ALGORITHM FOR FORECASTING THE SHAPE AND SIZE OF DENTAL ARCHES FRONT PART IN CASE OF THEIR DEFORMATIONS AND ANOMALIES

D.A. Domenyuk[2], V.V. Shkarin[1], 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.

Dmitry Domenyuk, *Doctor of Medicine, Professor*

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

Michael Porfyriadis, *Doctor of Medicine, Professor*

Dmitry Dmitrienko, *Doctor of Medicine, Associate Professor*

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

ABSTRACT — A study was conducted involving 96 people of both sexes with physiological occlusion and with no congenital maxillofacial pathology. As a result, an algorithm was proposed for forecasting the shape and dimensions of the dental arches, which is based on measuring relatively stable parameters, namely, the dimensions of the anterior teeth and the basic features in the maxillofacial area. The algorithm is based on mathematical calculations of the circle geometry and the dependence of the length of the arch, chord and height. The circle diameter was calculated as the ratio of the dental arch width between the canines to the sine of the central angle shaped by the radii of the circle limiting the chord. The size of the front-canine diagonal is comparable to the size of the front teeth in a certain ratio.

KEYWORDS — facial measurement methods, odontometry, dental arches study methods, gnathic type of dental arches, normodontia, macrodontia, microdontia.

INTRODUCTION

The progressive level of fundamental and applied research concerning the issues of morphogenesis, generic and individual variability of morphological structures in the maxillofacial area leads to significant successes in the contemporary modern clinical dentistry. However, despite the scale and the depth of the national and foreign research carried out in the area, most aspects of this important issue remain unclear [4, 7, 11, 19, 24].

Gaining the optimal morphological, functional and aesthetic balance in the maxillofacial area is a priority for any patient undergoing orthodontic treatment. Such a balance between morphology, function and aesthetics will make it much easier to achieve the most acceptable outcomes of treatment in each clinical situation [3, 14, 22, 25, 29, 35].

The announced results of anatomical and topographic studies create grounds for stating that one of the most important ways to evaluate the self-regulation of the dentoalveolar system involves the morphometric parameters establishing the consistency between the tooth sizes and the dentoalveolar arches parameters, which is due to the individual variability of maxillofacial features. Therefore, the identification and individualization of topographic anatomical maxillofacial features, performed through biometric research methods prior to orthodontic treatment, appear most relevant [10, 28, 33].

The algorithms employed to forecast the shape and size of dental arches have a long history and have already been described by domestic and foreign experts [2, 32].

The authors prove here that the dental arches frontal parts, which differ in the sagittal and transversal planes, often reveal anomalies and deformations whose etiology implies premature removal of milk teeth [1, 13, 26].

The variability of the main linear parameters is due to both the gnathic (dolicho-, meso- and brachygnathic), and the dental types of the face and dental arches [6, 9].

There has been a relationship shown between the size of different sections in dental arches [5, 16].

Until now, the measurement of dental arches has been mostly performed through the Pont (Linder-Hart) methods, which have become subject to criticism from specialists due to the different values of the proposed indices when measuring the same parameters. The anterior part is limited to the first premolars, which is not always used by clinical experts. In most cases, special attention is paid to the canines, seen as the key teeth, and the inter-canine distance [8, 15, 30, 34].

There has been the dependence shown between the inter-canine distance and the teeth size, for all gnathic types of dentoalveolar arches [17, 20].

Special emphasis has been put on the inter-canine distance, as well as the correlation shown with the external nose dimensions. Indices have been proposed for determining the inter-canine distance. However, the ***al*** point (located on the wings of the nose) has been recommended as the main points for measuring the external nose [12, 21].

The forecast for the shape of dental arches, depending on the size of the anterior teeth, relies on the Hawley-Gerber-Herbst arch. However, there have been some faults of this technique pointed, which are associated, first of all, with the length of the chord being shorter than the segment arch length, and the sum of the dimensions of the three front teeth always being smaller than the circle radius [18, 27, 32].

Attempts to link the construction of the arch with interdependent parameters, namely – the depth and the width, can take place only with physiological occlusion, and even then they depend on the specific features of the dental arches [23, 31].

Attention is to be paid to mathematical modeling of dental arches while taking into account the logic of the circle geometry; however, the proposed pattern is based on the measurement of the inter-canine distance, which can vary in case of abnormal canine location. At the same time, respective literature lacks information on forecasting the shape and dimensions of the dental arches relying on measuring relatively stable parameters.

Aim of study:

development of an algorithm for forecasting the shape and size of dental arches in view of the teeth size and the major maxillofacial parameters.

MATERIALS AND METHODS

The comparison group included 96 people of both sexes with a full set of permanent teeth, physiological occlusion and with no maxillofacial congenital pathology. The development of a forecast algorithm for the shape and size of the dental arches took, at the first stage of the study, a comparative analysis of the main linear parameters of the face and dental arches among the comparison group patients.

To do this, measurements were performed to check the distance between the ***ac–ac*** points (***alarcurvature***). The ***ac*** point is the commonly accepted point indicated in the “Biometric Identification” standards (GOST R ISO / IEC 19794-5-2006), and is located on the bend of the nose wing or as the most outward prominent point on the nose wing bend (Fig. 1).

Jaws cast models were used to carry out odontometry in the medial-distal plane as well as to measure dental arches in the sagittal, transversal and diagonal planes.

The width of the dental arch anterior section was measured between the points located on the canine cusps. The depth of the anterior part was taken as the distance from the interincisal point (between the medial incisors on the vestibular side) up to the conditional line connecting the points located on the canines. The front-canine diagonal corresponded to the distance from the inter-incisal point to the canines (Fig. 2).

Fig. 1. ***ac*** *point location on the face*

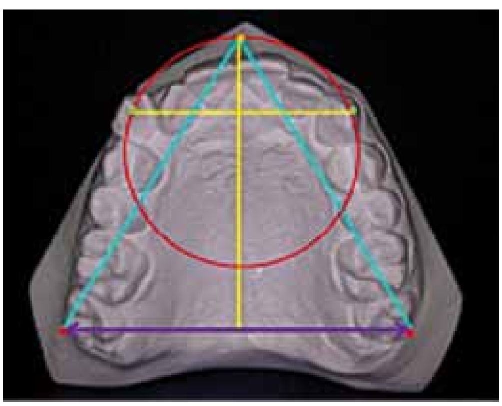

Fig. 2. Abnormal position of canines on the model with the target location of the key teeth and reference lines to measure the dental arch parameters

The actual values were compared to the estimate indicators.

The dependence of the length of the arch, chord and height was determined based on Huygens and calculated following the formula we used in our studies

$$64H^2 = 9L^2 + 6LX - 15X^2$$

H — the height of the segment; L — the arch length; X — the chord length.

The statistical processing was performed directly from the common data matrix of ECXEL 7.0 (Microsoft, USA) also involving certain features offered by the STATGRAPH 5.1 (Microsoft, USA) software, ARCADA (Dialog-MGU, Russia), and implied detecting the median values, its mean root square deviation, and the non-sampling error. Further on, following the patterns commonly employed for medical and biological studies (sample numbers; type of distribution; non-parametric criteria; reliability of the difference of 95%, etc.) the significance of the sampling difference was evaluated subject to the Student's criterion (t) and the respective significance index (p).

RESULTS AND DISCUSSION

Given the wide range of the linear values in humans, we carried out a comparative analysis of the calculated indices with linear dimensions of the dentoalveolar arches, taking into view the type of gnathic part of the face (dolicho-, brachy- and mesognathy) and tooth size features (micro-, macro- and normodontia) (Fig. 3–5).

A comparative analysis of the calculated and actual values, the discrepancies were found to be unreliable and due to insignificant measurement errors, as well as features of the material used for the jaw cast models, which allowed us developing an algorithm to forecast the shape and dimensions of the dental arches.

ALGORITHM FOR FORECASTING THE SHAPE AND SIZE OF DENTAL ARCHES IN VIEW OF THE TEETH SIZE AND THE BASIC MAXILLOFACIAL PARAMETERS

First, the mesial-distal (M–D) dimensions of the anterior teeth were measured as well as the length determined for the dental arch's anterior part, limited with the canine cusps (Fig. 6).

When determining the length of the anterior part of the dental arch, in view of the fact that the arch is bounded with the medial part of the canines, we recommend the length of the anterior part (L) be calculated as the sum of the medial-distal dimensions of the four incisors to be further added to the sum of the canine sizes multiplied by 0.75, following the formula below:

$$L = M\text{–}D_{\substack{\text{medial}\\\text{incisors}}} + M\text{–}D_{\substack{\text{lateral}\\\text{incisors}}} + (0.75 \cdot M\text{–}D_{\text{canines}})$$

Second, we determine the inter-canine distance. In case of anomalies, the canines often have abnormal position, due to which we recommend that the dental arch width between the canine cusps be estimated by the size of the external nose.

The dental arch width between canines ($W_{3\text{-}3}$) corresponds to the nose width between the ***ac–ac*** points.

In case of abnormal dental arch shapes, measuring the mesial-distal dimensions does not present any issue. However, it is hard to measure the front-canine diagonal and the depth of the dental arch's anterior part.

a b c

Fig. 3. Pictures of the oral cavity of the patient with permanent teeth microdonthism in the anterior (a), lateral right (b), and lateral (in) projections

a b c

Fig. 4. Pictures of the oral cavity of the patient with permanent teeth macrodonthism in the anterior (a), lateral right (b), and lateral (in) projections

a b c

Fig. 5. Pictures of the oral cavity of the patient with normodontism of permanent teeth in the anterior (a), lateral right (b), and lateral (c)

Fig. 6. Photo of a plaster model with a designated length of the anterior part of the dental arch

Given that the front teeth are located arch-wise, while the front-canine diagonal is a straight line, determining its size could be performed using the formula, which Huygens once noticed and pointed at the dependence of the length of the arch, chord and height. Therefore, the depth of the dental arch's anterior segment was calculated from formula:

$$D_{1-3} = \sqrt{[(9 \cdot L^2) + (6 \cdot L \cdot W_{3-3}/2) - (15 \cdot W_{3-3}/2)]/64}$$

The front-canine diagonal can be calculated as the sum of the product of the arch half-length by 0.75, and the half-width of the dental arch's anterior part by 0.25, following the formula:

$$\text{The front-canine diagonal} = (0.75 \cdot L/2)+(0.25 \cdot W_{3-3}/2)$$

Of particular interest is identifying the diameter (radius) of the circle on which the front teeth are to be located. In this case, the value of the central angle (α) shaped by the circle radii that bound the chord corresponds to twice the arctangent of the ratio of the doubled depth of the dental arch's anterior part to the width of the arch between the canines, and is subject to the formula:

$$\alpha = 2 \cdot \text{arctg}\, 2\, D_{1-3}/W_{3-3}$$

The circle diameter was defined as the ratio of the dental arch's width between the canines to the central angle sine:

$$\text{The circle diameter} = W_{3-3}/\sin\alpha$$

On the resulting circle, from its upper point on, we measure segments equal to the front-canine diagonal. The calculations based on these formulae may seem too complicated at first glance.

All the calculations can be downloaded in Excel while the clinical expert will only have to measure the medial-distal dimensions of the three front teeth and the nose width between the ***ac–ac*** points.

CONCLUSIONS

1. In view of the results of morphological, clinical studies and mathematical modeling, an algorithm for forecasting the shape and dimensions of dental arches has been proposed, based on measuring the relatively stable parameters, namely, the anterior teeth dimensions, and the basic parameters in the maxillofacial area.

2. The algorithm is based on mathematical calculations of the circle geometry and the dependence of the length of the arch, chord and height.

3. The circle diameter was defined as the ratio of the dental arch's width between the canines to the sine of the central angle formed by the circle radii limiting the chord.

4. The size of the front-canine diagonal is comparable with the size of the anterior teeth in a certain ratio.

5. The developed algorithm (a set of biometric measurements and mathematical calculations) is a highly informative, diagnostically significant sequence of actions that can be employed to describe physiological occlusion, make forecasts concerning the shape and size of dental arches when treating patients with dentoalveolar anomalies, as well as to select the tactics and the extent of orthodontic treatment.

6. In clinical orthodontics, the introduction of a forecast algorithm based on the measuring the relatively stable parameters will reveal the deviations in the teeth location as well as in the shape and size of the upper dental arch in the transversal and sagittal planes, reducing the time spent in the early diagnostics phase and increasing the effectiveness of monitoring the outcomes of orthodontic correction.

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