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Evolutionary Origins of Toothache

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ABSTRACT

One of the traits that make modern humans unique is chin; this protrusion of the mandible is not seen in any other hominid species. There are numerous reasons for this evolutionary leap such as bipedalism, speech, development of tools and pottery, use of fire and cooking, and agricultural revolution. As for our teeth, they are still having trouble to match with our jaw which is still forming. Dentist interventions are the most recent addition to these factors, which have resulted in the continuous shrinking of our teeth and negated selection pressures; one could say that the evolutionary pressures on our jaw, chin, and teeth are no longer at work.

Keywords: Tooth Evolution, Selection Pressures, Speech, Technology, Nutritional habits.

Introduction

Evolution, first and foremost, is a selection process, and carriers of traits who are unable to adapt to their environment are weeded out over generations as the chance of reproduction decreases [1]. Our inner caveman, who has survived with us to the present day, is in a state of mismatch with the modern environment we have created, and our teeth are no exception [2]. Teeth are mineralized hard structures located at the beginning of the digestive system in both vertebrates and invertebrates; thus, their primary function is to process and prepare food for digestion; they are also involved in the expression of emotions, defense, and pronunciation of words in human beings [3]. Adaptations to the environment and food sources in vertebrates have caused teeth to form in different shapes [4]. Therefore, the forms of cutting incisors, tearing canines, grinding premolars and molars have been diversified [5]. Teeth grow in some animals throughout the animal's life, while in others they are shed and replaced with new ones [6]. The thickness of tooth enamel layer varies considerably among animals; it would suffice to consider only elephants [7]. Despite these differences, however, tooth in almost all animals comes from a common precursor and develop by the similar molecular coding [8]; the dentition seen in the chicken embryo is a remnant of their dinosaur ancestors [9].

Our dentition has undergone great evolutionary changes until today; modern human teeth are very different from those of Neanderthals [10]. The human jaw and dentition have been steadily shrinking over the last 50,000 years; our teeth decreased in size by 1% every 2000 years during the Stone Age and by 1% every 1000 years since the Agricultural Revolution [5]. Environmental, cultural, and possibly evolutionary factors are responsible for this reduction [11]. Our hunter-gatherer ancestors subsisted on wild grains and raw meat had larger and stronger teeth, which they used to tear meat and crack the shell of nuts [12,13]. However, evolution has so badly "designed" our heads that there is no longer enough room in our jaws for our teeth [14]. Due to a lack of space in the dental arches, dental fusion and malocclusion occurred [15]. Molars and premolars grew relatively larger as our incisors shrank. Canines were larger in cousin apes, showed sexual dimorphism, and did not wear as much as posterior teeth [16]. In the modern humans, the first molar teeth are the largest among molars and

their size are reduced. While in early hominins, the second molars were the largest [17]. Skulls from the last few centuries are dental nightmares: their jaws are rife with cavities and infections, the jaws are packed with teeth, and a quarter of the skulls bear unerupted teeth [18]. Farmer's skulls before the industrial revolution were also riddled with cavities and abscesses that should have been painful [19]. Contrary to popular belief, hunter-gatherer ancestors' dental health was far from perfect [20]. This suggests that dental caries and malocclusions are not just associated with diet but may also be a by-product of the evolution of our jaws and the evolutionary compromise we paid for acquiring ability to speak [21].

Evolutionary Pressures, Bipedalism

Although these factors may all contribute to relieve selection pressures on tooth that would have favored larger teeth, they may not be the true cause of reduction in tooth size. According to a biological rule, when redundant structures are not used, they shrink or disappear completely [22]. The reason for this selection pressure is that eliminating additional biological structures provides a selective advantage due to their unnecessary resource consumption [23]. This mechanism may be at least partially responsible for the human tooth-size reduction. But many other evolutionary pressures could have played a role. The first of these is the evolution of bipedal locomotion, which helped to reduce the size of the bipedal jaw [24]. Bipedalism has played a fundamental role in the evolution of the human head, neck and face while enlarging the brain [25]. Evolution of bipedalism has tended to grow brain, and a growing brain necessitated a growing cranium [26]. Shortening the jaw is the best way to create such a large cranium; when the large brain was selected for due to obvious selection advantage, the jaw shortened to adapt the growing cranium. At this point, the previously advantageous large jaw and large teeth were rendered obsolete [11].

The Effect of Speech

The second is the evolution of speech, which has increased the demand for adaptable oral structures [27]. Our ancestors communicated through the sounds they made before they learned to speak; once we learned to speak, our vocal organization changed, with many changes in the oral cavity and larynx [28]. The evolution of speech is linked to changes in the cranium and pharynx, both of which influenced jaw and tooth structure indirectly [29]. The appearance of the chin is one of the most noticeable features that emerge with the evolution of speech [30]. The absence of a mental eminence or chin in the pre-speech human resulted in a retrognathic appearance; the chin became protruding through evolution [31]. The posterior flare of the lingual part of the mandible was an important feature of pre-speech humans like other primates; this structure has been lost in modern humans [32]. Speech should be a significant factor and stage in the evolution of the head and neck region. The formation of mandible protrusion may have been caused by repetitive contractions of the tongue and perioral muscles while speaking [29]. When the jaw shortened so quickly, the molars in the back of the mouth began to be squeezed and the tooth alignment became distorted [33].

Technological Advances

The advances in food preparation technology used by humans were a watershed in the evolution of our jaw and teeth [34]. Therefore, the strong teeth needed to grind plant foods have become less necessary over time, resulting in a reduced need for large, herbivores dentition [35]. The need for carnivorous adaptations such as large canines and strong jaws gradually decreased as humans invented stone tools that replaced sharp teeth [36]. Stone tools helped our ancestors in abandoning carnivorous adaptations, and these tools began to replace sharp incisors, large canines, and strong jaws as carnivore teeth [12]. The invention of pottery was another significant technological advancement that influenced human tooth size. Together, fire and pottery altered the structure of our food, resulting in new adaptive changes in our ancestors' faces [35]. Pottery enabled the preparation of soups and other soft foods that did not require the use of any teeth, allowing people to survive after losing their teeth [34]. With the spread of pottery, larger quantities of food could be prepared in stone mills. Finally, as humans began to cook their food in earthen ovens, meat and other foods softened and became easier to chew, reducing the need for a large, strong dentition even further [26]. These advancements softened food and made it easier to eat, reducing the selective advantage of having a large dentition [37]. Thus, the human diet today contains more meat than that of our ancestors [38]. The selective disadvantages of tooth loss have now been eliminated because of over processed foods and dentists [12].

Changes in Diet

Another distinction between our hunter-gatherer ancestors' teeth and modern teeth is the way they wear. Extreme tooth wear is visible almost to the roots of fossil teeth. Tooth wear occurs with aging in modern humans, whereas it occurred at a young age in our ancestors, implying that their teeth wore quickly [39,40]. Diet must have played an important role in this; the owners of these teeth must have eaten large, hard fruits [41]. Micro-erosion has decreased as our diet has shifted toward processed foods, while dental caries has increased [42]. The bacterial DNA of fossil teeth also differs from that of today, which appears to be related to dietary differences [43]. The human diet began to change with the advent of agriculture, and more processed foods were consumed. Gum diseases became more common as barley and wheat consumption increased [44]. Tooth decay also became more common as wheat and sugar consumption

increased [45]. Crooked teeth may be caused by today's widespread consumption of soft foods. And gum disease may be caused by tooth crooks. The anterior teeth and chin are used for tearing food and breaking it up into small pieces for chewing [46]. Molars are used to grind food and prepare it for swallowing. Switching to soft foods causes the human jaw to stop performing these tasks and shrink, this resulted in crooked teeth [47].

Evolution of Craniofacial Complex

The human craniofacial complex has evolved primarily with the influence of bipedalism, speech, and diet, resulting in a modern human head that looks very different from that of its ancestors [48]. The maxilla, mandible, teeth, temporomandibular joints, and the muscles of mastication comprise the human mastication system, which is primarily responsible for feeding and speech [49,50]. Chewing load in response to food variety, hardness and size of the piece is particularly important among the many factors shaping the evolving craniofacial complex [51]. The change in chewing load has influenced the evolution of the highly derived human face and is one of the main reasons contributing to the evolution of craniofacial structures [52]. There are clear differences in craniofacial features between prehistoric and modern humans [53]. Endocranial volume has increased throughout our evolution, beginning at 700 cc in primates and reaching 1400 cc in modern humans [54]. The cranial capacity of Homo neanderthalensis is the largest of any hominid species [55]. The maxilla's appearance indicates that our ancestor had a strong jaw and larger teeth [56]. Our ancestor's maxilla was rectangular in occlusion of the palate, with canines at the anterior corners [57]. The posterior teeth were placed quite parallel on both sides. The jaw was narrow and protruding [58]. The maxilla is thinner and slenderer today, the teeth are smaller, the palate is more ovoid, and the chin is wider but retrograde [59].

Evolution of the Chin Structure

One of the traits that make modern humans unique is our chin; this protrusion of the mandible is not seen in any other hominid species [58]. Essentially, chin may have evolved to protect the mouth from the stresses generated by the contraction of the tongue muscles in response to speech, as well as the forces generated by chewing food, or it may have evolved early in our species' history to resist the increased load on our ancestor's teeth as their mouths and chewing muscles shrank [28]. The shape of chin can also indicate mate characteristics. A large male chin could be associated with good genes, whereas a thin female chin could be associated with high levels of estrogen [60]. If the chin evolved in response to eating and speaking, there should be no gender difference in chin shape; men and women eat and speak in the same manner [61]. Maybe the chin first evolved to withstand mechanical stresses and then shaped by sexual selection [46].

Decreasing Impact of Masticating

The human jaw has enough bite force to break bone. This force not only breaks down food but also stretches the face [62]. This chewing deforms the jaw bones in the same way that walking and running does to the leg bones. Chewing also necessitates the repeated exertion of this force. Thousands of chews would have been required for a Stone Age meal such as meat with bones [13]. The high force exerted repeatedly has led to the jaw adapting to thickening over time. That is, a childhood spent consuming hard foods may help the jaw become large and strong [15]. The mechanical force generated by chewing food not only allows the jaw to achieve the proper shape and size, but it also paves the way for the teeth to be properly positioned in the jaw [15]. The cheek teeth have protrusions and pits that work like a mortar and pestle. We push the lower teeth towards the upper teeth with such precision that the lower teeth's protrusions fit perfectly into the pits of the upper teeth, and vice versa. Upper and lower teeth should be in exactly the right shape and position for effective chewing [63]. Chewing forces influence tooth condition in the oral cavity, but genes control tooth shape. As we chew, the teeth, gums, and jaws exert force on the tooth sockets, activating bone cells and allowing the tooth to settle into its proper position [15].

Those who do not chew sufficiently have an increased tendency for teeth to become misaligned; young aboriginal people whose families have adopted a western diet have jaws smaller than their grandparents' and suffer from severe dental impaction [64]. A certain amount of 'munching' is necessary for the system to function well [65].

Wisdom Teeth

Wisdom teeth depict human evolution very well [21]. Modern human skulls demonstrate that wisdom teeth are a perfect example of evolutionary mismatch [33]. Today's human beings no longer need the extra wisdom teeth, because of which they erupt later than others [66]. The problems caused by wisdom teeth in the past, such as pain and infection, must have created an evolutionary disadvantage for people with this trait. There are very few pre-industrial revolution farmer skulls that show wisdom teeth that haven't erupted [19]. The reason why there is no longer enough room for these teeth in our mouths, as previously discussed, could be bipedalism first, followed dietary and changes in lifestyle [41]. Today, we eat foods with forks and knives and prepare them with a variety of other tools and techniques. Our ancestors required wisdom teeth, a strong chewing capacity, and extra teeth because they ate unprocessed rough foods like meat, nuts, roots, and leaves [47]. Our ancestors' jaw muscles had to be strong, and the jaws that supported these muscles had to be larger, so that there was room for third molar teeth [67].

Wisdom teeth try to erupt in an insufficient space, rotate in the jawbone, and compress the roots of other teeth [67]. Apart from being painful, it displaces other teeth, can cause nerve damage, and, in the pre-antibiotic era, could lead to serious infections that could be life-threatening [12]. Human beings have not had a problem with wisdom teeth for millions of years, but the diversification of food preparation techniques has disrupted the ancient system in which genes and mechanical chewing load interacted to make teeth and jaw grow together harmoniously [68]. Unerupted wisdom teeth have many similarities with osteoporosis. When we do not strain our faces enough by chewing food, the jaw does not grow sufficiently to bare the teeth and the teeth do not fit into the jaw, just as the extremities and vertebrae do not become strong sufficiently when the bones are not forced enough by walking, running, and other activities [63]. When chewing is not strong enough in childhood, the teeth will not be in the proper position, and the jaw will not develop sufficiently to bear wisdom teeth [69].

Resulting Pathologies

Without intervention, various pathologies affecting dental health, such as fractures, decay, infections, and abscesses, eventually lead to tooth loss, which adversely effects overall human health, physically, mentally, and socially [70]. Oral diseases affect half of the world's population; one-third of the world's population enters the last third of their lives are completely toothless; dental diseases are the second most common human health problem, after viral infections [71]. Oral diseases, which frequently result in tooth loss, have a variety of causes, but microbes are almost always the cause of pulpitis, and dental caries is the most common cause of tooth extractions [72]. Although periodontal diseases have only recently been identified, they affect half of the world's adult population and, if left untreated, result in complete edentulism [71]. Almost all oral diseases are caused by dental caries, periodontitis, or edentulism, and their effects are not limited to the mouth, eventually leading to systemic complications [70]. Dental caries is a primary pulp disease of the oral cavity that, if left untreated, can cause abscesses, endocarditis, cardiovascular diseases, bacterial pneumonia, glomerulonephritis, rheumatoid arthritis, osteoporosis, and premature and low birth weight in pregnant women [73,74].

Periodontal diseases are also associated with cardiovascular conditions [ischemic heart disease and hypertension], lung and kidney damage, pancreatic and oral cancers, and dementia [75]. Being edentulous is associated with precocious and avoidable deaths, which are usually due to cardiovascular causes [76]. Being edentulous is directly associated with diabetes mellitus and insulin resistance, and gastritis, duodenal ulcer and esophageal cancers are more common in the edentulous [77-79]. Chewing disorders, which are frequently caused by edentulism, are the root cause of migraine and obstructive sleep apnea, increasing the risk of memory loss and dementia in the elderly, and hastening the onset of multiple sclerosis in younger people [80-82]. Oral cancers tend to increase in subgroups that were not previously considered at risk, such as youngsters, non-smokers, non-drinkers, and females [83-85].

Modern Dentistry Vs. Natural Selection

Endodontic treatment, tooth extraction, and implantation are examples of classical dental treatments. The way to stay away from these procedures is not to run away from the dentist, but oral hygiene and regular periodontal care [86]. Without these, caries and periodontal diseases cause tooth extraction and, eventually, complete edentulism [87]. Tooth extraction also creates further problems such as stomatognathic system impairment [88]. Periodic screening and timely treatment of caries is the core business of dental medicine [89]. However, visual examination by the dentist is not effective enough. The integration of fluorescence detectors for caries screening into dental examinations has increased the effectiveness of early detection and treatment. More specifically, tooth caries hidden from the eye by old amalgam can be diagnosed more accurately with this method [90]. The use of digital radiography as a dental diagnostic tool contributes significantly to caries and periodontal diagnosis by exposing the patient to far fewer x-rays [91]. Tomography and three-dimensional diagnostics have made it possible to provide the most effective treatment while minimizing iatrogenic effects [92]. In screening of oral cancers, combination of high-power LED lights and natural fluorescence to identify anomalies invisible to the naked eye and make biopsy more sensitive [93]. Dental lasers, which allow working on hard tissues like dental enamel and dentin rather than conventional drills, are increasingly preferred because they cause less damage to adjacent tissues and healing is faster [94]. The combination of tomography and laser appears promising for early diagnosis [95]. Photo-activated technologies are also increasingly used as they speed up healing and remove inflammation [96]. And dental impressions apparently will replace traditional tooth filling soon [97].

Conclusion

Even though our genes have not changed in tens of thousands of years, especially in the last few decades, our food has been processed and softened to such extent that it does no longer require chewing. We have taken food cooking and processing so far in the evolution of the genus Homo that our children now completely lack even the chewing power to allow normal jaw growth. Our jaw muscles are now too weak to chew a Stone Age food. The human face has decreased in size by about 5-10% relative to body size over the past few thousand years. As a result of this, malocclusions and non-erupting wisdom teeth have emerged as evolutionary

mismatches situations against which we have failed to protect. Human beings, nevertheless, are the only species capable of correcting and compensating for dental defects by using their own intelligence. This ability is shaping the human jaw and dentition today, and thanks to advanced technology and modern dentistry, even the near future of the human face and teeth is now impossible to predict.

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