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**The Subsistence and Foodways Transition during the Neolithization Process  
Glimpses from a Contextualized Dental Perspective\***

FANNY BOCQUENTIN

ArScAn, UMR 7041, CNRS – Laboratoire Cogitamus

BERENICE CHAMEL

Archéorient, UMR 5133, CNRS

MARIE ANTON

École Doctorale d’Archéologie, Université Paris 1 – Musée de l’Homme, UMR 7206, CNRS

CAMILLE NOUS

Laboratoire Cogitamus

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## Abstract

Dental pathologies constitute an important topic for the discussion of subsistence and foodways, especially during periods of major shifts in dietary behaviour. On the eve of the Neolithization process in the Levant, the Natufian period (13000-9500 cal. BC) bears witnesses to a new way of food procurement associated with a decrease in group mobility. New foodstuffs appeared with plant production and husbandry throughout the Early Neolithic period (9500-6400 cal. BC). This article describes both specific and non-specific oral pathologies linked to diet (cariou lesions, antemortem tooth loss, abscesses, alveolar resorption) and stress indicators such as Linear Enamel Hypoplasia among Natufian and Neolithic populations based on a huge corpus (over 8,600 teeth) of well contextualized samples that were recorded by the authors following the same procedures. Quantitative and qualitative information were analysed for 24 sites throughout the Levant, attributed to different periods and located in different ecosystems. The results demonstrate a clear increase in caries and associated diseases during the Neolithization process. This was first a gradual process that began as early as the Late/Final Natufian. The linear process was broken by the seventh millennium at which time new behaviours seem to have been introduced resulting in a new pathological pattern. The major changes at this time are observed in Mediterranean contexts where pottery is not yet attested. High biological stress, linked to socioeconomic level or infectious disease, is demonstrated in parallel. Over time, diet seems more and more gendered but less specifically associated with age groups.

## Keywords

Levant, Near East, Natufian, Pre-Pottery Neolithic, Pottery Neolithic, Primary data, Caries, Abscesses, Hypoplasia, Antemortem Loss, Postmortem loss, Carbohydrates, Correction factors, Health, Evolutionary Pattern.

## Résumé

Les pathologies dentaires constituent un aspect important de la discussion sur la subsistance et les comportements alimentaires, notamment au moment de transitions alimentaires radicales. À la veille du processus de néolithisation au Levant, la période natoufienne (13000-9500 cal. BC) témoigne d'un nouveau mode d'approvisionnement associé à une diminution de la mobilité des groupes. De nouvelles denrées alimentaires apparaissent avec la production de plantes et l'élevage tout au long du Néolithique ancien (9500-6400 cal. BC). Cet article décrit les pathologies buccales spécifiques et non spécifiques liées à l'alimentation (lésions carieuses, pertes *antemortem*, abcès, résorptions alvéolaires) et les indicateurs de stress tels que l'hypoplasie linéaire de l'émail dentaire chez les populations du Natoufien et du Néolithique à partir d'un vaste corpus (plus de 8 600 dents) provenant de corpus bien contextualisés et qui ont été enregistrés par les présents auteurs selon les mêmes procédures. Les données quantitatives et qualitatives ont été analysées pour 24 sites à travers le Levant, attribués à différentes périodes et situés dans différents écosystèmes. Les résultats démontrent une nette augmentation des caries et des maladies associées au cours du processus de néolithisation. Il s'agit d'abord d'un processus graduel qui se met en place dès le Natoufien récent/final. Par la suite, le processus linéaire est rompu au 7<sup>e</sup> millénaire, période à laquelle de nouveaux comportements alimentaires semblent avoir été introduits dans la mesure où un nouveau schéma pathologique domine. Ces changements majeurs sont observés dans des contextes méditerranéens où la céramique n'est pas encore attestée. Un stress biologique élevé, lié au niveau socio-économique ou aux maladies infectieuses, est démontré en parallèle. Au fil du temps, l'alimentation semble de plus en plus sexuée mais moins spécifiquement associée aux groupes d'âge.

## Mots clés

Levant, Proche-Orient, Natoufien, Néolithique pré-céramique, Néolithique céramique, données primaires, caries, abcès, hypoplasie, pertes antemortem, pertes postmortem, glucides, facteurs de correction, santé, tendances évolutives.

A number of climatic and environmental changes as well as radical modifications in food procurement and subsistence patterns mark the end of the Epipalaeolithic period in the Near East. This major transitional period corresponds to the development of the Natufian culture and sedentism (13000-9500 cal. BC). It immediately precedes the Early Neolithic (9500-6400 cal. BC) during which plant production and husbandry totally modified foodways to a point of no return. Natufian behaviour, such as reducing mobility and, in some cases, even the adoption of a fully sedentary way of life,<sup>1</sup> was the precursor of major changes in collecting, preserving and possibly storing food. Earlier Epipalaeolithic hunter-gatherers engaged in broad-spectrum hunting and gathering strategies<sup>2</sup> that likely resulted in a wide knowledge of available food resources. If not exclusively (see discussion below), predominantly, Natufians fed on products obtained from hunting, fishing and gathering. As preserved plant remains are scarce in Natufian sites, the possibility that they first cultivated vegetal species remains unclear and is still debated.<sup>3</sup> Without doubt, cultivation of wild cereals and pulses was widespread by the mid-tenth-ninth millennia BC. Intensification of the exploitation of wild species resulted in the appearance of the first domesticated plant species that gradually became dominant.<sup>4</sup> The process of animal domestication, considered for long to be a second step, may have, in fact, occurred in parallel in different regions driven by a similar protracted and multicentre control of wild species through commensalism and specialized hunting.<sup>5</sup> Finally, at the beginning of the seventh millennium, the adoption of pottery heralded a major shift in foodways due to new possibilities of transforming, cooking, fermenting, macerating and storing food.<sup>6</sup> If plant and

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<sup>1</sup> Recent discussions in Reuven YESHURUN, Guy BAR-OZ, “Ungulate skeletal element profiles: A possible marker for territorial contraction and sedentism in the Levantine Epipaleolithic”, *Quaternary International*, vol. 464 (2018), pp. 173-86; Lior WEISSBROD, Fiona B. MARSHALL, François R. VALLA et al., “Origins of house mice in ecological niches created by settled hunter-gatherers in the Levant 15,000 y ago”, *Proceedings of the National Academy of Sciences*, vol. 114, no. 16 (2017), pp. 4099-104; François R. VALLA, “Sedentism, the ‘point of no return’, and the Natufian issue. An historical perspective”, *Paléorient*, vol. 44, no. 1 (2018), pp. 19-33.

<sup>2</sup> Mary C. STEINER, Nathalie D. MUNRO, Todd A. SUROVELL et al., “Paleolithic population growth pulses evidenced by small animal exploitation”, *Science*, vol. 283, no. 5399 (1999), pp. 190-94; Ehud WEISS, Wilma WETTERSTROM, Dani NADEL et al., “The broad spectrum revisited: Evidence from plant remains”, *Proceedings of the National Academy of Sciences*, vol. 101, no. 26 (2004), pp. 9551-55; Aaron Jonas STUTZ, Natalie D. MUNRO, Guy BAR-OZ, “Increasing the resolution of the Broad Spectrum Revolution in the Southern Levantine Epipaleolithic (19-12 ka)”, *Journal of Human Evolution*, vol. 56, no. 3 (2009), pp. 294-306; Monica N. RAMSEY, Arlene M. ROSEN, “Wedded to wetlands: Exploring Late Pleistocene plant-use in the Eastern Levant”, *Quaternary International*, vol. 396 (2016), pp. 5-19.

<sup>3</sup> Gordon HILLMAN, Robert HEDGES, Andrew MOORE et al., “New evidence of Late glacial cereal cultivation at Abu Hureyra on the Euphrates”, *The Holocene*, vol. 11, no. 4 (2001), pp. 383-93; George WILLCOX, Ramon BUXO, Linda HERVEUX, “Late Pleistocene and early Holocene climate and the beginnings of cultivation in northern Syria”, *The Holocene*, vol. 19, no. 1 (2009), pp. 151-58; Ferran BORRELL, Aripekka JUNNO, Joan Antón BARCELÓ, “Synchronous environmental and cultural change in the emergence of agricultural economies 10,000 years ago in the Levant”, *Plos One*, vol. 10, no. 8 (2015), pp. 1-19; Juan José IBÁÑEZ, Jesús GONZÁLEZ-URQUIJO, Luis Cesar TEIRA-MAYOLINI et al., “The emergence of the Neolithic in the Near East: A protracted and multi-regional model”, *Quaternary International*, vol. 470 (2018), pp. 226-52.

<sup>4</sup> Juan José IBÁÑEZ, Jesús GONZÁLEZ-URQUIJO, Luis Cesar TEIRA-MAYOLINI et al., “The emergence of the Neolithic in the Near East ...”.

<sup>5</sup> Jean-Denis VIGNE, Lionel GOURICHON, Daniel HELMER et al., “The beginning of Animal domestication and Husbandry in Southwest Asia”, in Yehouda ENZEL, Ofer BAR-YOSEF (eds), *Quaternary of the Levant: environments, climate change, and humans* (Cambridge/New York, 2017), pp. 753-60; Kevin DALY, Pierpaolo MAISANO DELSER, Victoria MULLIN et al., “Ancient goat genomes reveal mosaic domestication in the Fertile Crescent”, *Science*, vol. 361 (2018), pp. 85-88.

<sup>6</sup> Kevin GIBBS, “Pottery invention and innovation in East Asia and the Near East”, *Cambridge Archaeological Journal*, vol. 25, no. 1 (2015), pp. 339-51; Olivier NIEUWENHUYSE, Stuart CAMPBELL, “Synthesis: The emergence of pottery in West Asia”, in Akira TSUNEKI (ed.), *The Emergence of Pottery in West Asia* (Philadelphia, 2017), pp. 167-92.

animal domestication are seen as nearly contemporary and interrelated processes between the northern and southern Levant, the appearance of pottery was delayed by a few centuries in the southern Levant preceded by a local evolution in the region during the Pre-Pottery Neolithic (PPN).

## Human remains as witnesses of food and foodways

With sedentism, the Natufians adopted new social practices and amongst others, funerary rituals show a major shift. Indeed, whereas Early Epipalaeolithic graves are notably scarce, from this point, the Natufian people buried some of their dead within their hamlets. They were usually buried in temporarily or permanently abandoned houses, in complex and varied ways<sup>7</sup> or in dedicated cemeteries.<sup>8</sup> The link between residential space and graves continued and even sometimes strengthened throughout the PPN<sup>9</sup> when dedicated (sometimes built) funerary structures emerged near the houses.<sup>10</sup> The presence of many human remains provides bioanthropologists with a rare opportunity to follow the biological effects of the Neolithization process on human bodies. Indeed, throughout life the skeleton records data on our biocultural behaviours expressed in physical activities, posture, hygiene, health, trauma, cultural modification, nutrition, subsistence and foodways. Bones and teeth, partly mineralized, are usually preserved in burial contexts that protected the corpse from scavengers and other natural agents. Both skeletal elements have different components and so provide bioanthropologists with complementary data. Bone tissue is constantly remodelled with a complete turnover of approximately a decade for adults, but variable during life and according to sex or skeletal

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<sup>7</sup> Most recent: Fanny BOCQUENTIN, Teresa CABELLOS, Nicolas SAMUELIAN, “Graves in context: Field anthropology and the investigation of interstratified floors and burials”, in Ofer BAR-YOSEF, François VALLA (eds), *Natufian Foragers in the Levant : Terminal Pleistocene Social Changes in Western Asia [papers from a symposium held in 2009]* (New York, 2013), pp. 185-92; Leore GROSMAN, Natalie D. MUNRO, Itay ABADI et al., “Nahal Ein Gev II, a Late Natufian Community at the Sea of Galilee”, *Plos One*, vol. 11, no. 1 (2016), pp. 21-48; Fanny BOCQUENTIN, “Sédentarisation”, in Albert PIETTE, Jean-Michel SALANSKIS (eds), *Dictionnaire de l'humain* (Nanterre, 2018), pp. 503-10; Tobias RICHTER, Emmy BOCAEGE, Peter ILSØE et al., “Ochre, Ground Stone, and Wrapping the Dead in the Late Epipalaeolithic (Natufian) Levant: Revealing the Funerary Practices at Shubayqa 1, Jordan”, *Journal of Field Archaeology*, vol. 44, no. 7 (2019), pp. 440-57.

<sup>8</sup> Tamar NOY, “Some aspects of Natufian mortuary behavior at Nahal Oren”, in Israel HERSHKOVITZ (ed.), *People and culture in change : proceedings of the second symposium on Upper Palaeolithic, Mesolithic and Neolithic populations of Europe and the Mediterranean Basin ; Part I* (Oxford, 1989), pp. 53-57; Leore GROSMAN, Natalie D. MUNRO, Anna BELFER-COHEN, “A 12,000-year-old Shaman burial from the southern Levant (Israel)”, *Proceedings of the National Academy of Sciences*, vol. 105, no. 46 (2008), pp. 17665-69; György LENGYEL, Dani NADEL, Fanny BOCQUENTIN, “The Natufian at Raqefet Cave”, in Ofer BAR-YOSEF, François R. VALLA (eds), *Natufian Foragers in the Levant ...*, pp. 271-84.

<sup>9</sup> Nigel Adrian GORING-MORRIS, Anna BELFER-COHEN, “Different strokes for different folks: Near Eastern Neolithic mortuary practices in perspective”, in Ian HODDER (ed.), *Religion at Work in a Neolithic Society: Vital Matters* (Cambridge, 2013), pp. 35-57; Anabel ORTIZ, Philippe CHAMBON, Miquel MOLIST, “‘Funerary bundles’ in the PPNB at the archaeological site of Tell Halula (middle Euphrates valley, Syria): analysis of the taphonomic dynamics of seated bodies”, *Journal of Archaeological Science*, vol. 40, no. 12 (2013), pp. 4150-61; Rima KHAWAM, “L’Homme et la mort au néolithique précéramique B : l’exemple de Tell Aswad”, thèse de doctorat (Université de Lyon 2, 2014); Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires des populations néolithiques du Proche-Orient : l’impact de la Néolithisation : étude de sept sites syriens – 9820-6000 cal. BC”, thèse de doctorat (Université de Lyon 2, 2014).

<sup>10</sup> Bérénice CHAMEL, Eric COQUEUGNIOT, “Human self-perception and self-expression during the 9<sup>th</sup> Millennium cal. BCE: Funerary practices and symbolic meaning of the human representations at Dja’dé (Syria)”, in Jörg BECKER, Claudia BEUGER, Bernd MÜLLER-NEUHOF (eds), *Iconography and Symbolic Meaning of the Human in Near Eastern Prehistory* (Vienna, 2019), pp. 57-70.

site.<sup>11</sup> On the contrary, enamel is a static tissue, once mineralized it does not undergo remodelling but alterations (wear, fracture, lesions, etc.). Consequently, if bone provides information about the last years of an individual's life, teeth also provide data on childhood. Macroscopic analyses (changes in mandibular and teeth morphology, in dental macro- and microwear, in oral pathology and bone disease) as well as microscopic analyses (isotopes, aDNA, residues from calculus) can provide us with data related to major shifts in diet, such as that which characterizes the Neolithization process. If calculus offers direct evidence of dietary and non-dietary intakes,<sup>12</sup> the other proxies provide indirect evidence of diet, such as hardness of the food, carbohydrate or protein contents, marine, plant and dairy consumption, nutritional deficiencies or high-calorie diet. When preserved, DNA can provide information on pathogens and food intolerance that is useful in debates on food preparation, cooking and long-term biological adaptations.

## The transition from hunter-gatherer to agricultural diet

The shift from a hunter-gatherer to an agricultural diet is commonly considered to be linked with a severe increase in oral disease.<sup>13</sup> An agriculture diet led to the consumption of more carbohydrate-rich plants (such as cereals), exposing teeth to more carious lesions. The introduction of new food processing techniques (such as the use of stone mortars which yield higher rates of attrition, or boiling techniques giving a sticky consistency to foods facilitating bacterial growth)<sup>14</sup> is also evoked as a potential dental health impactor.<sup>15</sup> It is a fact that an increase in caries rates over time has been observed worldwide and that past and present hunter-gatherers have a lower caries rate (average <4%) than agriculturists (average >7%).<sup>16</sup> This undeniable link between dental pathology and subsistence strategies should, however, be

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<sup>11</sup> Ronald RUIJERMAN, *Modeling and Remodeling in Bone Tissue* (Eindhoven, 2005).

<sup>12</sup> e.g. Christina WARINNER, Jessica HENDY, Camilla SPELLER et al., "Direct evidence of milk consumption from ancient human dental calculus", *Scientific Reports*, vol. 4, no. 1 (2015), <https://doi.org/10.1038/srep07104>.

<sup>13</sup> G. Richard SCOTT, Christy G. TURNER, *The Anthropology of Modern Human Teeth: Dental Morphology and Its Variation in Recent Human Populations* (Cambridge, 2000); Jay T. STOCK, Ron PINHASI, "Introduction: Changing paradigms in our understanding of the transition to agriculture: Human bioarchaeology, behaviour and adaptation", in Ron PINHASI, Jay T. STOCK (eds), *Human Bioarchaeology of the Transition to Agriculture* (Hoboken, 2011), pp. 1-13.

<sup>14</sup> Theya MOLLESON, "The importance of porridge", in Marcel OTTE (ed.), *Nature et Culture. Actes du colloque international de Liège, 13-17 décembre 1993*, (Liège, 1995), pp. 479-86.

<sup>15</sup> Bennett Holly SMITH, "Patterns of molar wear in hunter-gatherers and agriculturalists", *American Journal of Physical Anthropology*, vol. 63 (1984), pp. 39-56; Mary Lucas POWELL, "Analysis of dental wear and caries for dietary reconstruction", in Robert I. GILBERT, James H. MIELKE (eds), *The Analysis of Prehistoric Diets* (London, 1985), pp. 307-38; Clark Spencer LARSEN, "The agricultural revolution as environmental catastrophe: Implications for health and lifestyle in the Holocene", *Quaternary International*, vol. 150, no. 1 (2006), pp. 12-20.

<sup>16</sup> Christy G. TURNER, "Dental anthropological indications of agriculture among the Jomon people of central Japan", *American Journal of Physical Anthropology*, vol. 51, no. 4 (1979), pp. 619-35; Simon HILLSON, "Recording dental caries in archaeological human remains", *International Journal of Osteoarchaeology*, vol. 11, no. 4 (2001), pp. 249-89; Peter CASELITZ, "Caries. Ancient plague of humankind", in Kurt W. ALT, Friedrich W. RÖSING, Maria TESCHLER-NICOLA (eds), *Dental Anthropology: Fundamentals, Limits and Prospects* (Wien, 1998), pp. 203-26; Basak KOCA, Erksin GULEÇ, Timur GULTEKIN et al., "Implications of dental caries in Anatolia: From hunting-gathering to the present", *Human Evolution*, vol. 21, no. 3 (2006), pp. 215-22.

tempered by environmental contexts as non-agricultural diets may be high in carbohydrates<sup>17</sup> and agricultural diets may not be specifically cariogenic.<sup>18</sup> The presence or absence of bacterial colonies and their virulence is also critical for caries development.<sup>19</sup> Moreover, other contributing dietary factors such as fluoride in local water sources, regularity of meals, intake of meat and fat, or individual contributing factors such as age, sex, properties of saliva, resistance of tooth enamel, tooth morphology, rate of attrition and dental hygiene, should not be neglected.<sup>20</sup> Because of these multi-developmental factors, the carious lesion rate should be considered and interpreted in terms of overall dietary reconstructions for large groups of individuals over long periods of time.

Other macroscopic proxies, such as periapical abscesses, antemortem tooth loss (AMTL), tooth wear, periodontal disease (alveolar recession), calculus presence and thickness, or hypoplasia, can be discussed in terms of past subsistence strategies. However, multiple aetiologies exist for some of these conditions and so may bias interpretation. For instance, age-at-death criteria is a determinant factor for tooth wear and alveolar recession while differential mineralization and preservation of calculus deposit is a major limitation for interpretation. Other factors, such as periapical abscesses and AMTL, often the direct consequence of large dental caries, cannot be considered independently from the former. Dental hypoplasia is the result of a disruption event during enamel formation, and this is materialized macroscopically by either linear defects on the crown (LEH) or less frequently by pit type defects or surface defects.<sup>21</sup> Hypoplasia is known as a non-specific physiological stress, strongly linked to metabolic disorders and nutritional deficiency. Today, hypoplasia rate is highly related to socioeconomic levels.<sup>22</sup> Long-term studies tend to show an increase in hypoplasia with the Neolithization process,<sup>23</sup> and this is interpreted as a consequence of a more impoverished and less varied diet, resulting in malnutrition, and/or of increasing infectious disease due to animal domestication (zoonoses) and population aggregation. That said, we should keep in mind that

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<sup>17</sup> Louise T. HUMPHREY, Isabelle DE GROOTE, Jacob MORALES et al., “Earliest evidence for caries and exploitation of starchy plant foods in Pleistocene hunter-gatherers from Morocco”, *Proceedings of the National Academy of Sciences*, vol. 111, no. 3 (2014), pp. 954-59.

<sup>18</sup> Nancy TAYLES, Kate DOMETT, Kirsten NELSEN, “Agriculture and dental caries? The case of rice in Prehistoric Southeast Asia”, *World Archaeology*, vol. 32, no. 1 (2000), pp. 68-83.

<sup>19</sup> Christina J ADLER, Keith DOBNEY, Laura S WEYRICH et al., “Sequencing ancient calcified dental plaque shows changes in oral microbiota with dietary shifts of the Neolithic and Industrial revolutions”, *Nature Genetics*, vol. 45 (2013), pp. 450-55.

<sup>20</sup> Elmar. REICH, Adrian LUSSI, Ernest NEWBRUN, “Caries-risk assessment”, *International Dental Journal*, vol. 49, no. 1 (1999), pp. 15-26; John R. LUKACS, “Fertility and agriculture accentuate sex differences in dental caries rates”, *Current Anthropology*, vol. 49, no. 5 (2008), pp. 901-14.

<sup>21</sup> Mahmoud Y. EL-NAJJAR, Mike V. DESANTI, Leon OZEBEK, “Prevalence and possible etiology of dental enamel hypoplasia”, *American Journal of Physical Anthropology*, vol. 48, no. 2 (1978), pp. 185-92; Alan H. GOODMAN, George J. ARMELAGOS, Jerome C. ROSE, “The chronological distribution of enamel hypoplasias from prehistoric Dickson mounds populations”, *American Journal of Physical Anthropology*, vol. 65, no. 3 (1984), pp. 259-66.

<sup>22</sup> Alan GOODMAN, Jerome C. ROSE, “Dental enamel hypoplasias as indicators of nutritional status”, in Marc A. KELLEY, Clark Spencer LARSEN (eds), *Advances in Dental Anthropology. Conference Held in Kansas City, Missouri, 1988* (New York, 1991), pp. 279-93; Mark SKINNER, Alan GOODMAN, “Anthropological uses of developmental defects of enamel”, in Shelley Rae SAUNDERS, Mary Ann KATZENBERG (eds), *Skeletal Biology of Past Peoples: Research Methods*. (New York, 1992), pp. 153-74.

<sup>23</sup> See Alan GOODMAN, Jerome C. ROSE, “Dental enamel hypoplasias ...”; Clark Spencer LARSEN, “The agricultural revolution as environmental catastrophe ...”; Mark Nathan COHEN, George J. ARMELAGOS, Clark Spencer LARSEN (eds), *Paleopathology at the Origins of Agriculture* (2nd ed., Gainesville, 2013); Patricia SMITH, Liora HORWITZ, “Ancestors and inheritors: A bio-cultural perspective of the transition to agropastoralism in the Southern Levant”, in Mark Nathan COHEN, Gillian Margaret Mountford CRANE-KRAMER (eds), *Ancient Health: Skeletal Indicators of Agricultural and Economic Intensification* (Gainesville, 2012), pp. 201-39.

in the Near East, although interrupted by clear phases of breakdowns, the long evolutionary trend towards growth of site density and size,<sup>24</sup> a testimony of the demographic revolution, cannot be compatible with a long-term drastic reduction in health. More likely, communities experienced alternating improvements and deterioration in health levels owing to and/or responsible for a non-continuous rate of socioeconomic advances as evidenced by archaeological data.<sup>25</sup>

## Diet transition in the Near East from a dental diseases perspective: a brief state of the art

Dental attrition and diseases during the Natufian and Neolithic periods have been the focus of several studies. Beside site-specific reports, comparisons between groups of the same economic-cultural horizon have shown interesting discrepancies raising the question of variability in plant resource exploitation amongst sub-contemporaneous communities.<sup>26</sup> However, few articles have proposed cross-cultural studies comparing hunter-gatherers and agriculturists in the Near East resulting in the proposition of an evolutionary pattern though the

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<sup>24</sup> Jean-Pierre BOCQUET-APPEL, Ofer BAR-YOSEF, *The Neolithic Demographic Transition and its Consequences* (Dordrecht/London, 2008).

<sup>25</sup> Kathleen Mary KENYON, *Digging up Jericho* (London, 1957); Patricia SMITH, Liora HORWITZ, “Ancestors and inheritors ...”; Arlene M. ROSEN, Isabel RIVERA-COLLAZO, “Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant”, *Proceedings of the National Academy of Sciences*, vol. 109, no. 10 (2012), pp. 3640-45; Ferran BORRELL, Aripekka JUNNO, Joan Antón BARCELÓ, “Synchronous Environmental and Cultural Change ...”; Pascal FLOHR, Dominik FLEITMANN, Roger MATTHEWS et al., “Evidence of resilience to past climate change in Southwest Asia: Early farming communities and the 9.2 and 8.2 ka events”, *Quaternary Science Reviews*, vol. 136 (2015), pp. 23-69.

<sup>26</sup> Patricia SMITH, *Dental Morphology and Pathology in the Natufians: The Dental Evidence for Dietary Specializations* (Chicago, 1970); Patricia SMITH, “Diet and attrition in the Natufians”, *American Journal of Physical Anthropology*, vol. 37 (1972), pp. 233-38; Patricia SMITH, “Paleonutrition and subsistence patterns in the Natufians”, in Israel HERSHKOVITZ (ed.), *People and Culture in Change. Proceedings of The Second Symposium on Upper Palaeolithic, Mesolithic and Neolithic Populations of Europe and the Mediterranean Basin* (Oxford, 1989), pp. 375-84; Theya MOLLESON, Karen JONES, Stephen JONES, “Dietary change and the effects of food preparation on microwear patterns in the Late Neolithic of abu Hureyra, northern Syria”, *Journal of Human Evolution*, vol. 24, no. 6 (1993), pp. 455-68; Fanny BOCQUENTIN, “Pratiques funéraires, paramètres biologiques et identités culturelles au Natoufien : une analyse archéo-anthropologique”, thèse de doctorat (Université Bordeaux 1, 2003); Fanny BOCQUENTIN, “A Final Natufian population: health and burial status at Eynan-Mallaha”, in Uri ZILBERMAN, Marina FAERMAN, Liora Kolska HORWITZ et al. (eds), *Faces from the Past: Diachronic Patterns in the Biology of Human Populations from the Eastern Mediterranean Papers in Honour of Patricia Smith* (Oxford, 2007), pp. 66-81; Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires ...”; Deborah Claire MERRETT, “Bioarchaeology in Early Neolithic Iran : assessment of health status and subsistence strategy”, PhD thesis (University of Manitoba, 2004); Başak BOZ, “The oral health of Çatalhöyük Neolithic people”, in Ian HODDER (ed.), *Inhabiting Çatalhöyük: Reports from the 1995-1999 Seasons* (Cambridge/London, 2005), pp. 587-91; Theya MOLLESON, Peter ANDREWS, Başak BOZ, “Reconstruction of the Neolithic people of Catalhöyük”, in Ian HODDER (ed.), *Inhabiting Çatalhöyük ...*, pp. 279-301; Josep ANFRUNS, Josep I. OMS, “Un nouveau regard sur les restes anthropologiques du site néolithique de Tell Ramad (Syrie)”, *Syria*, vol. 83 (2006), pp. 115-24; Josep ANFRUNS, Josep I. OMS, “Antropología y paleopatología dentarias de la población neolítica de Tell Halula”, in Miquel MOLIST (ed.), *Tell Halula: un poblado de los primeros agricultores en el valle del Eufrates, Siria*, vol. 2 (Madrid, 2013), pp. 450-69; Michael SCHULTZ, Tyede H. SCHMIDT-SCHULTZ, Julia GRESKY et al., “Morbidity and mortality in the Late PPNB populations from Basta and Ba’ja (Jordan)”, in Uri ZILBERMAN, Marina FAERMAN, Liora Kolska HORWITZ et al. (eds), *Faces from the Past ...*, pp. 82-99.



Neolithization process.<sup>27</sup> The most comprehensive study so far is based on 1,964 teeth from various sites located in the southern Levant and attributed to the Natufian and PPN periods.<sup>28</sup> The major results in relation to diet can be summarized as follow: the authors observed a slightly higher wear rate in hunter-gatherer teeth with a clear shift in dental wear pattern; a similar caries rate; a significantly higher rate of calculus in Neolithic jaws; a low rate of periapical abscesses in both populations; similar rates of AMTL, but with significantly more anterior teeth lost in the Natufian and more lower molars lost in the Neolithic; and a significantly higher rate of periodontal disease in Natufian populations.<sup>29</sup> A cautious interpretation of these results, which seem sometimes contradictory, led the authors to emphasize the multifactorial aspects of the proxies they studied and the difficulty of interpreting their data in terms of dietary habits. They concluded that no major discrepancies between Natufians and agriculturalists were found, as witnessed by their similar caries rates (6.4 % and 6.7 % respectively), but they emphasized a likely reduction in dietary hardness during the Neolithic period according to observed changes in dental wear pattern.<sup>30</sup> The gross caries rate obtained for Natufians was significantly higher than the comprehensive studies undertaken earlier and consistent between each others.<sup>31</sup> Moreover, in line with a number of articles on the topic, the representativeness of the samples and the value of the gross caries rate have shown obvious limitations<sup>32</sup> that we hope to overcome here.

## Material and methods

Our corpus comprises some 8,637 observable teeth (erupted, isolated crowns or dental germs: 7,524 permanents, 1,113 deciduous) belonging to a minimum of 583 clearly identified individuals (plus isolated teeth) recovered from 24 different sites from the southern and northern Levant and attributed to hunter-gatherers or agriculturalists (the latter with and without pottery) spanning c. 13000-5800 cal. BC (table 1 and map 1). The maximal numbers of observations will fluctuate slightly according to the criteria selected for the different steps of the analyses and the available data (see below).

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<sup>27</sup> Patricia SMITH, Ofer BAR-YOSEF, Andrew SILLEN, “Archaeological and skeletal evidence for dietary change during the Late Pleistocene/Holocene in the Levant”, in Mark Nathan COHEN, George J. ARMELAGOS (eds), *Paleopathology at the Origins of Agriculture* (New York, 1984), pp. 101-36; Patrick MAHONEY, *Dental Microwear in Natufian Hunter-Gatherers and Pre-Pottery Neolithic Agriculturalists from Northern Israel* (Oxford, 2005); Patricia SMITH, Liora HORWITZ, “Ancestors and inheritors ...”.

<sup>28</sup> Vered ESHED, Avi GOPHER, Israel HERSHKOVITZ, “Tooth wear and dental pathology at the advent of agriculture: new evidence from the Levant”, *American Journal of Physical Anthropology*, vol. 130, no. 2 (2006), pp. 145-59.

<sup>29</sup> *Ibid.*, pp. 149-50.

<sup>30</sup> See, as well, Patricia SMITH, “Diet and attrition ...”; Bennett Holly SMITH, “Patterns of molar wear ...”; Hila MAY, Tanya SELLA-TUNIS, Ariel POKHOJAEV et al., “Changes in mandible characteristics during the terminal Pleistocene to Holocene Levant and their association with dietary habits”, *Journal of Archaeological Science: Reports*, vol. 22 (2018), pp. 413-19; but see also *contra* from micro-wear research: Patrick MAHONEY, *Dental Microwear ...*

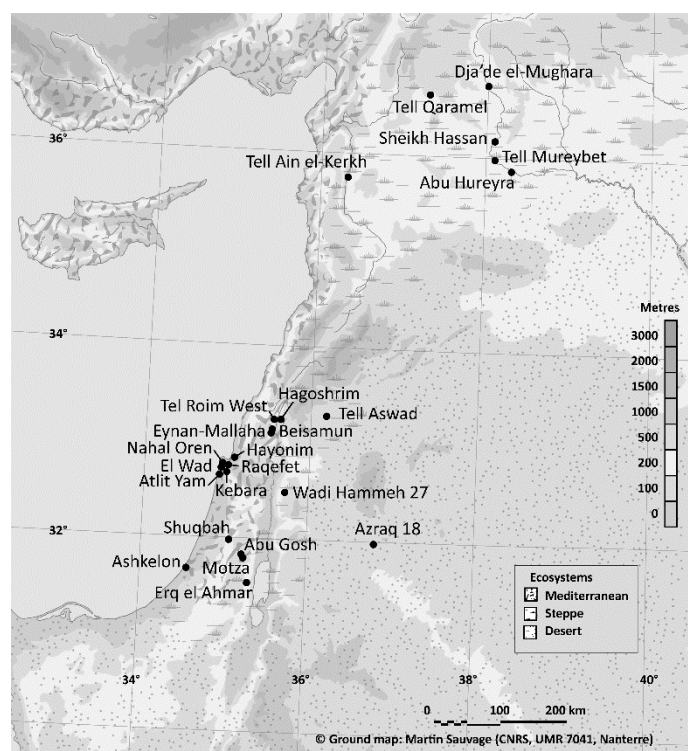
<sup>31</sup> Patricia SMITH, *Dental Morphology ...*; Fanny BOCQUENTIN, “Pratiques funéraires, paramètres biologiques ...”.

<sup>32</sup> John R. LUKACS, “The ‘caries correction factor’: A new method of calibrating dental caries rates to compensate for antemortem loss of teeth”, *International Journal of Osteoarchaeology*, vol. 5, no. 2 (1995), pp. 151-56; Yilmaz S. ERDAL, İzzet DUYAR, “A new correction procedure for calibrating dental caries frequency”, *American Journal of Physical Anthropology*, vol. 108, no. 2 (1999), pp. 237-40; İzzet DUYAR, Yilmaz Selim ERDAL, “A new approach for calibrating dental caries frequency of skeletal remains”, *HOMO*, vol. 54, no. 1 (2003), pp. 57-70.

<i>Sites</i>	<i>No. Teeth (MNI individuals)</i>	<i>Region</i>	<i>Ecosystem today</i>	<i>Anthropologist for this article</i>	<i>Excavators</i>	<i>Chrono-cultural attribution of the skeletons</i>
<b><i>Abu Ghosh</i></b>	48 (5)	South Levant	Mediterranean	MA	H. Khalaily, O. Marder	PPNB, 7th millennium (PPNC and PN)
<b><i>Abu Hureyra</i></b>	1284 (87)	North Levant	Steppe	BC	A. M. T. Moore	Natufian (Late), PPNB, 7th millennium (PN)
<b><i>Ashkelon</i></b>	55(7)	South Levant	Mediterranean	MA	Y. Garfinkel	7th millennium (PPNC)
<b><i>Atlit Yam</i></b>	233 (23)	South Levant	Mediterranean	MA	E. Galili	7th millennium (PPNC)
<b><i>Azraq 18</i></b>	85 (8)	South Levant	Desert	FB	A. Garrard	Natufian (Early)
<b><i>Beisamun</i></b>	147 (15)	South Levant	Mediterranean	MA	F. Bocquentin, H. Khalaily	7th millennium (PPNC)
<b><i>Sheikh Hassan</i></b>	130 (7)	North Levant	Steppe	BC	J. Cauvin	PPNA
<b><i>Dja'de el-Mughara</i></b>	824 (50)	North Levant	Steppe	BC	E. Coqueugniot	PPNA, PPNB
<b><i>El Wad</i></b>	1133 (52)	South Levant	Mediterranean	FB	D.A.E. Garrod	Natufian (Early, Late)
<b><i>Erq-el-Ahmar</i></b>	45 (3)	South Levant	Steppe	FB	R. Neuville	Natufian (Early)
<b><i>Hagoshrim</i></b>	35 (4)	South Levant	Mediterranean	MA	N. Getzov	7th millennium (PPNC)
<b><i>Hayonim Cave</i></b>	558 (38)	South Levant	Mediterranean	FB	O. Bar-Yosef, E. Tchernov, B. Arensburg, N. Goren	Natufian (Early, Late)
<b><i>Kebara</i></b>	186 (42)	South Levant	Mediterranean	FB	F. Turville-Petre and C.A. Baynes	Natufian (Early)
<b><i>Eynan-Mallaha</i></b>	1271 (88)	South Levant	Mediterranean	FB	J. Perrot, M. Lechevallier, F. Valla, H. Khalaily	Natufian (Early, Late, Final)
<b><i>Motza</i></b>	107 (13)	South Levant	Mediterranean	FB	H. Khalaily	PPNB

<i>Nahal-Oren</i>	446 (28)	South Levant	Mediterranean	FB	M. Stekelis, T. Noy and E.S. Higgs	Natufian (Late/Final)
<i>Raqefet</i>	478 (31)	South Levant	Mediterranean	FB	E.S. Higgs, T. Noy, D. Nadel, G. Lengyel	Natufian (Early/Late)
<i>Shukbah</i>	47 (4)	South Levant	Mediterranean	FB	D.A.E. Garrod, E.T. Woodbury	Natufian (Late)
<i>Tel Roim West</i>	79 (6)	South Levant	Mediterranean	MA	D. Nadel	PPNB, 7th millennium (PPNC and PN)
<i>Tell Ain el- Kerkh</i>	1070 (46)	North Levant	Steppe	BC	A. Tsuneki	7th millenium (PN)
<i>Tell Aswad</i>	50 (5)	South Levant	Steppe	BC	H. de Contenson	PPNB
<i>Tell Mureybet</i>	121 (7)	North Levant	Steppe	BC	J. Cauvin	PPNA, PPNB
<i>Tell Qaramel</i>	109 (9)	North Levant	Steppe	BC	Y. Kanjou, R.F. Mazurowski	PPNA
<i>Wadi- Hammeh 27</i>	96 (5)	South Levant	Steppe	FB	P. Edwards	Natufian (Early)

Table 1. List of the anthropological collections included in the current study. MA: Marie Anton; FB: Fanny Bocquentin; BC: Berenice Chamel.



Map 1. Location of the sites included in the corpus

According to the archaeological data available, we subdivided our corpus into five major chrono-cultural phases: the Early Natufian (c. 13000-11600 cal. BC), the Late/Final Natufian (c. 11600-9600 cal. BC), the Pre-Pottery Neolithic A (PPNA, c. 9600-8500 cal. BC), the Pre-Pottery Neolithic B (PPNB, c. 8500-7000 cal. BC) and the Pre-Pottery Neolithic C/Pottery Neolithic (PPNC/PN entities, c. 7000-5800 cal. BC).<sup>1</sup> From the northern to southern Levant, a few centuries time lag existed in the onset of the different chrono-cultural phases.<sup>2</sup> Although somehow artificial, these pan-regional clusters assemble communities with close lifestyles and broadly speaking economic status. Our last cluster includes communities from the seventh millennium without pottery (Final PPNB or PPNC entities in the southern Levant, c. 7000-6400 cal. BC) or with pottery (Early Pottery Neolithic in the north, c. 7000-6000 cal. BC; Early Pottery Neolithic in the south, c. 6400-5800 cal. BC). This discrepancy in material culture will be taken into account as a second step. The PPNA period has yielded few skeletons as yet and consequently this part of the corpus cannot be considered as representative as the samples attributed to the other comparative periods. However, we will try to follow trends that may or may not be confirmed by future findings. Sites are currently located in specific environmental zones: desert, steppe or Mediterranean (map 1). However, major climatic variations occurred over the chronological timespan covered by our research (Bølling-Allerød, Younger Dryas, Holocene Rapid Climate Change, 9.2 and 8.2 cal. ka. BP events), to which we will refer later, and these may have shifted the environmental conditions experienced.

<sup>1</sup> Following Lisa A. MAHER, Edward B. BANNING, Michael CHAZAN, “Oasis or mirage? Assessing the role of abrupt climate change in the prehistory of the Southern Levant”, *Cambridge Archaeological Journal*, vol. 21, no. 1 (2011), pp. 1-30; Leore GROSMAN, “The Natufian chronology scheme – New insights and their implications”, in Ofer BAR-YOSEF, François VALLA (eds), *Natufian Foragers in the Levant* ..., pp. 622-37.

<sup>2</sup> Phillip C. EDWARDS, “The chronology and dispersal of the Pre-Pottery Neolithic B cultural complex in the Levant”, in Ianir MILEVSKI, Fanny BOCQUENTIN, Miquel MOLLIST (eds), *Connections and Disconnections between the Northern and Southern Levant in the Late Prehistory and Protohistory (12th – mid-2nd mill. BC)* (Paris, 2016), pp. 53-72.

All qualitative and quantitative data used in this research (identification of teeth and individual skeletons; age, sex, ante- and postmortem tooth loss; abscesses, carious lesions and hypoplasia) are primary data collected, in person, by the three authors of the article, following the same recording system and methodological grid described in detail elsewhere.<sup>3</sup> Chronological attribution follows the archaeologists' determination with critical adjustment (or deletion) for the oldest skeletons unearthed.<sup>4</sup> All data were gathered in a single database for the purpose of this article. We believe that this broad database, despite not being exhaustive, has the great advantage of limiting biases that are common in compilations based on published data from multi-observers.

We have focused our attention on four critical and complementary proxies: carious lesions, periapical abscesses, AMTL and dental hypoplasia. Tooth wear, alveolar recession and calculus presence and quantity were not included in this study for the reasons described above. We decided to examine the data by tooth categories. The analysis by individual, which provides additional information, has been excluded because it is highly biased when the dentition is not complete.<sup>5</sup> This is the case in our corpus, especially for the Neolithic dentitions, due to complex and multi-stepped funeral practices.

## From gross caries rate to corrected caries rates: a crucial adjustment

Our corpus comprises 7,044 permanent erupted teeth and 975 erupted deciduous teeth suitable for caries search. First permanent teeth appear in the mouth at the age of c. 5-8 years old, while last deciduous teeth are exfoliated at c. 10-12 years old.<sup>6</sup> Deciduous teeth have yielded very few lesions and these will be discussed later on with age distribution. Among our corpus of permanent erupted teeth, 3.76 % (265/7044) yielded at least one carious lesion. Not surprisingly,<sup>7</sup> upper as well as lower molars are by far the most affected categories of teeth in all periods and sites (graph 1). The evolution of this gross rate displays an irregular curve with a decrease from the Natufian to the PPN followed by a slow rise and a sudden proliferation during the seventh millennium (table 2; graph 2). This is an unexpected trend compared to observations worldwide (see above). Before making any assumptions, the validity of this gross rate must be questioned. Indeed, considering the well-known differential susceptibility of the different categories of teeth to caries, the incomplete archaeological dental arches of this study do introduce a major bias in counting caries.<sup>8</sup> Among the missing teeth, some have been lost antemortem, others postmortem. AMTL can be the result of an accidental loss (trauma), an intentional extraction (therapeutic or cultural), the result of periodontal disease, heavy attrition, caries and abscesses. The former two (attrition and caries) are thought to be the two main factors causing AMTL,<sup>9</sup> therefore ignoring AMTL greatly minimizes the real rate of caries. Postmortem tooth loss (PMTL), for its part, is due to the decay of the ligaments, sometimes causing the loss of the tooth out of the alveolar bone. Monoradicular anterior teeth (incisors,

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<sup>3</sup> Fanny BOCQUENTIN, "Pratiques funéraires, paramètres biologiques ..."; Fanny BOCQUENTIN, "A Final Natufian population ..."; Bérénice CHAMEL, "Bioanthropologie et pratiques funéraires ...".

<sup>4</sup> Ibid.

<sup>5</sup> Simon HILLSON, "Recording dental caries ...".

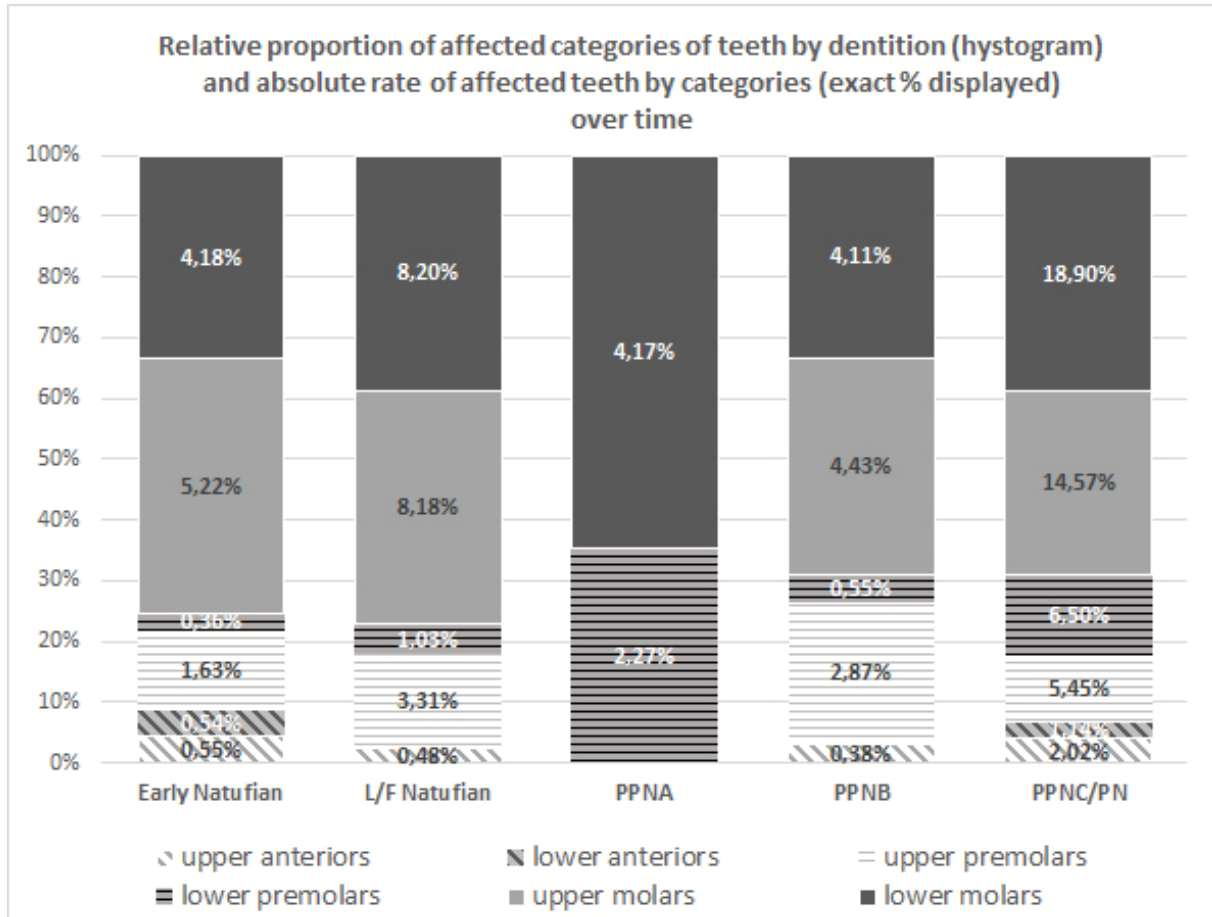
<sup>6</sup> Douglas H. UBELAKER, *Human Skeletal Remains: Excavation, Analysis, Interpretation* (Chicago, 1978).

<sup>7</sup> See Simon HILLSON, "Recording dental caries ...".

<sup>8</sup> See John R. LUKACS, "The 'caries correction factor' ..."; Yilmaz S. ERDAL, İzzet DUYAR, "A new correction procedure ..."; İzzet DUYAR, Yilmaz Selim ERDAL, "A new approach for calibrating ...".

<sup>9</sup> John R. LUKACS, "The 'caries correction factor' ...".

canines) are particularly affected by PMTL (lost during primarily stages in several steps funerary handling, they end up in burrows in the case of bioturbation or wasted in case of unsieved excavations, etc...). Because anterior teeth are less susceptible to caries than posterior ones, if PMTL is not taken into account the rate of caries might be overstated.<sup>10</sup> Therefore, the gross caries rate must be corrected taking into account AMTL and PMTL and corrections must be evaluated separately for anterior and posterior teeth.<sup>11</sup>



Graph 1. Relative proportion of affected categories of teeth by dentition (hystogram) and the absolute rate of affected teeth by categories (exact % displayed) over time. PPNA's corpus is too small to be considered representative.

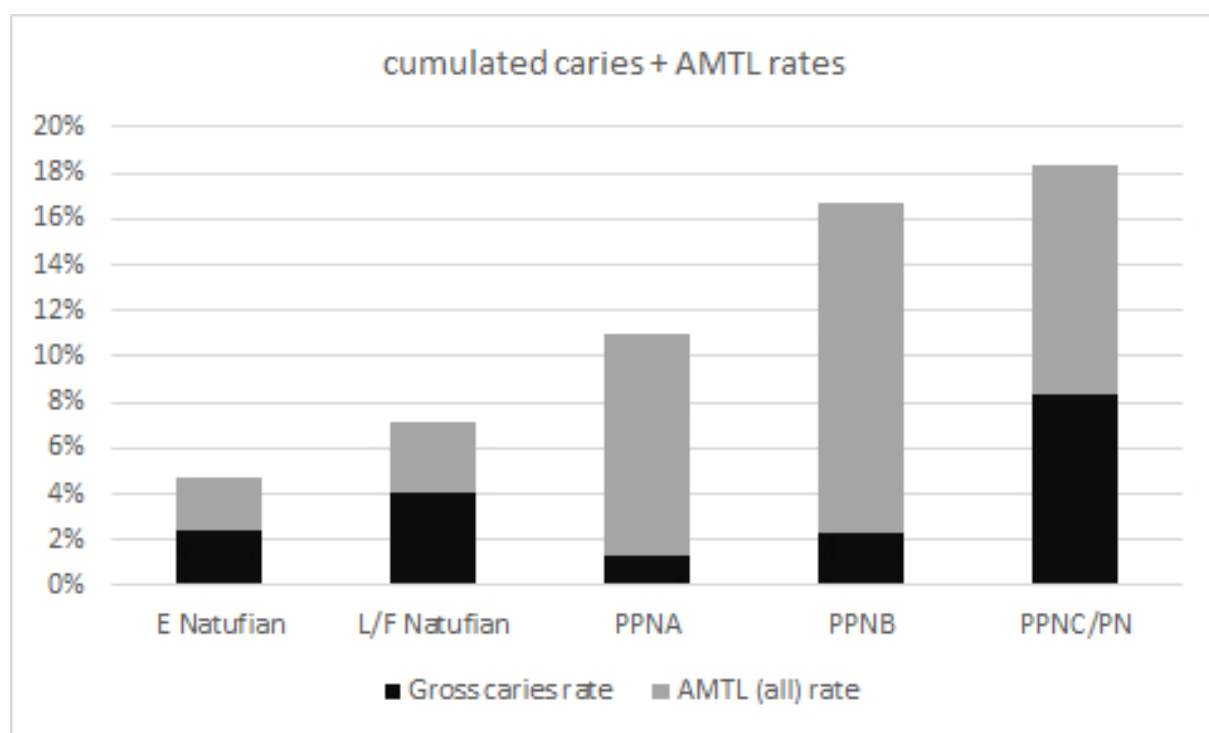
<sup>10</sup> Yilmaz S. ERDAL, İzzet DUYAR, "A new correction procedure ...".

<sup>11</sup> İzzet DUYAR, Yilmaz Selim ERDAL, "A new approach for calibrating ...".

Table 2. Caries gross rates and AMTL rates by chronological phases.

\* Number of affected teeth/number of observed teeth. All categories of teeth are considered.

Periods <sup>12</sup> (No. observed teeth)	Caries gross rate*	Periods (No. observed sockets)	AMTL (all) rate
Early Natufian (N = 2240)	2.37 %	Early Natufian (N = 2768)	2.38 %
Late/Final Natufian (N = 1414)	4.03 %	Late/Final Natufian (N = 1617)	3.09 %
PPNA (N = 310)	1.29 %	PPNA (N = 228)	9.65 %
PPNB (N = 1539)	2.34 %	PPNB (N = 921)	14.33 %
PPNC/PN (N = 1366)	8.35 %	PPNC/PN (N = 893)	9.97 %



Graph 2. Evolutionary trend of cumulated dental pathologies (Gross caries rate + AMTL rates).

Indeed, considering all AMTL as potential lost carious teeth, we obtain a completely different trend (graph 2). Gross caries rates calculated taking into account AMTL show a progressive increase in caries lesions through the Neolithization process. Such cumulated rates are however overestimated because other reasons for AMTL coexist with carious lesions. If severe periodontal disease is rare in our corpus,<sup>13</sup> the use of teeth as a tool which results in high levels of attrition and loss is documented for specific individuals.<sup>14</sup> Moreover, culturally dictated extraction of the upper central incisors did exist in a significant proportion during the

<sup>12</sup> Not all the teeth in the corpus could be assigned to one of our chronological periods, it explains why the total number of the table is different from the total corpus.

<sup>13</sup> See Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires ...”.

<sup>14</sup> Theya MOLLESON, “The eloquent bones of Abu Hureyra”, *Scientific American*, vol. 271, no. 2 (1994), pp. 70-75; Fanny BOCQUENTIN, Pascal SELLIER, Pascal MURAIL, “Abrasion dentaire et travail spécialisé dans la population natoufienne de Mallaha (Israël)”, *Comptes Rendus Palevol*, vol. 4, no. 4 (2005), pp. 351-57.

Natufian<sup>15</sup> and is highly suspected during the PPNB.<sup>16</sup> Therefore, in order to eliminate this former bias, we have decided to omit upper central incisor loss from the rate of AMTL. In addition, we applied the “proportional correction factor” (x3/8 for anterior teeth; x 5/8 for posterior teeth) as proposed by Duyar and Erdal<sup>17</sup> for overcoming the disproportion caused by PMTL. Finally, we obtained corrected caries rates (table 3, graph 3), although these are likely to be still slightly overestimated but are certainly the closest to the real caries rates that we can obtain.

Table 3. Corrected caries rates over time. \*Proportional Correction Factor: (anterior rate x 0.375)+(posterior rate x 0.625).<sup>18</sup>

Periods	Categories of teeth	Caries+AMTL (upper incisors excluded)	Observed teeth + AMTL+ agenesis	Estimated caries rate by categories	Estimated caries rate after PCF*
Early Natufian	anterior	16	773	2.07%	4.34%
	posterior	90	1580	5.70%	
Late/Final Natufian	anterior	7	477	1.47%	5.75%
	posterior	84	1009	8.33%	
PPNA	anterior	1	104	0.96%	6.53%
	posterior	23	233	9.87%	
PPNB	anterior	23	549	4.19%	8.17%
	posterior	120	1137	10.55%	
PPNC/PN	anterior	31	537	5.77%	13.47%
	posterior	169	934	18.09%	

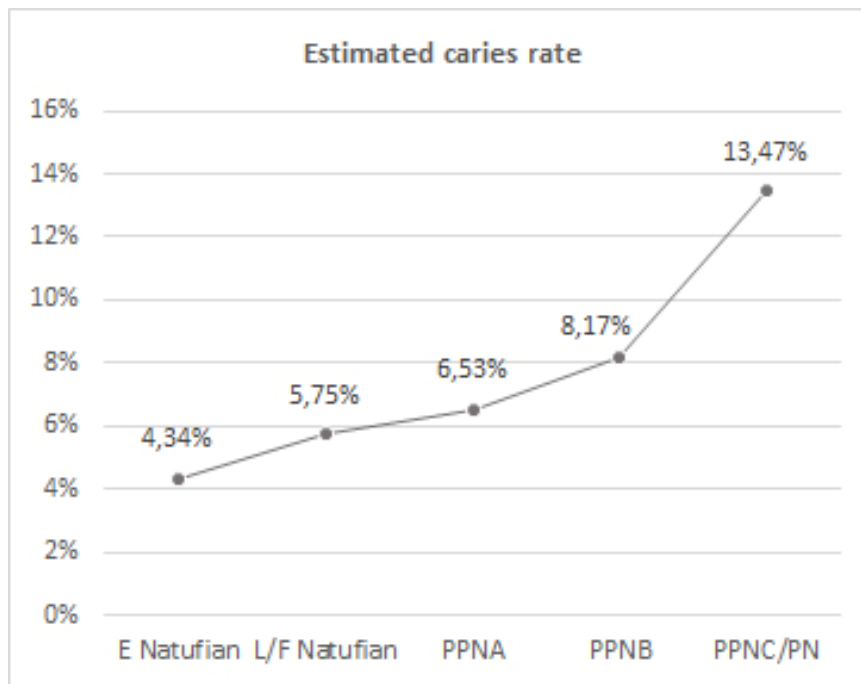
<sup>15</sup> Theodore D. MCCOWN, *The Natufian Crania from Mount Carmel, Palestine, and their Inter-Relationships* (Berkeley, 1939); Patricia SMITH, *Dental Morphology ...*; Patricia SMITH, “The dental evidence for nutritional status in the Natufians”, in Ofer BAR-YOSEF, François R. VALLA (eds), *The Natufian Culture in the Levant* (Ann Arbor, 1991), pp. 425-32; Denise FEREMBACH, “Squelettes du Natoufien d’Israël, étude anthropologique”, *L’Anthropologie*, vol. 65, no. 2 (1961), pp. 46-66; Fanny BOCQUENTIN, “A Final Natufian population ...”; Fanny BOCQUENTIN, “Avulsions dentaires et identités régionales chez les Natoufiens”, *Türkiye Bilimler Akademisi Arkeoloji Dergisi*, vol. 14 (2011), pp. 261-70.

<sup>16</sup> Personal observations of Bérénice CHAMEL.

<sup>17</sup> Izzet DUYAR, Yılmaz Selim ERDAL, “A new approach for calibrating ...”

<sup>18</sup> Izzet DUYAR, Yılmaz Selim ERDAL, “A new approach for calibrating ...”.





Graph 3. Estimated caries rate after correction over time.

This robust curve built from corrected caries rates completely revises the evolutionary pattern suggested before. The Natufian hunter-gatherers have less carious teeth than their agriculturalist successors. However, their caries rate is slightly higher than expected for hunter-gatherers (see above). Natural carbohydrate resources were available, such as wild cereals, legumes, acorns, tubers, berries and figs,<sup>19</sup> and these probably provided a substantial part of Natufian diet. The most notable aspect is the significant increase in caries from the Early to the Recent/Final Natufian ( $\chi^2$  test,  $p = 0.026$ ) witnessing a change in food procurement before the Neolithic. However, this phase corresponds to the Younger Dryas climatic cooling<sup>20</sup> (onset c. 10900 cal. BC) during which oak forest, wild cereals and legumes decreased.<sup>21</sup> Consequently, our current observations are consistent with claims that Natufians might have started to cultivate

<sup>19</sup> See Ehud WEISS, Wilma WETTERSTROM, Dani NADEL et al., “The broad spectrum revisited ...”; Amaia ARRANZ-OTAEGUI, Lara GONZÁLEZ CARRETERO, Joe ROE et al., “‘Founder crops’ v. wild plants: Assessing the plant-based diet of the last hunter-gatherers in southwest Asia”, *Quaternary Science Reviews*, vol. 186 (2018), pp. 263-83; Daniel ZOHARY, Maria HOPF, Ehud WEISS, *Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin* (4<sup>th</sup> ed., Oxford, 2012); Shahal ABBO, Avi GOPHER, Simcha LEV-YADUN, “Fruit domestication in the Near East”, *Plant Breeding Reviews*, vol. 39 (2015), pp. 325-78; Ehud WEISS, “Palaeolithic vegetal diet in the Southern Levant: The archaeobotanical evidence”, in Yehouda ENZEL, Ofer BAR-YOSEF (eds), *Quaternary of the Levant* (Cambridge, 2017), pp. 329-36.

<sup>20</sup> Cooling is well attested, drying is however still debated as different proxies show contradicting reconstructions (e.g.: synthesis in Stuart A. ROBINSON, Stuart BLACK, Bruce W. SELLWOOD et al., “A review of palaeoclimates and palaeoenvironments in the Levant and Eastern Mediterranean from 25,000 to 5000 years BP: setting the environmental background for the evolution of human civilisation”, *Quaternary Science Reviews*, vol. 25, no. 13-14 (2006), pp. 1517-41; Gideon HARTMAN, Ofer BAR-YOSEF, Alex BRITTINGHAM et al., “Hunted gazelles evidence cooling, but not drying, during the Younger Dryas in the southern Levant”, *Proceedings of the National Academy of Sciences*, vol. 113, no. 15 (2016), pp. 3997-4002.

<sup>21</sup> Cheryl MAKAREWICZ, “The Younger Dryas and hunter-gatherer transitions to food production in the Near East”, in Metin I. IREN (ed.), *Hunter-gatherer Behavior: Human Response during the Younger Dryas* (Walnut Creek, 2012), pp. 195-230; Arlene M. ROSEN, Isabel RIVERA-COLLAZO, “Climate change, adaptive cycles ...”; Gideon HARTMAN, Ofer BAR-YOSEF, Alex BRITTINGHAM et al., “Hunted gazelles evidence cooling ...”.

wild species in response to their natural decrease.<sup>22</sup> This hypothesis finds additional support in the evolution of cereal grain morphology<sup>23</sup> and changes in sickle blade gloss.<sup>24</sup> At Eynan-Mallaha, where Late (c. 11000-10400 cal. BC) and Final (10400-9800 cal. BC) Natufian layers are clearly separated by stratigraphic and cultural evidence,<sup>25</sup> this scenario can be even further refined. Grinding stones show an intensification in the exploitation of vegetal resources during the Final Natufian<sup>26</sup> associated with a drastic increase in caries compared to the Late phase during which caries declined dramatically.<sup>27</sup> These data support a sudden rise in carbohydrate-rich plant exploitation as cereals, preceding the end of the Younger Dryas climatic crisis, following the same pattern of decline/sudden rise as proposed for Abu Hureyra based on botanical studies.<sup>28</sup> The progressive and almost linear increase in caries from the Natufian to the PPNB observed in graph 3 offers additional support for this early cultivation hypothesis. It shows no sudden shift from a Natufian to a Neolithic-style diet but, on the contrary, a gradual richer carbohydrate intake over the Neolithization process.

By the seventh millennium the regularity of the curve is broken by a spectacular increase in carious lesions ( $\chi^2$  test,  $p < 0.001$ ).<sup>29</sup> This could be the result of a major shift in foodways or other independent factors which we will try to define better by examining the qualitative data we collected on caries and hypoplasia.

## Qualitative data: some keys to food behaviours?

The size of carious lesions varies over time as well.<sup>30</sup> There is a general trend towards an increase in caries size, together with an increase in abscess incidence from the Early Natufian to the PPNB (graph 4). Later, during the seventh millennium, both trends decline. There is therefore a relationship, if not strict but at least close, between caries size and the prevalence of dental abscesses. When comparing the proportions of large carious lesions vs smaller ones from one period to another, it appears that the major shifts occurred from the Early to Late Natufian ( $p = 0.01$ ) and from the PPNA/PPNB to the seventh millennium ( $p = 0.02$ ). Once again, although launched in the same evolutionary direction, the Late/Final Natufian population and

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<sup>22</sup> Gordon HILLMAN, Robert HEDGES, Andrew MOORE et al., “New evidence of Late Glacial ...”; Ofer BAR-YOSEF, Anna BELFER-COHEN, “Facing environmental crisis. Societal and cultural changes at the transition from the Younger Dryas to the Holocene in the Levant”, in René T. J. CAPPERS, Sytze BOTTCMA (eds), *The Dawn of Farming in the Near East* (Berlin, 2002), pp. 55-66.

<sup>23</sup> George WILLCOX, Ramon BUXO, Linda HERVEUX, “Late Pleistocene and early Holocene ...”.

<sup>24</sup> Juan José IBÁÑEZ, Jesús GONZÁLEZ-URQUIJO, Juan GIBAJA, “Discriminating wild vs domestic cereal harvesting micropolish through laser confocal microscopy”, *Journal of Archaeological Science*, vol. 48 (2014), pp. 96-103; Juan José IBÁÑEZ, Jesús GONZÁLEZ-URQUIJO, Luis Cesar TEIRA-MAYOLINI et al., “The emergence of the Neolithic ...”.

<sup>25</sup> e.g. François VALLA, Fanny BOCQUENTIN, Hugues PLISSON et al., “Le Natoufien Final et les Nouvelles Fouilles a Mallaha (Eynan), Israel 1996-1997”, *Journal of the Israel Prehistoric Society*, vol. 28 (1999), pp. 105-76; François R. VALLA, Hamoudi KHALAILY, Nicolas SAMUELIAN et al., “Eynan (Ain Mallaha)” in Yehouda ENZEL, Ofer BAR-YOSEF (eds), *Quaternary of the Levant: Environments, Climate Change, and Humans* (Cambridge/New York, 2017), pp. 295-302.

<sup>26</sup> Laure DUBREUIL, “Long-term trends in Natufian subsistence: a use-wear analysis of ground stone tools”, *Journal of Archaeological Science*, vol. 31, no. 11 (2004), pp. 1613-29.

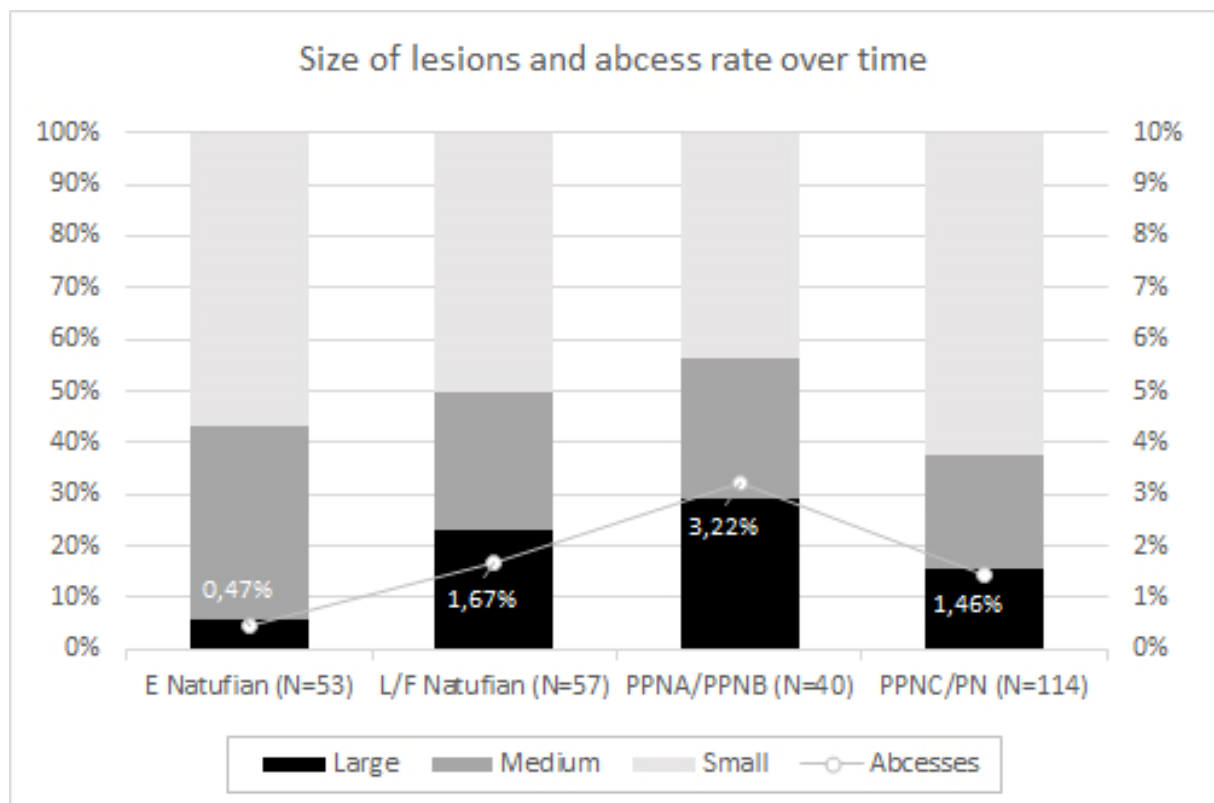
<sup>27</sup> Fanny BOCQUENTIN, “A Final Natufian population ...”.

<sup>28</sup> Gordon HILLMAN, Robert HEDGES, Andrew MOORE et al., “New evidence of Late Glacial ...”.

<sup>29</sup> See also for the northern Levant: Theya MOLLESON, “The importance of porridge ...”; Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires ...”.

<sup>30</sup> PPNA and PPNB caries were grouped together because the number of known lesions in PPNA is too low to be representative by itself.

the PPNA/PPNB population do not differ to the point of reaching statistical significance. For abscess frequency, the increase and decrease over time are all significant.<sup>31</sup>



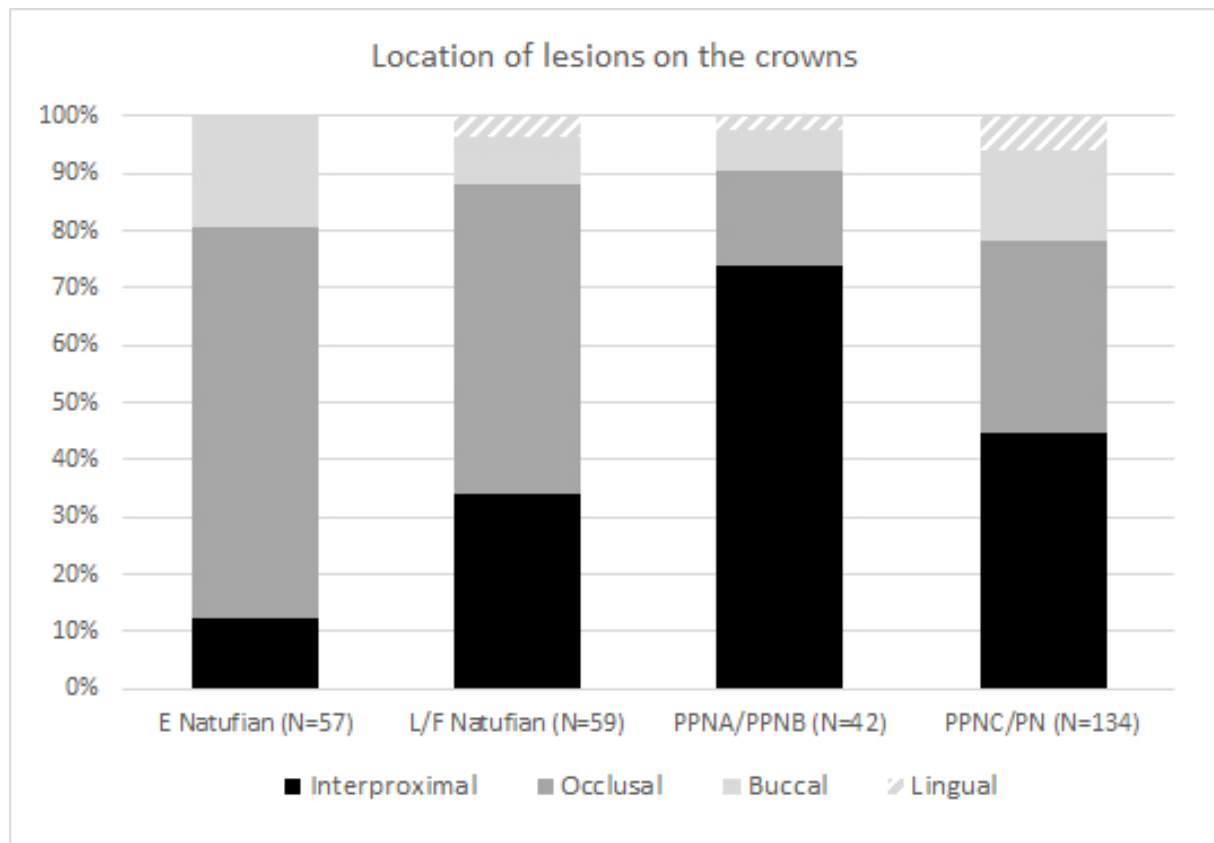
Graph 4. Size of lesions and abscess rate over time (N is the total number of observed carious lesions).

The location of the lesions on the four faces of the crown provides another clue to understanding the observed pattern. Occlusal caries were most common during the Natufian but interproximal lesions (between two adjacent teeth) gained ground significantly from one period to another (graph 5). This evolution must be linked to the progressive growth in the intake of cereals rich in carbohydrates and starch.<sup>32</sup> Again, while the Late/Final Natufian and PPN groups are ascribed within the same evolutionary pattern, the seventh millennium populations introduce a new pathological pattern, possibly linked to a different way of eating. It is worth noting that, contrary to the general view that the quantity of interproximal lesions should increase with the invention of pottery due to its potential role in introducing sticky porridge to the diet,<sup>33</sup> in our data corpus the number decreases significantly ( $p = 0.001$ ).

<sup>31</sup> From Early to L/F Natufian  $p < 0.001$ ; from the L/F Natufian to the PPNA/B  $p = 0.007$ ; from PPNA/B to 7<sup>th</sup> millennium  $p = 0.02$ .

<sup>32</sup> Simon HILLSON, "Recording dental caries ...".

<sup>33</sup> Theya MOLLESON, "The importance of porridge ...".



Graph 5. Location of the lesions on the crowns (N is the total number of observed carious lesions: lesions on several locations were counted several times).

To conclude on these evolutionary aspects of cavities and associated pathologies, we will retain three major elements for discussion: 1. A substantial increase in caries before the Neolithic during the Late/Final Natufian period. 2. A sharp increase in AMTL, which indirectly reflects an increase in caries; this hypothesis is confirmed by the increased size of the observed carious lesions and the rise in the number of abscesses during the PPN period. This progression of dental pathology is in line with the dynamic initiated in the Natufian period, which suggests a sustained increase in carbohydrate intake. 3. A major break in this progressive evolution in the seventh millennium, common to aceramic (PPNC) or ceramic (PN) contexts. The frequency of cavities by then increases considerably but decreases in size. This phenomenon was already mentioned for the northern Levant.<sup>34</sup> AMTL and abscesses also decrease and the pattern of lesions changes with a decrease in interproximal caries for the rest of the crown. Is this phenomenon related to the introduction of a new carbohydrate source? New foodways? Or better hygienic practices? Other aspects must be taken into consideration in this discussion.

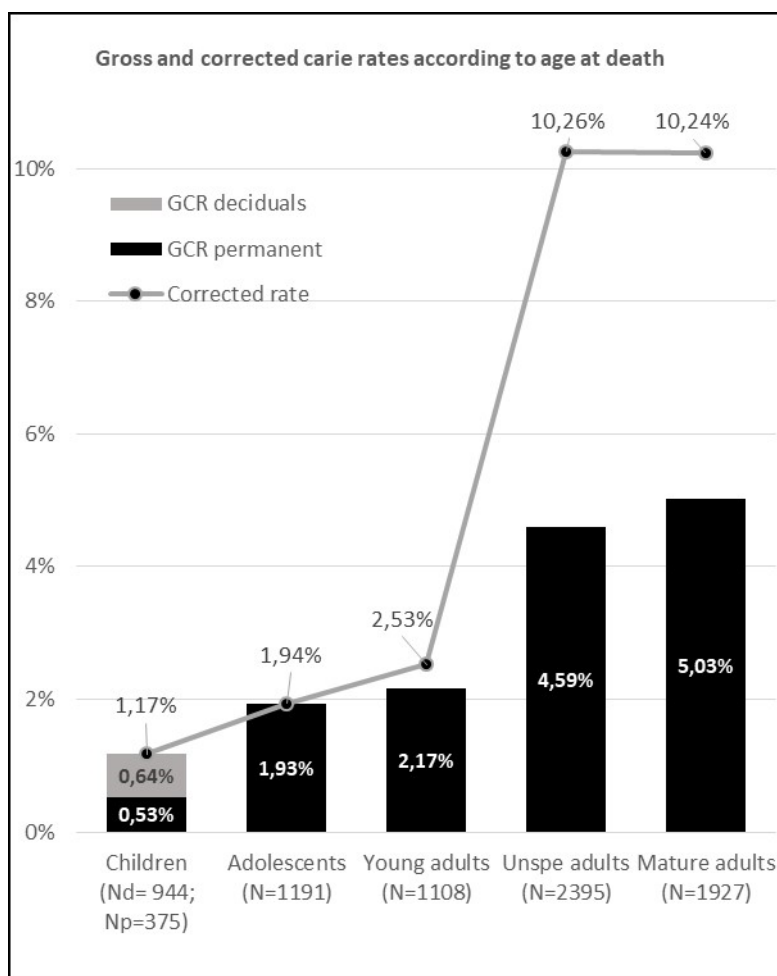
## Considering age and sex

Age is a determining factor in carious lesion prevalence due to their cumulative nature over an individual's lifespan. Our prehistoric corpus of teeth, distributed between large age groups,<sup>35</sup> is

<sup>34</sup> Bérénice CHAMEL, "Bioanthropologie et pratiques funéraires ...", pp. 615-18.

<sup>35</sup> "Children" regroups teeth belonging to either deciduous or mixed dentitions (from 6 months to 10-12 years old individuals approximately); "adolescents" regroups individuals with permanent dentition but immature skeletons (from approximately 10-12 to 18-22 years old); "young adults" individuals with almost complete mature skeleton except for coxae, clavicles (<25-30 years old); "mature adults" all secondary ossification centres fused

no exception to this rule (graph 6). The high increase in cavities after the age of 25-30 is related to the long duration of the next age group. However, it is remarkable to note the explosion of AMTL (apparent through the corrected rate), almost non-existent in previous age groups. It should be noted that the first three age groups, although of equivalent duration, do not show a continuous progression of lesions. Only the gap between children and adolescents is statistically significant ( $p = 0.002$ ). It is therefore possible that adolescence may mark a turning point in dietary behaviour, where carbohydrate-rich resources become more commonly ingested than in childhood. This is especially true for the Early Natufian during which no children's teeth (deciduous or permanent) are decayed. By the seventh millennium decayed deciduous teeth are found, a phenomenon that remains exceptional in previous periods.



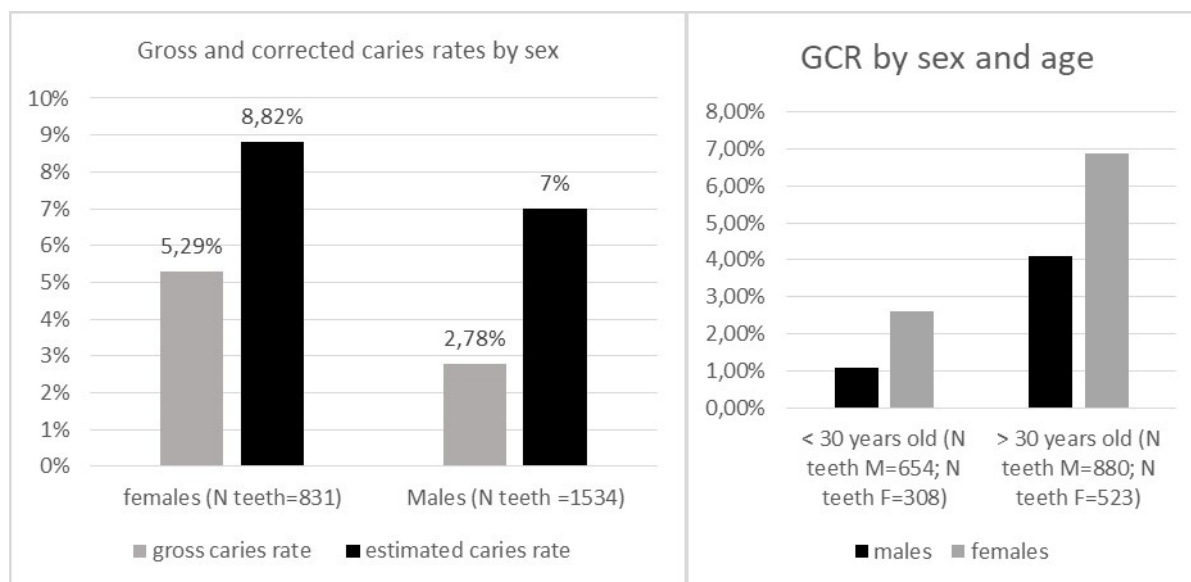
Graph 6. Frequency of caries (gross and corrected rates) according to age-at-death (N: total teeth observed; Nd: deciduals; Np: permanent).

Considering either gross caries rate or corrected rate (see above), females and males show significant differences (respectively,  $p = 0.002$  and  $p = 0.049$ ) (graph 7A). Females have more carious lesions than males. This is still the case when considering the age data (graph 7B), which means that the potential bias associated with differential age distribution is eliminated. Unfortunately, the number of teeth belonging to skeletons of known age and sex is too small to be assessed by chronological periods in order to consider these data over time with the

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including medial epiphysis of the clavicle (>25-30 years old); “Unspecified adults”: young or mature adults not determined (clavicle absent). For more details, see Fanny BOCQUENTIN, “Pratiques funéraires, paramètres biologiques ...”; Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires ...”.

appropriate statistical robustness. However, considering sex only, the tendency is clearly towards a rise in the gender gap over time ( $p = 0.8$ ;  $p = 0.1$ ;  $p < 0.001$  between caries rates in males and females during Early Natufian, Late/Final Natufian and Neolithic periods respectively). We can consequently conclude that diet and/or foodways were gendered, especially from the later phases of the Natufian and possibly throughout the Neolithic. Gendered food, more cariogenic and poorer in proteins for females, can be seen today in certain communities of hunter-gatherers<sup>36</sup> and echoes numerous archaeological observations.<sup>37</sup>

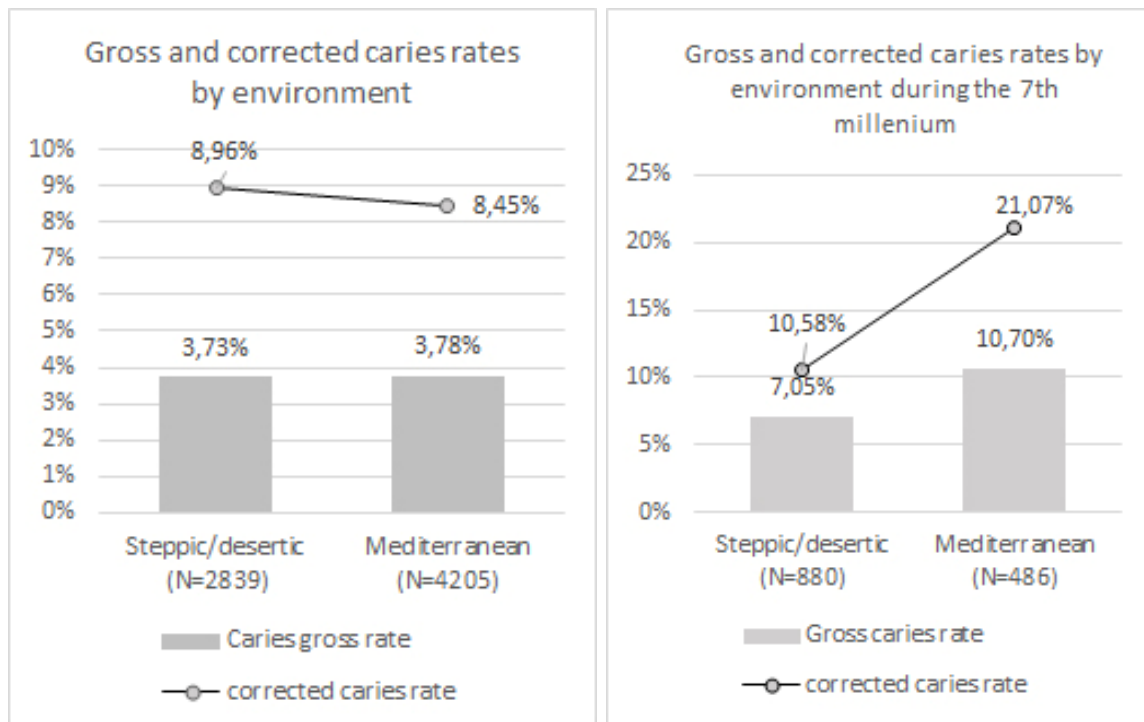


Graph 7A. Frequency of caries (gross and corrected rates) according to sex. 7B. Frequency of caries (GCR = gross caries rate) according to sex and age.

Last, but not least, the impact of environmental conditions on dental caries must be addressed. Our corpus shows an unexpected similar level of gross as well as corrected caries in Mediterranean and steppe/desert settlements (graph 8A). A similar result is found amongst hunter-gatherers (Natufian) as amongst early agriculturalists (PPNA and PPNB). It means that environmental conditions did not significantly influence carbohydrate intake at the beginning of the Neolithic. On the other hand, during the seventh millennium, when, as we have shown before, the carious lesions rate increased very sharply, a clear difference existed between the two types of environments ( $p = 0.017$ ) (graph 8B). In fact, it is essentially in Mediterranean contexts that the gap widens with previous periods. The introduction into these contexts of a new foodstuff or new food behaviours, independent to the introduction of ceramics in the northern Levant, should be considered.

<sup>36</sup> Phillip L. WALKER, Barry S. HEWLETT, "Dental health diet and social status among Central African foragers and farmers", *American Anthropologist*, vol. 92, no. 2 (1990), pp. 383-98.

<sup>37</sup> e.g.: Simon HILLSON, "Recording dental caries ..."; John R. LUKACS, "Fertility and agriculture ...".



Graph 8A. Frequency of caries (gross and corrected rates) according to environment. 8B. Same for the seventh millennium alone.

## Stress marker: Linear Enamel Hypoplasia

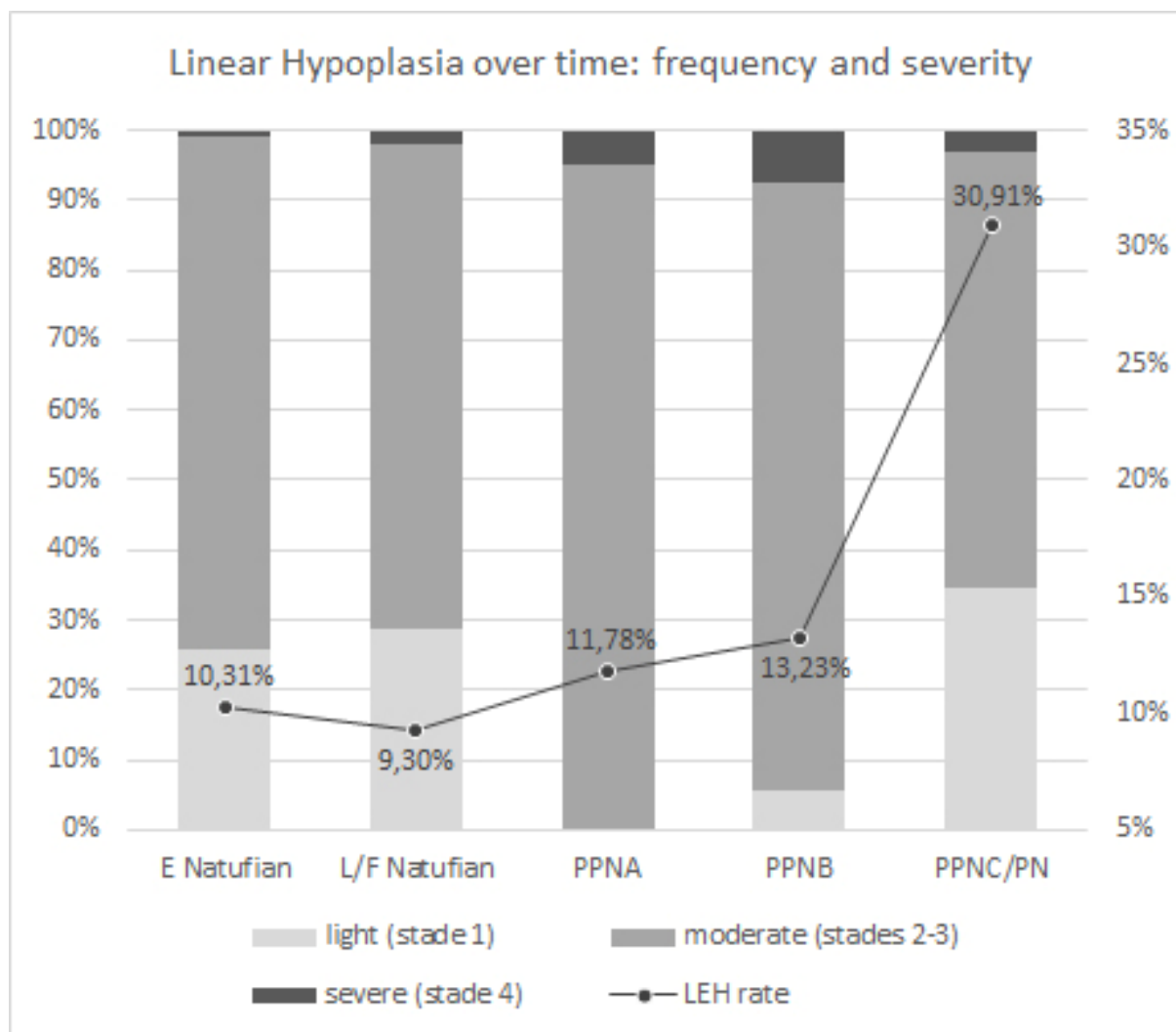
In parallel, the evolutionary pattern of Linear Enamel Hypoplasia (LEH) witnesses three major trends over time (table 4 and graph 9): 1) a decrease of biological stress over the course of the Natufian period (not significant,  $p = 0.3$ ), followed by 2) a limited, but statistically significant, increase during the PPNA ( $p = 0.04$ ) which continues slightly during the PPNB and 3) rises drastically during the seventh millennium ( $p < 0.001$ ), whatever the cultural context (PPNC and PN). That said, the severity of the lesions, on a scale from 1 to 4, decreases at the end of the Neolithic period compared with the PPN. This is especially true for the PPNC cultural context where the lesions are rarely higher than grade 2. This dramatic rise in biological stress during the seventh millennium has already been described on smaller corpus,<sup>38</sup> associated with the introduction or the development of infectious diseases including tuberculosis and endemic malaria.<sup>39</sup>

<sup>38</sup> Patricia SMITH, Liora HORWITZ, “Ancestors and inheritors ...” and references therein.

<sup>39</sup> Israel HERSHKOVITZ, Gordon EDELSON, “The first identified case of thalassemia?”, *Human Evolution*, vol. 6, no. 1 (1991), pp. 49-54; Oussama BAKER, Bérénice CHAMEL, Rima KHAWAM et al., “Prehistory of human tuberculosis: Earliest evidence from the onset of animal husbandry in the Near East”, *Paléorient*, vol. 43, no. 2 (2017), pp. 35-51 and references therein.

	Affected teeth	LEH rate <sup>40</sup>
E Natufian (2270)*	234	10.31%
L/F Natufian (1451)	135	9.30%
PPNA (331)	39	11.78%
PPNB (1799)	238	13.23%
PPNC/PN (1498)	463	30,91%

Table 4. Frequency of Linear Enamel Hypoplasia (LEH) over time (\*Observed permanent teeth: complete crowns, erupted or isolated germs with clear chrono-cultural attribution).



Graph 9. Linear Hypoplasia over time: frequency and severity.<sup>41</sup>

<sup>40</sup> These rates should be considered as minimal as only macroscopic observation (with magnifying glasses) has been made.

<sup>41</sup> For the definition of the grades: Fanny BOCQUENTIN, "Pratiques funéraires, paramètres biologiques ...".



# Discussion

We should keep in mind that the real percentage of caries in an archaeological population will remain unknown. Antemortem loss and taphonomic processes introduce a bias that must be considered and accounted for. Moreover, the multifactorial aetiology and development of caries cannot be ignored. In order to limit these issues, we analysed a wide corpus of data and proceeded by per tooth counting. In this study, we took into account ante- and postmortem losses and analysed dental pathologies by looking for significant parameters in their evolution. All data were collected by the authors following the same methodological protocols.

We observed an increase in caries and associated diseases during the Neolithization process. At our relatively large-study scale, this increase appears linear but is not continuous. From the Natufian to the end of the PPNB, the populations are part of the same dynamic and gradual process (first period), while a clear break occurs with the seventh millennium (second period).

In the first period, the Late/Final Natufian appears as a major transitional phase. The observed pathological pattern (frequency of caries, size of the lesions, their location, AMTL, presence of abscesses) observed at the end of the Natufian more closely resembles the Neolithic than the Early Natufian. These data therefore suggest that the food transition began before the PPNA. The exact time of the split would require a finer chronological attribution of the corpus. At Eynan-Mallaha the clear chronological subdivision between Late and Final Natufian highlights that the diet transition occurred at the very end of the Natufian, during the Final phase. This result obtained from caries substantiates previous studies based on other direct or indirect proxies. It is remarkable to note that this hypothesis places the major dietary shift as taking place during the Late Dryas, a period of cooling and plant reduction. The substantial introduction of additional cariogenic plants within the diet must be due, consequently, to a new way of food procurement. This hypothesis is consistent with the suggestions of early wild cereal cultivation. This dietary change does not seem to have led, at least not immediately, to an increase in biological stress. This is even decreasing during the Late/Final Natufian. It may then be related to a greater dispersion of groups, a lower density of occupation or even a successful social reorganization of societies.<sup>42</sup> Throughout the PPN, the dental pathologies we studied gradually increased. If the number of decayed teeth declines (gross rate), the caries phenomenon is nevertheless increasing. Indeed, the lesions become larger and lead to abscesses and frequent AMTL. All this suggests that the proportion of carbohydrates in the diet is increasing. It comes from cereals but probably also from plant species whose development was favoured by global warming at the beginning of the Holocene (acorns, fruits and berries, for instance). In addition, if the increase of plants in the diet was accompanied by a decrease in meat consumption, this would have led to a greater susceptibility of the teeth to bacteria. Indeed, cavities are much less likely to occur when protein forms a significant part of the diet.<sup>43</sup> The increase in caries from Palaeolithic to Neolithic diet is usually understood as the consequence of an introduction of cereals in the meals. However, in the Near Eastern context, wild cereals and grasses were already an important part of the diet during the Palaeolithic, in cold (Last Glacial Maximum) as in warm climatic variations (Bølling-Allerød).<sup>44</sup> Thus, the sudden and linear rise in caries

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<sup>42</sup> See recent discussion in: Cheryl MAKAREWICZ, “The Younger Dryas ...”; Gideon HARTMAN, Ofer BAR-YOSEF, Alex BRITTINGHAM et al., “Hunted gazelles evidence cooling ...”; Reuven YESHURUN, Guy BAR-OZ, “Ungulate skeletal element profiles ...”; Lior WEISSBROD, Fiona B. MARSHALL, François R. VALLA et al., “Origins of house mice ...”.

<sup>43</sup> Simon HILLSON, “Recording dental caries ...”.

<sup>44</sup> Eleni ASOUTI, Dorian FULLER, “A Contextual approach to the emergence of agriculture in Southwest Asia: Reconstructing Early Neolithic plant-food production”, *Current Anthropology*, vol. 54 (2013), pp. 299-345;

must be understood as a shift towards a cereal-based subsistence. Moreover, we must consider the impact of domestication on the nutritional qualities of the diet (table 5). Indeed, a recent comparison of cultivated cereals (barley and emmer wheat) with their wild progenitors suggests an evolution towards bigger grains with higher glycaemic loads contained in the starch and lower relative protein, fibre and mineral contents.<sup>45</sup> Kim Hebelstrup asserts that “not only did the relative carbohydrate fraction increase during domestication, but there was also a clear increase in digestible carbohydrate on the premise of relatively lower levels of non-digestible carbohydrate”.<sup>46</sup> Thus, this nutritional decrease would have been counterbalanced by energetic improvements having a positive impact on physical performance and reproductive success.

Table 5. Comparison of some potential sources of carbohydrates in the studied area.<sup>47</sup> Those nutritional values must be considered as informative. They are variable according to time of harvest (seasons and germination cycle), environment of plant growth (temperature, altitude, moisture, etc.), wild or domesticated status and transforming/cooking processes.<sup>48</sup>

Common Name	Species	Nutritional Value (g/100g)		
		Carbohydrates	Fats	Proteins
Tabor Oak (acorn) <sup>1</sup>	<i>Quercus ithaburensis</i>	58.94 ± 2.5	0.76 ± 0.03	2.84 ± 0.3
Pistachio <sup>2</sup>	<i>Pistacia Atlantica</i>	14.9- 17.7	55.2-60.5	15.0-21.2
Wild Fig. <sup>3</sup>	<i>Ficus Carica</i>	71.20 ± 0.29	1.50 ± 1.32	8.60 ± 0.96
Chick Pea <sup>4</sup>	<i>Cicer arietinum</i>	60.7	6.04	25.3-28.9
Pea <sup>5</sup>	<i>Pisum Sativum</i>	7	0.55	5.84
Lentil <sup>5</sup>	<i>Lens culinaris</i>	50.6	1.34	25.4
Einkorn <sup>5</sup>	<i>T. monococcum</i>	59.5	2.43	15.6
Wheat <sup>5</sup>	<i>Triticum dicoccum</i>	41.4	1.27	8.03
Barley <sup>5</sup>	<i>Hordeum vulgare</i>	56.2	2.3	13.4
Rye <sup>5</sup>	<i>Secale cereal C.</i>	61	1.97	10.5
Honey <sup>5</sup>		81.3	0	0.52

Monica N. RAMSEY, Arlene M. ROSEN, “Wedded to wetlands ...”; Amaia ARRANZ-OTAEGUI, Lara GONZALEZ CARRETERO, Monica N. RAMSEY et al., “Archaeobotanical evidence reveals the origins of bread 14,400 years ago in northeastern Jordan”, *Proceedings of the National Academy of Sciences*, vol. 115, no. 31 (2018), pp. 7925-30.

<sup>45</sup> Kim Henrik HEBELSTRUP, “Differences in nutritional quality between wild and domesticated forms of barley and emmer wheat”, *Plant Science*, vol. 256 (2017), pp. 1-4.

<sup>46</sup> Ibid., p. 2.

<sup>47</sup> Following: Eleni ASOUTI, Dorian FULLER, “A contextual approach ...”; Ehud WEISS, “Palaeolithic vegetal diet ...”; Daniel ZOHARY, Maria HOPF, Ehud WEISS, *Domestication of Plants in the Old World ...*; Anat HARTMANN-SHENKMAN, Mordechai E. KISLEV, Ehud GALILI et al., “Invading a new niche: obligatory weeds at Neolithic Atlit-Yam, Israel”, *Vegetation History and Archaeobotany*, vol. 24, no. 1 (2015), pp. 9-18.

<sup>48</sup> For table 5 references see <sup>1</sup>) Taha M RABABAH, Khalil I EREIFEJ, Majdi A AL-MAHASNEH et al., “The physicochemical composition of acorns for two Mediterranean *Quercus* species”, *Jordan Journal of Agricultural Sciences*, vol. 4, no. 2 (2008), pp. 131-36; <sup>2</sup>) T. KAMANGAR, Hassan FARSAF, “Composition of pistachio kernels of various Iranian origins”, *Journal of Food Science*, vol. 42, no. 4 (1977), pp. 1135-36; <sup>3</sup>) Haleema SADIA, Mushtaq AHMAD, Shazia SULTANA et al., “Nutrient and mineral assessment of edible wild fig and mulberry fruits”, *Fruits*, vol. 69, no. 2 (2014), pp. 159-66; <sup>4</sup>) Aravind Kumar JUKANTI, Pooran M. GAUR, C. L. Laxmipathi GOWDA et al., “Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): a review”, *British Journal of Nutrition*, vol. 108, no. S1 (2012), pp. S11-26, <https://doi.org/10.1017/S0007114512000797>; <sup>5</sup>) <https://ciqual.anses.fr/> (accessed August 23, 2012): values are given for actual uncooked seeds, sub-species unknown.

The second period, which started with the seventh millennium, was marked by radical changes in oral pathology. On the one hand, the quantity of decayed teeth drastically increased, while, on the other, lesion size, AMTL and abscesses significantly decreased. This means that prevalence of caries increased but lesion severity declined. Moreover, their distribution in the mouth changed: not only occurring in the molars but henceforth also in premolars and, to a lesser extent, to anterior teeth. Interproximal caries decrease and lesions are better distributed among the four faces of the crowns. Finally, caries might start early in age, sometimes resulting in decay of deciduous teeth, a phenomenon that was rare through the first period. In parallel, the major rise of hypoplasia during the seventh millennium must be considered. The rise concerns the number of teeth affected but not the severity of the enamel defect, which, to the contrary, seems to decrease with time and specially in PPNC cultural contexts (aceramic and within the Mediterranean ecosystem). Altogether, the proxies recorded for the seventh millennium show a complex evolutionary trend of dental pathologies. The sudden drastic increase in carious lesions would suggest several potential reasons: 1) the introduction of a new highly cariogenic foodstuff such as honey, attested in Anatolia in the seventh millennium;<sup>49</sup> 2) the introduction of a new way of transforming foodstuffs having a consequence on the structure of the carbohydrates themselves (cooking, boiling, fermenting) or on the sticky texture of the food (porridge), both promoting the proliferation of bacteria; 3) the appearance of new bacteria with a higher cariogenic power; 4) a significant increase in the glycaemic index of the domesticated crops in the framework of advanced agriculture; 5) a decline in the resistance of the enamel. On the other hand, the decrease in the severity of the lesions could be linked, among other hypotheses to 1) better dental care and even possibly treatment;<sup>50</sup> and 2) a significant increase in protein and lipid intake. Indeed, the qualitative and quantitative data we gathered on dental pathologies are not necessarily contradictory but might result from a combination of factors, which are of course difficult to untangle today. However, some aspects, specific to the seventh millennium, must be considered in this debate. First of all, the high level of stress endured during childhood and materialized by hypoplasia certainly weakened the enamel of the permanent teeth,<sup>51</sup> promoting carious lesions for all categories of teeth as observed in our corpus. On the contrary, the development of a full-fledged agro-pastoral economy by the PPNC may have promoted increasing milk and dairy product consumption and consequently protein and lipid intakes.<sup>52</sup> However, while residue analyses from pottery have attested to the processing of dairy products in early pottery sherds from the northern Levant, to date this has not been the case for meridional samples.<sup>53</sup> Moreover, the faunal spectrum from the southern Levant was narrow<sup>54</sup> and sometimes reveals a high pig/boar component, as at the site of Beisamoun<sup>55</sup> which has provided an important part of our seventh millennium anthropological corpus, suggesting a meat-focused production. Finally, the role of the invention of ceramics and its impact on food preparation is crucial. As stated before, the use of ceramics is generally

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<sup>49</sup> Mélanie ROFFET-SALQUE, Martine REGERT, Richard P. EVERSLED et al., “Widespread exploitation of the honeybee by Early Neolithic farmers”, *Nature*, vol. 527 (2015), pp. 226-30.

<sup>50</sup> See Alfredo COPPA, Luca BONDIOLI, Andrea CUCINA et al., “Early Neolithic tradition of dentistry”, *Nature*, vol. 440, no. 7085 (2006), pp. 755-56; Bérénice CHAMEL, “Bioanthropologie et pratiques funéraires ...”.

<sup>51</sup> Simon HILLSON, “Recording dental caries ...”.

<sup>52</sup> Jean-Denis VIGNE, Daniel HELMER, “Was milk a ‘secondary product’ in the Old World Neolithisation process? Its role in the domestication of cattle, sheep and goats”, *Anthropozoologica*, vol. 42, no. 2 (2007), pp. 9-40; Richard EVERSLED, Sebastian PAYNE, Andrew G. SHERRATT et al., “Earliest date for milk use in the Near East and Southeastern Europe linked to cattle herding”, *Nature*, vol. 455 (2008), pp. 528-31.

<sup>53</sup> Richard EVERSLED, Sebastian PAYNE, Andrew G. SHERRATT et al., “Earliest date for milk use ...”.

<sup>54</sup> Liora HORWITZ, Eitan TCHERNOV, Pierre DUCOS et al., “Animal domestication in the Southern Levant”, *Paléorient*, vol. 25 (1999), pp. 63-80.

<sup>55</sup> Fanny BOCQUENTIN, Hamoudi KHALAILY, Daniella BAR-YOSEF MAYER et al., “Renewed excavations at Beisamoun: Investigating the 7th Millennium cal. BC of the Southern Levant”, *Journal of the Israel prehistoric society*, vol. 44 (2014), pp. 5-100.

regarded as being responsible for the appearance of more cariogenic food due to the transformation of more sticky food, like porridge.<sup>56</sup> Our data nuances these previous assumptions. The reduction of interproximal lesions, the reduction of the size of the lesions and the extension of caries towards anterior teeth are, on the contrary, evidence of food that may have been less sticky than before. Moreover, we have shown that the spectacular increase in caries during the seventh millennium is mainly seen in Mediterranean sites, which in our corpus are mainly aceramic sites (PPNC). This means that the sudden rise in caries, in this context, is totally independent of pottery use and is linked to the introduction of a new determinant of cariogenic factors of unknown nature, in a context of increasing biological stress (at least during childhood) and infectious diseases.<sup>57</sup> The nutritional balance may have been disrupted. These observations echo a major shift in settlement patterns in the southern Levant that suggest a drastic demographic decline at the beginning of the seventh millennium.<sup>58</sup>

## Conclusion

Our conclusion, based on a vast corpus with no previous equivalent and a rigorous data collection and analysis protocol, is that dental pathologies increased significantly with the Neolithization process in the Near East. On the contrary, biological stress shows a certain stability over time. If animal proteins initially played a major part in the diet, cariogenic plants, in all likelihood cereals (in accordance with the botanical data), gradually took on a greater role and their importance in the diet and the process of cereal domestication induced in parallel an increase in the glycaemic index of the grains increasing caries risk. Our dental data show that the Late/Final Natufian played a determinant role in this dietary shift. Over time, diet seems more and more gendered but less specific by age groups.

At the end of the PPN, new behaviours seem to have been introduced resulting in a new pathological pattern. The major changes are observed in Mediterranean contexts where pottery is not yet attested. High biological stress, linked to reduced socioeconomic level or infectious disease, is attested in parallel all over the Levant. The potential link with the 9.2 cal. ka. BP climatic event has been little questioned<sup>59</sup> and should be investigated further in the future. We hope that additional research and multidisciplinary approaches will allow a finer interpretative scale. More specifically, crossing these dental data with archaeobotanical and faunal assemblages, nutritional values, bone pathologies and oral microbiota samples would certainly allow a better understanding of the observed dental pathological pattern and hopefully more generally of the evolution of health during the Neolithization process.

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<sup>56</sup> Theya MOLLESON, “The importance of porridge ...”.

<sup>57</sup> e.g.: Patricia SMITH, Liora HORWITZ, “Ancestors and inheritors ...”.

<sup>58</sup> e.g.: Gary ROLLEFSON, Ilse KOHLER-ROLLEFSON, “PPNC adaptations in the first half of the 6<sup>th</sup> millennium BC”, *Paléorient*, vol. 19, no. 1 (1993), pp. 33-42; Ian KUIJT, “People and space in early agricultural villages: exploring daily lives, community size, and architecture in the Late Pre-Pottery Neolithic”, *Journal of Anthropological Archaeology*, vol. 19, no. 1 (2000), pp. 75-102; Ofer BAR-YOSEF, Daniella BAR-YOSEF MAYER, “Early Neolithic tribes in the Levant”, in William A. PARKINSON (ed.), *The Archaeology of Tribal Societies* (Ann Arbor, 2002), pp. 340-71; Alan H. SIMMONS, *The Neolithic Revolution in the Near East: Transforming the Human Landscape* (Tucson, 2011); Gary O. ROLLEFSON, “Tumultuous times in the Eighth and Seventh Millennia BC in the Southern Levant” in Arkadiusz MARCINIAK (ed.), *Concluding the Neolithic: The Near East in the Second Half of the Seventh Millennium BCE* (Atlanta, 2019), pp. 41-60.

<sup>59</sup> Pascal FLOHR, Dominik FLEITMANN, Roger MATTHEWS et al., “Evidence of resilience ...”.