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DARWINIAN DENTISTRY PART 1:

AN EVOLUTIONARY PERSPECTIVE ON THE ETIOLOGY OF MALOCCLUSION

By Kevin L. Boyd, M.Sc., DDS

With their 1991 publication in *The Quarterly Review of Biology*, *The Dawn of Darwinian Medicine*,[1] George C. Williams, an evolutionary biologist, and Randolph Nesse, an evolutionary psychiatrist, essentially established the foundation for a new subject to be incorporated into the medical school curriculum; Evolutionary Medicine (EM), also referred to as Darwinian Medicine, are terms used to describe a new paradigm in medical education that attempts to understand modern diseases through application of evolutionary theory and human ecology.

Over the past 20 years, the subject of Evolutionary Medicine has been gradually emerging across North America and is now quickly growing throughout Europe and other parts of the world into a legitimate academic discipline. Presently, there are several textbooks, peer-reviewed scientific articles, websites and blogs, major international symposiums, medical school curriculum modules and advanced post-graduate courses of study, all dedicated to this exciting new field of scientific inquiry (Appendix-The Evolutionary & Medicine Review). It appears EM is here to stay for, the medical profession….but what about the rest of the allied-health professions?

Evolutionary Dentistry

In the spring of 2012, the National Evolutionary Synthesis Center (NESCent) will host a 'catalysis meeting' that will bring together clinicians and researchers from several disparate fields (e.g., evolutionary biology, paleopathology, biomechanics and food science) to explore the implications of the evolution of human teeth and jaws for dentistry and orthodontics. The program, *"EVOLUTION OF HUMAN TEETH AND JAWS: Implications for Dentistry and Orthodontics"*, will explore the idea that many of our current dental and orthodontic problems relate to a mismatch between the chemical and physical properties of the foods we eat today, and those to which our ancestors' jaws and teeth had been best adapted.

The subject of Evolutionary Oral Medicine (EOM) as a proposed academic discipline within the field of dentistry, was recently introduced at The Ancestral Health Society's (AHS) First Symposium on Ancestral Health held at UCLA in August 2011 by Kevin Boyd, a pediatric dentist/nutritionist who is currently studying Biological Anthropology, and Michael Mew, an orthodontist in the UK who is interested in EOM as it pertains to understanding the etiology of malocclusion (Appendix-Y Crooked Teeth).

Consistent with the aforementioned NESCent program theme, their presentation, "Where is Darwin on Dentistry? Caries and Malocclusion from an Evolutionary Perspective,[2] centered around the observation that dental caries and malocclusion, while now highly prevalent public health diseases, are both surprisingly rare within the pre-Industrial skeletal and pre-historic fossil records, and also seldom seen in many present-day *non-westernized* cultures.[3, 4, 5] (Figs.1, 2 and 3) According to Profit,[6] the fact that malocclusion now occurs in a major-

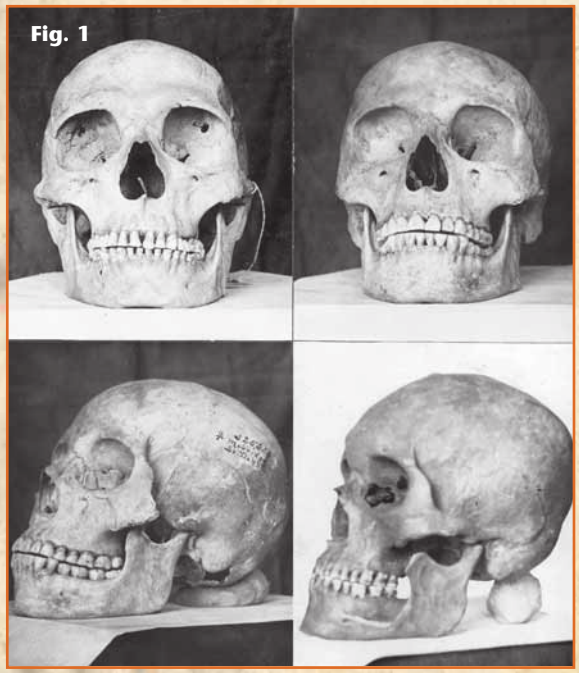
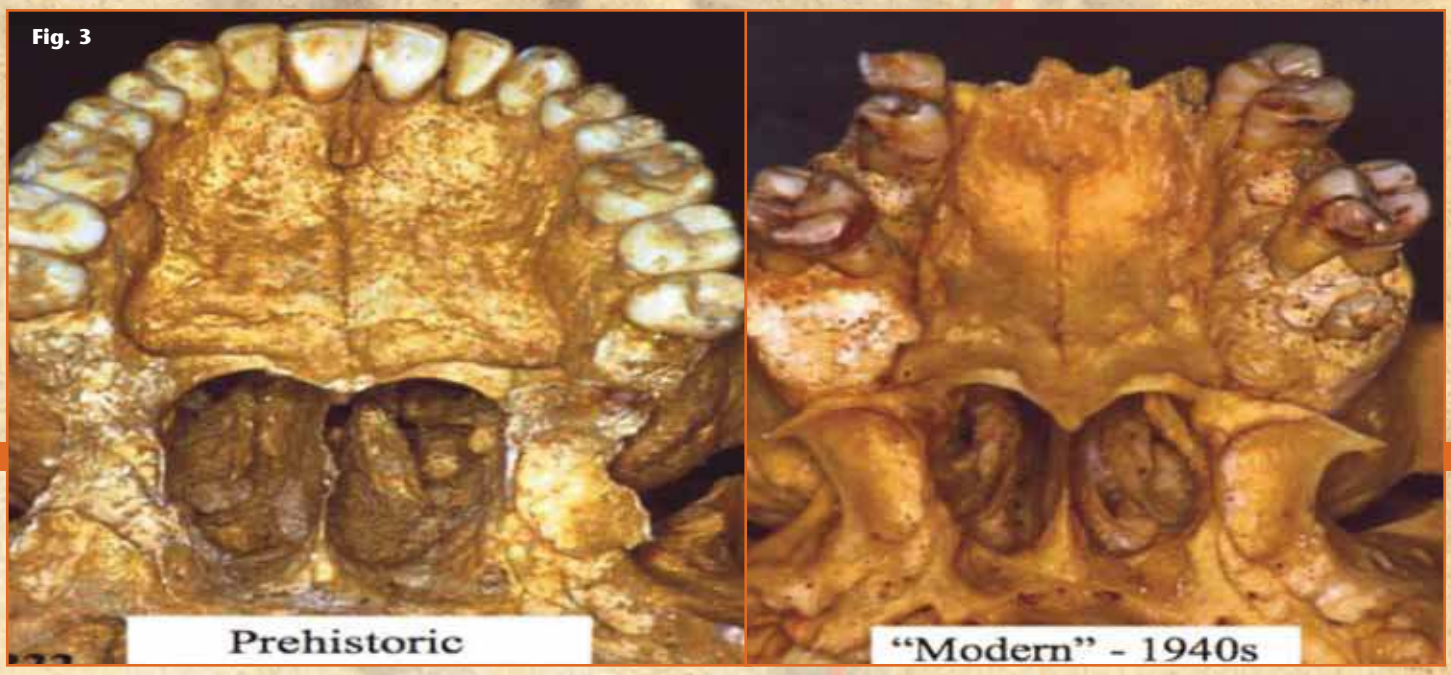


Fig. 1

Indian skulls studied by Dr. Weston A. Price. Each skull has nice occlusion and no decay. Adapted from Palmer, 2003. (Copyright© Price-Pottenger Nutrition Foundation®)

Fig. 2

70,000 year old skull with nice occlusion and no decay. Adapted from Palmer, 2003.



Prehistoric skull with normal palate, wide dental arch, and large posterior nasal aperture. Note the U-shaped arch (left). Younger, "modern" skull (1940s) with a high palate, narrow dental arch, and small, congested posterior nasal aperture. Adapted from Palmer, 2003.

ity of the population does not mean that it is normal; skeletal remains indicate that the present prevalences are several times greater than it was only a few hundred years ago. Crowding and malalignment of teeth was unusual until relatively recently, but not unknown.

Furthermore, other than some fossil evidence of anterior incisor crowding in ancient Egyptian skulls, it is unlikely that class II and class III skeletal malocclusion appeared appreciably in humans until around the time of the Industrial Revolution in Western Europe during the mid-18th century,[7] and when detected, it was usually confined to privileged-class individuals. Dental caries on the other hand has been plaguing mankind since the advent of agriculture some 10,000 years ago, and there is even fossil evidence of tooth decay as far back as 1.5 million years ago in one (pre-human) *Paranthropus robustus* skull.[8]

A sharp rise in caries prevalence, however, doesn't appear in modern humans until nearly 1,000 years ago (Fig.4) with the introduction of cane sugar to Western Europe,[8] and only began to reach epidemic proportions in the late 19th/early 20th centuries. Susceptibility to dental caries, clearly a dietary-infectious disease caused by increased sugar consumption resulting in increased acid production by oral bacteria, is not likely influenced by large genetic changes that might have occurred since the *Agricultural Revolution* some 10-15,000 years ago.

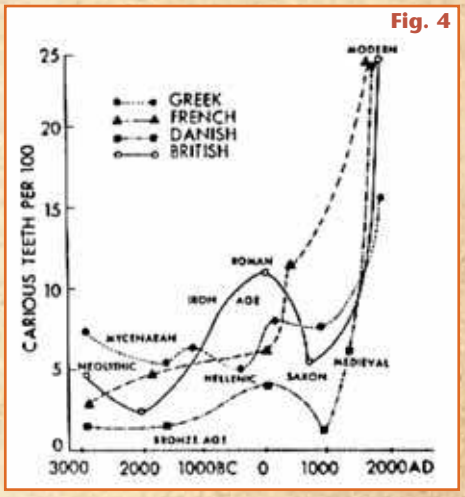
"ACCORDING TO PROFIT,[6] THE FACT THAT MALOCCLUSION NOW OCCURS IN A MAJORITY OF THE POPULATION DOES NOT MEAN THAT IT IS NORMAL; SKELETAL REMAINS INDICATE THAT THE PRESENT PREVALENCES ARE SEVERAL TIMES GREATER THAN IT WAS ONLY A FEW HUNDRED YEARS AGO."

While the cause of malocclusion is less clear, it is also not likely a result of recent genomic change. This article will develop the hypothesis that malocclusion, when viewed from an EM perspective, results from a consequential mismatch between a stone-age adapted masticatory apparatus, and a *post-Industrial* feeding environment.

Evolutionary Biology; Basic Science

According to Nesse[9] "…few physicians and medical researchers have taken a course on evolutionary biology, and no medical school teaches evolutionary biology as a basic science for medicine. It is as if engineering students never learned physics." Perlman[10] suggests that the reason for this void in pre-medical and medical school educational requirements is related to the origins of the framework for the current medical didactic model, the Flexner Report.[11]

At the behest of the American Medical Association in the early 1900s, the highly respected American education researcher, Abraham Flexner, was given a commission by the Carnegie Foundation to reform medical education; at that time, even without a high school diploma one could essentially buy a medical degree after serving an apprenticeship in much the same manner as any other trade school of that era. The AMA, a



Number of carious teeth per 100 teeth in four European populations. Adapted from Kean, 1980.

relatively weak organization then, recruited Flexner to help elevate medical educational institutions to the standards of a few US schools, like John's Hopkins, Michigan and Harvard that followed the German model for physician training. According to Perlman, "Evolutionary biology was a poorly developed discipline at the time of the Flexner Report and was not included in his recommendations for premedical or medical education….". Diller[12] recently stated, "America and the medical profession desperately need a new Flexner Report for the 21st century."

Following the AMA and Flexner's lead, in mid-1920s, William Gies, a Columbia University biochemistry professor and future founder of the Journal of Dental Research, at the behest of a consortium of university-affiliated dental schools, also received a commission from Carnegie to help elevate dental education; dental schools in the 1920s suffered from many of the same problems as pre-Flexner Report medical schools—they were mostly low-grade trade schools unaffiliated with universities. In 1926, the Gies Report[13] on Dental Education in the United States and Canada was released as a follow-up to the 1910 Flexner, and similarly, did not include a recommendation for including courses in evolutionary biology into the didactic curriculum.

In reference to the present didactic curriculum in dental education, Baum[14] states, "… many changes have been made since then, but the basic design and approach remain the same." Dr. Baum also argues that, while dentistry has benefitted tremendously from the findings contained within the 1926 Geis Report, "…we should be mindful that it was written a full 80 years ago. At that time, the biological sciences were much more primitive and phenomenological, the population had very different kinds of dental problems…".

Evolution and Vulnerability to Disease

In their 1994 book, *Why We Get Sick: The New Science of Darwinian Medicine*, Nesse and Williams[15] describe how bodies have traits that can often leave them vulnerable to disease for a variety of reasons: 'co-evolution with pathogens' and 'genomic mismatch with the modern environments' are at the top of their list; other explanations include 'trade-offs', 'constraints on natural selection', 'reproductive success at the expense of health' and 'protective defenses that are easily confused with diseases'.

Dental Caries

The cariogenic group of bacteria most commonly implicated in dental caries, *Mutans streptococcus* (MS) has been co-evolving with humans since we began migrating out of Africa tens of thousands of years ago. In line with Nesse and Williams' 'human co-evolution with pathogens' hypothesis, Caufield[16] suggests that, similar to mitochondrial DNA, genetic mapping of MS' DNA could represent a 'second genome' that might someday be used to verify early human migratory patterns throughout the world. Additionally, the 'genomic mismatch with the modern environments' hypothesis might also be a good explanation for why dental caries is only a relatively recent finding in human history that also seems to coincide with the first appearance of refined grains and sugars in the diet.

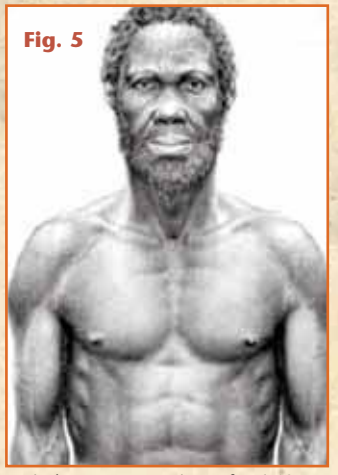


Fig. 5

Artist's reconstruction of a 160, 000 year-old AMH. Adapted from Sanders, 2003.

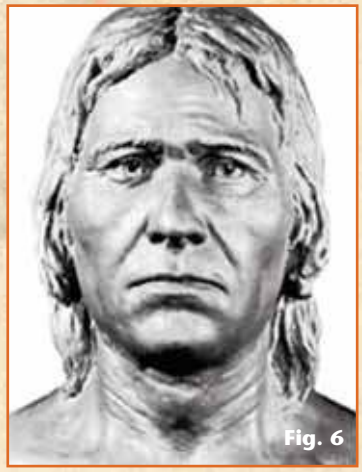


Fig. 6

Artist's reconstruction of a 35,000 year-old Cro-Magnon. Adapted from American Museum of Natural History, 2011.

Malocclusion

Anthropologists have long reported that human craniofacial volume has been diminishing since the advent of agriculture in the Middle East, and most rapidly since the early/mid-18th century in Western Europe: Larsen[17] reports, "…a shift to agriculture or more intensified agriculture was accompanied by an increase in dental crowding and malocclusion."; Gilbert[5] states, "… jaw anomalies (malocclusions wherein the teeth cannot fit properly in the jaw) are relatively new to European populations.

Well-preserved skeletons from the 15th and 16th centuries show almost no malocclusion in the population…."; and Lieberman[18] reports in his recent book, *Evolution of the Human Head*, "….there is much circumstantial evidence that jaws and faces do not grow to the same size that they used to…".

Corruccini[19] has hypothesized, "An epidemiologic transition to high prevalence of such diseases as diabetes and coronary heart disease accompanies the process of modernization/industrialization. I suggest that an equally clearly defined epidemiologic transition characterizes malaligned and discrepant dental occlusal relations in western societies, and others undergoing urbanization, and that the rapidity of the transition is proportional to the rapidity of urbanizational change. This phenomenon rather throws the weight of suspicion toward environmental, not genetic, etiologic factors."

Anatomically Modern Humans & the Masticatory Apparatus

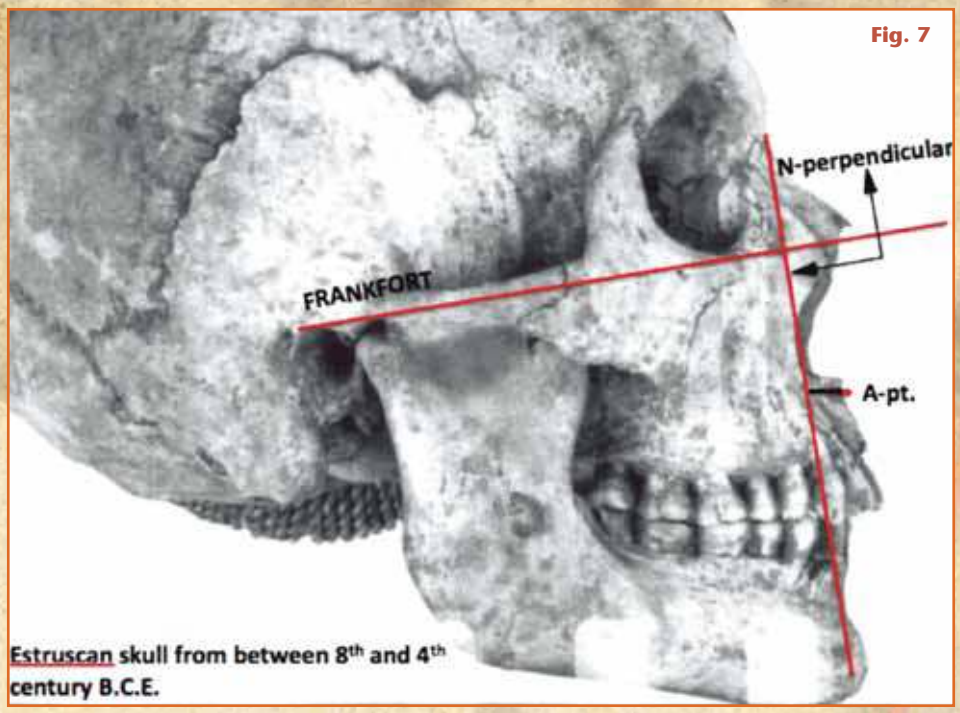
Fossil evidence from East Africa is consistent with recent genetic evidence indicating that modern-day humans (*Homo sapiens*) have likely been in their present anatomic form (Anatomically Modern Human/ AMH-Fig.5) for approximately150,000-200,000 years;[20] the first evidence of modern European (Fig. 6) *Homo sapiens* (Cro-Magnons) can be dated to approximately 35,000 years ago.[21] This implies that the genome coding for the modern anatomic form (phenotype) of our ancient

African ancestors, is also very little, if at all, changed over thousands of generations. This has significant implications for why we are presently experiencing such high prevalence of malocclusion over the past few hundred years… Macrogenomic change has not been shown to occur over such a relatively short time span.

The component of the craniofacial complex that is dedicated to the function of initiating mechanical/ chemical processing of food prior to its subsequent digestion and assimilation of nutrients for later biological utilization, is called the human masticatory apparatus (HMA). As our pre-modern human ancestors evolved away from their common ancestor with the modern chimpanzee over 6 million years ago, the HMA had to have been indispensible to their ultimate evolutionary success. Thus, the combination of genes involved in coding for the modern HMA-phenotype is likely little changed since modern Europeans first appeared nearly 35,000 years ago, and many anthropologists speculate that our complete genome has probably not undergone any Macroevolutionary change since we first appeared in Africa as AMH's nearly 200,000 years ago.

Mismatch to Modernity & Malocclusion

As Corruccini implies, the relatively recent appearance of malocclusion in humans is not best explained as resulting from a recent and anomalous Macroevolutionary genomic change...that would require a vast amount of geological time. A more plausible explanation would be one that is consistent with Nesse and Williams' 'Mismatch' explanation for disease vulnerability; an unchanged ancient genome exposed to a less-challenging modern feeding environment (since the *Industrial Revolution*) is now the leading hypothesis for understanding malocclusion etiology that is accepted by many anthropologists and anthropologically-informed orthodontic clinicians and researchers…but seemingly at odds with current orthodontic teaching and clinical practice.



Notice the forward position of A-point relative to the N-perpendicular to the Frankfort horizontal plane; this is a common finding in pre-Industrial skulls but would indicate an abnormally protrusive maxilla by most currently used cephalometric analyses. Adapted from Corruccini 1989.

In the most recently published edition of the widely-used textbook *Contemporary Orthodontics*,[6] coauthor William Proffit posits the question, "Is it possible that a child's masticatory effort plays a major role in determining dental arch dimensions?"; and then provides an answer, "That seems unlikely." Dr. Proffit's conclusion might be at odds with the observation that ancestral-type infant/early childhood feeding environments (breastfeeding at-will into the third year of life and weaning to fibrous/firm-textured first foods) seems to provide some protective benefit against the later development of malocclusion in *pre-Industrialized*, prehistoric and *non-Westernized* modern-day cultures. Furthermore, there are multiple studies[22, 23, 24] that clearly indicate a negative effect of bottle-feeding versus breastfeeding with respect to later development of anterior open-bites and/or posterior crossbites.

A Need for Change

Anthropological Norm (AN) is a concept that is currently being explored by several disciplines in healthcare;[25] for example, it is now routine to look at free ranging South African Bushman, Khoisan people, and others for an "anthropologically normal"/ prehistorically "natural" level of serum cholesterol, LDL to HDL ratio, blood pressure, sodium, blood sugar. All these variables are at unnaturally high levels in modernized/westernized populations.

Hypothetically, AN implies the existence of a *pre-Industrial* phenotypic range for a variety of physical/physiological phenotypic traits (e.g., the human masticatory apparatus, salivary pH, etc.) that are normal for assuring maximum survival, thriving and reproductive fitness. The AN hypothesis is predicated on the observation that the human genome is best adapted to *pre-Industrial* diets, lifestyles and environments as it (the human genome) has undergone virtually no Macroevolutionary change in perhaps the last 60,000-200,000 years. As the alleles that code for the human masticatory apparatus are likely unchanged for thousands of generations, to suggest revision of current "anthropologically" uninformed cephalometric norms, which are almost entirely based upon 20th-century skulls, does not seem unreasonable.

In 1981, a paper by James McNamara appeared in the *Angle Orthodontist*[26] describing a study showing that most of the skeletal Class II malocclusion subjects in a cohort of 8- to

10-year-olds were not maxillary protrusive, rather, most had retrusive maxillas; the conclusions regarding relative maxillary skeletal retrusion in the A/P dimension were based upon two pre-treatment cephalometric angular values: 1.) SNA (Steiner) angles-less than 81 degrees; and 2.) the distance of A-point from Nasion perpendicular (less than 0mm).

When utilizing McNamara's A-point to N-perpendicular cephalometric angular measurement, *pre-Industrial*, prehistoric and *pre-Westernized* skulls are somewhat maxillary protrusive (Fig. 8), these data seem to be at least circumstantially supportive of the hypothesis that human malocclusion is a relatively recent phenomenon since technological advances stemming from the *Industrial Revolution* in Western Europe.Furthermore, because they were largely developed from early 20th-century (*post-Industrial*) databases, currently used orthodontic cephalometric normative values should now be revised as they likely do not represent anthropologically-accurate ideals for true genomic craniofacial growth potential.

As it becomes increasingly clear that malocclusion is a predisposing factor for certain chronic systemic diseases[27] that were likely never suffered by our ancestors (e.g., apnea, hypertension, CVD, etc.), existing criteria for determining orthodontic success (e.g., well-aligned and straight teeth, pathology-free and esthetically-positioned jaw relationship, etc.) should also include factors related to long-term systemic health (e.g., adequate posterior airway volume) (Figs. 8, 9, 10 & 11).

This framework holds significant implications to currently accepted theories about malocclusion etiology, clinical diagnostic criteria, treatment option selections and ultimate orthodontic treatment success; these and other EOM-related issues will be addressed in a proposed follow-up to this paper.

Summary & Conclusions

For millions of years, our pre-human and anatomically modern human ancestors evolved a masticatory apparatus (MA) that was best adapted to foods that required prolonged and forceful chewing of varied Paleolithic-type diets (e.g., wild whole grains, fibrous fruits and vegetables, nuts, seeds, raw and cooked meats and fish, etc.).

Constantly changing feeding environments over the several millions of years time-span of human evolution are known to have been an extreme challenge to our early human ancestors. As the various pre-human (hominid) species evolved away from their common ancestor with the modern chimpanzee, an MA phenotype that was best adapted to Paleolithic-type diets offered the best chance for surviving and reproducing (i.e., becoming our ancestors). In what is now called the *Agricultural Revolution*, also called the *Neolithic Revolution*, sometime around the 10-century B.C.E. (Before Common Era) in the Fertile Crescent region of the Middle East (what is now Turkey), mankind began a gradual shift to becoming primarily sedentary agriculturists from having been nomadic hunter-gatherer/foragers (H-G/F's) for nearly their entire existence.

When viewed from an evolutionary timescale perspective, the *Agricultural Revolution* represented a relatively abrupt change in mankind's means of acquiring food for themselves. This and subsequent changes in the human diet have been accompanied by an increased incidence of a myriad of chronic and non-communicable systemic diseases (CNCD's) like obesity, Type 2 diabetes, CVD and some cancers.[28] Likewise, modern

Fig. 8: Retruded maxilla and mandible (pre-Biobloc). **Fig. 9:** Forward maxilla and mandible (post-Biobloc). Notice more protrusive profile and associated increase in posterior airway volume (red arrows) on the post-Biobloc images. Adapted from Hockel 2011. A significant relationship (reduction) has been demonstrated between the pre-and post-treatment posterior airway volume and the retraction distance of lower incisors in this study. **Fig. 10:** Posterior airway volume before bicuspid-extraction/incisor-retraction Tx. Adapted from *Wang et al, Angle Orthodontist* 2011. **Fig. 11:** Posterior airway volume after bicuspid-extraction/incisor-retraction Tx. Adapted from *Wang et al, Angle Orthodontist* 2011.

Western lifestyle and foods (i.e., softened/highly processed, fatty, salty, sweetened, etc.) are major causes of two plaque-mediated (dieto-infectous) oral maladies, dental caries and periodontal disease.[29] These dental CNCDs, like their systemic counterparts, are often referred to as *diseases of civilization* or *Western-lifestyle* diseases. Although many anthropologists and other scientists have suggested that malocclusion is another *Western-lifestyle* related disease, this view does not yet seem to be accepted by the dental community.

As dental and other allied-health professionals become better informed about the evolutionary history of the human genome, and how its relative plasticity and ability to respond to harsh and ever-changing feeding environments has allowed us to survive as a species into the present day, it should become easier to understand that malocclusion is indeed, a *dental disease of civilization*.

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Editor's Note: Article references are available upon request or for download in the digital version at www.orthodontics.com.

Figures-websources

Figs. 1 & 2-**Palmer**- www.brianpalmerdds.com/pdf/section_A.pdf

Fig. 3- **Palmer**- www.brianpalmerdds.com/pdf/adsm_section_b.pdf

Fig. 4- **Kean**- www.uic.edu/classes/osci/osci590/11_1Epidemiology.htm

Fig. 5- **Sanders**-http://berkeley.edu/news/media/releases/2003/06/11_idaltu.shtml

Fig. 6-**AMNH**- www.britannica.com/EBchecked/media/36968/Artists-reconstruction-of-a-Cro-Magnon-an-early-version-of

Fig. 7- **Corruccini**- www.angle.org/doi/abs/10.1043/0003-3219(1989)059%3C0061%3AOADOIE%3E2.0.CO%3B2

Figs. 8 & 9- **Hockel**-www.hockel.com/Orthotropics.html

Figs. 10 & 11- **Wang et al**-www.angle.org/doi/pdf/10.2319/011011-13.1

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Appendix

Evolutionary Medicine at Durham, UK
http://www.dur.ac.uk/ev.med/

The Evolutionary & Medicine Review
http://evmedreview.com/

NESCent catalysis meeting-Evolution of Human Teeth and Jaws: Implications for Dentistry and Orthodontics
http://www.nescent.org/science/awards_summary.php?id=309

The Ancestral Health Society
http://ancestryfoundation.org/AHS.html

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