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Have the third molars become vestigial due to the industrialization of our diet?

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Project thesis for the Integrated Master's Program in Odontology

January 2023 Bergen

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Abstract

Introduction: Human jaws have been proven to be subject to morphological changes through the course of evolution. The diet of the human species has evolved from tough and abrasive to soft and processed food. This is hypothesized to have had some consequences on the jaws and third molars in particular.

Aim: This literary review aims to investigate the correlation between dietary habits and dysfunctionality of the third molars in light of the increased prevalence of third molar complications in recent human history and the evolution of diet. Complications regarding third molars in the mandible will mainly be regarded.

Methods: This is a literary review using PubMed, ResearchGate, and Google Scholar as core databases. Specific keywords were used to gather data for our search. We also used the reference lists of the articles we read for further searches for scientific publications regarding the research in question.

Results/review: The jaw of the human lineage appears to have gone through developmental and morphological changes concurrent with the dietary shift from tough and abrasive to soft and processed food. The available data suggests that in comparison with their ancestors, modern humans appear to experience more developmental and pathological complications with their third molars. Modern human dentitions are more overcrowded, and there are more complications associated with third molars than ever before recorded. In some cases, third molars fail to develop entirely, which is also known as agenesis. The changes in the dietary habits of the extinct hominins seem to have some correlation with the jaws of their successors having less room for third molars to develop and erupt into a well-aligned position in the dental arch.

Conclusion: The data found in the present literary review study indicates that there have been evolutionary changes in development in the maxilla and mandible, and localization and development of third molars. These changes are hypothesized to have been a result of the changes in dietary habits and subsistence strategies throughout human evolution. However, it is evident

that diet is not the only factor that has affected the anatomical evolution of humans. Genetics and other environmental factors are believed to have an important role regarding this issue as well. Although third molar complications have become more prevalent in recent years, third molars are yet to be definitively proven to be vestigial. In conclusion, there is not enough available research on the topic to draw a definitive conclusion regarding the etiology of the increased prevalence of third molar complications. The topic in question is understood to be subject to a multifactorial etiology, so that more multidisciplinary research would be beneficial for a better understanding.

Introduction

All the anatomic features of the Homo Sapiens have evolved throughout the history of Hominins (*def. "Any of a taxonomic tribe (Hominini) of hominids that includes recent humans together with extinct ancestral and related forms"*). Specifically, the mandible has been proven to have gone through developmental changes concurrently with the change in human subsistence strategies.(1, 2) This is believed to have resulted in the species of Homo Sapiens experiencing a higher prevalence of malocclusion (*def. "improper occlusion, especially abnormality in the coming together of teeth"*), and complications with their third molars, commonly known as wisdom teeth.(3-5) Because of the possible correlation between diet and dental complications, it is discussed whether or not third molars have become vestigial *(def. "remaining in a form that is small or imperfectly developed and not able to function"*) organs due to the evolution of diet.(6, 7) The discussion in question is based upon the fact that third molars most often do not erupt before young adulthood, they are frequently the cause of pathology in the oral cavity, and in some cases, they fail to form completely.(7-9) Third molars are considerably more susceptible to complications and are usually extracted earlier and more frequently than other teeth. Furthermore, they are also far more prone to variation than other molars, both in terms of size, shape, and their time of eruption.(6, 8-10) Besides causing pathology in the oral cavity, they are futile in a vast number of people, and often need to be surgically removed.(8, 11) According to a research where rats were raised on a diet of soft, processed foods, the rats showed many of the same dental arch complications as modern humans, including malocclusion, smaller arches, and crowded dentitions.(5, 12-14)

Some studies have found implications of a considerable reduction in the size of the jaws of the human lineage throughout evolution, which they correlated to the shift from the primitive diet to the modern diet consisting of processed and prepared foods.(1, 15-17) Due to the use of cooking and preparing procedures for food acquired through gradual civilization and industrialization, the current human diet is softer compared to that of the primitive diet. Modern human dentitions have evidently become more subject to malocclusion,(4, 18) and the dental arch space for many individuals has come to the point where the third molars have restricted room to emerge.(19)

The goal of this literature review is to investigate the correlation between nutritional habits and the dysfunctionality (*def. "not functioning properly: marked by impaired or abnormal functioning"*) of the third molars in light of the increased prevalence of third molar issues and the evolution of diet.

Material and method

We performed a literary review and aimed to collect data from the listed references to address the possible correlation between nutritional habits and the dysfunctionality of the third molars in light of the increased prevalence of third molar issues and the evolution of diet.
The specific questions of the study were defined as follows:

1. Has the gradual increase in industrial processing and softening of our food caused permanent alterations on the human jaw anatomy?
2. Is the anatomical evolution of our jaws the reason for the high prevalence of complications regarding third molars in modern humans?

PubMed, ResearchGate, and Google Scholar were the databases we primarily used. Only some articles were available through our primary database; therefore, information from other sources was also retrieved after validating their credibility and reliability. Furthermore, relevant papers from the reference lists of the main sources were also used. The following keywords were mainly searched for: evolution, industrialization, human dentition, maxilla, mandible, human jaw, diet, third molars, impaction, malocclusion, vestigiality, and hominins. Dentists, doctors, anthropologists, paleontologists, biologists, scientists, and surgeons were deliberately selected as the publications' authors. Relevant keywords were also combined to generate the searches. Not every article had listed its keywords; however, the keywords we searched for matched certain words in the title of the articles.

Inclusion criteria:

- Credible databases from which the articles were retrieved from
- Available and relevant information in the abstract

Exclusion criteria:

- No reference lists
- Unreliable databases
- Language restrictions
- Full text not available

Table 1. Table for the references used for this thesis.

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
1. William R. Leonard	Human nutritional evolution	ResearchGate	Chapter from book: Human Biology – An Evolutionary and Biocultural Perspective 2nd ed.
2. Milford H. Wolpoff	Paleoanthropology: Controversy without end or an end without controversy?	ResearchGate	Review article published in peer-reviewed journal (Reviews in Anthropology)
3. Julia C-Boughner	Implications of Vertebrate Craniodental Evo-Devo for Human Oral Health	PubMed, ResearchGate	Review article published in peer-reviewed journal (Journal of Experimental Zoology Part B: Molecular and Developmental Evolution)
4. Elsa M. van Ankum	Changes in Dietary Consistency and the Epidemiological Occlusal Transition	ResearchGate	Review article published in COMPASS: The Student Anthropology Journal of Alberta
5. Akshay Satwik	Third molar impaction – Review	ResearchGate	Review article published in peer-reviewed journal (Research Journal of

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
			Pharmacy and Technology)
6. Jerry Bergman	Are Wisdom Teeth (Third Molars) Vestiges of Human Evolution?	Journal of Creation	Review article published in peer-reviewed journal (Journal of Creation)
7. A. Alagu Rathi Bharathi	Vestigiality of Wisdom Teeth in Relation to Human Evolution and Lifestyle Modification	ResearchGate	Peer-reviewed cross-sectional study published in Drug Invent Today
8. John H. Campbell	Pathology Associated with the third molar	PubMed	Review article published in peer-reviewed journal (Oral and Maxillofacial Surgery Clinics of North America)
9. Ashraf I. Shaweesh	Timing of Clinical Eruption of Third Molars in a Jordanian Population	PubMed	Clinical study published in peer-reviewed Journal (Archives of Oral Biology)
10. Charles Darwin	The Descent of Man and Selection in Relation to Sex	JSTOR, Library of University of Bergen	Book
11. James S. Rogers	Man and the Biological World	Biodiversity Heritage Library, Library of University of Bergen	Book
12. Daniel E. Lieberman	The Story of the Human Body: Evolution, Health, and Disease	Library of University of Bergen	Book
13. Reiko Sakashita	Diet and Discrepancy Between Tooth and Jaw Size in the Yin-Shang Period of China	PubMed	Article published in peer-reviewed journal (American Journal of Physical Anthropology)
14. Robert M. Beecher	Effects of dietary consistency on	PubMed	Experimental study published in peer-

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
	craniofacial and occlusal development in the rat		reviewed journal (The Angle Orthodontist)
15. Stanley M. Garn	What did our ancestors eat?	Library of University of Michigan	Article published in peer-reviewed journal (Nutrition Reviews)
16. Arofi Kurniawan	Lifestyle changes and its effect towards the evolution of human dentition	SpringerOpen	Review article published in peer-reviewed journal (Egyptian Journal of Forensic Sciences)
17. Noreen von Cramon-Taubadel	Global human mandibular variation reflects differences in agricultural and hunter-gatherer subsistence strategies	PubMed	Research article published in peer-reviewed journal (Proceedings of the National Academy of Sciences of the United States of America)
18. Jon P. Evensen	Are malocclusions more prevalent and severe now? A comparative study of medieval skulls from Norway	PubMed, ResearchGate	Comparative study published in peer-reviewed journal (American Journal of Orthodontics and Dentofacial Orthopedics)
19. Pratiwi Soesilawati	Diet as a Partial Explanation for Wisdom Teeth Problem	e-GiGi	Article published in peer-reviewed journal (e-GiGi)
20. Chris Stringer	The origin and evolution of Homo Sapiens	PubMed, ResearchGate	Review article published in peer-reviewed journal (Philosophical Transactions of the Royal Society B)
21. Ian Tatterstal	Homo Sapiens	Encyclopedia of Britannica	Article from Encyclopedia of Britannica

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
22. Mary Ellen Ruvolo	Genetic diversity in hominoid primates	ProQuest	Review article published in peer-reviewed journal (Annual Review of Anthropology)
23. Maria Hovorakova	Early development of the human dentition revisited	PubMed	Review article published in peer-reviewed journal (Journal of Anatomy)
24. Fu Wang	Tracking diphyodont development in miniature pigs in vitro and in vivo	PubMed	Experimental study published in peer-reviewed journal (Biology Open)
25. James Q. Swift	The nature of third molars: are third molars different than other teeth?	PubMed	Review article published in peer-reviewed journal (Atlas of the Oral and Maxillofacial Surgery Clinics)
26. Jay W. Friedman	The Prophylactic Extraction of Third Molars: A Public Health Hazard	PubMed	Review article published in peer-reviewed journal (American Journal of Public Health)
27. Marvin Harris	Food and Evolution	Google Books	Book
28. Leslie C. Aiello	The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution	JSTOR	Article published in peer-reviewed journal (Current Anthropology)
29. Michael Hofreiter	Ecological change, range fluctuations and population dynamics during the Pleistocene	PubMed	Review article published in peer-reviewed journal (Current Biology)
30. William Philip T. James	Nutrition and its role in human evolution	PubMed	Review article published in peer-reviewed journal

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
			(Journal of Internal Medicine)
31. G. Philip Rightmire	Homo Erectus	Encyclopedia of Britannica	Article published in Encyclopedia of Britannica
32. Susan C. Antón	Natural history of Homo erectus	PubMed	Review article published in peer-reviewed journal (American Journal of Physical Anthropology)
33. Umberto di Porzio	A bigger brain for a more complex environment	PubMed	Review article published in peer-reviewed journal (Reviews in the Neurosciences)
34. Loren Cordain	Fatty acid composition and energy density of foods available to African hominids. Evolutionary implications for human brain development	PubMed	Research article published in peer-reviewed journal (World review of nutrition and dietetics)
35. Tina Lüdecke	Dietary versatility of Early Pleistocene hominins	PubMed	Research article published in peer-reviewed journal (Proceedings of the National Academy of Sciences, PNAS)
36. Richard Wrangham	Cooking as a biological trait	PubMed	Review article published in peer-reviewed journal (Comparative biochemistry and physiology. Part A, Molecular & Integrative Physiology)

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
37. Katherine D. Zink	Impact of meat and Lower Paleolithic food processing techniques on chewing in humans	PubMed	Experimental study published in peer-reviewed journal (Nature)
38. Alejandra Garcia-Alonso	Effect of processing on potato starch: in vitro availability and glycaemic index	PubMed	Research article published in peer-reviewed journal (Nahrung)
39. Richard Wrangham	Catching fire : how cooking made us human	Google Books	Book
40. Henry M. McHenry	Australopithecus to Homo: transformations in body and mind	ResearchGate	Article published in peer-reviewed journal (Annual Review of Anthropology)
41. William R. Leonard	Effects of Brain Evolution on Human Nutrition and Metabolism	PubMed	Review article published in peer-reviewed journal (Annual Review of Nutrition)
42. Kurt W. Alt	Nutrition and Health in Human Evolution-Past to Present	PubMed	Review article published in peer-reviewed journal (Nutrients)
43. Wayne D. Rasmussen	Origins of agriculture	Britannica Encyclopedia	Article from Britannica Encyclopedia
44. Jean-Denis Vigne	The origins of animal domestication and husbandry: a major change in the history of humanity and the biosphere	PubMed	Review article published in peer-reviewed journal (Comptes Rendus Biologies)
45. Jane Buikstra	Paleopathology: An American Account. Annual Review of Anthropology	PubMed	Article published in peer-reviewed journal (Annual Review of Anthropology)

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
46. Alan H. Goodman	The chronological distribution of enamel hypoplasias from prehistoric Dickson Mounds populations.	PubMed	Comparative study published in peer-reviewed journal (American Journal of Physical Anthropology)
47. The Editors of Encyclopedia Britannica	Industrial Revolution	Britannica Encyclopedia	Article from Britannica Encyclopedia
48. Thomas Philbeck,	The Fourth Industrial Revolution: Shaping a New Era	JSTOR	Article published in peer-reviewed journal (Journal of International Affairs)
49. Abdo Hassoun	The fourth industrial revolution in the food industry—part II: Emerging food trends	Taylor&Francis Online	Review article published in peer-reviewed journal (Critical Reviews in Food Science and Nutrition)
50. Basavaraj S. Phulari	History of Orthodontics	Google Books	Book
51. Jerome C. Rose	Origins of dental crowding and malocclusions: an anthropological perspective.	PubMed	Research article published in peer-reviewed journal (Compendium of Continuing Education in Dentistry)
52. Arofi Kurniawan	Tooth evolution and its effect on the malocclusion in modern human dentition	Bulletin of the International Association for Paleodontology	Research article published in peer-reviewed journal (Bulletin of the International Association for Paleodontology)
53. Rachel Sarig	Malocclusion in Early Anatomically Modern	PubMed	Research article published in peer-

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
	Human: A Reflection on the Etiology of Modern Dental Misalignment		reviewed journal (PloS One)
54. Laura Krooks	Prevalence of malocclusion traits and orthodontic treatment in a Finnish adult population	PubMed	Research article published in peer-reviewed journal (Acta Odontologica Scandinavica)
55. Guido Lombardo	Worldwide prevalence of malocclusion in the different stages of dentition	PubMed	Systematic review and meta-analysis published in peer-reviewed journal (European Journal of Paediatric Dentistry)
56. Karen Hardy	Diet and environment 1.2 million years ago revealed through analysis of dental calculus from Europe's oldest hominin at Sima del Elefante, Spain	PubMed	Research article published in peer-reviewed journal (The Science of Nature and Naturwissenchaften)
57. Ozana-Maria Petraru	Dental microwear as a diet indicator in the seventeenth-century human population from Iasi City, Romania	ResearchGate	Comparative study published in peer-reviewed journal (Springer)
58. Mark F. Teaford	Diet and the evolution of the earliest human ancestors	PNAS	Research article published in peer-reviewed journal (Proceedings of the National Academy of Sciences of the United States of America)

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
59. Diana Rabenold	Abrasive, silica phytoliths and the evolution of thick molar enamel in primates, with implications for the diet of Paranthropus boisei	PubMed	Comparative study published in peer-reviewed journal (PLOS ONE)
60. Gabriela A. Macho	Reduction of maxillary molars in Homo sapiens: a different perspective	PubMed	Comparative study published in peer-reviewed journal (American Journal of Physical Anthropology)
61. Alan Stuart Ryan	Anterior dental microwear in hominid evolution: Comparison with human and nonhuman primates	ProQuest, Library of University of Bergen	Book
62. Bengt Ingervall	A pilot study of the effect of masticatory muscle training on facial growth in long-face children	PubMed	Experimental study published in peer-reviewed journal (European Journal of Orthodontics)
63. Yousuke Kaifu	Tooth wear and the "design" of the human dentition: a perspective from evolutionary medicine	PubMed	Review article published in peer-reviewed journal (American Journal of Physical Anthropology)
64. Myra F. Laird	Spatial determinants of the mandibular curve of Spee in modern and archaic Homo	PubMed	Comparative study published in peer-reviewed journal (American Journal of Physical Anthropology)
65. Daniel E. Lieberman	Effects of food processing on	PubMed	Comparative study published in a peer-

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
	masticatory strain and craniofacial growth in a retrognathic face		reviewed journal (Journal of Human Evolution)
66. Kazuro Hanihara	Microevolution and Tooth to Denture Base Discrepancy in Japanese Dentition	Semantic Scholar	Comparative study published in peer-reviewed journal (Journal of the Anthropological Society of Nippon)
67. Testuya Kamegai	Dental Diseases and Disorders in Māori.	Not available, found from the reference list of 13	Not available, found from the reference list of 13
68. Kuroe, K. O.	Study on Living Environment and Occlusion in Kenya	Not available, found from the reference list of 13	Study published in peer-reviewed journal (Anthropological Science vol. 103)
69. Weston A. Price	Nutrition and physical degeneration	Library of University of Bergen	Book
70. Raymond P. Howe	An examination of dental crowding and its relationship to tooth size and arch dimension	PubMed	Comparative study published in peer-reviewed journal (American Journal of Orthodontics)
71. Christina J. Adler	Sequencing ancient calcified dental plaque shows changes in oral microbiota with dietary shifts of the Neolithic and Industrial revolutions	PubMed	Comparative study published in peer-reviewed journal (Nature Genetics)
72. Loren Cordain	Origins and evolution of the Western diet: health	PubMed	Review article published in peer-reviewed journal

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
	implications for the 21st century		(The American Journal of Clinical Nutrition)
73. AJ. MacGregor	The impacted lower wisdom tooth	Library of University of Bergen	Book (Oxford Medical Publications)
74. Robert S. Corruccini	How Anthropology Informs the Orthodontic Diagnosis of Malocclusion's causes	Library of University of Bergen	Book
75. Lina M. Moreno Uribe	Genetics of the dentofacial variation in human malocclusion	PubMed	Review article published in peer-reviewed journal (Orthodontics & craniofacial research)
76. Tusar Kanti Nayak	The basic genetics of malocclusion	ResearchGate	Review article published in peer-reviewed journal (Indian journal of public health research and development)
77. Joel D. Irish	Ancient teeth and modern human origins: An expanded comparison of African Plio-Pleistocene and recent world dental samples	PubMed	Comparative study published in peer-reviewed journal (Journal of Human Evolution)
78. Mahmoud Al-Dajani	A cohort study of the patterns of third molar impaction in panoramic radiographs in Saudi population	PubMed	Retrospective cohort study published in peer-reviewed journal (The Open Dentistry Journal)
79. Maryam A. Hashemipour	Incidence of impacted mandibular and maxillary third molars: a radiographic study in a	PubMed	Retrospective study published in peer-reviewed journal (Medicina Oral,

First author	Title	Database from which the information the article/text was retrieved from	Type of article/text
	Southeast Iran population.		Patologia Oral y Cirurgia Bucal)
80. Dana Shoshani-Dror	Impacted wisdom teeth: To extract or not to extract? Review of the literature	PubMed	Literature review published in peer-reviewed journal (Refuat Hapeh Vehashinayim)
81. A. Hugoson	The prevalence of third molars in a Swedish population	PubMed	Epidemiological study published in peer-reviewed journal (Community Dental Health)
82. Bushra Alkhen	Are we going to have wisdom teeth in the future?	Scholarly Commons ISSN: 2572-6803	Literature, research review published in Scholarly Commons
83. Giedre Trakiene	Impact of genetics on third molar agenesis	PubMed	Experimental study published in peer-reviewed journal (Scientific Reports)

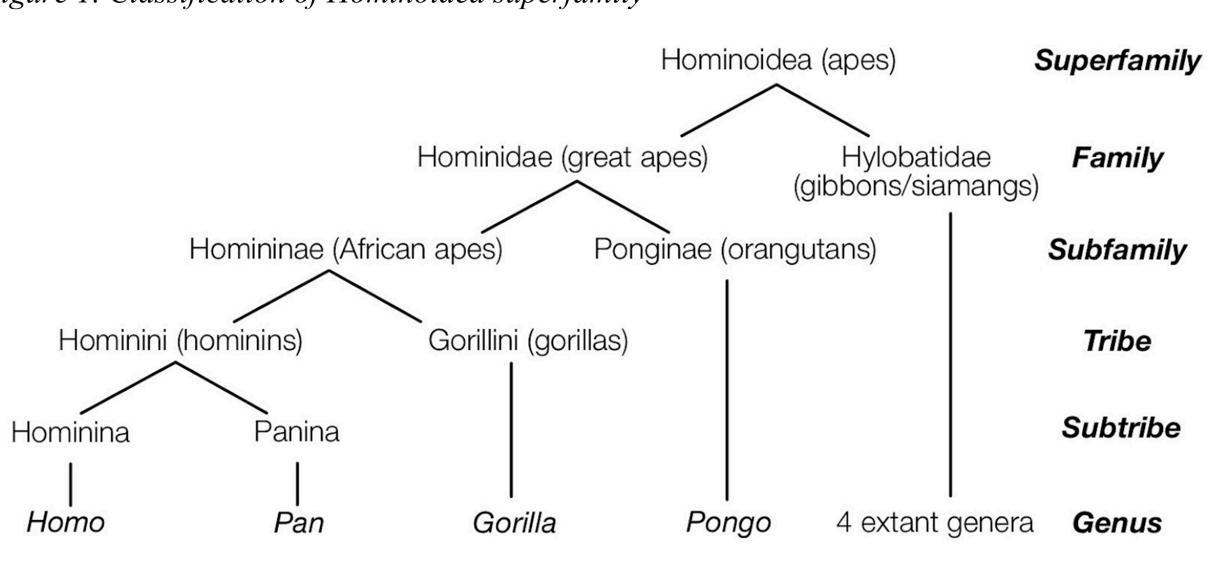
Results and review of literature

This thesis is a literary review, meaning it is based on literature that is currently available. We have primarily gathered information from different books, databases, and reference lists of the articles we initially read. The latter was not always available in our databases, such as PubMed, ResearchGate, and Google Scholar. We tried mainly citing newer studies and articles; however, some references are older but still relevant and fundamental for the scientific information and our thesis.

Human taxonomy

The Hominidae, whose members are known as the great apes or hominids, are a family of primates that include four extant species, one of them being the systematic genus of Homo, to which both anatomically modern humans and extinct varieties of archaic humans belong, but only the modern human species, Homo Sapiens, remain.[20] Along with the gibbons, also referred to as the lesser apes, hominids belong to the superfamily Hominoidea. Humans and their extinct species belong to the tribe Hominini.

Figure 1. Classification of Hominoidea superfamily



Retrieved from Genezys, 2019 (https://commons.wikimedia.org/wiki/File:Classification_of_genus_Pan_within_tribe_Hominini.jpg)

The genus Homo is believed to have first appeared about two million years ago. It is separated into two species: the ancient Homo Erectus and the modern Homo Sapiens, whose name is derived from the Latin for "wise man".[21] The human lineage is also thought to have diverged from the other hominoids between 5 and 8 million years ago.[22]

Human dentition

Human dentition consists of two different subgroups: heterodont and diphyodont.[23] The heterodonty is contemplated with the aid of using four teeth classes: incisors, canines, premolars, and molars. A human's functional teeth come in two generations throughout the course of their lifetime: 20 deciduous teeth and 32 permanent teeth. Those two subgroups constitute the Diphyodonty.[23, 24] The successor teeth group takes the place of the deciduous teeth and helps develop the shape of the jaws. The permanent molars are teeth that are positioned behind the deciduous dentition group with later emergence and development. Human dentition serves several purposes, not only eating and chewing but also speech.

Third molars

Third molars, also known as wisdom teeth, are teeth that are located caudally in the oral cavity. Their well-known term comes from the fact that they erupt when people were believed to acquire more wisdom in their late teens and early adulthood. Third molars are the very last teeth of the human dentition to erupt, and they typically erupt around young adulthood.[25] Third molars are occasionally associated with dental decomposition in the form of caries lesions on the adjacent teeth and difficult conditions for cleaning. They can also cause severe pain, either from the local infection and inflammation in the surrounding soft tissues, the dissemination of the infections, or pressure on the adjacent tooth or its root complex.[8] In addition, they do not always erupt into full occlusion. They are often extracted prophylactic or therapeutic due to the high risk of inflammation or an already established infection in the oral cavity.[26]

Dietary evolution

Examining human nutrition from an evolutionary viewpoint suggests several crucial turning points in our dietary history. It is evident that humans have many similarities regarding nutritional biology with their extinct ancestors.[15]

Modern humans differ from other primates by consuming a diet that is higher in quality and in variety of nutrients than what is expected for a primate our size. The adaptation to this broad-spectrum diet is reflected in the gastrointestinal and brain morphology of humans.[1, 27, 28] It seems this dietary adjustment is the product of evolutionary progressions to meet the nutritional requirements of the growing brain.

Another characteristic which is distinctive for the modern human species is the ability to cook a meal and thereby optimize the nutritional outcome of food. Humans are also able to survive, reproduce and thrive under very different and sometimes extreme conditions, and consequently on a broad spectrum of diets. These abilities have given the human species the framework for our evolutionary success.[1]

There is evidence suggesting that there was a noticeable shift in the climate about 2-3 million years ago, which resulted in far less rain and thus far less green forested areas.[29] These drier environments caused a redistribution of available resources, and the newly emerging open grasslands were most likely inhabited by a variety of both small and larger animals.[15] To be able to adapt to these environmental changes, the ancestors of the human species would have had to acquire important modifications in their foraging and co-habitual behavior to protect their homes and one another from predators.[30]

As these prehistoric humans no longer were able to rely on nutritional fruits and green leaves, they had to adapt to their new environment by hunting animals and picking roots and tubers.[15] These circumstances resulted in a substantial change in their subsistence strategies. Paleontological evidence proposes that this occurred with the appearance of H. Erectus which caused a marked redirection in human evolution.[1] H. Erectus is the species affiliated with stone tools and the development of the first primitive hunter-gatherer society and is considered H. Sapiens' most recent common ancestor.[31, 32]

It is believed that these new abilities ensured a higher of protein, fat, and minerals in their diets.[15] The newly acquired nutrients allowed growth and expansion of the brain, and concurrently detrimental behavioral and social changes. The brain grew larger in volume and surface area and started to develop complex invaginations and interconnections between different parts of the brain.[30, 33] This rapid anatomical evolution and growth of the brain demanded an even higher intake of energy in the form of fatty acids for normal brain metabolism.[34] The high metabolic cost of the human brain reflects our species' diverse and highly nutritional dietary pattern.[35]

It has been suggested that cooking allowed early hominins to improve the nutritional value of their diet. The heating of different food resources served to both soften them and increase their nutritional content.[1, 36, 37] Raw roots and tubers contain a significant amount of starch, which is not absorbable through the small intestine. If cooked, the starch granules swell and make the starch more accessible to be broken down by digestive enzymes.[38] This means that the discovery of fire and cooking made the nutrients of the food more available and softened the consistency of the food.[1, 36, 39]

Insight into when these distinctive patterns arose comes from comparative data of several prehistoric hominin species and modern humans:

Figure 2. Geological ages (Millions of Years Ago), Brain Size (cm^3), Estimated Male and Female Body Weights (kg), and Post canine Tooth surface Areas (mm^2) for Selected Fossil Hominin Species.

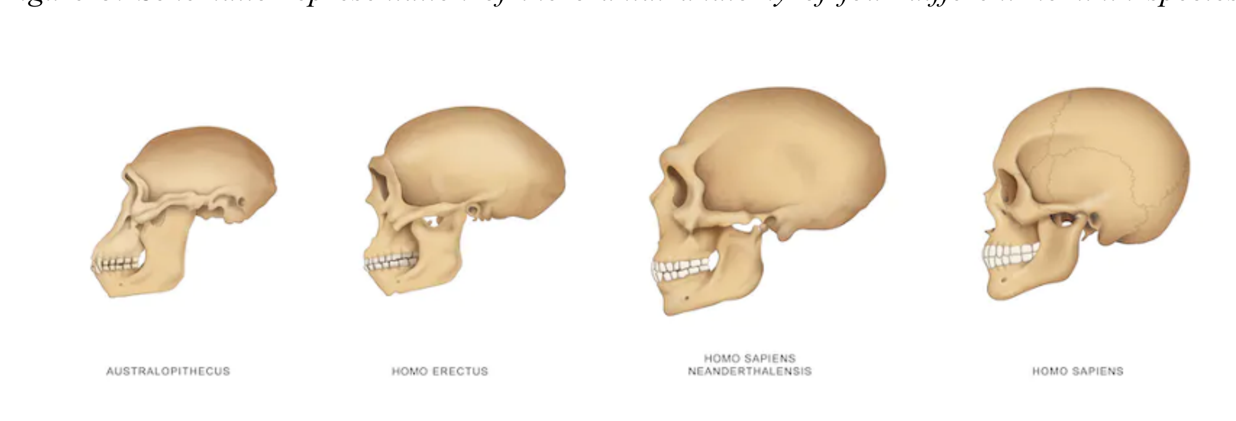
Species	Geological Age (mya)	Brain Size (cm^3)	Body Weight		Postcanine Tooth Surface Area (mm^2)
			Male (kg)	Female (kg)	
A. afarensis	3.9–3.0	438	45	29	460
A. africanus	3.0–2.4	452	41	30	516
A. boisei	2.3–1.4	521	49	34	756
A. robustus	1.9–1.4	530	40	32	588
Homo habilis (sensu strictu)	1.9–1.6	612	37	32	478
H. erectus (early)	1.8–1.5	863	66	54	377
H. erectus (late)	0.5–0.3	980	60	55	390
H. sapiens	0.4–0.0	1350	58	49	334

Retrieved from Leonard, W.R. et al., 2007, Effects of Brain Evolution on Human Nutrition and Metabolism. Annu. Rev. Nutr. 2007; 27:311-327

The rates of the evolutionary changes in the human anatomy, in particular brain and body size, were highly variable.[1, 40] The results of the H. Sapiens samples show a reduction in post canine tooth surface, indicating a simultaneous reduction in the overall size of the maxilla and mandible, with respect to the samples from the Australopithecine species, H. Habilis and H. Erectus. Despite having a smaller overall dentition and jaws, H. Erectus and H. Sapiens were and are larger animals than the Australopithecines.[32, 40]

The large discrepancy in brain volume and post canine tooth area between Australopithecines and Homo Erectus suggest that these species had different diets, both in terms of volume and nutritional value, and perhaps also in consistency. The concurrent increase in brain volume and body size, and reduction in tooth area surface may suggest that H. Erectus had a diet that was more manageable for the digestive system and richer in energy, than the Australopithecines.[1, 41]

Figure 3. Schematic representation of the cranial anatomy of four different hominin species.



Retrieved from Griskeviciene, A.
https://www.shutterstock.com/nb/image-illustration/evolution-skull-1097845550

The common notion that the primitive diet was healthy, safe, and adequate is slowly becoming more rejected. It is evident that our ancestors were faced with obstacles such as vitamin deficiencies, food-borne pathogens, and neurotoxins. Some grains and leaves may have been toxic in large quantities, and meat and fish were not guaranteed to be free of parasites.[15] Neither can adequate caloric intake be assumed in every climate or season. With the invention of modern food processing technologies came food safety and stability.

Agriculture has no single point in time of onset but is estimated to have begun approximately 12.000 years ago.[42] Different species of animals and plants have been domesticated at several places in the world at different times.[43, 44] Even though the origin of agriculture is debated, the results are evident; agriculture allowed growth and expansion so that sites became villages, and tribes became populations.

Archeologists have observed a reduction in overall body size and weight with the advent of the agriculture era. Single-crop agriculture is also proven to be the cause of growth-anomalies due to nutrient deficiency.(45, 46) Agriculture itself is not the cause of these deficiencies but rather the abandonment of the previously varied and nutrient-rich diet.(15)

The progression from a hunter-gather lifestyle to an agricultural way of life gave rise to social, economic, and cultural changes. This new way of living spread across the globe gradually, and populations began to grow in optimal settlement conditions. With the increase in population density came new forms of human dependency on nature, and consequently led to food shortages and famine. Humans compromised the shortages by controlling access to limited resources and introducing social hierarchization.(42) Some studies document smaller seasonal fluctuations in food availability consumed by the wealthier class and greater cyclic discrepancy in the availability of food for the lower class.(15) In conclusion, the onset of agriculture led to the replacement of nature by culture. In addition, it also led to trading between populations and later societies which slowly introduced the modern-day way of living.(42)

The industrial revolution, which marched through the Western World during the 18th and 19th centuries, industrialized agriculture and manifested as plentiful technological innovations and advancements, as well as new ways to handle and capitalize on available resources. Previously raw or lightly processed foods now started to become more processed with the help of the new available technologies.(42, 47)

In 2016 the book "*The fourth industrial revolution*" was published, which introduced the term (abbreviated 4IR). It has been used to describe the entire scope of human development in the early 21st century, characterized by development within technology, politics and international relations.(48) The evolutionary trends that have been seen in this era are affected by the modern major global challenges such as the climate crisis, overpopulation, and world economics. The fourth industrial revolution has revolutionized the way we produce, store and transport food over international borders.(49) This has led to the need for drying, freezing, and adding conservatives to foods, meaning that a major section of the food we consume today is no longer readily available in its raw form, but rather as a processed version of it. This entails the softening and sometimes devaluing of the nutritional value of these foods.

Table 2. Chronological survey of food acquisition and dietary behavior in nonhuman primates and human groups from prehistory and the Neolithic transition to a farming lifestyle up to the industrial revolution and the present.

	Hunter-gatherers	Neolithic period	Bronze age/middle age	Post industrial revolution
Way of life	Small nomadic groups	Sedentary, agricultural groups, profound social and cultural change	Sedentary, agricultural societies, increasing social differentiation and first elites, rise in violence	Sedentary, industrial societies, social stratification, large disparities in wealth
Dietary description	Variety of seasonally available plant food supplemented by hunting and fishing, low processed food	Intense consumption of cereals supplemented by vegetables and domestic animals, low proportion of meat, few wild animals, few dairy products, low processed food	Cereal species diversification, extension of horticultural crops, more meat consumption, more dairy, mainly low processed food	Global diets, cheap meat from factory farming is popular, bread from white flour is staple, primarily highly processed food, healthy food is expensive, organic farming is expanding, diverse food trends are rising in popularity
Food preparation	Processing with stone and bone tools, fire use, fermentation of vegetables	Fireplaces for cooking and baking, ceramic cooking vessels	Ovens for cooking and baking, metal items for food preparation and consumption	Increasingly industrialized cooking
Medical significance	Ideally biologically adapted, low birth rate and population density, communicable diseases low, chronic non-communicable diseases absent, very low rates of caries	High proportion of starchy foods, high birth rate, population density increasing, close contact between humans and animals, increase in communicable and degenerative diseases, first civilization diseases, increase in oral diseases	High proportion of starchy foods, high birth rate and population density, rise in infectious diseases, epidemics, continues increase in civilization diseases, further increase in oral diseases	Overpopulation, chronic non-communicable diseases as main cause of premature death, global pandemics, increase in mal- and undernutrition, high rates of caries and periodontal disease

Modified from the table published in Alt, KW. et al., 2022, Nutrition and health in human evolution – past to present.

Concurrent with the relatively recent industrial, technological, and societal changes came advances in medicine and odontology. Many advances in dentistry began in the 18th century, but it was mainly after the 19th and early 20th century that the specialty of orthodontics became its own well recognized branch of dentistry.

Edward Hartley Angle (1855-1930) is considered the “Father of Modern Orthodontics”. Angle developed the Angle-classification for diagnosis of malocclusions, which is still used by orthodontists all over the world today. Angle believed that malocclusion was a disease of the modern society.[50, 51]

Malocclusions are common in industrialized countries today. The growth and acceleration of malocclusion cases are believed to be related to the evolution of our species, which is guided both by increased genetic variability and the changes in our dietary and intelligence patterns.[52] Certain studies have found that modern pre-industrial populations have a significantly lower prevalence and severity of malocclusions than post-industrial populations.[52, 53] In Norway, medieval skeletal remains were compared to a sample of present-day Norwegian children. The study found that only 36% of the medieval skull sample had a professionally assessed need for orthodontic treatment, compared to 65% of the present-day sample. They concluded that this indicates a significant increase in both prevalence and severity of malocclusions over the last 400 to 700 years in Norway.[18] In Finland, there was found that 39.5% of an adult population had at least one malocclusion trait.[54] One systematic review and meta-analysis examined the prevalence of malocclusion in the different stages of dentition. The results of this study showed that the average prevalence of malocclusion worldwide was 56%, with no gender discrepancies. Furthermore, the highest prevalence of malocclusion was found in Africa (81%) and Europe (72%). America (53%) and Asia (48%) followed thereafter.[55]

Discussion

The present thesis is aimed to address the possible correlation between the change in dietary habits through evolution and dysfunctionality of third molars, in light of the increased prevalence of third molar issues and the evolution of diet. In particular, we have aimed to find out if the gradual increase in industrial processing and softening of our food could have caused permanent alterations on the human jaw anatomy and if this could have resulted in the high prevalence of impacted third molars in modern humans.

It was found that the amount of information is limited due to the topic of the present work currently still being a hypothesis. Due to its complex nature, it is difficult to establish definitive conclusions for our research questions. As the available information regarding our specific questions appeared to be partly evidence-based and partly hypothetical, we had to put the conclusions of the articles up against each other to eliminate source of bias and present all aspects of the current views of the topic.

Researchers hypothesize that fossil dentitions provide insight into primitive diets.[16, 17, 56] The findings from the examination of these fossils, combined with evidence of available food resources and primitive tools our ancestors had access to give us a somewhat reliable understanding of their diets and their impact it had on our anatomical evolution.[16, 57-59] However, measuring the dimensions of teeth of fossil skulls that are erupted in occlusion, is highly susceptible to source of bias due to the wear from the environment. However, unerupted teeth will not be subject to the same wear and can thus be used for comparative studies.[6, 60] Additionally, the fossil skulls being used for most of these comparative studies come from adult individuals, which may also act as a source of bias. We know teeth have been used as tools, as well as for mastication, for many centuries, but we do not know to which extent the extinct hominins used their teeth as tools. We also do not know much about their non-food related chewing habits. They might have been chewing on certain plants or organic materials such as bone or sticks as a behavior of habit or addiction. If so, these often-overlooked possibilities might affect the result and conclusion of any micro-wear study done on the teeth of these fossil skulls.

Nevertheless, several paleontological and anthropological studies indicate that extinct hominins survived on a diet consisting largely of coarse and abrasive food like roots, grains, tubers, and nuts, as well as tough meats.[58, 59] Dental microwear analyses of the dentition of Australopithecine species and H. Erectus suggest a diet not only rich in animal flesh, but also a high quantity of grit.[61] This type of diet caused a significant strain on the masticatory system of these primates, that along with increased biteforce and number of chewing cycles has been shown to facilitate a flatter Curve of Spee(COS), greater prognathism, and increased tooth wear, which in turn promotes better occlusion.[62-65] The strain owing the bite stimulates the alveolar bone and thereby affects the development and maintenance of it.[65] This indicates that the diets of our ancestors both caused and maintained their robust and strong jaws, which contributes to archeological skull samples revealing a lesser prevalence of malocclusions compared to modern population samples.[18] After rice farming was introduced to Japan, the incidence of discrepancy between tooth and jaw size was approximately 15%.[13] Because the food was highly processed and soft, it has been suggested that the discrepancy was brought on by a decrease in chewing activity. A decreased masticatory system would result from adaptation to minimal load.[13, 66] Numerous studies in different countries all over the world have shown a cause-and-effect connection between food and the lack of space in the dental arch.[13, 67, 68] According to the statistics, followed by the experimental evidence, the rate of discrepancy increases as the strain on the masticatory system decreases.[13, 14] A study on rats showed that malnutrition and nutritional deficiency cause issues with jaw forming and occlusion.[14] Experimental evidence of this connection has been shown.[13, 14]

Dr. Weston Price was a dentist who studied most of the primitive tribes in the world and their dietary habits. Many of these tribes were not introduced to western food and culture, like flour, sugar, and soft food. His conclusion was that because of westernized diet, people formed overcrowding and shrinkage of the size of the jaws. For comparison, he used members of the same tribe where one of them was fed with modern diet, and the other one was fed with non-westernized, indigenous diet. He then looked at the forms of the face and teeth and observed that tribes with non-westernized diet formed fully and well-developed faces with nicely aligned teeth avoiding the overcrowding of the teeth. He concludes that certain elements of the westernized diet lead to nutritional inadequacies that are the root of numerous dental disorders and health difficulties.[69]

This evolutionary perspective on malocclusions and our smaller jaws not being able to contain the comparatively large teeth is, however, not shared by all researchers across the board and thus has been challenged in recent years. H. Sapiens has smaller third molars compared to other living primates and when the third molars are bound to develop and erupt into a restricted space, they tend to decrease in size and sometimes never develop at all rather than becoming retained or impacted.[6, 60, 70]

A diet consisting of tough and abrasive food has been the norm for most of human history.[1, 15, 42] This took a prominent turn after the industrial revolution that occurred in the Western world in the 18th to 19th centuries. The post-industrial populations in England consumed a very different diet from their predecessors.[4, 42, 47] The new technologies that arose during the industrial revolution resulted in changes in food regarding not only availability, production, and consumption but also nutritional value and consistency.[42] This, in turn, caused a significant growth in sugar consumption and the use of finely milled flour.[42, 71] During the 20th century came the invention of fast food along with similar inventions like microwavable meals and numerous kinds of snacks full of highly processed carbohydrates.[72] Briefly, the abrasive foods became replaced by softer foods that did not cause as significant of a strain on the masticatory system as the earlier, tougher, and abrasive diets. These changes altered the orofacial morphology and, in turn, also the occlusion.[3, 4] Research on the effects of mastication on orofacial development showed that modern day children that consume a diet consisting of largely processed food will more likely experience skeletal or dentofacial malocclusion and tooth impaction[3]. Another experimental study measuring mandibular growth according to dietary consistency and masticatory strain in the rock hyrax[65] showed that the adult dentition of this animal, which has comparable dynamic jaw movement and distribution of masticatory force as humans, has the shape that is most suitable for mastication according to the shape, consistency, and friction of the food that has been masticated during development. Some researchers state that animals and post-industrial indigenous human tribes who eat food primarily in their raw or slightly processed form infrequently have impacted teeth,[3, 69] which suggests that recent changes in human environmental, cultural and societal factors are to blame for the complications regarding malocclusion and third molars.[6, 73, 74]

Despite having smaller jaws, the presumptive problem is that modern humans still have as many teeth as their predecessors. As a result, there is an issue with the third molars trying to erupt into a restricted room[13, 70]. However, an examination of the jaws and teeth of a fossil skull called "The

Qafzeh 9 specimen", from the Qafzeh Cave in Israel, concluded that malocclusions were present in early anatomically modern humans.(53) These analysis results challenge the sentiment that early anatomically modern humans had less to no cases of malocclusion, and that malocclusion is a disease of the modern post-industrial era. It also challenges the common notion that soft foods have been the cause of the increasing prevalence of malocclusion, meaning that it rather might be genetics that plays a more significant role.(53, 75, 76) This leads back to the question of bias, stating that the skulls being analyzed for other similar comparative studies mainly being from adult individuals.(18, 57, 77) The skull analyzed for this study was estimated to be between 16 and 21 years old due to the open root apices of the third molars.(53) Due to the short-lived life of the Qafzeh 9 specimen, the teeth of this individual would not have been subject to the same amount of attrition, in particular inter-proximal attrition, as many of the other fossil skulls that have been analyzed by other researchers cited in this thesis. Still, it is important to keep in mind that the research done on the Qafzeh 9 specimen also might be prone to bias, considering it was the only specimen examined, and from this, the researchers drew a general conclusion.

With the basis of the available research today, it would not be controversial to claim that third molar impaction is becoming more common in the world's population while not occurring as frequently prior to the industrialization of our food. Impaction prevents the tooth from reaching its optimal position in the oral cavity within the estimated time frame. As a result of the adjacent teeth, a dense bone structure, abundant soft tissue, or a hereditary anomaly, teeth may become partially or fully impacted.(5, 78) The most common reason for third molar complications, in particular impaction, is believed to be a lack of space in the dental arch.(19) Third molars are the most likely teeth to become impacted, and those in the mandible are more predisposed than those in the maxilla.(78, 79) This is most likely due to the fact that they are the last teeth to erupt according to normal eruption pattern.(5, 9) After the rest of the teeth have found their place in the dental arch and become well aligned, the space might be too restricted for the third molars.

The third molar's inability to erupt properly due to the lack of space, is frequently to blame for the tooth's incorrect direction. This results in malposition of the teeth, where they tend to tilt mesially or distally, or in some cases buccally or lingually within the osseous limits of the jaw.(5, 79)

The impacted third molar can cause a series of pathological complications for the patient. Most often, the pathology manifests as pericoronitis. This can cause pain, bad taste and smell, general discomfort, dysphagia, and trismus.(8, 80) It is either treated conventionally or with antibiotics. If not treated, or if there are no results of the primary treatment, the condition can worsen and, in rare cases, spread to a systemic infection.(5)

The prevalence of the mandibular third molars is more than 72% in a Swedish population between the ages of 20 to 30 years.(81) Third molar complications seem to be growing in number of cases. Whether they are impacted, partially, or completely erupted, they are frequently surgically removed as a prophylactic solution to prevent later discomfort and infection.(26) Prophylactic removal of the third molars is becoming more common in our modern dental clinics, which brings the hypothesis that an organ that is not used and often removed to hinder further complications may die down by natural selection during the evolutionary process.(6, 26) So, will the human species still have third molars in the future, or will we eventually lose them completely? It has been documented that early human species have also experienced missing third molars, but it has become more common as the Homo species has evolved.(3, 53) However, it is also believed that genetics play a significant role regarding this issue.(82) Many researchers believe that agenesis (*def. "lack or failure of development (as of a body part)"*) of third molars is determined by genetics. A clinical study on same-sex twins, both monozygotic and dizygotic, has been conducted to determine the impact of heritability of third molar agenesis in twins.(83) They concluded that agenesis of third molars is strongly affected by additive genetics. However, they also concluded that further research on larger populations was necessary to assess the true role of genes, epigenetics, and environment more precisely.(83)

Conclusion

This literary review aimed to investigate the correlation between dietary habits and dysfunctionality of third molars in light of the increased prevalence of third molar complications in recent human history and the evolution of diet. Our specific questions were as follows:

- Has the gradual increase in industrial processing and softening of our food caused permanent alterations on the human jaw anatomy?

The data found for this literary review suggests that there have been changes in localization and development in the maxilla and mandible. They have become smaller and narrower compared to the extinct hominins, resulting in smaller dental arches, which often restrict all of the teeth from erupting into a well-aligned position. The cause of this is hypothesized to be a combination between the changes in dietary habits throughout human history. The shift from primitive diet consisting of tough and abrasive food to an industrialized diet which consists largely of soft and processed food, resulted in a lesser requirement for mastication. This, in turn, fails to stimulate the alveolar bone sufficiently to develop strong and robust jaws, similar to what the extinct hominins had.

- Is the anatomical evolution of our jaws the reason for the high prevalence of complications regarding third molars in modern humans?

Due to the shorter dental arches in modern humans, third molars often have trouble with development and eruption. As a result, their functionality seems to have the tendency to die down in the general population. It goes without saying that smaller jaws and restricted space in the dental arch result in several dental issues, such as impaction, overcrowded teeth, agenesis and malocclusions.

Although changes in subsistence strategies are shown to have some correlation with the anatomical evolution of the jaws of humans, and thereby the increase in the prevalence of third molar complications, it cannot be held solely responsible as the only contributing factor. Evidence also suggests malocclusion and third molar complications are influenced by genetics and environmental factors.

The topic in question is understood to be subject to a multifactorial etiology, so that more multidisciplinary research would be beneficial for a better understanding.

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