MATHEMATICAL & GRAPHICS SIMULATION FOR INDIVIDUAL SHAPE OF MAXILLARY DENTAL ARCH

V.V. Shkarin[1], D.A. Domenyuk[2], M.P. Porfyriadis[2], D.S. Dmitrienko[3], S.V. Dmitrienko[4]

[1] Department of public health and health care of doctor's improvement faculty, Volgograd state medical university of Ministry of healthcare, Russian Federation,
square of the Fallen Fighters, 1, Volgograd, Russia 400131.
E-mail: fuv-ozz@yandex.ru, tel: +7(8442)38-21-78.

[2] Department of general practice dentistry and child dentistry, Stavropol state medical university of Ministry of healthcare,
310, Mira Street, Stavropol, Russia 355017.
E-mail: domenyukda@mail.ru, tel: +7(918)870-1205.

[3] Department of pediatric dentistry, Volgograd state medical university of Ministry of healthcare, Russian Federation,
Square of the Fallen Fighters, 1, Volgograd, Russia 400131.
E-mail: pk.volgmed@mail.ru, tel: +7(8442)73-04-26.

[4] Department of Dentistry, Pyatigorsk Medical-Pharmaceutical Institute (Branch of Volgograd State Medical University, Ministry of Healthcare, Russian Federation),
11, pr. Kalinina, Pyatigorsk-32, Stavropol Region, Russia 357532.
E-mail: s.v.dmitrienko@pmedpharm.ru , tel: +7(8793)32-44-74.

Vladimir Shkarin, *Candidate of Medical Science, Associate Professor, Head of Department*

Dmitry Domenyuk, *Doctor of Medicine, Professor*

Michael Porfyriadis, *Doctor of Medicine, Professor*

Dmitry Dmitrienko, *Doctor of Medicine, Associate Professor*

Sergey Dmitrienko *Doctor of Medicine, Professor, Head of Department*

ABSTRACT — The item contains a method for mathematical simulation of dental arch, where the diameter of the front segment is determined by the ratio of the length of the arch limited by the chord corresponding to the arch width between the canines, to the angle limited by the radii coming from the chord edges. At the same time, the central angle value was taken as the double arc-tangent of the ratio between the dental-arch double depth and its width between the canines. On the continued diameter of the circumference a location was identified that corresponded to the value of the dental arch depth. A line was drawn perpendicular to it, which had on its both sides lengths equal to half-width of the dental arch between the second molars. A line was drawn connecting the spots that corresponded to the position of the canines and the vestibular distal odontomeres (cusps) on the second molars. The arches were outlined to locate the position of the grinder teeth.

KEYWORDS — howley arch, mathematical simulation of dental arches, geometric graphic reproduction of dental arches.

INTRODUCTION

At present, there have been a variety of methods proposed for examining the maxillofacial area, which can be employed for diagnosing anomalies and deformations as well as selecting the right treatment [1, 5, 15, 23, 25, 32]. Of particular importance are the methods for forecasting the shape of dental arches in order to select the parameters of

metal arches and the prescription of brackets to offer patients treatment employing the edgewise technique [7, 8, 12, 13, 22, 28, 31].

Constructing a dental arch based on the geometric & graphic method has been the focus of attention for many decades now [3, 4, 14].

The proposed graphic reproduction of the dental arch following the Howley-Herber-Herbst method has already become part of educational and special literature, and is part and parcel in diagnostics of occlusion anomalies [26].

Recently, clinicians have noticed certain errors in the structure arrangements, which led to a discrepancy between the true parameters of the dental arch and its graphic construction. It has been noted that the sum of the medial-distal dimensions of the three anterior teeth (medial and lateral incisors, and the canine on one of the sides of the arch) cannot be used simultaneously as the circle diameter and the length of the sector bounded by a chord equal to the radius. Given this, some corrections have been made making it possible to offer a more accurate mark for the position of the canines on the dental arch. However, these observations were good for dental arches where the width between the canines was twice that of the anterior section of the dental arch [3].

Mention should be also made of experts who believe that even in case of equal dimensions of the teeth, the shape of the anterior dental arch may be different [2, 6]. In this connection, it was proposed to employ two interdependent values, such as the width and the depth of the anterior part of the dental arch bounded by the permanent canines [4].

A method of constructing an arch has been developed, where the value of the difference between the width and depth of the dental arch to the level of the canines' location was accepted as the diameter [10]. This study, however, was carried out involving humans with physiological occlusion of the permanent teeth.

In case of abnormal occlusion, torsiversions, protrusion or retrusion of medial incisors, determining the depth of the dental arch remains quite a challenge and questionable in view of setting the diagnosis. Besides, even on case of physiological occlusion, there is still a great variety of the shape and size of dental arches [9, 17, 20]. There have been shown the dimensions of dental arches and the interrelation between the linear parameters [16, 27, 30]. There is also a description offered for the features of incomplete dental arches caused by lack of one of the premolars on each side of the arch [21].

In view of the above-said, it has been concluded that a graphic development of a dental arch employing the Howley-Herber-Herbst method requires some refinement. This statement is based on the opinion expressed by researchers who have proposed various options for the shape and size of dental arches, taking into account the gnathic (meso-, brachy- and dolichognathy) and dental (normo-, macro- and microdontia) types [11, 18, 19, 24, 29].

Aim of study:

improved methods for design as well as development of a mathematical & graphic reproduction of dental arches allowing determining the shape and size of the dental arch irrespective of the gnathic and dental types.

MATERIALS AND METHODS

43 persons in their mature age with a full set of permanent teeth and physiological occlusion had a comparative analysis done on their true shape of the dental arches with a geometric & graphic reproduction relying on mathematical simulation.

The radius for the circumference to serve location for the six front teeth, was done through the commonly accepted geometric method for calculating the diameter based on the length and the height of the sector bounded by the chord (Fig. 1).

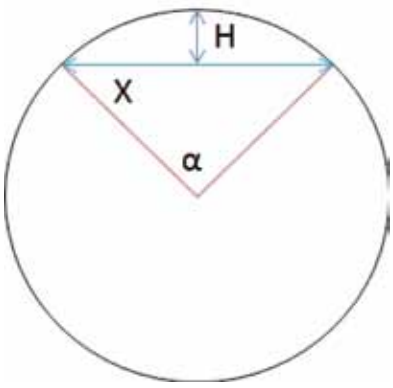

Fig. 1. *Determining the diameter through the length of the chord (X) and the height of the segment (H). Center angle (α)*

Following the method in question, the diameter (D) is to be calculated by the ratio of the curve length (L) to the center angle (α):

$$D = \frac{L}{\alpha}$$

The center angle is formed by the radii bounding the chord and was calculated subject to the formula:

$$\alpha = 2 \cdot \text{arctg}\,\frac{2H}{X}$$

H — the height of the segment, X — the length of the chord.

The length of the curve bounded by the chord was calculated as the product of the chord length and the relation of the center angle to its sinus:

$$L = X \cdot \frac{\alpha}{\sin\alpha}$$

To calculate the diameter of a circumference when building the dental arch, the chord length (X) corresponded the inter-canine gap. The segment height (H) determined the depth of dental arch front part and was calculated as the leg of a rightangled triangle shaped by the frontal-canine (canine) diagonal and the half-width of the dental arch between the canines (fig. 2).

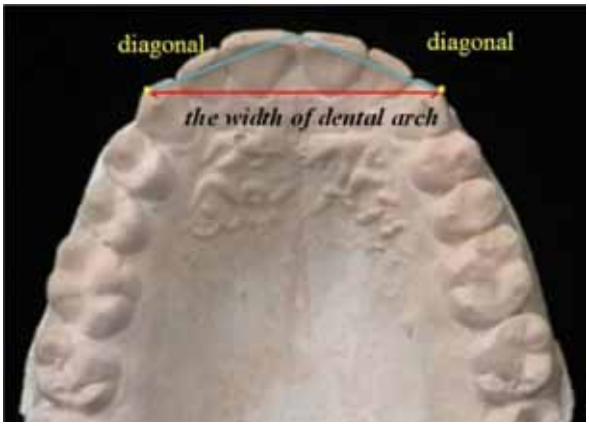

Fig. 2. Dental arch benchmarks for graphic imaging of dental arch anterior section

A chart was developed based on the benchmarks proposed as well as the method for mathematical simulation of a circumference to locate the anterior teeth.

RESULTS AND DISCUSSION

In view of the specific features for building a circumference based on the chord length and the segment height, we developed a way to set up an individual shape of the dental arch.

To determine the diameter of the circumference to host the front teeth, two relatively stable values were used, namely the width of the dental arch between the canines and the frontal-canine diagonal. The major measuring points were located on the tearing cusps of the canine teeth. The inter-incisal point was located on the vestibular side between the medial incisors in the occlusal norm. The diameter and the radius of the circle were calculated, which was done in order to construct a circle whose upper spot was used as a starting point to two segments deviating both sides, each of these equal to the frontal-canine diagonal. The continuation of the diameter of the circle was used to detect the position of the point corresponding to the depth of the dental arch. Perpendicular to it, a line was produced, on both sides of which segments were drawn, each equal to half-width of the dental arch between the second molars (Fig. 3).

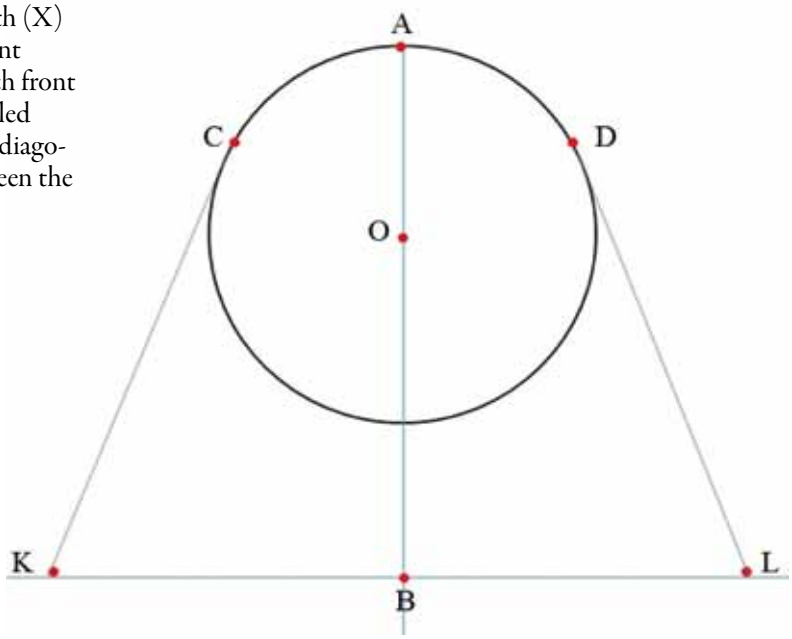

Fig. 3. Developing an individual shape for the dental arch in view of the mathematical simulation of the circumference to host the anterior teeth and locating the major linear parameters

A straight line connected the points corresponding to the position of the canines and the distal vestibular odontomeres (tubercles) on the second molars.

From the middle of diagonals, perpendiculars were produced on both sides of the circumference. The resulting line then was marked with segments equal to the sum of the dental arch width and depth (Fig. 4).

On both sides curves were produced with a radius equal to the distance from the obtained points to the points where the canines and/or the second molars were located (Fig. 5).

The shape of the curve thus obtained was then compared to the true curve on the cast model of the jaw.

CONCLUSIONS

The above-mentioned shows that the proposed production of a dental arch matches fully the shape and the size of the dental arches irrespective of their gnathic and dental type.

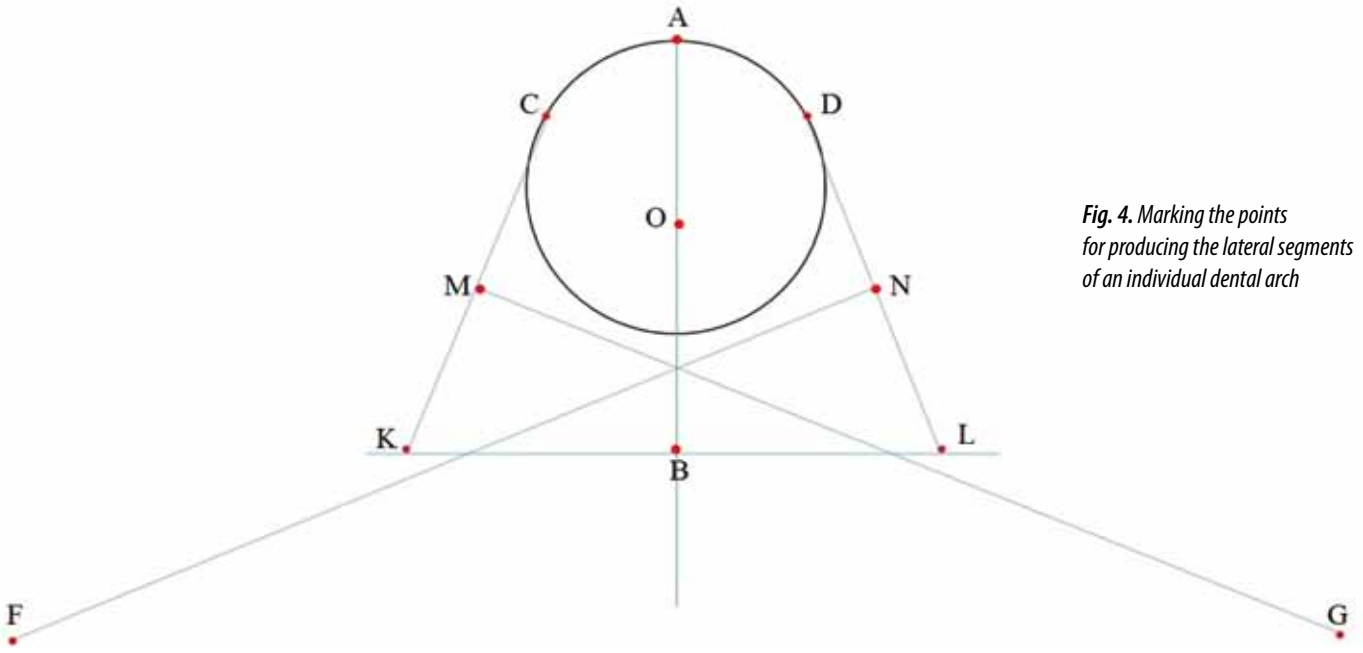

Fig. 4. *Marking the points for producing the lateral segments of an individual dental arch*

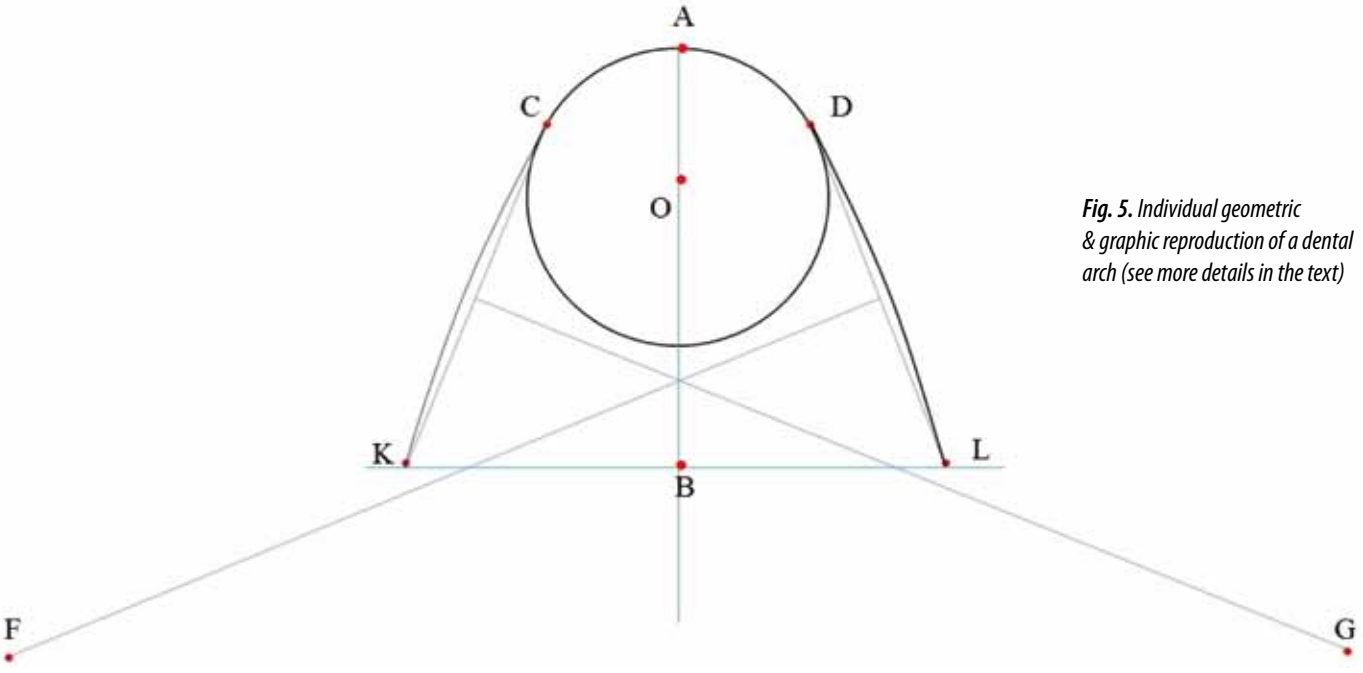

Fig. 5. *Individual geometric & graphic reproduction of a dental arch (see more details in the text)*

REFERENCES

1. Diagnosis and treatment of patients ' dental profile discrepancy between the size of permanent teeth and dental arch parameters: Scholarly monograph / D.A. Domenyuk, D.S. Dmitrienko, A.A. Korobkeev [et al.]. – Stavropol: Publishing House of Stavropol State Medical University, 2015. – 272 p.
2. **Dmitrienko S.V., Domenyuk D.A., Dmitrienko D.S.** Interrelation between sagittal and transversal sizes in form variations of maxillary dental arches // Archiv EuroMedica, 2014. – Vol. 4. – № 2. – P. 10–13.
3. **Dmitrienko S.V., Dmitrienko D.S., Klimova N.N. [et al.].** The question of the construction of the arc Howley // Orthodontics. – 2011. – № 2 (54). – P. 11–13.
4. **Dmitrienko S.V., Domenyuk D.A., Vedeshina E.G.** Shape individualization in lower dental arches drawn on basic morphometric features // Archiv EuroMedica, 2015. – Vol. 5. – № 1. – P. 11–15.
5. **Dmitrienko S.V., Chizhikova T.S., Klimova N.N., Filimonova E.V., Kravchenko E.V.** The evaluation of the tooth size on the individual param-

eters of the person. The patent for invention RUS 2402265 18.03.2009.

6. **Domenyuk, D.A.** Basic morphometric parameters of the dental arches in people with brachygnathic the form of a dental arch and the macro-, micro - and normodontia types of dental systems / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 68. – № 3. – P. 44–48.

7. **Domenyuk, D.A.** Biometric justification of main linear dimensions of the dental arches in orthodontic treatment tactics' development using edgewise orthodontic technique (part I) / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2016. – Vol. 70. – № 1. – P. 76–78.

8. **Domenyuk, D.A** Biometric justification of main linear dimensions of the dental arches in orthodontic treatment tactics' development using edgewise orthodontic technique (part II) / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2016. – Vol. 71. – № 2. – P. 66–67.

9. **Domenyuk D.A., Vedeshina E.G., Dmitrienko S.V.** Correlation of dental arch major linear parameters and odontometric indices given physiological occlusion of permanent teeth in various face types // Archiv EuroMedica, 2016. – Vol. 6. – № 2. – P. 18–22.

10. **Domenyuk, D.A.** Clinical anatomy of teeth and dentofacial segments: Scholarly monograph / D.A. Domenyuk, E.G. Vedeshina, S.V. Dmitrienko. – Stavropol: Publishing House of Stavropol State Medical University, 2015. – 210 p.

11. **Domenyuk, D.A.** Dependence between size of permanent teeth and linear parameters of mesognathic dental arches / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 69. – № 4. – P. 78–80.

12. **Domenyuk, D.A.** Factors determining choice of metal arches and braces specification in edgewise technique-based orthodontic treatment (part I) / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 69. – № 4. – P. 92–93.

13. **Domenyuk, D.A.** Factors determining choice of metal arches and braces specification in edgewise technique-based orthodontic treatment (part II) / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2016. – Vol. 70. – № 1. – P. 54–57.

14. **Domenyuk, D.A.** Geometrical and graphic reproduction of dentoalveolar arches in physiological occlusion of permanent teeth / D.A. Domenyuk, S.V. Dmitrienko, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 66. – № 1. – P. 62–64.

15. **Domenyuk D.A., Vedeshina E.G., Dmitrienko S.V.** Mistakes in Pont (Linder-Harth) method used for diagnosing abnormal dental arches in transversal plane // Archiv EuroMedica, 2016. – Vol. 6. – № 2. – P. 23–26.

16. **Domenyuk, D.A.** Modern classification of dental arches / D.A. Domenyuk, S.V. Dmitrienko // Archiv EuroMedica, 2014. – Vol. 4. – № 2. – P. 14–16.

17. **Domenyuk, D.A.** Morphometric analysis of dental arches in physiological occlusion of permanent teeth / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 69. – № 4. – P. 74–77.

18. **Domenyuk, D.A.** Sagittal and transversal dimensions of dolichognathic dental arches in humans with macrodontia, microdontia, and normodontia / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2016. – Vol. 71. – № 2. – P. 60–63.

19. **Domenyuk, D.A.** The main forms of individual microdontia formed in the mixed dentition of permanent teeth / D.A. Domenyuk, A.A. Korobkeev, E.G. Vedeshina [et al.] // Medical news of North Caucasus, 2016. – Vol. 11. – № 3. – P. 474–476.

20. **Domenyuk, D.A.** Variability of odontometric parameters in patients with physiological occlusion of permanent teeth and mesognathic dental arches / D.A. Domenyuk, B.N. Davydov, E.G. Vedeshina [et al.] // Institute of dentistry, 2015. – Vol. 68. – № 3. – P. 74–77.

21. **Domenyuk D.A., Vedeshina E., Dmitrienko S.V.** Certain parameters of incomplete dental arches with missing premolars after orthodontic treatment // Socially Significant Human Diseases: Medical, Environmental and Technical Problems, and these Solutions III Japanese-Russian International Conference. – 2016. – P. 81–82.

22. **Domenyuk D.A., Vedeshina E., Dmitrienko S.V.** Choice of metallic arches and braces press ription in view of individual shape of dental arche // Socially Significant Human Diseases: Medical, Environmental and Technical Problems, and these Solutions III Japanese-Russian International Conference. – 2016. – P. 83–84.

23. **Domenyuk D.A., Vedeshina E.G., Dmitrienko S.V.** Efficiency evaluation for integrated approach to choice of orthodontic and prosthetic treatments in patients with reduced gnathic region // Archiv EuroMedica. – 2015. – Vol. 5. – № 2. – P. 6–12.

24. Features of the maxillofacial region when macrodontia permanent teeth: Scholarly monograph / D.A. Domenyuk, E.G. Vedeshina, S.V. Dmitrienko [et al.]. – Stavropol: Publishing House of Stavropol State Medical University, 2016. – 159 p.

25. Optimization modern methods of diagnosis and treatment of patients with various forms to reduce the height of the lower portion of the face: Scholarly monograph / D.A. Domenyuk, E.G. Vedeshina, S.V. Dmitrienko [et al.]. – Stavropol: Publishing House of Stavropol State Medical University, 2015. – 260 p.

26. **Proffit, W.R.** Contemporary orthodontics / U.R. Profit; under the editorship of L.S. Persin. – M.: Med Press-Inform, 2008. – 560 p.

27. Variant anatomy of the dentoalveolar segments: Scholarly monograph / D. A. Domenyuk, A. A. Korobkeev. – Stavropol: Publishing House of Stavropol State Medical University, 2016. – 200 p.

28. Variations of the structure and relative size of the facial skeleton and the dentition of metaflow: Scholarly monograph / D.A. Domenyuk, E.G. Vedeshina, S.V. Dmitrienko [et al.]. – Stavropol: Publishing House of Stavropol State Medical University, 2016. – 140 p.

29. **Vedeshina, E.G.** Determining torque and angulation of permanent teeth in cases of brachygnathic dental arches depending on dentition type / E.G. Vedeshina, D.A. Domenyuk, S.V. Dmitrienko // Kuban scientific medical Herald, 2015. – Vol. 155. – № 6. – P. 23–30.

30. **Vedeshina, E.G.** Correlation between shapes and sizes of dentofacial arches and their stable parameters / E.G. Vedeshina, D.A. Domenyuk, S.V. Dmitrienko // Kuban scientific medical Herald, 2016. – Vol. 158. – № 3. – P. 33–38.

31. **Vedeshina, E.G.** Odontometric parameters in cases with mesognathic dental arches / E.G. Vedeshina, D.A. Domenyuk, S.V. Dmitrienko // Kuban scientific medical Herald, 2015. – Vol. 153. – № 4. – P. 44–48.

32. X-ray morphometric techniques in the evaluation of the mullet dental status of patients with an established orthognathic occlusion of permanent teeth: Scholarly monograph / D.A. Domenyuk, E.G. Vedeshina, S.V. Dmitrienko [et al.]. – Stavropol: Publishing House of Stavropol State Medical University, 2015. – 76 p.