Atlantic J Med Sci Res 2024;4(4):102-8
DOI: 10.5455/atjmed.2024.09.016

THE ATLANTIC Journal of Medical Science and Research

Original Article

Sevda Canbay Durmaz[1], Gunes Bolatli[2]

[1]Mardin Artuklu University, Faculty of Medicine, Department of Anatomy, Mardin, Türkiye
[2]Yalova University, Faculty of Medicine, Department of Anatomy, Yalova, Türkiye

Received: 26 September, 2024
Accepted: 18 November, 2024
Published: 16 December, 2024

Corresponding Author: Sevda Canbay Durmaz, Mardin Artuklu University, Faculty of Medicine, Department of Anatomy, Mardin, Türkiye
Email: sevdacnby@hotmail.com

CITATION
Canbay Durmaz S, Bolatli G. Changes in human skull anatomy from past to today: Systematic review. Atlantic J Med Sci Res. 2024;4(4):102-8. DOI: 10.5455/atjmed.2024.09.016

Changes in human skull anatomy from past to today: Systematic review

Abstract

Aim: Changes in human populations and anatomical features are explained by various evolutionary processes, with cranial diversity being among the most striking. The skull is composed of three regions with distinct developmental origins: the cranial vault, face, and skull base. Skull morphology is known to have evolved significantly over centuries. This study aims to systematically examine anatomical changes in the skull and its formations over time by reviewing studies on skull morphology.
Materials and Methods: The systematic review was conducted between November 8, 2023, and December 20, 2023. Publications were accessed by searching PubMed, Springer, and Google Scholar databases using the keywords “human evolution”, “cranial anatomy evolution”, and “evolution homo skull”.
Results: A total of 82,043 articles were initially identified through the search. Of the 16 studies selected for in-depth review, 10 provided data on the geographic regions to which the skulls belonged, and 6 provided data on their estimated time period. All studies analyzed skull morphology through three-dimensional imaging, which was generated using various computer software programs.
Conclusion: Our review of studies examining skull morphology across different centuries suggests that factors such as time, temperature, location, climate, and environmental conditions contribute to variations in skull shapes and sizes. The findings indicate that skull morphology shows greater similarity across certain groups at younger ages, with differentiation increasing over time.

Keywords: Human evolution, cranial anatomy evolution, evolution of Homo skull, systematic review

INTRODUCTION

Human history, which spans thousands of years, has been the focus of curiosity and study across many scientific fields. In biological classification, humans are categorized within the genus Homo. Existing human populations display considerable diversity on both biological and behavioral levels, leading to species-level classifications among early human groups (e.g., Homo habilis, Homo erectus, Homo neanderthalensis, and Homo sapiens). While the exact number of species is debated, estimates suggest there may have been between 7 and 12 distinct species, though this figure could rise as new fossil discoveries are made. All these species are regarded as "human". Today, Homo sapiens is the only known surviving human species, and the term "anatomically modern human" is often used to describe Homo sapiens specifically (1).

The estimated age of Homo sapiens was long thought to be around 200,000 years, but dating advancements in 2017 extended this estimate to approximately 315,000 years (2). Although the exact origin of Homo sapiens remains uncertain, several hypotheses exist (3). One prominent theory proposed that Homo sapiens emerged as a single species in South Africa about 70,000 years ago and subsequently spread worldwide. However, recent

DOI: 10.5455/atjmed.2024.09.016

research and discoveries of human fossils in Africa, dating back 200,000 to 400,000 years, indicate that multiple human species coexisted rather than a single lineage (4).

Changes in human populations and body structures can be attributed to various evolutionary processes, with cranial diversity being one of the most notable (5,6). Brain size and behavioral complexity have consistently been considered fundamental characteristics in the study of evolution, drawing significant attention in evolutionary anthropology. However, distinctions among skulls of different human species remain subtle and are not always easily discernible (7). Research on human evolutionary history spans multiple scientific disciplines, including physical anthropology, paleoanthropology, primatology, archaeology, linguistics, genetics, and embryology (8). Understanding the anatomical changes in the human skull continues to be an area of interest.

The skull is composed of three regions with distinct developmental origins: the cranial vault, face, and skull base. Among these, the skull base is the oldest structure (9). Research suggests that changes in the skull base are more strongly governed by genetic factors compared to changes in the cranial vault and face (10). Thus, the skull base serves as a foundational region that connects with facial structures and influences overall skull development. By contrast, morphological changes in the face are influenced by both genetic and non-genetic factors, such as environmental adaptation (11). Skull morphology is known to change continuously over time (7). Therefore, this review aims to examine anatomical changes in skull morphology and formations across time.

MATERIALS AND METHODS

This article is a systematic review conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol for systematic reviews and meta-analyses (12,13). To minimize potential bias, literature searches, article selection, data extraction, and quality assessment of articles were performed independently by two researchers. The study protocol was registered in the PROSPERO database (Registration Number: CRD42023488672).

Scanning Strategy

Searches for this systematic review were conducted between November 8, 2023, and December 20, 2023. Publications were accessed by searching the PubMed, Springer, and Google Scholar databases using the keywords "human evolution", "cranial anatomy evolution", and "evolution homo skull". Reference lists of studies included in this review were not examined.

A total of 82,043 articles were initially identified. To narrow down relevant studies, the first researcher screened the titles and abstracts to assess their relevance to the topic. The second researcher independently reviewed and evaluated these titles and abstracts as well. Duplicate studies were identified and removed. Studies available in full text and meeting the inclusion criteria were then reviewed in detail by both researchers. Sixteen articles were ultimately selected for evaluation in this systematic review.

To minimize bias:

- Keywords were selected carefully following preliminary research.
- As the study focuses on measured dry bone samples, sample bias risk is negligible.
- The research process was conducted by two independent reviewers.

Inclusion Criteria

In this systematic review, inclusion criteria were defined according to the PICOS framework (P: Population/Participants, I: Interventions, C: Comparisons, O: Outcomes, S: Study Design) (JBI, 2014) (9):

- **Participants:** Studies that include human skull bone remains.
- **Interventions:** Analysis of skull remains, specifically examining volume and shape.
- **Comparison Groups:** Comparisons between the cranial bones of modern humans and those of ancient humans.
- **Outcomes:** Evaluation of anatomical evolutionary changes in cranial bones.
- **Study Design:** Full-text studies available in English.

Exclusion Criteria

The following publications were excluded from the systematic review:

- Studies not available in full text.
- Studies written in languages other than English.
- Publications that were not original research articles.

RESULTS

Out of the 16 studies reviewed, 10 provided data on the regions to which the skull samples belonged, and 6 included data on the approximate age of the skulls. All studies measured skull characteristics by converting samples into three-dimensional images using specialized computer software.

Table 1 summarizes each study, listing the publication year, sample size, journal name, region of origin, estimated age of the skull samples, and criteria used for comparison. Sample sizes varied, with the smallest study including 2 samples and the largest comprising 361 samples.

DOI: 10.5455/atjmed.2024.09.016

Table 1. Summary of studies reviewed

Study name	Journal name, year of publication	Skull information	Number of samples
1. Moderate climate signature in cranial anatomy of late Holocene human populations from Southern South America	American Journal of Physical Anthropology, 2017	South and North America (No year information)	361
2. Heritability of human cranial dimensions: comparing the evolvability of different cranial regions	Journal of Anatomy, 2009	Austria (18th-19th century)	355
3. The evolution and development of cranial form in Homo sapiens	PNAS, 2002	H. sapiens, Pleistocene H. sapiens, Archaic Homo spp. (No year and location information)	119
4. Middle Cranial Fossa Anatomy and the Origin of Modern Humans	The Anatomical Record, 2008	22 chimpanzees, 51 modern human and 14 fossil skulls (No year and location information)	87
5. The cranial base and related internal anatomical features in Homo neanderthalensis and Homo sapiens	The Anatomical Record, 2021	1. La Chapelleaux-Saints, H. neanderthalensis (young male); 2. Pataud 1, France (young adult female, 28,000 and 26,000 years old)	2
6. A frontal lobe surface analysis in three archaic African human fossils: OH 9, Buia, and Bodo	Human Palaeontology and Prehistory, 2017	OH 9 (Homo erectus), Bodo (between Homo erectus and later Pleistocene humans), UA 31 (combination of Homo erectuslike and derived features)	3
7. Endocranial ontogeny and evolution in early Homo sapiens: The evidence from Herto, Ethiopia	PNAS, 2022	160,000 years ago, Herto, Ethiopia	175 (50 fossils, 125 people)
8. Comparing Frontal Cranial Profiles in Archaic and Modern Homo by Morphometric Analysis	The Anatomical Record, 1999	More than 32,000 years old, 5 Pleistocene and Neanderthal skulls, 16 modern humans (Central Europe)	21
9. Sulci 3D mapping from human cranial endocasts: A powerful tool to study hominin brain evolution	Hum Brain Mapp, 2021	Bones from the Pretoria bone collection	20
10. A New Virtual Reconstruction of the Ndutu Cranium	Heritage, 2023	Cranium fragments found in Tanzania	11
11. Reconstructing cranial evolution in an extinct hominin	Royal Society Publishing, 2021	Most parts from 130,000 years old, Ngandong and Sambungmacan/ Ngawi	32
12. Brain size and organization in the Middle Pleistocene hominins from Sima de los Huesos. Inferences from endocranial variation	Journal of Human Evolution, 2019	Spain, Ruins from different times: Homo erectus, Middle Pleistocene Homo, H. neanderthalensis, Fossil H. sapiens	16
13. Massive cranium from Harbin in northeastern China establishes a new Middle Pleistocene human line-age	The Innovation, 2021	146,000 years ago, Chinese	95
14. Temporal lobe evolution in Javanese Homo erectus and African Homo ergaster: Inferences from the cranial base	Quaternary International, 2021	Homo erectus (South Africa)	51
15. Three-dimensional geometric morphometric study of the Xuchang 2 Cranium	Journal of Human Evolution, 2023	Homo erectus, Middle Pleistocene, Neanderthals, early modern, and current modern humans (Chinese)	35
16. Cranial base topology and basic trends in the facial evolution of Homo	Journal of Human Evolution, 2016	Middle and Late Pleistocene hominins	10

DOI: 10.5455/atjmed.2024.09.016

3. Content Analysis

Study 1:

This study focused on the impact of seasonal changes on cranial morphology. Findings showed that the facial skeleton in hotter regions is generally larger, while the skull and skull base are larger in colder regions. Samples from cold and semi-arid climates exhibited smaller, rounder facial structures, narrower nasal bones, and broader cheekbones (14).

Study 2:

This study compared hereditary characteristics and genetic diversity in skull morphology. Results indicated that the facial region demonstrated the highest hereditary traits (81%), while the overall facial circumference (including maximum facial width, length, and height) showed moderate heritability. The orbital, nasal (height and length), and zygomatic regions exhibited the most genetic diversity, whereas nose width displayed minimal genetic variation (7).

3. Study

Study 3:

This study examined cranial development trends, noting increases in facial retraction and neurocranial sphericity. Researchers observed that facial and neurocranial changes begin early, reflecting the combined effects of brain development and growth over time (8).

Study 4:

This study analyzed changes in the fossa crani media. Notable findings included unique transformations in structures such as the apex petrosa, porus acousticus internus, foramen ovale, foramen rotundum, and foramen opticum. Measurements revealed significant differences in these structures over time (15).

Study 5:

This study examined external facial development in the temporal bone. Findings indicated that, compared to modern skulls, historical samples showed the zygomatic bone positioned more inferiorly along the fossa mandibularis eminentia articularis, a thicker and more circular external auditory meatus, a wider sphenoparietal sinus, and a broader proc mastoideus. The overall endocranial structure, however, was similar to that of modern humans (16).

Study 6:

This study focused on frontal lobe development. Findings suggested that the endocast of ancient specimens was smoother and longer than that of modern humans. Additionally, the endocast in modern humans displayed wider lateral frontal lobes and longer orbital regions compared to historical specimens (17).

Study 7:

This study analyzed endocranial and viscerocranial growth variations in Homo sapiens fossils. Results showed that fossil samples had a larger endocranium compared to modern human skulls. However, when comparing skulls of modern human children to fossil children, no significant differences were observed (18).

Study 8:

In this study, researchers found that the modern human skull has remained relatively unchanged when compared to fossil remains in Central Europe over the past 500,000 years. The most notable difference identified was in the arcus superciliaris (brow ridge) (19).

Study 9:

This study represents the first documentation of sulcus patterns on the lateral surface of the brain using community-based atlas techniques applied to human skull surfaces. Cranial fossils were scanned with CT, and sulcus models were generated. The study found significant overlaps in the sylvian fissure, occipital fissures, and calcarine sulcus when compared to modern human patterns (20).

Study 10:

Comparison of NDUTU crania with modern human skulls showed that the NDUTU samples exhibit a lower, more prognathic facial structure, narrower cranium, and reduced, narrower supraorbital projection (21).

Study 11:

This study identified evolutionary differences in frontal bone development between Homo erectus and Homo sapiens populations from Israel, China, Kenya, Papua New Guinea, Australia, and the Andaman Islands. Results indicated that cranial variation was greater in H. erectus, with these differences attributed to brain development processes (22).

Study 12:

Early Neanderthals and later Neanderthals show both similarities and differences in brain size and skull anatomy when compared to fossil modern humans. The brain volume of Early Neanderthals is similar to that of Middle Pleistocene Homo, with a smaller volume than classic Neanderthals but with a greater expansion in the posterior (temporo-parietal and occipital) regions. Classic Neanderthals, however, had relatively elongated brain structures, particularly in the anterior regions. Key differences in frontal and occipital bone anatomy between classic Neanderthals and modern humans are thought to be associated with parietal cortex enlargement (23).

Study 13:

This sample skull, with a cranial capacity comparable to modern humans (~1,420 mL), features a highly voluminous cranial dome and a wide supraorbital torus. The base and palate structures are broad, with a relatively low facial height in profile and a large upper face and nasal opening. While the zygomaxillary area is transversely flat, resembling Homo sapiens morphology, the skull reaches its widest point in the supramastoid region, with pronounced mastoid processes below (24).

DOI: 10.5455/atjmed.2024.09.016

Study 14:

Comparisons between fossil samples revealed that Homo sapiens has a relatively larger middle cranial fossa compared to other species. Additionally, Homo erectus possesses a middle cranial fossa that is both longer and wider than that of Homo ergaster (25).

Study 15:

This study found that Homo erectus has smaller cranial and cerebellar lobes compared to other Homo species, with a notably larger nuchal plane than that of Homo sapiens (26).

Study 16:

Over the past 500 years, brain size in humans has increased, while facial area dimensions have shown a corresponding decrease (27).

DISCUSSION

Our systematic review of studies examining skull morphology across various historical populations indicates that factors such as time, environmental temperature, geographical location, climate, and other natural conditions have contributed significantly to variations in skull shape and size. These findings suggest that early skull morphology among certain Homo species exhibits greater similarity, while differences become more pronounced with age.

When examining fossil remains, it becomes evident that the evolutionary trajectory from early species to modern humans unfolded through five distinct stages. The first group includes early genera such as Sahelanthropus, Orrorin, and Ardipithecus, which existed approximately 4 to 7 million years ago. In the second stage, members of the genus Australopithecus emerged, living between roughly 4 million and 1 million years ago. The third stage saw the appearance of robust Paranthropus species, which inhabited regions from approximately 2.5 to perhaps 1 million years ago. During the fourth stage, transitional forms appeared with characteristics intermediate between Australopithecus and Homo, but were taxonomically classified within the genus Homo. This stage includes species such as Homo antecessor, estimated to have emerged around 800,000 years ago, and Homo heidelbergensis, which appeared about 600,000 years ago. Finally, anatomically modern humans, Homo sapiens, emerged approximately 200,000 years ago (28).

In the studies we reviewed, fossil specimens include those from Australopithecus africanus, Homo erectus/ergaster, Homo heidelbergensis s.l., and Homo sapiens. These fossils were excavated across diverse regions, including South and North America, Australia, the Awash River Valley in Ethiopia, Central Europe, Tanzania, Spain, China, and South Africa. Over the last 10 million years, global climate shifts have significantly impacted both human evolution and other living species. In particular, temperature fluctuations are thought to have strongly influenced body size, limb proportions, hand and foot dimensions, and skull anatomy (29,30).

However, cranial features-such as the cranial vault, facial skeleton size and shape, temporal bone dimensions, orbital area, maxillary and zygomatic bones, and nasal cavity structure-also show significant correlations with temperature variations. Generally, individuals residing in colder climates tend to have larger and more robust cranial structures compared to those in warmer regions (31,32).

In South America, where agricultural communities are predominantly located in the north and hunter-gatherer groups in the south, observed relationships between temperature and cranial structure may actually stem from nutritional differences across communities. Including diet as a variable in models of skull morphology would therefore help clarify the distinct contributions of ecological factors to cranial shape variation. Recent studies also suggest that elevation may be one of the primary environmental influences on skull morphology; however, the specific mechanisms underlying this relationship remain unexplored (33).

The brain volume of Homo erectus ranges from approximately 775 to 1300 cm^3. Its skull features a prominent and well-developed arcus superciliaris (brow ridge) and a pronounced occipital protuberance at the back. Unlike modern humans, Homo erectus lacks the menton, or chin protrusion, resulting in a flatter jaw profile. The facial skeleton is broad with a prognathic (forward-projecting) structure, while the teeth are generally similar to those of later human species. With the control of fire, Homo erectus began cooking food, which influenced both dietary habits and living conditions (34).

Due to the presence of Homo erectus in diverse environments around the world over the past 1.5 million years, some regional variations are observed within this species. Although morphological differences among these fossils are minimal, they have historically been classified under various names, including Pithecanthropus erectus, Meganthropus paleojavanicus, Sinanthropus pekinensis, and Archanthropus (35). Since the 1960s, however, there has been a movement to unify these fossil classifications under the name Homo erectus to reduce scientific ambiguity (36).

Neanderthals are characterized by a low, backward-sloping forehead and a long, flat skull with a flattened roof. Their eyebrow arches are prominently developed in the middle, and they possess a large cranial capacity, ranging from approximately 1300 to 1750 cc. Their facial structure is broad with a prominent midface, high cheekbones, and large sinuses. The jawbone is robust, with sizable teeth, particularly large front teeth, which were likely used as tools. Additionally, their limb bones, particularly the calves and forearms, are curved, and they have short, stout fingers.

Some anthropologists suggest that Neanderthals' larger brain size relative to Homo sapiens contributed to their adaptability in cold climates. The wide nasal cavity is also thought to have facilitated adaptation to cold by allowing greater airflow and warming of inhaled air before reaching the lungs, thus retaining warmth longer in the body (37,38).

DOI: 10.5455/atjmed.2024.09.016

CONCLUSION

From past to present, skull morphology has evolved due to factors like climate, environmental conditions, natural pressures, and time. Research on this topic remains active, with ongoing studies aimed at understanding these changes in greater detail. Given the continued advancements in technology and shifts in human living conditions, it is likely that subtle changes in the human skull and bone structure will continue into the future.

Limitations

The limitation of our study is that we only scanned articles written in English and for which we had access to the full text.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Ethics committee approval is not required for this study.

REFERENCES

1. Aytek Aİ.; Kozmopolit aydınlar. Paleolitik dönem anadolu insanları. https://evrimteorisionline.com/2017/09/07/paleolitik-donem-anadolu-insanlari/ access date 07.09.2017
2. Hublin JJ, Ben-Ncer A, Bailey S. et al. New fossils from Jebel Irhoud, Morocco and the pan-African origin of Homo sapiens. Nature. 2017;546:289-92. Erratum in: Nature. 2018;558:E6.
3. Tracy DK. Hominin Evolution I. In: Abed R, St John-Smith P, eds, Evolutionary Psychiatry: Current Perspectives on Evolution and Mental Health. Cambridge universty press. 2022;35-44.
4. Tokalak I. İnsanlığın son bin yılı. 1st edition. Ataç Publications. 2019;63-75.
5. Lieberman DE. The evolution of the human head. Harvard University Press. 2011;20-8.
6. Reyes-Centeno H, Ghirotto S, Harvati K. Genomic validation of the differential preservation of population history in modern human cranial anatomy. Am J Phys Anthropol. 2017;162:170-9.
7. Martínez-Abadías N, Esparza M, Sjøvold T, et al. Heritability of human cranial dimensions: comparing the evolvability of different cranial regions. J Anat. 2009;214:19-35.
8. Lieberman DE, McBratney BM, Krovitz G. The evolution and development of cranial form in Homosapiens. Proc Natl Acad Sci U S A. 2002;99:1134-9.
9. Weinfield NS, Sroufe LA, Egeland B, Carlson E. Individual differences in infant-caregiver attachment: Conceptual and empirical aspects of security. In: Cassidy J, Shaver PR, eds, Handbook of attachment: Theory, research, and clinical applications. The Guilford Press. 2008;2:78-101.
10. Schilling, TF, Thorogood P. Development, Growth and Evolution. Implications for the Study of the Hominid Skeleton. Antropologia Biologia, Bienni. 2000;41-7.
11. Siebert JR, Swindler DR. Evolutionary changes in the midface and mandible: establishing the primate form. Understanding craniofacial anomalies, 2022;343-78.
12. Deliktaş A, Kabukcuoğlu K, Kış A. Meta-analysis application process in nursing: a guide intended for methodology. Journal of Human Sciences. 2016;13:1906-25.
13. Karaçam Z. Systematic review methodology: a guide to preparing systematic reviews. Dokuz Eylül University Faculty of Nursing Electronic Journal. 2013;6:26-33.
14. Paula Menéndez L. Moderate climate signature in cranial anatomy of late holocene human populations from Southern South America. Am J Phys Anthropol. 2018;165:309-26.
15. Bastir M, Rosas A, Lieberman DE, O'Higgins P. Middle cranial fossa anatomy and the origin of modern humans. Anat Rec (Hoboken). 2008;291:130-40.
16. Balzeau A, Pagano A. The cranial base and related internal anatomical features in Homo neanderthalensis and Homo sapiens. The Anatomical Record. 2022;305:2030-7.
17. Beaudet A, Bruner E. A frontal lobe surface analysis in three archaic African human fossils: OH 9, Buia, and Bodo. Comptes Rendus Palevol. 2017;16:499-507.
18. Zollikofer CPE, Bienvenu T, Beyene Y, et al. Endocranial ontogeny and evolution in early Homo sapiens: The evidence from Herto, Ethiopia. Proc Natl Acad Sci U S A. 2022;119:e2123553119.
19. Bookstein F, Schäfer K, Prossinger H, et al. Comparing frontal cranial profiles in archaic and modern homo by morphometric analysis. Anat Rec. 1999;257:217-24.
20. de Jager EJ, Risser L, Mescam M, et al. Sulci 3D mapping from human cranial endocasts: A powerful tool to study hominin brain evolution. Hum Brain Mapp. 2022;43:4433.
21. Montiel G, Lorenzo C. A new virtual reconstruction of the Ndutu Cranium. Heritage. 2023;6:2822-50.
22. Baab KL. Reconstructing cranial evolution in an extinct hominin. Proceedings of the Royal Society B, 2021;288:20202604.
23. Poza-Rey EM, Gómez-Robles A, Arsuaga JL. Brain size and organization in the Middle Pleistocene hominins from Sima de los Huesos. Inferences from endocranial variation. J Hum Evol. 2019;129:67-90.
24. Ni X, Ji Q, Wu W, et al. Massive cranium from Harbin in northeastern China establishes a new Middle Pleistocene human lineage. Innovation (Camb). 2021;2:100130.
25. Pearson A, Polly PD, Bruner E. Temporal lobe evolution in Javanese Homo erectus and African Homo ergaster: Inferences from the cranial base. Quaternary International. 2021;603:5-21.
26. Zhang Y, Li Z. Three-dimensional geometric morphometric study of the Xuchang 2 cranium. J Hum Evol. 2023;178:103347.
27. Bastir M, Rosas A. Cranial base topology and basic trends in the facial evolution of Homo. J Hum Evol. 2016;91:26-35.

DOI: 10.5455/atjmed.2024.09.016

28. Kaya F. Human evolution in East Africa under the influence of environmental and paleoclimatic factors. Kebikeç. 2016;41:259-81.

29. Sepulchre P, Ramstein G, Fluteau F, et al. Tectonic uplift and Eastern Africa aridification. Science. 2006;313:1419-23.

30. Betti L, von Cramon-Taubadel N, Lycett SJ. Human pelvis and long bones reveal differential preservation of ancient population history and migration out of Africa. Human Biology. 2012;84:139-52.

31. Hubbe M, Hanihara T, Harvati K. Climate signatures in the morphological differentiation of worldwide modern human populations. Anat Rec (Hoboken). 2009;292:1720-33.

32. Terhune CE, Kimbel WH, Lockwood CA. Postnatal temporal bone ontogeny in Pan, Gorilla, and Homo, and the implications for temporal bone ontogeny in Australopithecus afarensis. Am J Phys Anthropol. 2013;151:630-42.

33. Heng HH. The genome-centric concept: resynthesis of evolutionary theory. Bioessays. 2009;31:512-25.

34. Angel JL. Paleodemography and evolution. American Journal of Physical Anthropology. 1969;31:343-53.

35. Howell FC. The place of Neanderthal man in human evolution. Am J Phys Anthropol. 1951;9:379-416.

36. Henke W. Historical overview of paleoanthropological research. Handbook of Paleoanthropology. Heidelberg: Springer-Verlag. 2007;1-14.

37. Şimşek F. Paleolitik dönemde insan türleri. Amisos. 2017;2:66-85.

38. Başoğlu O. The paleodemographic structure of human throughout the evolution period. Electronic Journal of Social Sciences. 2010;9:341-9.