bacillus dentalis viridans and Bacillus pulpae piogenes. The ex-

periment demonstrated that both germs were able to induce septicemia if they were inoculated into animals [38]. It showed that caries represented an infectious disease, Koch's postulates were fulfilled and at the same time the role of etiologic agents (microbes harbored in the mouth) and the pathogenic mechanism were clarified. Afterwards, the Miller's chemical-parasitic theory was challenged, because the acids resulting from the fermentation of food waste, had very low concentrations (0.75%). According to those who denying Miller's hypothesis, concentration of acids would not have reached a concentration sufficient to trigger caries development, because the calcium content of the tooth would have not decreased [39]. In this reductive vision only bacterial action would have caused the development of acids able to remove the calcium in the teeth. In summary, in the mouth the fermentation of carbohydrates detectable in the food scraps, would have not exerted the activity that Miller instead considered decisive. Once again, a step back seemed to occurr, from this point of view, it is interesting to reconsider what Avicenna thought. Nearly 900 years before, he had given a role in the pathogenesis of caries to the "Worm Rodendi" only, while long before Hippocrates had recognized both the action of the "worm" and also the pathogenic role of a "chemical" factor, and Paul of Aegina, about 11 centuries after Hippocrates, even took into account the action of gastric acids.

To date, according to available scientific literature, although no bacterium has yet been identified as primary cause for dental caries, it is known that the absence of oral hygiene plays an important role in the origin of dental caries. The nature of this process is infectious. In conclusion, the insights and the experiments of the American scientist Willoughby D. Miller, at the end of nineteenth century, have still a great importance in the possible explanation of the infectious pathogenesis of dental caries.

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REFERRENCES

[1] Brown F., J. Harris, Leakey R. A. Walker: *Early Homo erectus skeleton from west Lake Turkana, Kenya.* Nature Band. 316, S. 788-792, 1985.

[2] Belcastro M. G. Facchini F. (a cura di) *La lunga storia di Neandertal.* Jaca Bock Milano 2009.

[3] Belcastro M.G., Todero A., Rastelli E., Faccini F., Mariotti V. I Neandertaliani di Krapina (Croazia, 130.000 A. C.): stile di vita e pratiche funerarie. XVII Congresso degli Antropologi italiani. Cagliari 26-29 settembre 2007.

[4] Sabbatani S. Fiorino S. Apporti della paleopatologia alla definizione della Patocenosi delle malattie Infettive. (I parte). *Infez. Med*. 4, 236-250, 2008.

[5] Sabbatani S., Apporti della Paleopatologia alla definizione della Patocenosi delle malattie infettive (II parte). *Infez. Med*. 1, 47-63, 2009.

[6] Coppa A., Bondioli L., Cucina A., et al. Palaeontology. Early Neolithic tradition of dentistry. *Nature.* 440, 755-756. 2006.

[7] Bellagarda G. Storia illustrata dell'Odontoiatria. Ed. A. Delfino, Roma, 1989.

[8] www.treccani.it › Enciclopedia. Vicino Oriente Antico. La cura del corpo.

[9] www.sapere.it › ... › Storia › L'antico Egitto › La vita quotidiana.

10] Bardinet T. I testi medici dell'antico Egitto". "Le Scienze (America Scientific)", 340, 1996, 74-80, 1996.

[11] Contin F. La medicina nell'antico Egitto. *Antrocom.* (1) 2, 115-120, 2005.

[12] Haliqua B. *La médicine au temps des pharaon*. Liana Levi. Parigi, 2002.

[13] Miller J. Down in the mouth in Ancient Egypt. Dept Hist, 42, 7-20, 2006

[14] Smith N. J. D., *Dental pathology in an Ancient Egyptian population*. (in A.R. Davis) Science in Egyptology. Manchester University press. Manchester, pp. 43-48, 1986.

[15] Leek F.F. Observations on the dental pathology seen in ancient Egyptian skulls. *Journal of Egyptian Archaeology.* 52, 59-64, 1966.

[16] Leek F.F. Bite, attrition and associated oral conditions as seen in Ancient Egyptian skulls. *Journal of Human Evolution* I, 289-295, 1972a.

[17] Leek F.F. Teeth and bread in Ancient Egypt. *Journal of Egyptian Archaelogy* 58, 126-132, 1972a.

[18] Leek F.F. Dental problems during the Old Kingdom. Facts and legends. (in) A.R. David, E. Tap (eds) Evidence embalmed. Modern medicine and the mummies of Ancient Egypt. Manchester University press, Manchester, 126-127, 1984.

[19] Giuffra V., Pangoli D., Cosmacini P., caramella D., Silvano F., Fornaciari. G, Ciranni R. Paleopathological evaluation and radiological study of 46 Egyptian mummified specimens in Italian Museums. EVO XXXI, 121-155, 2009.

[20] Menconi A., Fornaciari G. L'odontoiatria etrusca. In: Vogel G, Gambacorta G, *Storia della Odontoiatria.* Ars Medica Antiqua, Milano, pp 89-97. 1985.
[21] Brothwell D.R. *Digging up bones*. Oxford 1981.
[22] Fornaciari G., Mallegni F. Paleobiologia: possibilità di un'analisi concreta dei resti umani antichi. Comunicazione generale presentata al Secondo Congresso Internazionale Etrusco. Firenze 26 maggio-2 giugno 1985.
[23] Fornaciari G., Mallegni F. Alimentazione e paleobiologia. *Archeologia Medievale*, 8, 353-368, 1981.
[24] Mallegni F., Fornaciari G., Tarabella N. Studio antropologico dei resti scheletrici della necropoli dei Monyetrozzi (Tarquinia). Atti della Società Toscana di Scienze Naturali, Memorie, serie B, 86: 185-311, 1979.
[25] Fornaciari G., Brogi M.G., Balducci E. Dental pathology of the skeletal remaine of Pontecagnano (Salerno, Italy) VII-IV centuries B.C. *Ossa,* 12 (4): 9-31, 1985.
[26] Manfredi V.M. Gli Etruschi in Val Padana. I Edizione Oscar Saggi Mondadori 2003.
[27] Marzi M., Onisto N., Gualdi Russo E. A proposito di carie…L'alimentazione nella popolazione etrusca di Spina. XVII Congresso degli Antropologi italiani. Cagliari 26-29 settembre 2007.
[28] Capasso L., Di Tota G. Le malattie infettive degli Etruschi. (In) aspetti della cultura etrusca di Volterra Etrusca tra l'età del ferro e l'età ellenistica e contributi della ricerca antropologica alla conoscenza del popolo etrusco. *Atti del XIX convegno di Studi Etruschi ed Italici*. Volterra Firenze: Leo S. Olschki Editore. Pp. 55-557, 1985.
[29] Fornaciari G. Torino M. Paleopatologia degli individui nella casa di Giulio Polibio, (in) La casa di Giulio Polibio. Studi interdisciplinari. (A cura di) A.M Ciarallo e De Carolis. pp 93- 106. Pompei 2001.
[30] Torino M., Rognini M., Fornaciari G. Dental fluorosis in ancient Herculaneum. *The Lancet* 345, 1306- 1995.
[31] Fornaciari G., Menicagli Trevisani E., Ceccanti B. Indagini paleo nutrizionali e determinazione del Piombo psseo mediante spettroscopia ad assorbimento atomico sui resti scheletrici di epoca tardo-romana (IV sec. D.C.) della "Villa dei Gordiani" (Roma*). Archivio per l'Antropologia e la Etnologia*, 114: 149-176, 1984.
[32] Catalano P., Minozzi s., Caladarini C., Pantano W., Arrighetti B., Reale B. Condizioni di vita e salute nel suburbio romano durante l'età imperiale attraverso lo studio delle affezioni dento alveolari**.** XVII Congresso degli Antropologi Italiani. Cagliari 26-29 settembre 2007.
[33] Pistacchi E., Disperati S. La carie dentaria: da malattia verminosa a malattia infettiva. *Infez. Med*. 4, 245-248, 2000.
[34] Ring M.E. *Storia Illustrata dell'Odontoiatria*. Ed. A. Delfino, Roma 1989.
[35] Scervini P. Trattato completo di odontoiatria. Ed. De Angelis Bellisario. Napoli, 1899.
[36] Aguzzi A. La vita e le opere di W. D. Miller. *La Stomatologia*. 6, 39-45, 1907.
[37] Jacobs F.O. Dr. Miller's Theory of Dental caries. *The Dental Cosmos*. 35, 546-548, 1893.
[38] Miller W.D. Einfluss der Microorganismen auf die caries der Menschlichen zahne. *Arch. fur Exper. Pathologie.* XVI, 220-284, 1882.
[39] Black G.v. Theories of the cause of caries. *The dental cosmos*, 30, 352-356, 398-402, 1895.