ANATOMICAL VARIABILITY OF THE SHAPE AND DIMENSIONS OF THE INFRATEMPORAL FOSSA IN POSTNATAL HUMAN ONTOGENESIS

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https://doi.org/10.35339/ic.2026.13.2.kss

ABSTRACT

Background. The complex configuration of the infratemporal fossa and the many bones forming it make it difficult to study. Analysis of individual variability within the normal range is the basis for minimizing surgical trauma in maxillofacial surgery, neurosurgery, otorhinolaryngology, and for correct interpretation of Computed Tomography (CT) data.

Aim. To determine the age-related morphometric parameters (anteroposterior dimension, width, and height) of the right and left infratemporal fossae in postnatal human ontogenesis.

Materials and Methods. The material included 28 dry human skull specimens of both sexes from the collection of Bukovinian State Medical University (BSMU) and 49 head CT examinations of patients aged 1–60 years without bone pathology. The anteroposterior dimension, width, and height were measured by digital morphometry in RadiAnt DICOM Viewer with 3D reconstruction. Age-related changes were described by logarithmic regression ($y = a + b \cdot \ln(x)$) with the coefficient of determination (R^2) and the 95% confidence interval; normality was verified by the Shapiro–Wilk test, $p<0.05$. Processing: "IBM SPSS Statistics" 26.0 (IBM, USA). The study is a fragment of the research topic of the Department of Anatomy, Clinical Anatomy and Operative Surgery of BSMU (state registration No.0125U001531).

Research Ethics. The study was performed in accordance with the World Medical Association Declaration of Helsinki (1964–2024) and was approved by the Commission on Biomedical Ethics of BSMU (protocol No.2 of October 16, 2025). Written informed consent was obtained from all adult participants and from the parents or guardians of the children.

Results. The ontogenetic patterns are described by logarithmic regression. The anteroposterior dimension showed the strongest association with age (R^2=0.754); for height (R^2=0.698) and width (R^2=0.667) it was lower. The maximum increase in all linear parameters was observed between 1 and 5 years, with the greatest scatter at 15–25 years. Between 30 and 60 years, the parameters acquire relative constancy: anteroposterior dimension, 45.0–51.0 mm; width, 32.0–34.0 mm; height, 45.0–49.0 mm.

Conclusions. Postnatal transformation of the dimensions of the infratemporal fossae follows a logarithmic pattern, strongest in the anteroposterior direction (R^2=0.754). Development is two-phase: maximum linear growth from 1 to 5 years and definitive dimensions at 20–25 years; from 30 to 60 years, the parameters remain relatively constant.

Keywords: *theoretical medicine, medical radiology, postnatal ontogenesis, digital morphometry, logarithmic regression, computed tomography.*

Introduction

Due to the general development of science and technology and the widespread adoption of technological advances (Computed Tomography (CT), magnetic resonance imaging, and ultrasound) across all branches of medicine, the interest of researchers in these technologies is also increasing. Although anatomists mainly perform dissections, prepare anatomical specimens and study cadaveric material, in recent years they have been intensively developing a new direction – *in vivo* age-related anatomy [1–3]. At present, it is relevant not only to establish the chronological sequence of development and the specific features of the structure, position and shape of organs and structures of individual

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body regions, but also to determine the morphometric parameters of organs and formations and to clarify their syntopic and functional relationships throughout human ontogenesis [4–6].

Extreme variants of variability of a feature within the normal range are also of interest from the viewpoint of practical medicine. A lack of knowledge of extreme variants in the shape, structure, and morphometric characteristics of organs, bone, muscular, and neurovascular formations in different body regions, particularly in the lateral aspect of the skull, is often associated with medical errors. Within the normal range, quantitative changes are not accompanied by qualitative ones [7; 8]. One manifestation of variability is the variation of a feature within bilateral symmetry, termed dissymmetry [9; 10].

The anatomical complexity of the skull is associated not only with the large number of bones that form it, but also with the enormous diversity of their size, shape, and thickness. The radiological image of even isolated skull bones is rather difficult to interpret; this becomes many times more complicated when the skull as a whole is examined, with the summation of the shadows of numerous bone details. As is known, CT makes it possible to eliminate these difficulties and to represent the radiological image of bone elements in separate preselected layers [11; 12].

The complex configuration of the infratemporal fossa, the depth of its location, and the large number of bone structures involved in its formation cause certain difficulties in its radiological study, particularly in establishing the sex- and age-related dynamics of changes in morphometric parameters of the infratemporal fossa in the postnatal period of human ontogenesis [13].

Determination of accurate morphometric parameters of the infratemporal fossa and their sex- and age-related dynamics is of decisive importance for modern clinical medicine, particularly for maxillofacial surgery, neurosurgery, and otorhinolaryngology. Since this deep space of the facial skull contains such vital structures as the mandibular nerve, the pterygoid venous plexus and the maxillary artery, any surgical interventions or manipulations (for example, conduction anesthesia) in this region require the physician to have a precise knowledge of topographic and anatomical landmarks. Detailed morphometric analysis not only minimizes the risk of accidental injury to neurovascular bundles during surgical approaches to the skull base but also provides an individualized treatment, taking into account the constitutional and age-related characteristics of the patient [14–16].

In addition, a clear understanding of *in vivo* anatomy and the extreme variants of individual variability of the infratemporal fossa is a fundamental basis for the correct interpretation of radiological diagnostic data [17–19]. The complex three-dimensional architecture of the infratemporal fossa and its direct communication with the pterygopalatine fossa, orbit, temporal fossa and cranial cavity [11; 12] determine a high probability of spread of infectious-inflammatory processes and tumor invasion [20]. Without knowledge of age- and sex-related standards for volume, linear dimensions and angular characteristics of the walls of the infratemporal fossa, it is impossible to identify early destructive or deformational changes in bone structures promptly, which once again emphasizes the scientific and practical relevance of studying this anatomical formation in the postnatal period of ontogenesis.

The aim of the present study was to determine the age-related morphometric parameters (anteroposterior dimension, width, and height) of the right and left infratemporal fossae during the postnatal stages of human ontogenesis.

Materials and Methods

The material used to clarify the anatomical variability of the shape and dimensions of the right and left infratemporal fossae in people of different ages comprised 28 dry human skull specimens of both sexes from the collection of the morphological departments of Bukovinian State Medical University (BSMU), as well as 49 head CT examinations obtained in different age periods (from 1 to 60 years) of postnatal human ontogenesis in individuals without bone pathology.

Using digital morphometry tools in "RadiAnt DICOM Viewer" 2025.2 (Medixant, Poland), the anteroposterior dimension, width, and height of the infratemporal fossa were measured. CT scans from the collection of the Department of Anatomy, Clinical Anatomy and Operative Surgery of Bukovinian State Medical University were used.

The linear characteristics of the infratemporal fossa were determined according to the following topographic landmarks:

• anteroposterior dimension: measured as the distance from the dorsal edge of the base of the temporal process of the zygomatic bone to the ventral edge of the condylar process of the mandible;

• width: assessed as the distance between the outer wall of the lateral plate of the pterygoid process and the inner edge of the mandibular ramus;

• height: determined as the length of the vertical vector drawn from the infratemporal surface of the

greater wing of the sphenoid bone to the horizontal level corresponding to the lower edge of the lateral plate of the pterygoid process.

To clarify the spatial and temporal transformations and variant anatomy of the human infratemporal fossa under normal conditions, we considered it appropriate to use computer 3D reconstruction models in this anatomical study, covering the age range from 1 to 60 years (*Fig. 1, 2*).

Statistical processing was performed in IBM SPSS Statistics 26.0 (IBM, USA). Age-related changes in the dimensions of the infratemporal fossa (anteroposterior dimension, width, and height) were evaluated by logarithmic regression modeling ($y = a + b \cdot \ln(x)$); the goodness of fit of the model was assessed by the coefficient of determination (R^2) and the 95% Confidence Interval (CI). Normality of the distribution was assessed using the Shapiro–Wilk test. A value of $p<0.05$ was considered statistically significant.

In our work, the classification of age periodization of human life was used, according to which mature age includes men aged 22–60 years and women aged 21–55 years. This classification is recommended by the Ministry of Health of Ukraine (letter No.08.01-22/2472 of December 9, 2008).

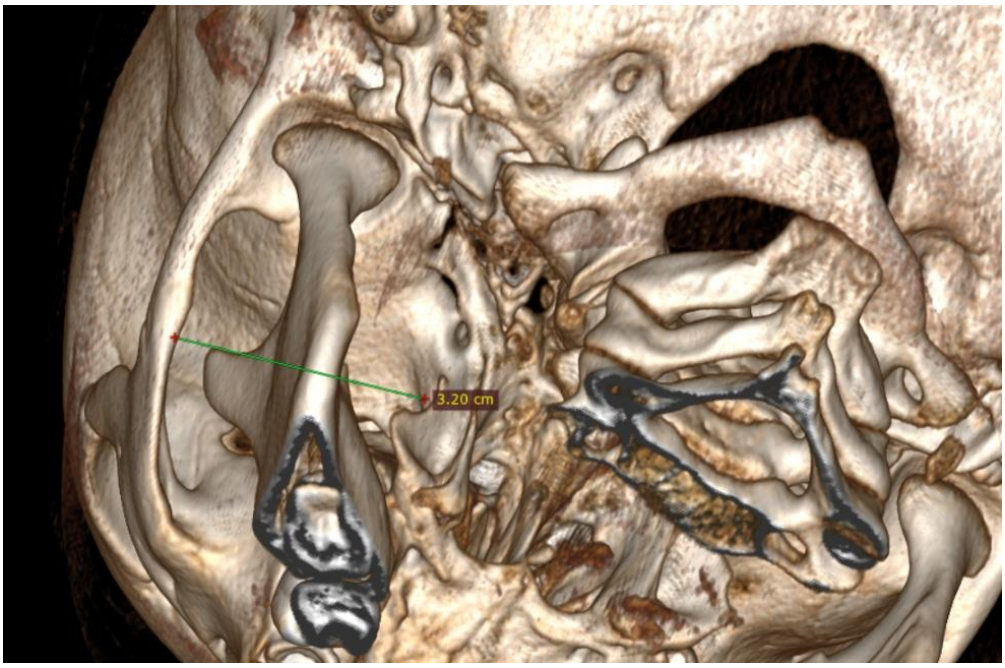


Fig. 1. 3D reconstruction of a series of CT scans of the head of a 23-year-old person. Left inferior projection

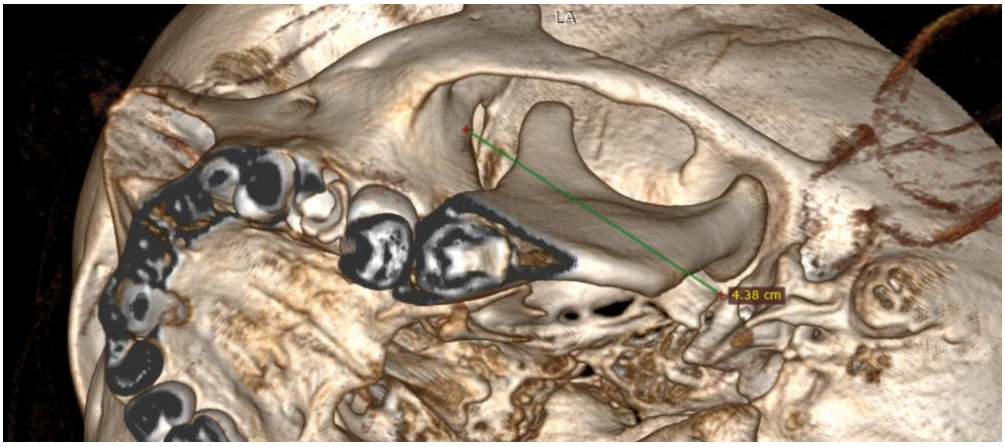


Fig. 2. 3D reconstruction of a series of CT scans of the head of a 23-year-old person. Left inferolateral projection

CT scans of individuals of both sexes aged from 1 to 60 years were obtained from the collection of the Department of Anatomy, Clinical Anatomy and Operative Surgery of Bukovinian State Medical University.

Research Ethics

The study was conducted in accordance with the main bioethical provisions of the Council of Europe Convention on Human Rights and Biomedicine (of April 4, 1997), the Declaration of Helsinki of the World Medical Association on ethical principles for medical research involving human subjects (1964–2024), and Order of the Ministry of Health of Ukraine No.690 of September 23, 2009. The Commission on Biomedical Ethics of BSMU (Protocol No.2 of October 16, 2025) found no violations of moral and legal norms in the research.

Written informed consent was obtained from all adult participants, and from the parents or legal guardians of all enrolled children prior to data collection.

Results

The changes in the anteroposterior dimension of the infratemporal fossa in human postnatal ontogenesis were considered first (*Fig. 3*).

The graph (*Fig. 3*) shows the relationship between the anteroposterior dimension and age. The mathematical model is described by the logarithmic regression equation (1):

$$y = 31.19 + 4.92 \cdot \ln(x) \quad (1),$$

where: y – the anteroposterior dimension of the infratemporal fossa, mm; x – the age of the subject, years.

The coefficient of determination R^2 is 0.754, indicating a high-quality model: approximately 75.4% of the variability in the anteroposterior dimension of the infratemporal fossa is explained by age-related changes in the subjects. This model also includes shaded zones on both sides of the trend line, which visualize the 95% CI.

The nature of the logarithmic curve demonstrates uneven dynamics of this parameter with age. In early life (approximately up to 10 years), a rapid, almost linear increase in the anteroposterior dimension is observed, from minimum values (28.0 mm) to maximum values of approximately 41.0–43.0 mm.

Such intensive development has a profound anatomical basis, since at this time teeth erupt, the primary occlusion is formed, and the masticatory apparatus develops intensively; this directly acts as a mechanical stimulus for active modeling of the bones of the facial and cerebral skull, particularly

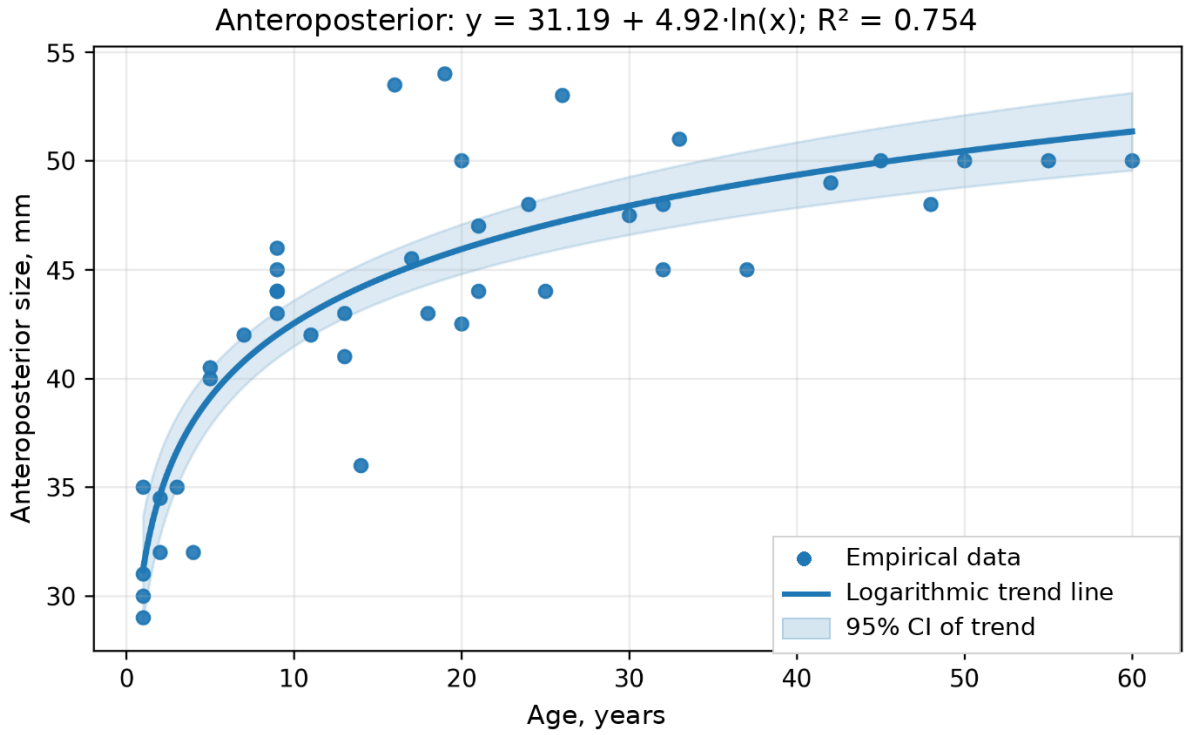


Fig. 3. Regression diagram of the anteroposterior dimension of the infratemporal fossa against age, with a 95% confidence interval of the trend

the greater wing of the sphenoid bone and the ramus of the mandible.

Starting from adolescence and early adulthood (after 15–20 years), the growth rate slows considerably and enters a plateau phase. In adulthood and mature age (from 30 to 60 years), the anteroposterior dimension remains relatively stable, ranging from 45.0 to 51.0 mm, which indicates completion of the active processes of infratemporal fossa formation.

The distribution of empirical data indicates individual variability among the subjects. The greatest scatter of points (dispersion) relative to the trend line is noticeable in the age range from 5 to 25 years, where both pronounced upward outliers (for example, values over 53.0 mm at 16–19 years) and downward outliers (approximately 36.0 mm at 14 years) are present. In contrast, in the older age group (after 40 years), the results become more clustered and almost ideally fall within the 95% CI, confirming the stability of this anthropometric or anatomical parameter of the infratemporal fossa in mature age. Changes in the width of the infratemporal fossa in the postnatal period of human ontogenesis were also analyzed (*Fig. 4*).

Fig. 4 shows the relationship between the width of the infratemporal fossa and age. The mathematical model was constructed using a logarithmic regression equation (2):

$$y = 21.93 + 3.00 \cdot \ln(x) \quad (2),$$

where: y – the width of the infratemporal fossa, mm; x – the age of the subject, years.

The coefficient of determination (R^2) is 0.667, indicating a moderately strong relationship: 66.7% of the variation in the width of the infratemporal fossa is explained by the age of the subjects. The light-green area around the regression line indicates the 95% CI, which remains stable throughout the trend, confirming the reliability of the model.

The maximum increase in the width of the infratemporal fossa is observed in early childhood, from 1 to 5 years. During this period, the logarithmic curve rises steeply, increasing from a minimum of 21.0 mm to approximately 27.0 mm. Such rapid dynamics indicate intensive development and active widening of the anatomical object at the initial stages of life. After the age of 10 years, the rate of this process noticeably decreases. This intensive development in the width of the infratemporal fossa has a profound anatomical basis, since during this period the permanent occlusion and transverse (lateral) dimensions of the skull are

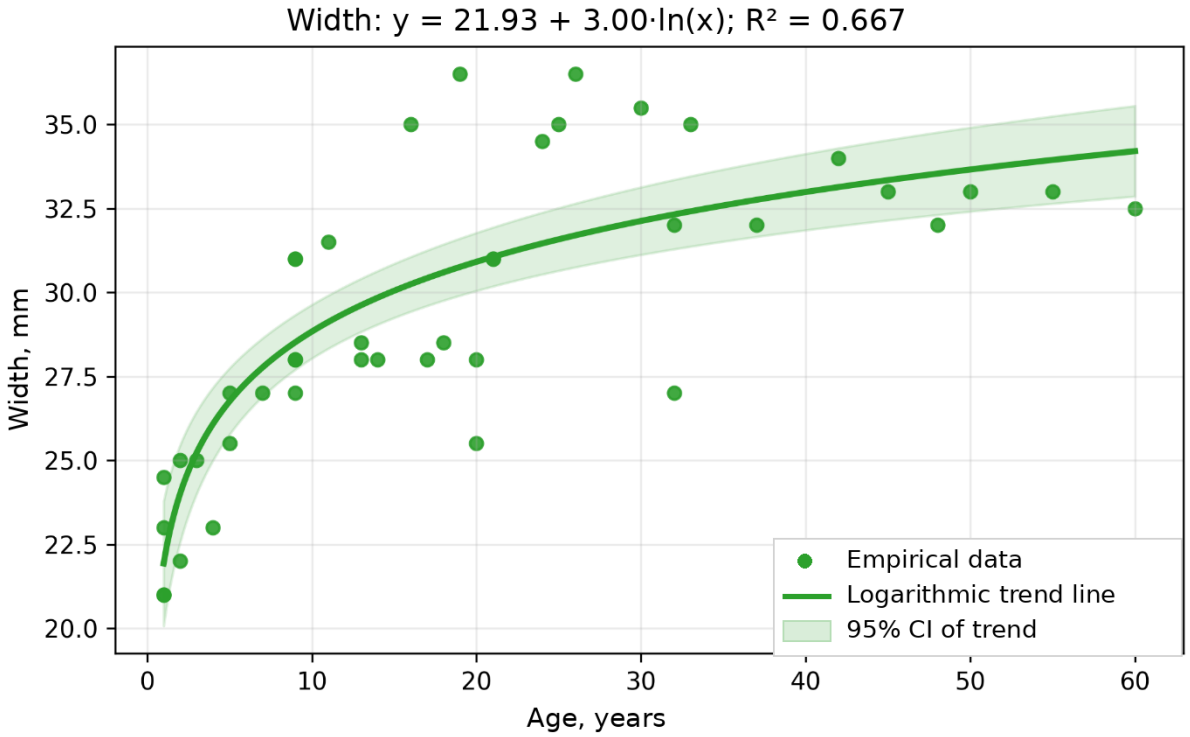


Fig. 4. Regression diagram of the width of the infratemporal fossa against age, with a 95% confidence interval of the trend

actively formed, accompanied by lateral growth of the mandibular ramus and an increase in the angle of departure of the lateral plate of the pterygoid process.

A substantial slowdown in the increase in the width of the infratemporal fossa and a transition to a phase of relative plateau occur after 20 years. In the age interval from 30 to 60 years, the trend line levels off and shows a minimal rise (within 32.0–34.0 mm), indicating almost complete cessation of active growth in the width of the infratemporal fossa in mature age. It is also worth noting the high individual scatter of data between 15 and 35 years, with considerable fluctuations (upward deviations of points to 36.5 mm and downward to 25.5 mm), indicating unevenness and individual features of stabilization of this parameter of the infratemporal fossa in young age.

Changes in the height of the infratemporal fossa in human postnatal ontogenesis were analyzed (*Fig. 5*).

Fig. 5 shows the age dynamics of changes in the height of the infratemporal fossa from birth to 60 years. The relationship between the features is modeled using a logarithmic regression equation (3):

$$y = 25.35 + 5.75 \cdot \ln(x) \quad (3),$$

where: y – the height of the infratemporal fossa, mm; x – the age of the subject, years.

The coefficient of determination (R^2) is 0.698, indicating good predictive power of the model: approximately 69.8% of the variation in the height of the infratemporal fossa is explained by the age of the subjects. The shaded zone around the trend line demonstrates the limits of the 95% CI, which slightly widen toward older age due to the lower density of points.

The maximum increase in the height of the infratemporal fossa is observed in early childhood (from 1 to 5 years). At this stage, the logarithmic curve rises steeply upward, demonstrating a jump in values from minimum values of 17.0–23.0 mm to approximately 35.0 mm. Such a rapid increase in the height of the infratemporal fossa is characteristic of active phases of growth and formation of the organism. After this period, beginning at approximately 10 years of age, the growth rate of the infratemporal fossa gradually begins to decline.

A substantial slowdown in the increase in the height of the infratemporal fossa and a transition

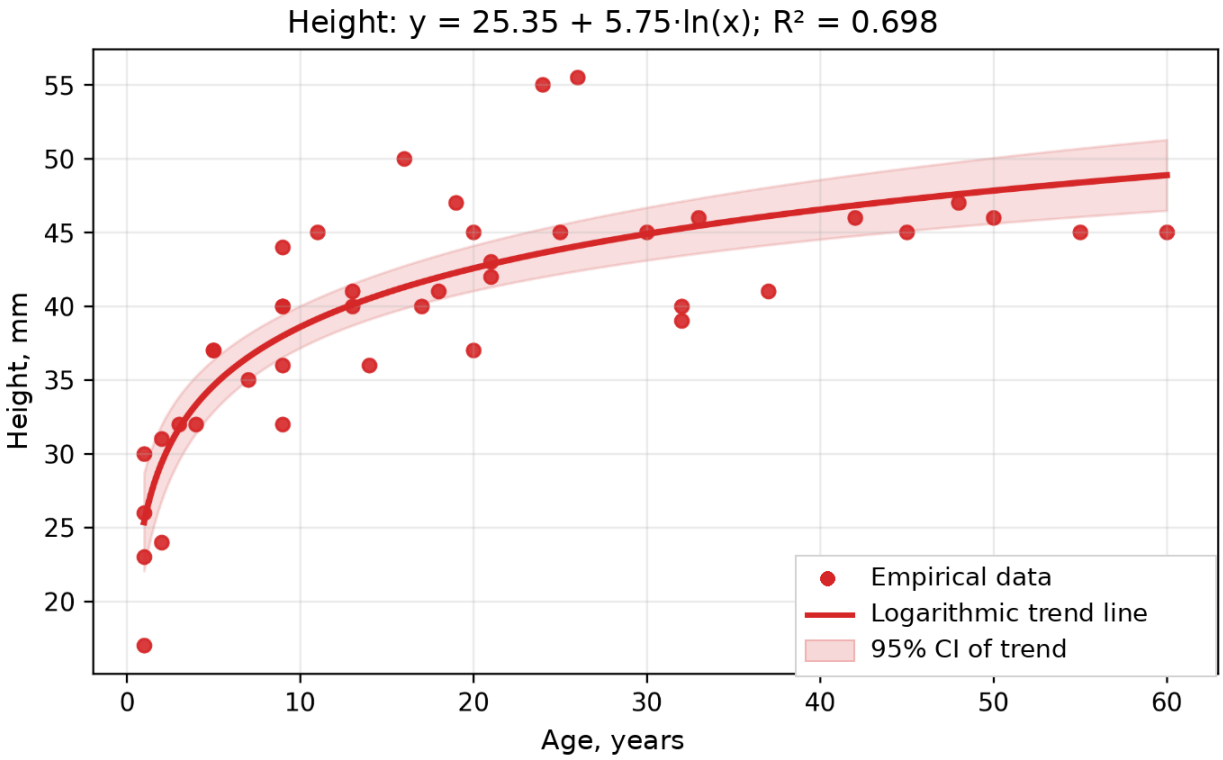


Fig. 5. Regression diagram of the height of the infratemporal fossa against age, with a 95% confidence interval of the trend

to a plateau occur after 20–25 years. In the age interval from 30 to 60 years, the regression line becomes nearly flat, showing minimal change (within 45.0–49.0 mm). This indicates final stabilization of the height of the infratemporal fossa in mature age. It should also be noted that the greatest individual scatter of data is observed in the period from 10 to 25 years: pronounced maxima (over 55.0 mm at ages 24–26 years) are present, reflecting significant variability in developmental rates during adolescence and early adulthood.

Discussion

Analysis of the presented regression models made it possible to establish clear mathematical patterns of ontogenetic transformation of the linear parameters of the infratemporal fossa within the age interval from 1 to 60 years. A common feature across all three geometric dimensions (anteroposterior dimension, width, and height) is a pronounced nonlinear developmental pattern, best described by logarithmic functions. The identified regularity is consistent with fundamental biological principles of allometric growth of most human organs and tissues, which are characterized by intensive primary differentiation and gradual stabilization of definitive dimensions in mature age [21; 22].

The most significant contribution of the age factor was recorded for the anteroposterior dimension of the infratemporal fossa, where the coefficient of determination reached the highest value (R^2=0.754). This indicates that more than 75% of the variability of this feature is strictly determined by age-related processes. For height (R^2=0.698) and width (R^2=0.667), this indicator is somewhat lower, suggesting a greater level of influence of extraneous endogenous and exogenous factors (for example, genetic predisposition, somatotype, or sex-related differences) on the formation of these spatial axes [23; 24]. A similar discrepancy in the strength of the relationship among different linear parameters of the same anatomical formation is typical for morphometric studies and is described in the literature as a manifestation of spatial asymmetry in growth [25].

Critical analysis of the dynamics of the regression curves made it possible to clearly differentiate two key periods of ontogenesis: the phase of hyperbolic growth and the phase of stabilization. The maximum rate of increase in all three parameters of the infratemporal fossa occurs in the first decade of life, with particular emphasis on the interval from 1 to 5 years. During this period, a steep vertical rise of the trend lines is observed. This coincides with the period of the most intensive nonlinear growth of the bones of the cranial base and the facial skull described for the same age interval [26], when the bones that bound the fossa, above all the lateral plate of the pterygoid process, acquire their definitive spatial relationships [27]. Closer to the pubertal period (12–15 years), the growth gradient gradually declines.

Complete slowing of growth processes of the infratemporal fossa and transition of the curves to a conditional plateau are recorded after reaching 20–25 years of age. In the age range from 30 to 60 years, the linear parameters acquire relative constancy (anteroposterior dimension, 45.0–51.0 mm; width, 32.0–34.0 mm; height, 45.0–49.0 mm). It should be emphasized that within the age range of 15–25 years, the greatest individual scatter of empirical data (dispersion) is observed, visualized by individual points extending beyond the limits of the 95% CI. This variability in the obtained results indicates individual differences in development: in adolescence and early adulthood, growth rates differ substantially, as some individuals mature faster and others more slowly. Mechanical loading of the region by the masticatory muscles is one of the factors that shape these differences [28], and the variability of the bony walls of the fossa persists into adulthood [29]. In contrast, in the individuals older than 40 years, the data become homogeneous and cluster closely around the trend line, indicating that within the age range studied the parameters of the infratemporal fossa remain stable, unlike structures in which age-related remodeling continues into the later decades of life [30].

Study Limitations. The analyzed sample was restricted to individuals up to 60 years of age, so the cross-sectional dataset does not allow definitive conclusions regarding age-related involutionary changes or late remodeling of the infratemporal fossa in elderly populations. The linear parameters were obtained from two different types of material (dry skulls and CT scans) measured using different techniques and were analyzed as a single pooled set. The right and left fossae were not compared with each other; no comparison between male and female subjects was performed; the size of the sample was not substantiated by a power analysis; and the intra- and interobserver reproducibility of the measurements was not assessed. The study was carried out in a single center. Further investigations incorporating cohorts aged 61 years and older, separate analysis of the sides and of the sexes, and an assessment of measurement reproducibility are required to evaluate the morphological changes across the entire lifespan.

Conclusions

1. The changes in the anteroposterior dimension, width, and height of the infratemporal fossa between 1 and 60 years are nonlinear and are best described by logarithmic regression models. The highest degree of dependence on the age factor was observed for the anteroposterior dimension of the infratemporal fossa (R^2=0.754), somewhat lower for its height (R^2=0.698) and width (R^2=0.667).

2. Two key stages of infratemporal fossa ontogenesis were determined: the phase of maximum increase in all three linear parameters in early childhood (1–5 years) and the stabilization phase (plateau) after 20–25 years. In the age interval of 30–60 years, the parameters of the infratemporal fossa reach definitive values and remain within the following ranges: anteroposterior dimension, 45.0–51.0 mm; width, 32.0–34.0 mm; height, 45.0–49.0 mm.

3. The highest dispersion of empirical data is observed in adolescence and early adulthood (15–25 years), which is caused by heterochrony of individual developmental rates. After 40 years, variability is minimized, and the parameters are tightly clustered around the trend line, confirming the stability of infratemporal fossa parameters up to 60 years of age.

Funding and Acknowledgments

The study is a fragment of the comprehensive research topic of the Department of Anatomy, Clinical Anatomy and Operative Surgery of BSMU, "Sex- and age-related patterns of ontogenetic transformations and morphometric parameters of organs and structures under normal and experimental conditions. Morphofunctional and anthropometric features of the musculoskeletal system in athletes" (state registration No.0125U001531, period of implementation 01.2025–12.2029).

Author Contributions

Contribution / Authors	A	B	C	D	E	F
Khmara T.V.	+			+	+	+
Soltys R.M.	+	+	+	+		+
Soltys O.M.	+		+			+

Notes: A – concept; B – design; C – data collection;
D – statistical processing and interpretation of data;
E – writing or critical editing of the article;
F – approval of the final version for publication and agreement to be responsible for all aspects of the work.

Declarations

Conflict of interest is absent.

All authors have agreed to the publication of the article under the terms of the Creative Commons BY-NC-SA 4.0 licence and of the public agreement with Kharkiv National Medical University as the founder and publisher of the journal, and to the processing and publication of their personal data.

The authors of the manuscript declare that in the process of conducting research, preparing, and editing this manuscript, they did not use any generative artificial intelligence tools or services to perform any of the tasks listed in the Generative Artificial Intelligence Delegation Taxonomy (GAIDeT, 2025). All stages of the work (from the development of the research concept to the final editing) were performed without the involvement of generative artificial intelligence, exclusively by the authors.

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Received: 29 Mar 2026
Accepted: 29 Jun 2026
Published: 30 Jun 2026

Cite in Vancouver style as: Khmara TV, Soltys RM, Soltys OM. Anatomical variability of the shape and dimensions of the infratemporal fossa in postnatal human ontogenesis. Inter Collegas. 2026;13(2):10p. In press. https://doi.org/10.35339/ic.2026.13.2.kss

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