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PECULIARITIES OF MORPHOGENESIS AND VARIANT ANATOMY OF THE MANDIBLE IN HUMAN FETUSES

Summary

In order to determine the regularities of morphogenesis, variant anatomy and dynamic peculiarities of space-time changes in the mandibular structure at the early period of human ontogenesis 60 specimens of human fetuses 160,0–450,0 mm of their parietal-coccygeal length (4–9th months of the intrauterine development) were examined using a complex of traditional and up-to-date methods of morphological study (anthropometry, computed tomography, morphometry, making the series of sequential histologic sections, microscopy, three-dimensional computer reconstruction, statistical analysis). The regularities of individual anatomical variability, sex-age and constitutional peculiarities of the mandibular structure in the fetal period of human ontogenesis are determined. Critical periods of ontogenesis of mandibular morphogenesis at the pre-natal term of human ontogenesis are detected. Reconstructive and mathematical models of the mandible to determine its functional morphology and embryo topography are designed.

Introduction

Exploration of sources, examination of chronologic sequence of the main embryogenesis periods and clarifying peculiarities of the mandibular structure in age dynamics of its development is a topical issue of

morphology. Answering these issues will enable to develop new and improve existing preventive measures, methods of early diagnostics and surgical correction of congenital defects of the human mandible [1]. Congenital malformations of the human maxillofacial area occupy the third position among congenital defects. Annually approximately 600 children are born in Ukraine with maxillofacial defects, in an average for every region – from 15 to 46 cases a year [4–6]. Cosmetic defects usually referred as a result of congenital maxillofacial deformities can be considered as psycho-traumatic conditions. Thus, in case of various kinds of mandibular pathology patients are functionally inadequate, since such vital functions suffer as chewing, swallowing, breathing, articulation. In addition, various degree of facial asymmetry may occur, distorting children which lead to social maladjustment and development of a complex of general inferiority. Defects or/and mandibular hypoplasia not eliminated in childhood cause coarse secondary deformities of the facial bones which respond to treatment with great complications at the senior age [2; 3].

The analysis of scientific sources of information is indicative of the fact that a certain lack of evidence concerning comprehensive morphological studies of the maxillofacial structures, age anatomy of the human mandible is experienced. The data concerning peculiarities of mandibular development are fragmentary and disputable, and therefore they do not satisfy the needs of modern practical medicine.

Therefore, clarification of peculiarities of mandibular development, formation of its structural variants and regularities of space-time changes during the period of human ontogenesis will enable to substantiate scientifically development and implementation of new methods of prevention, early diagnostics and timely rational surgical correction of congenital maxillofacial human defects.

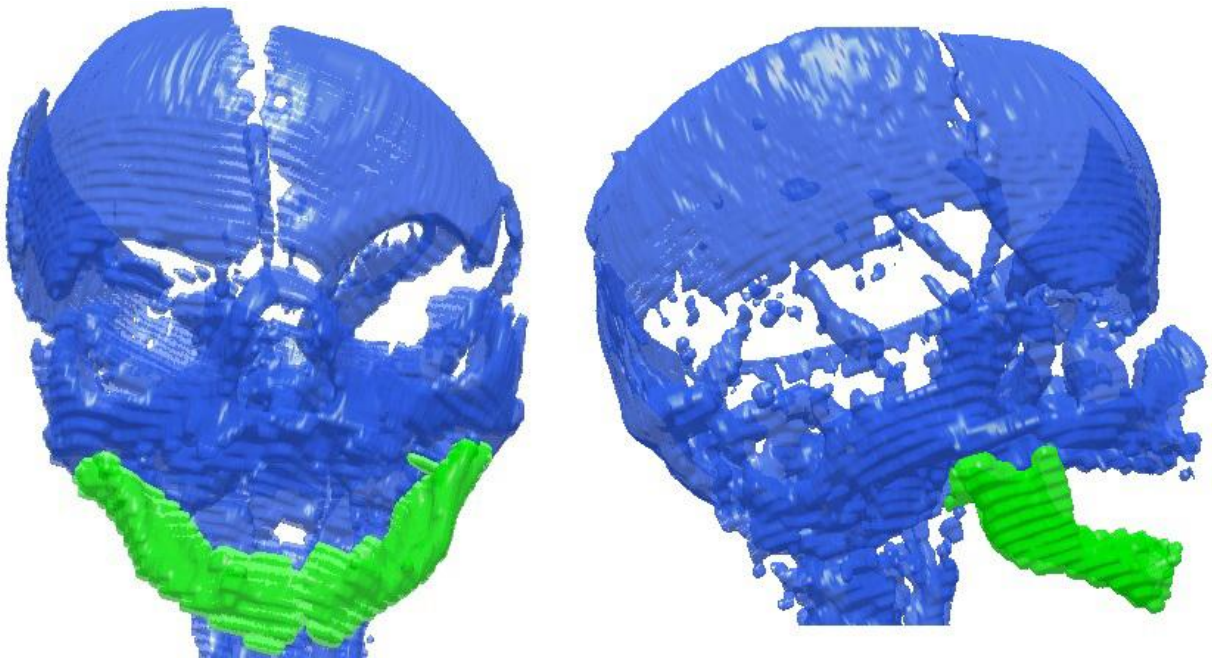
Objective – to determine individual anatomical variability, sex-age and constitutional peculiarities of the mandibular structure during the fetal period of human ontogenesis, to find out critical periods of mandibular morphogenesis and design reconstructive and mathematical models of the organ in order to determine peculiarities of its functional morphology and embryo topography.

1. Materials and methods

60 specimens of human fetuses 160,0–450,0 mm of their parietal-coccygeal length (PCT) (4–9^{th} months of the intrauterine development) were examined. A complex of methods of morphological examination was applied including anthropometry, computed tomography, morphometry, making the series of sequential histologic sections, microscopy, three-

dimensional computer reconstruction, statistical analysis. All the studies were conducted according to the major bioethics GCP principles (1996), European Convention on Human Rights and Biomedicine (04.04.1997), the World Medical Association Declaration of Helsinki – Ethical Principles for Medical Research (1964–2013), the Orders of the Ministry of Public Health of Ukraine № 690 dated 23.09.2009, № 616 dated 03.08.2012, and according to methodical guides. Morphometric parameters of fetal human heads (linear size, angles and mandibular volume) were obtained due to measurement of three-dimensional reconstructions of the mandibular models (Fig. 1–3) by means of specialized computer programs for reconstruction and analysis of computed tomograms (3D-doctor 4.0, RadiAnt DICOM Viewer). Constitutional K type coefficient was calculated by the results of measurements according to the formula (Yu.N. Vovk, 2009) [7]:

K = interparietal distance / frontal-parietal distance x 100



A **B**

Fig. 1. Three-dimensional reconstruction of head computed tomogram of 5-month human fetus. A – frontal view, B – right lateral view

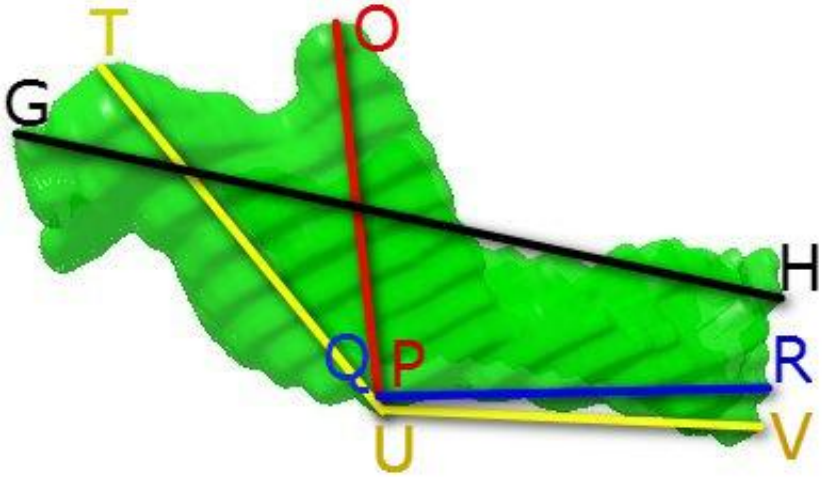


Fig. 2. Three-dimensional reconstructive mandibular model of 5-month human fetus in the lateral view with position-finding points and measuring lines. O-P – mandibular height; Q-R – mandibular body length; G-H – maximal mandibular length;<TUV – mandibular angle

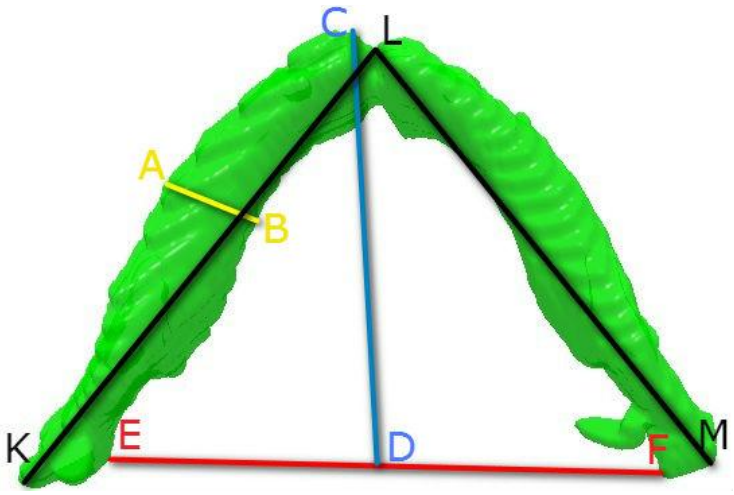


Fig. 3. Three-dimensional reconstructive mandibular model of 5-month human fetus in the horizontal plane with position-finding points and measuring lines. A-B – mandibular body thickness; C-D – mandibular length in the sagittal plane; E-F – distance between mandibular articular processes;<KLM – mandibular body angle

2. Results and discussion

Clarification of regularities of sex-age and individual variability of the human organs and systems in the process of development is a topical issue of morphological studies. Comprehensive knowledge concerning the

peculiarities of dynamic changes of the mandibular morphometric parameters in correlation with age, sex and the type of constitutional coefficient will enable to determine precisely the degree of fetus maturation by means of prenatal diagnostic methods, to implement preventive and diagnostic measures of structural variants and congenital defects of the maxillofacial human area.

Dynamic changes of the major mandibular morphometric parameters in correlation with age, sex and the type of constitutional coefficient have been investigated by means of the methods of multiple-factor regression analysis.

Analysis of distance interrelations between the articular mandibular processes and age, sex and constitutional type in human fetuses (Fig. 4, 5) demonstrated practically similar dynamic changes of this morphological index in fetuses of both sexes with the biggest and mean values of the constitutional type coefficient. Although, female fetuses with the lowest constitutional type coefficients (dolichomorphic type) since the 6th months of the intrauterine development demonstrate accelerated growth rates of the distance between the mandibular articular processes, and the dynamics of acceleration is close to a linear one. Therefore, a conclusion can be drawn that the distance between the articular mandibular processes is characterized by extreme forms of anatomical variability (the highest parameters) in female fetuses of brachymorphic constitutional type.

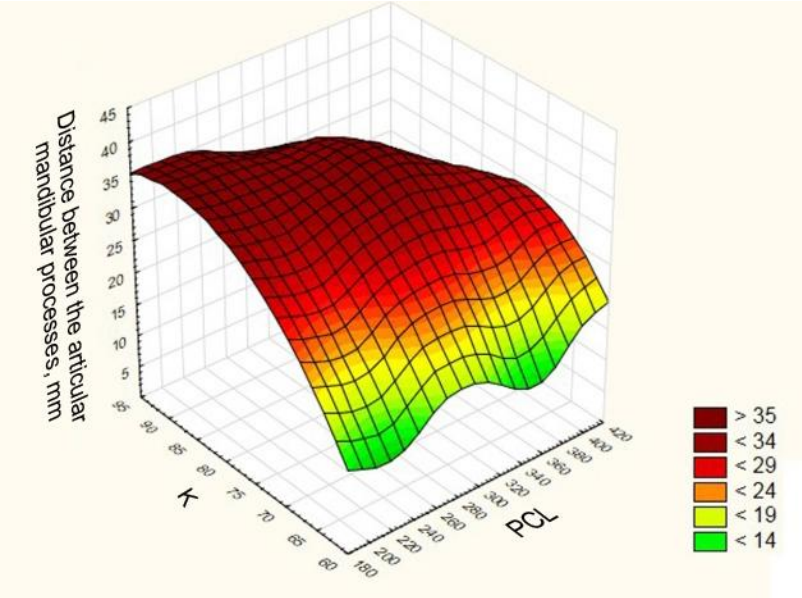


Fig. 4. Interdependence of the distance between the articular mandibular processes on age, sex and constitutional type of human male fetuses

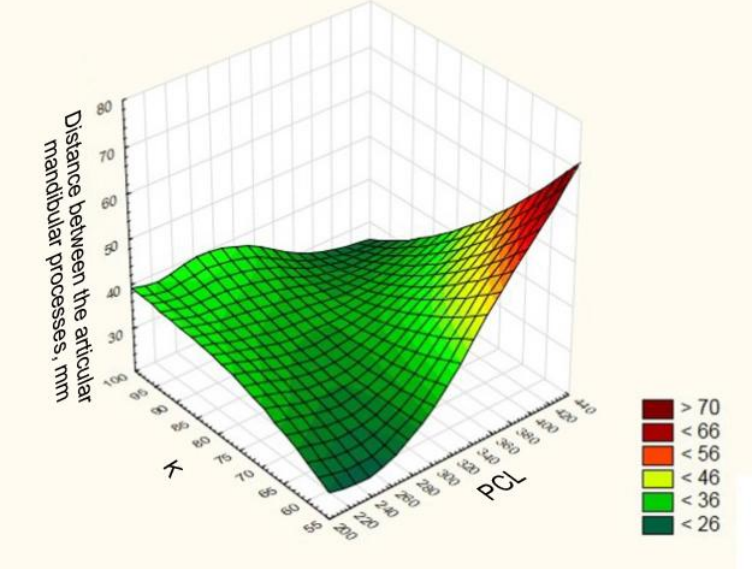


Fig. 5. Interdependence of the distance between the articular mandibular processes on age, sex and constitutional type of human female fetuses

Investigation of the correlation between the mandibular angle and sex, age and constitutional type (Fig. 6, 7) determined that in male fetuses the mandibular angle decreases equally with the decrease of constitutional coefficient type. Although, in fetuses with the biggest parameters of the constitutional type (dolichomorphic type) the angle decreases with age.

In female fetuses with average and highest parameters of the constitutional type similar to that of male correlation of the mandibular angle and age occurs, but in brachyomorphic objects since the 6th month of intrauterine development the angle is characterized by a tendency to a quick linear increase till the end of the prenatal period of development.

Examination of interdependence of the mandibular body angle parameter and sex, age and constitutional type (Fig. 8, 9) enabled to state the fact of asymmetrical sex-age dynamic of changes of this morphometric parameter. Thus, since the angle parameter for fetuses of both sexes with average values of the constitutional type coefficient during the fetal period of development does not practically change (in male fetuses it is changed a little at the 6–7th month of intrauterine development, and on the contrary in female fetuses it increases), then on the borders of the range of constitutional variability (in brachyomorphic and dolichomorphic) it is larger in male fetuses and smaller – in female fetuses as compared to mesomorphic types. Since the 6th month of the intrauterine development the mandibular body angle of male objects with dolichomorphic constitutional type and female

objects with dolichomorphic constitutional type were found to have a tendency to linear increase till the moment of birth.

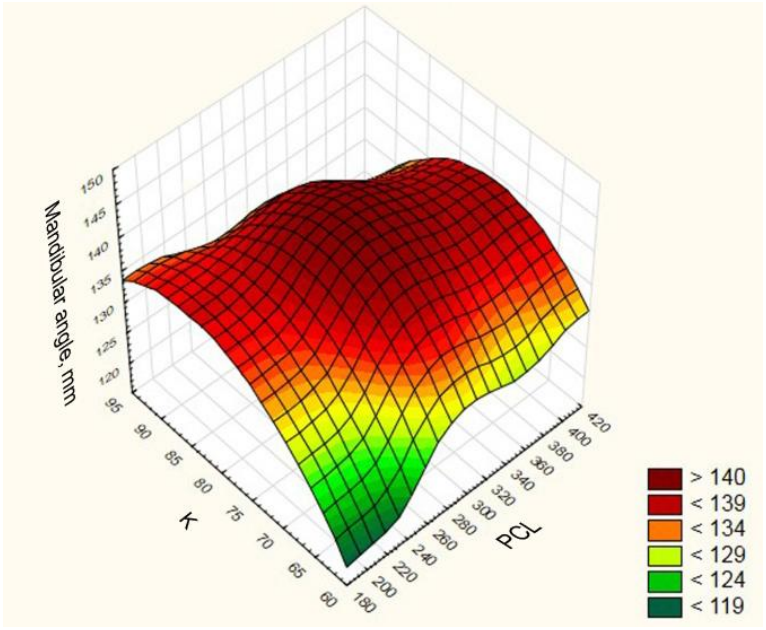


Fig. 6. Interdependence of the mandibular angle on sex, age and constitutional type in male fetuses

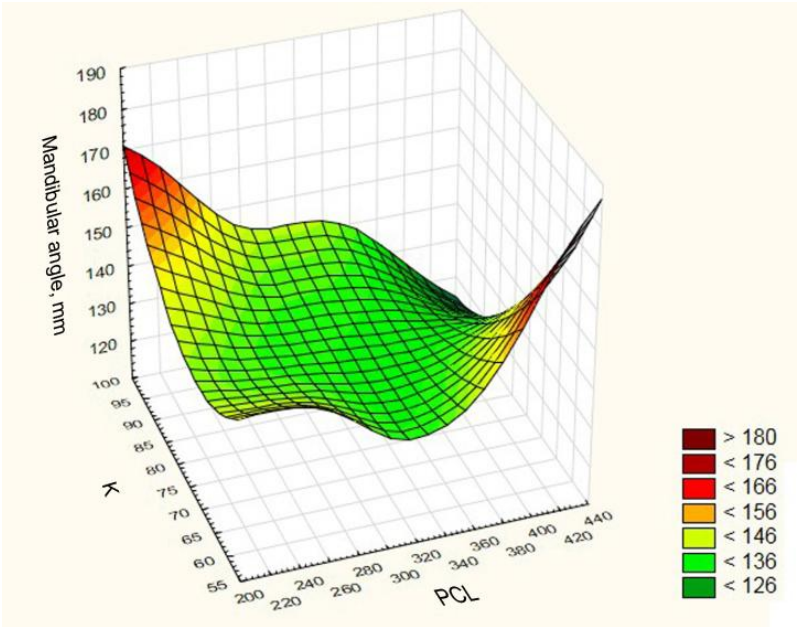


Fig. 7. Interdependence of the mandibular angle on sex, age and constitutional type in female fetuses

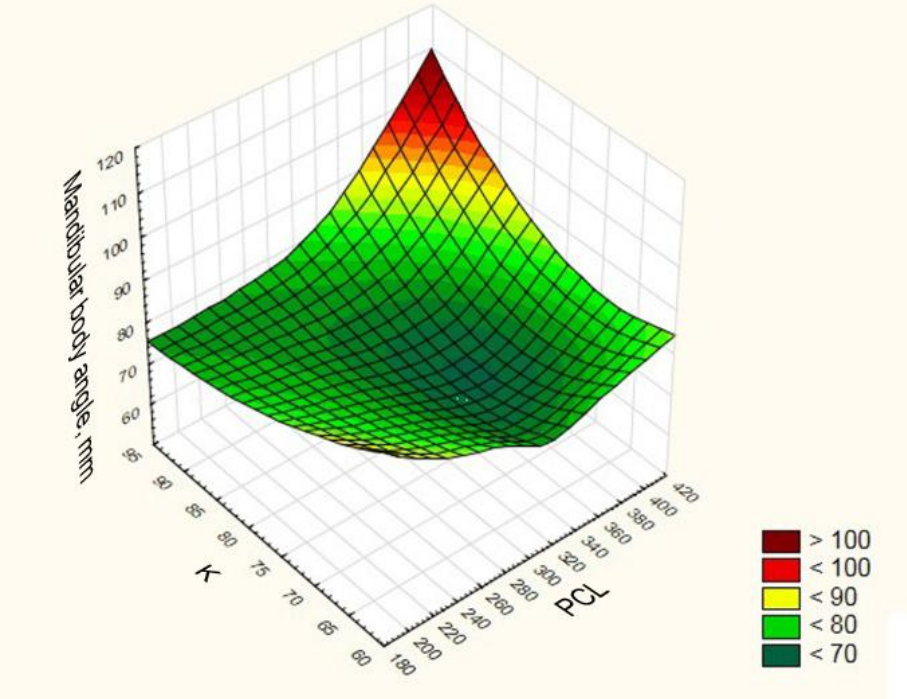


Fig. 8. Interdependence of the mandibular body angle on sex, age and constitutional type in male fetuses

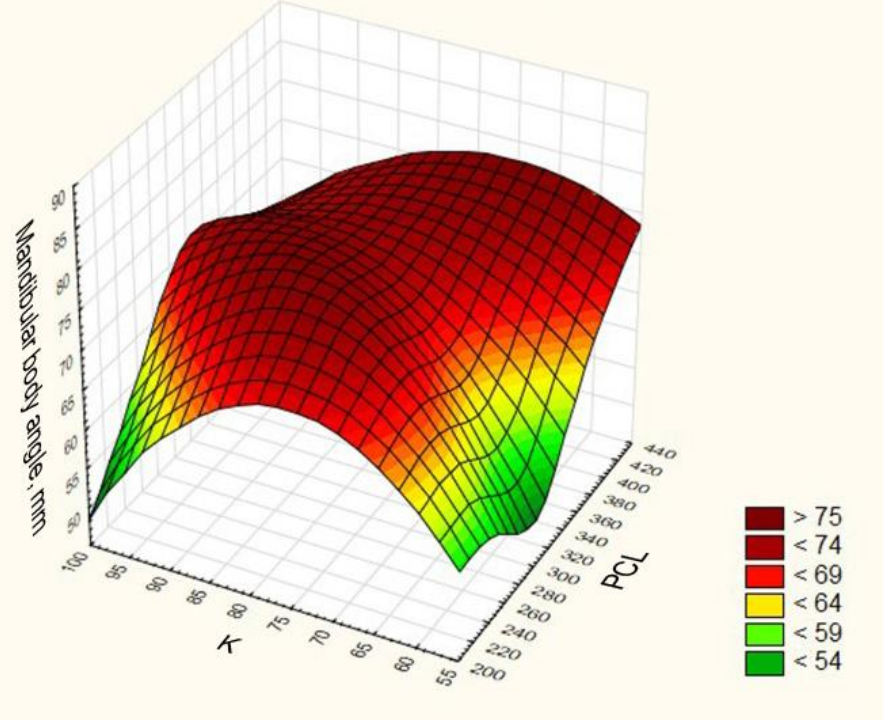


Fig. 9. Interdependence of the mandibular body angle on sex, age and constitutional type in female fetuses

Multiple-factor regression analysis concerning the correlation of the mandibular height, sex, age and constitutional type in human fetuses (Fig. 10, 11) demonstrated weak interdependence of the examined parameters in mesomorphic objects of both sexes (except inconsiderable decrease of the mandibular height in female fetuses during the 6th month of intrauterine development). In brachyomorphic female fetuses at the end of the 6th month of their intrauterine development linear increase occurs, while in male fetuses on the contrary – decrease of this morphometric parameter. Dolichomorphic female fetuses are characterized by the largest mandibular height at the 7th months of their intrauterine development, and male fetuses – reduced rates of growth of this parameter at the same period followed by its stabilization till birth.

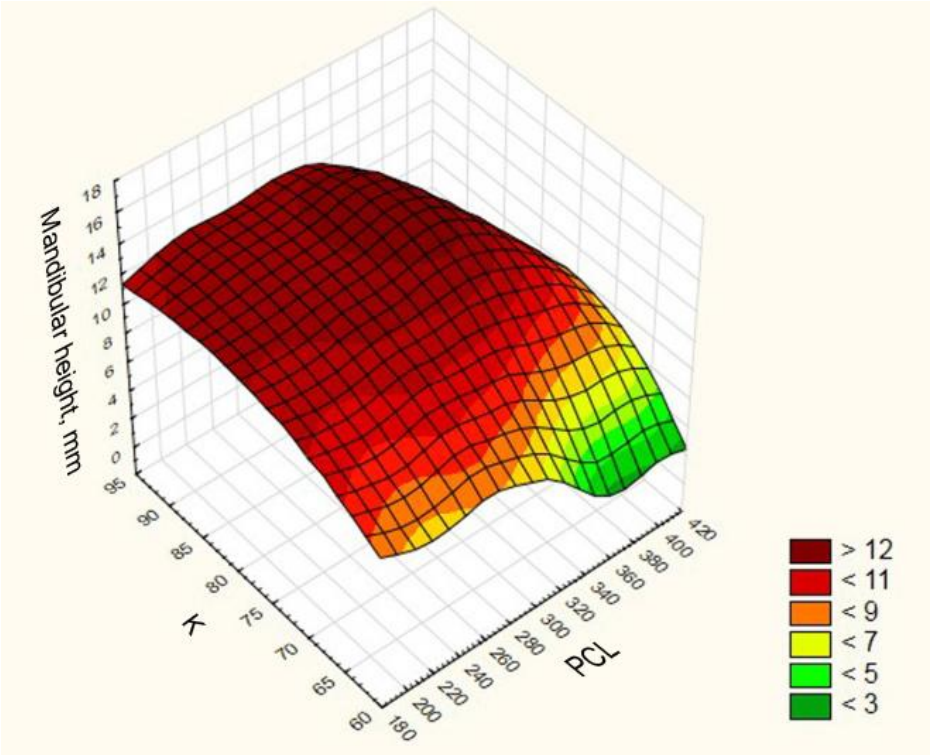


Fig. 10. Interdependence of the mandibular height on sex, age and constitutional type in male fetuses

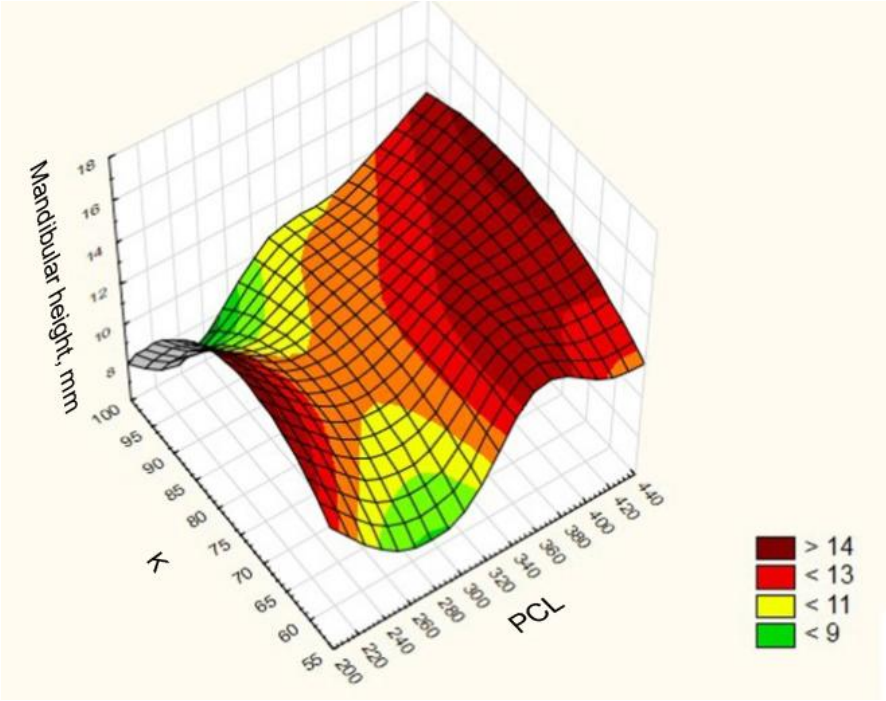


Fig. 11. Interdependence of the mandibular height on sex, age and constitutional type in female fetuses

Examination of interdependence of the mandibular body length and sex, age and constitutional type in human fetuses (Fig. 12, 13) demonstrated decrease of this morphometric parameter in male fetuses of brachyomorphic type, and its decrease in female fetuses with dolichomorphic type at the 6th month of their intrauterine development with its further increase till the end of the fetal period of development.

Examination of the character of interdependence of the mandibular maximum length and sex, age and constitutional type in human fetuses (Fig. 14, 15) determined decrease of this morphometric parameter in male fetuses with brachyomorphic type, and in female fetuses of all the constitutional types it decreases at the 6th month of their intrauterine development with their further increase till the end of the fetal development. It should be noted that female fetuses with dolichomorphic constitutional type are characterized by practically linear rate of increase of the mandibular maximum length during the fetal period of the intrauterine development.

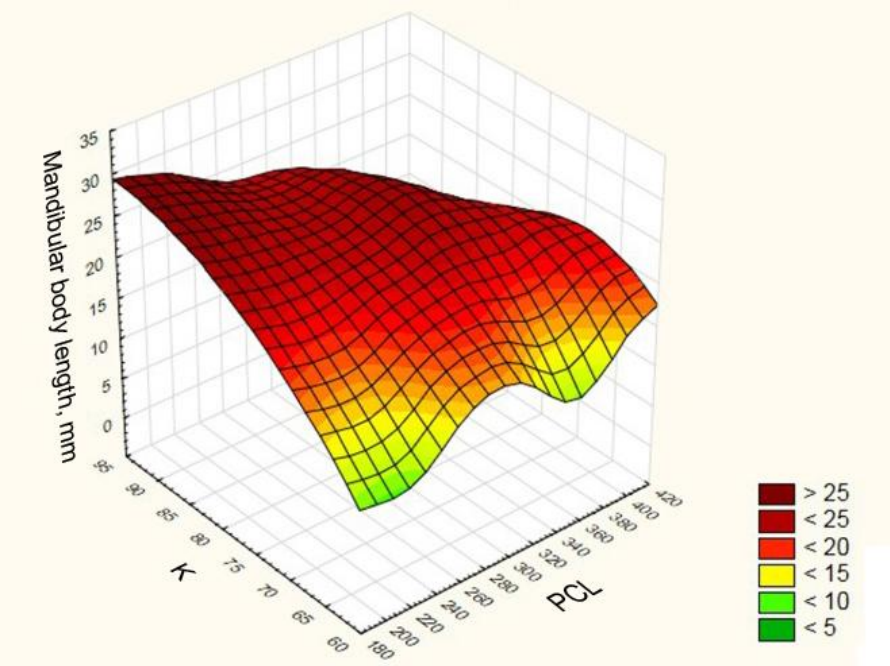


Fig. 12. Interdependence of the mandibular body length on sex, age and constitutional type in male fetuses

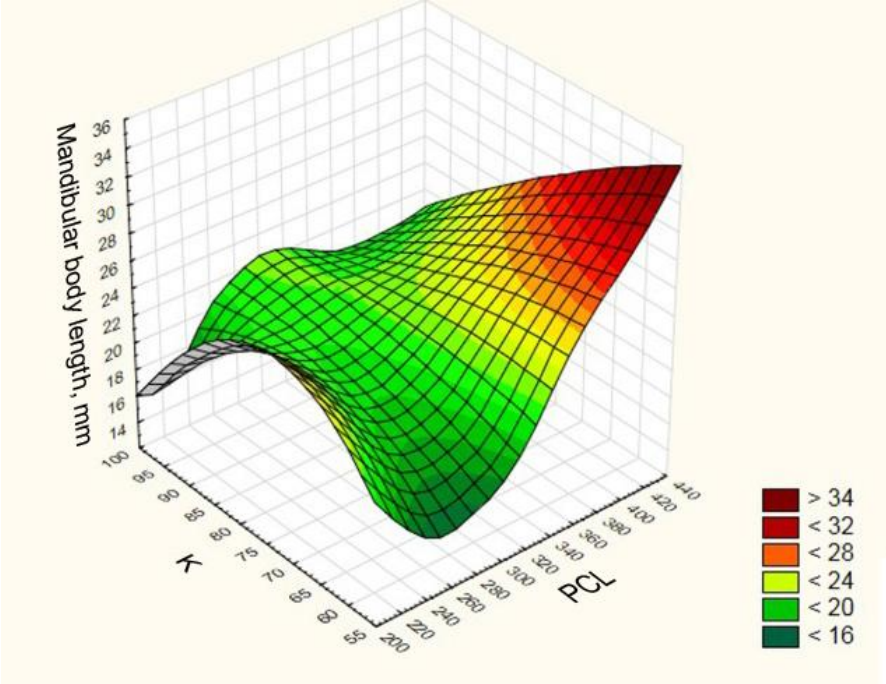


Fig. 13. Interdependence of the mandibular body length on sex, age and constitutional type in female fetuses

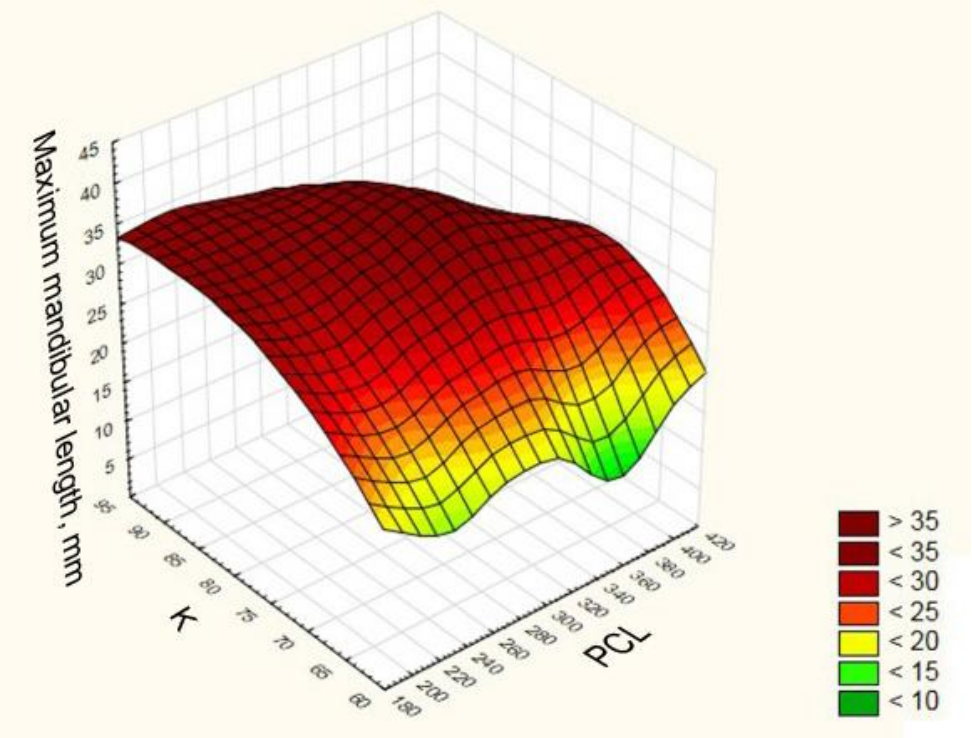


Fig. 14. Interdependence of the maximum mandibular length on sex, age and constitutional type in male fetuses

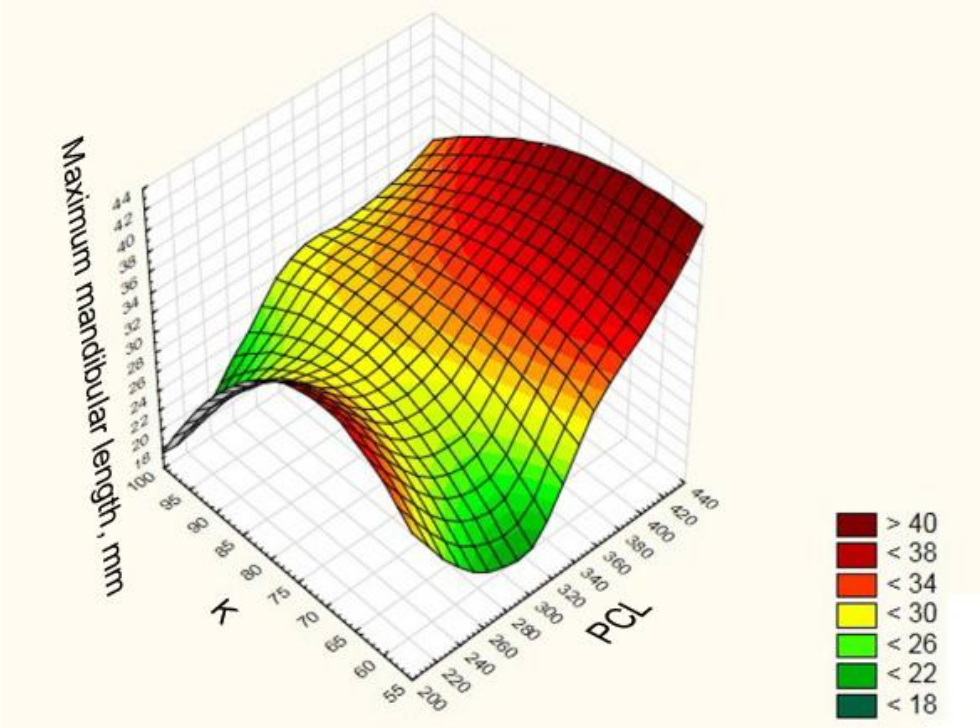


Fig. 15. Interdependence of the maximum mandibular length on sex, age and constitutional type in female fetuses

Examination of the features of interrelations between changes of the mandibular length, age and constitutional type in human fetuses (Fig. 16, 17) determined that this morphometric parameter in brachyomorphic objects of both sexes is characterized by a tendency to slow growth rate, and in dolichomorphic objects of female fetuses – it increases linearly beginning with the 6th month of fetal development.

A similar character of individual constitutional variability is peculiar for changes of the mandibular thickness during the fetal period of the intrauterine development (Fig. 18, 19). It should be noted that this morphometric parameter in female fetuses of all the constitutional types decreases during the 6th month of development.

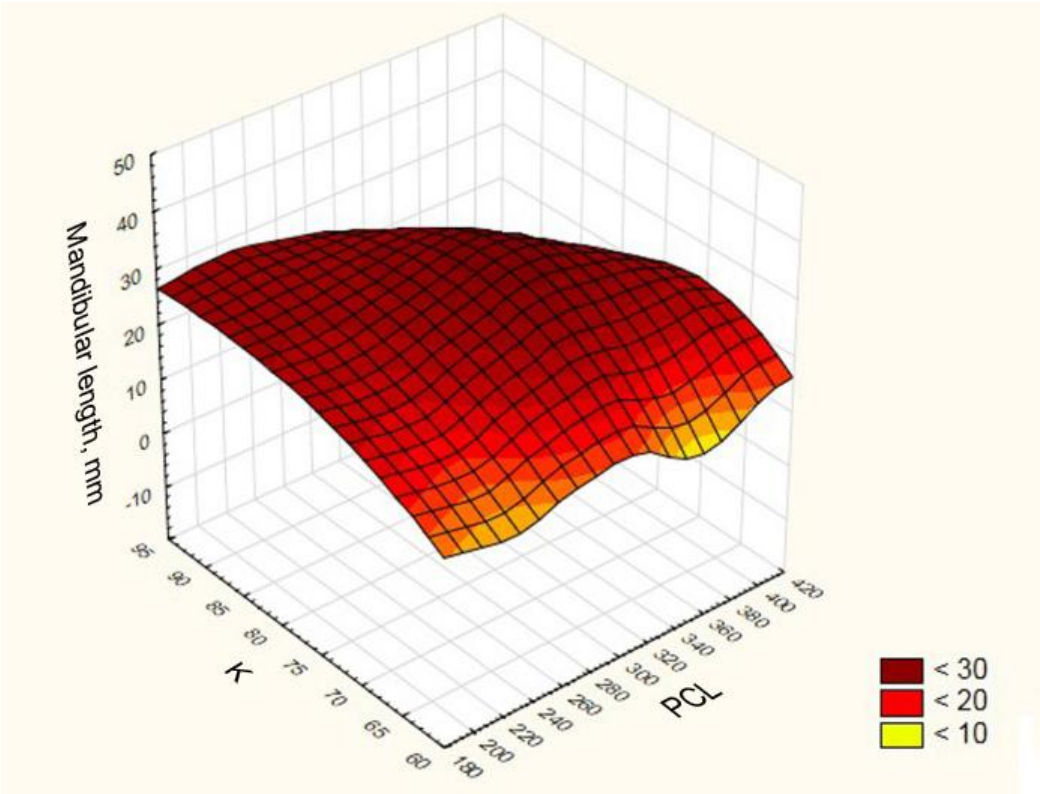


Fig. 16. Interdependence of the mandibular length on sex, age and constitutional type in male fetuses

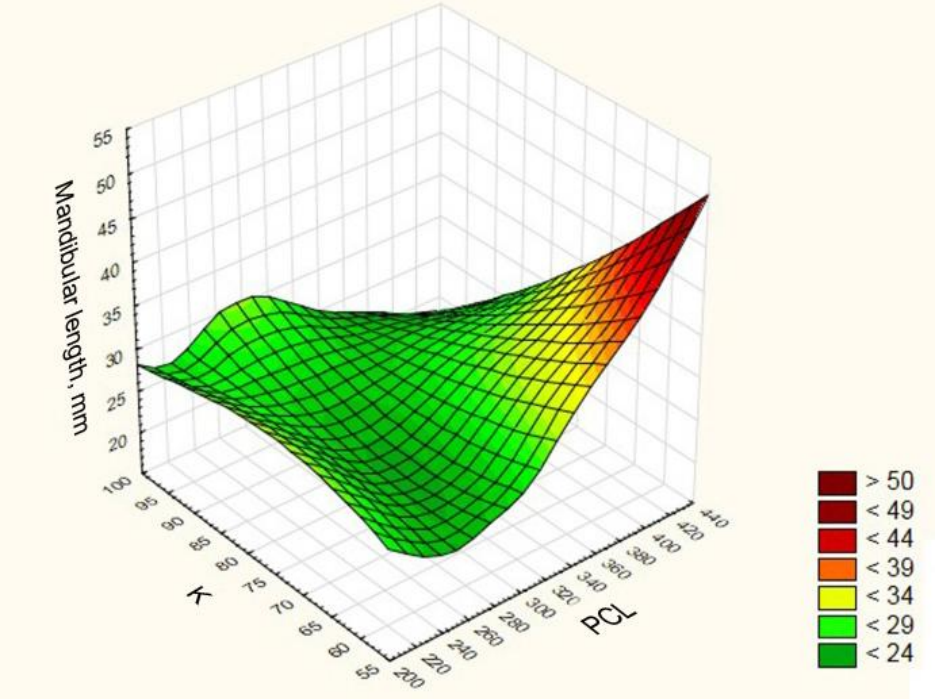


Fig. 17. Interdependence of the mandibular length on sex, age and constitutional type in female fetuses

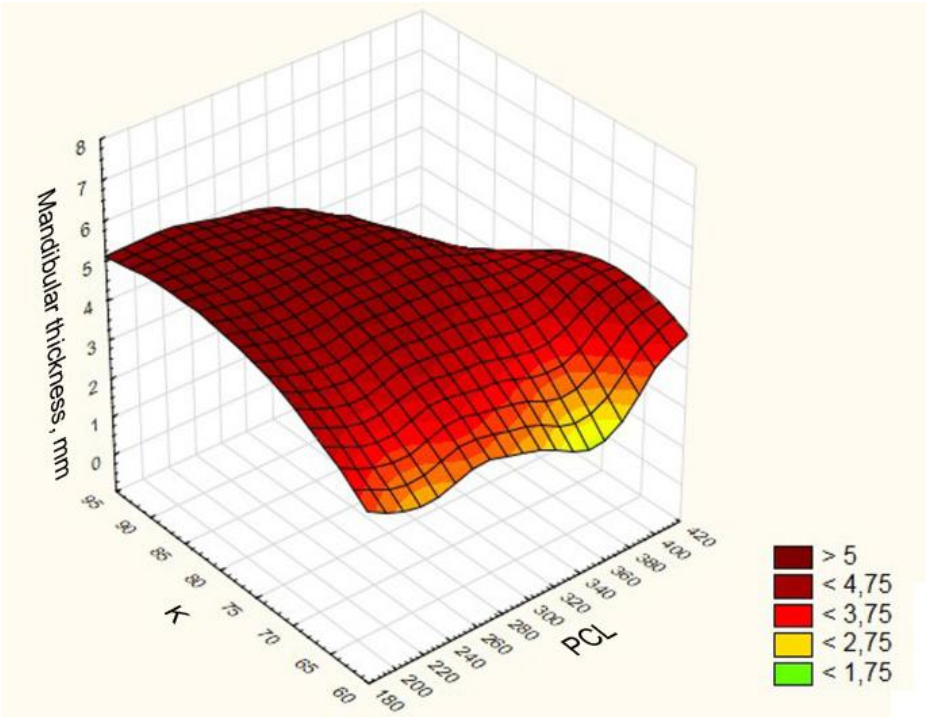


Fig. 18. Interdependence of the mandibular thickness on sex, age and constitutional type in male fetuses

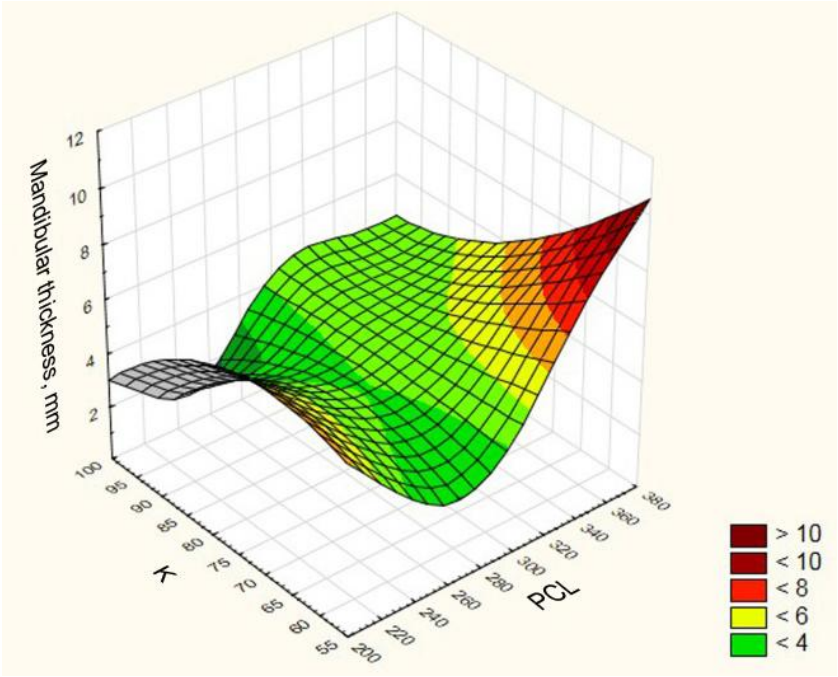


Fig. 19. Interdependence of the mandibular thickness on sex, age and constitutional type in female fetuses

Interdependence of the mandibular volume and sex, age and constitutional type in human fetuses (Fig. 20, 21) is characterized by the highest values of this parameter in female fetuses with brachyomorphic constitutional type, and the lowest values – in male fetuses with dolichomorphic structure at the end of the fetal period and in brachyomorphic female fetuses at the 6-7th month of development.

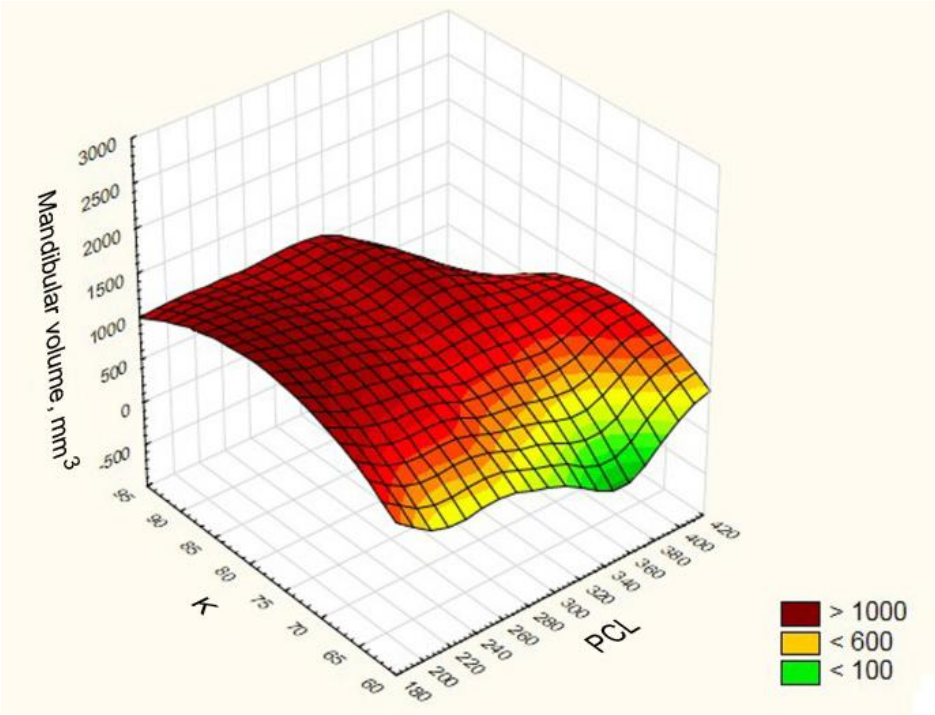


Fig. 20. Interdependence of the mandibular volume on sex, age and constitutional type in male fetuses

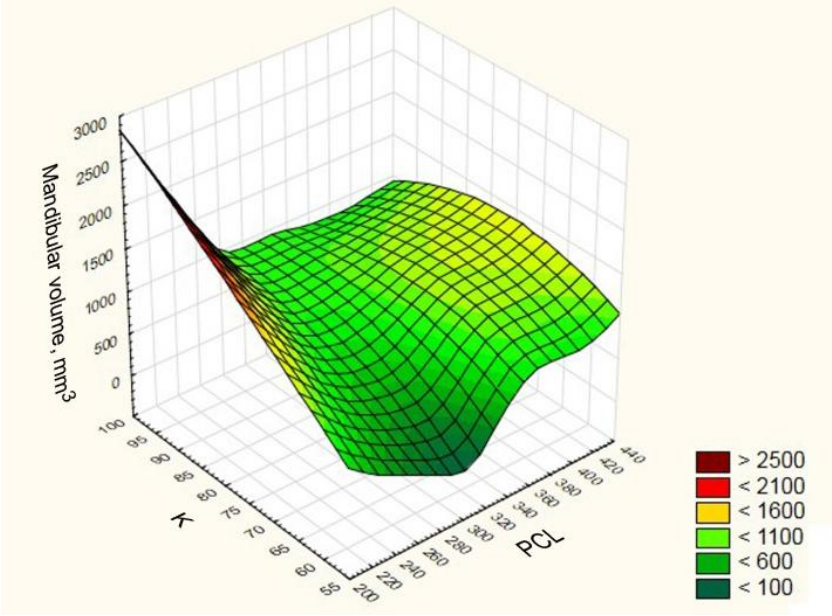


Fig. 21. Interdependence of the mandibular volume on sex, age and constitutional type in female fetuses

Analysis of interdependence of the mandibular square, age and constitutional type (Fig. 22, 23) enabled to determine that this morphometric

parameter is the lowest in male fetuses with dolichomorphic constitutional type and 4–6th month female fetuses, as well as in male fetuses with brachyomorphic constitutional type since the 6th month of their intrauterine development. The highest values of the mandibular square are characteristic for 4–6th month female fetuses with dolichomorphic constitutional type. It should be noted that in general the character of dependence of this morphometric parameter on sex, age and constitutional type coefficient is similar to that of individual variability of the mandibular volume.

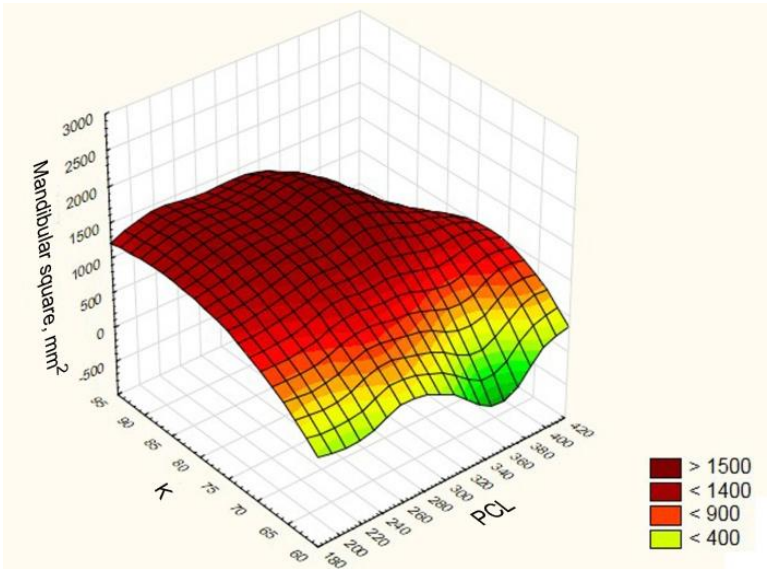


Fig. 22. Interdependence of the mandibular square on sex, age and constitutional type in male fetuses

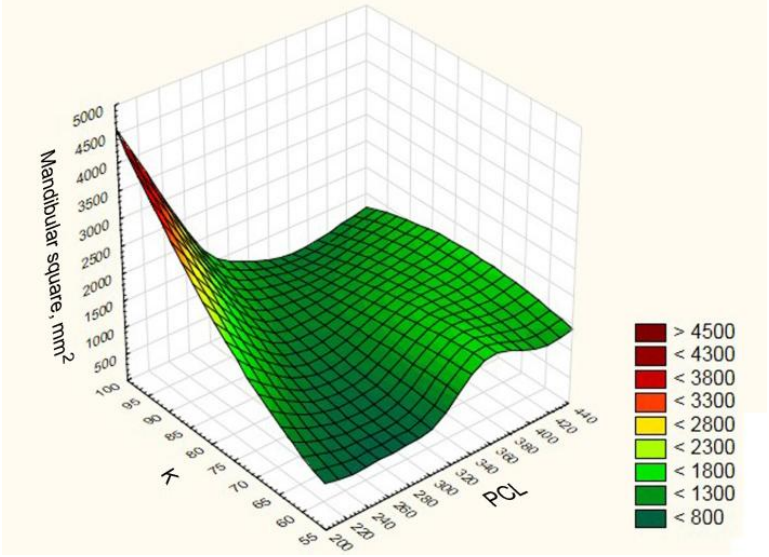


Fig. 23. Interdependence of the mandibular square on sex, age and constitutional type in female fetuses

Conclusions

1. The distance between the articular mandibular processes in human fetuses of both sexes increases evenly, although in dolichomorphic female fetuses the rates of growth of this parameter increase intensively since the 6th month of the intrauterine development.

2. The mandibular angle of human fetuses decreases during the prenatal period, except female objects with brachyomorphic type, as on the contrary this morphometric parameter increases since the 4th month of development till birth. The mandibular angle is characterized by a tendency to increase for all the examined fetuses, except brachyomorphic objects, as this parameter decreases during the prenatal period of development.

3. The mandibular height of brachyomorphic objects of human fetuses of both sexes decreases, while it increases in the rest of fetuses.

4. The length of the mandibular body and maximum mandibular length in all the examined human fetuses decreases, although in female fetuses of all the constitutional types this parameter begins to grow intensively since the 6th month and till the end of the prenatal period of human ontogenesis.

5. Sagittal length and thickness of the mandible in fetuses of both sexes with brachyomorphic constitutional types are characterized by a tendency to decrease, but in dolichomorphic female fetuses it increases linearly since the 6th month of development.

6. The volume and square of the mandibular surface in human fetuses prevail in female fetuses with brachyomorphic constitutional type, and the smallest values of these parameters are found in male fetuses with dolichomorphic constitutional type at the end of fetal period and in female fetuses with brachyomorphic constitutional type at 6–7th month of their intrauterine development.

7. Critical periods of morphogenesis of the human mandible, the period of changes of growth rate depending on sex, age and constitutional type, are 6-7th months of intrauterine development which can be indicative of the formation of structural variants at this term, and is the time of possible occurrence of congenital defects of the maxillofacial area.

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