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A METHOD FOR MODELING ARTIFICIAL DENTURES IN PATIENTS WITH ADENTIA BASED ON INDIVIDUAL SIZES OF ALVEOLAR ARCHES AND CONSTITUTION TYPES

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ABSTRACT — 87 persons of older age groups with complete adentia underwent somatometric (anthropometric) as well as biometric measurements with cast models of the toothless jaws. The linear and index somatometric parameters, and linear and index parameters for the upper jaw alveolar arches, were calculated. Alveolar arches were classified in view of the total sum of the diagonal dimensions (macro-, micro- and normodiagonal type), the arch index (brachy-, dolicho- and mesoarch type). Modelling the projected shape of the dental arch was based on the parameters of length (the sum of the alveolar arches diagonals multiplied by the 1.06 coefficient), width (the product of the width of the alveolar arches by a coefficient of 1.16). The depth of the dental arch frontal segment was calculated as the product of the diagonal by the incisor-canine angle sine, which in case of mesotrusion arches is 0.42 (angle value — 25°), for protrusion arches — 0.5 (angle value — 30°), for retrusion arches — 0.34 (angle value — 20°).
Given the regularities of the circle geometry, the frontal segment dimensions served to determine the radius of the circle where the front teeth sat. The graphical method developed to construct the forecasted upper dental arch shape, based on the balance of the alveolar and dental arches major parameters, allows forecasting the optimal shape and size of the artificial dental arch, achieving a balanced relationship between the shapes of the teeth and the alveolar arches, as well as constructing a balanced articulatory relationship while achieving optimal functional and aesthetic results.

KEYWORDS — complete adentia, alveolar arches, dental arches, constitutional anatomy, somatometrics, biometrics, alveolar triangle, dental triangle.

INTRODUCTION

Currently, the issue of studying human constitution features, which provides the basis for clinical and anthropological areas, refers to the field of both theoretical and clinical medicine. However, classical anthropometric methods can be well complemented by modern innovative research methods, thus, increasing precision and effectiveness of the outcomes[2, 4, 16, 18, 22, 32, 38, 49, 52].

Personalized medicine is, currently, a rapidly emerging field of healthcare, aimed to improve treatment protocols considering patient's body constitution and typology features, determined by a complex set of phenotypic and genetic markers. It offers an objective reflection to morphological, functional and biochemical specificity, remain stable through ontogenesis, and have individual anatomical variability with insignificant intra-individual variability [1, 15, 20, 23, 33, 36, 39, 51, 54].

According to epidemiological studies, the average prevalence of complete secondary adentia in Russia is 8.4–18.0%, while in the age category of 50–59 this rate is 8.9-21.6%; among the populations aged 60–69 — 9.3–25.2%; 70–79 — 17.4–29.5%, and in the category over 80 — 27.8–46.7%. The surge in the number of patients with complete loss of teeth can be observed annually not only among older patients , yet also among those who fall within the group of the middle-aged [59].

Complete absence of teeth in the maxillofacial area entails the following functional and morphological changes: disturbed anatomical and topographic ratio of the facial skeleton and soft tissues; increased jaw bones osteoporosis; discoordinated neuro-reflex action; progressing in the toothless jaws and the covering mucosa atrophy; decrease in the masticatory muscles volume and tone; developing dysfunction of the temporomandibular joint (TMJ). In addition, there are psychoemotional tension, chewing and speech problems, which limit quality of life, communication and lead to social isolation [5, 27, 42, 48, 58].

The success of the diagnosis and the quality of the diagnosis are determined not only by the introduction of instrumental and technical methods for recognizing diseases in clinical medicine, but also by the ability of practicing physicians for analytical and logical thinking. With the increase in information on diseases, the process of mental activity of the doctor becomes more complicated, the requirements for the logical validity, timeliness, completeness and accuracy of the diagnosis has been accelerated [7–12, 21, 26, 30, 40, 45, 55].

The effectiveness of prosthetic treatment for edentulous patients, which is performed in view of the pathogenetic maxillofacial changes, is determined by restoring oral function, delivering prosthesis stabilization through functional suction capacity and anatomical retention, improved aesthetics, as well as preserving the jaw hard tissues under the prosthesis base, and reducing the period of functional adaptation. Implementing these provisions will create conditions for proper social adjustment, systemic improvements in the patient's body and the quality of life [13, 29, 35, 50].

When designing tooth rows on toothless alveolar processes, the priority task is to restore a balanced occlusal and articulatory relationship, where the TMJ functional features are compensated by the shape of the artificial teeth chewing surface, while the angle of any slope of the tubercle corresponds to the movement trajectory of the articular mandibular head, thus ensuring equal loading of all tissues in the prosthetic bed. Besides, when shaping the dentition, it is important to reach an optimal balance between the impacts caused by the neuro-musculoskeletal system of the jaw bones and the physical and mechanical interactions occurring between the prosthesis and the prosthetic bed tissues, providing for multiple interdental contacts of the same power under equally distributed and slight pressure on the denture base supporting tissues [24, 28, 31, 46].

Of reasonable interest are studies focusing on the most variable part of the dental arch — the frontal area, while the biometric features of the anterior part serve the basis for the forecasted graphic reproductions of the dental arches. Here the authors present calculations of the circle radius, offer grounds for mathematical modeling methods of artificial and abnormal dental arches [3, 19, 25, 44, 47, 53, 56, 57].

The data suggest that the central (interincisal) point of the dental arch has an anterior location of the alveolar arch central point in people with protrusion, mesotrusion and retrusion arches at a distance of 3.5 mm, 2.5 mm and 1.5 mm, respectively [37, 43]. In this case, the angle between the anterior diagonal and the width of the arch depends on the front teeth location. In people with a normal tooth torque, the incisor-canine angle is about 25°. In case of incisors protrusion and retrusion, this angle is 30° and 20°, respectively [17, 41]. At the stages of identifying the teeth size, experts recommend focusing on the arches' diagonal dimensions. The diagonal of the upper dental arch has been noted to exceed the diagonal dimensions of the alveolar arch by 1.06 times, while the sum of the six anterior teeth crowns width is 2.45 times as low as the length of a dental arch comprising 14 permanent teeth [34]. The width of the upper dental arch has been proven to be 1.16 times the width of the alveolar arch, this fact being of practical value in clinical dentistry [6, 14].

Despite the algorithms described in the reference literature for treating patients with dental arches anomalies and defects, the data on making forecasts regarding the parameters of artificial dental arches based on the alveolar arch major dimensions in people with complete adentia is neither systematic nor complete, which underlies a rationale for a morphometric study.

Aim of the study:

to develop a method for constructing an upper dental arch of a forecasted shape based on the alveolar process size of a toothless jaw in patients with complete adentia.

MATERIALS AND METHODS

The study used cast models obtained from 87 persons (38 males and 49 females; median age — 74.1±3.2), elderly and old, with complete absence of teeth. All the patients gave their written informed consent in compliance with the guidelines for the Ethics Committee.

When studying the cast models of jaws, measurements were made between the designated points. The central point of the upper alveolar arch corresponded to the location of the alveolar process anterior point in the incisor papilla (in_{al}). The reference points were the upper frenulum and the median palatal suture line. The retromolar points were placed on both sides on the maxillary tubercles tops in the center of the alveolar process (m_{al}). The alveolar arches width was measured between the m_{al} points, whereas the diagonal dimensions were measured between the central and the retromolar points ($in_{al} – m_{al}$). The total size of the diagonals of the upper normodiagonal arches varied from 103 to 112 mm. Micro- and macrodiagonal arches included types where the total diagonal size indicator was below or above the value of the considered range.

The ratio of the arch width to the total sum value of the diagonals determined the arch index, which varied from 0.46 to 0.5 for meso-arch types. An increase in the index indicated belonging to the brachy-arch type, whereas a decrease pointed at the dolicho-arch type of the alveolar arches.

The dental arch length was calculated as the product of the total value of the alveolar arches diagonals to a factor of 1.06. At the same time, calculating the size of the six upper front teeth implied dividing the calculated value of the dental arch length by a factor of 2.45. The resulting value allowed identifying the approximate width of each tooth. The medial-distal diameter of the upper canine, therefore, corresponded to 1/6 of the arch anterior segment length. The width of the medial and lateral incisors was calculated relying on the size of the canine (key tooth), employing the factors of 1.1 and 0.9, respectively.

The product of the alveolar arch width by a factor of 1.16 allowed identifying the calculated width of the upper dental arch. The arch depth was calculated based on the Pythagorean theorem.

The length and width of the dental arch anterior segment was determined between the tearing tubercles (cd points). The length of the anterior segment corresponds to the sum of width of 4 incisors crowns and the half-sum of the mesial-distal diameters of the canines. Half the length of the anterior segment was close to the size of the anterior (incisor-canine) diagonal. The depth of the anterior segment was calculated as the product of the diagonal by the sine of the incisor-canine angle, which for mesotrusion arch type was 0.42 (an angle of 25°), for protrusion type — 0.5 (angle of 30°), and in case of retrusion of incisors – 0.34 (angle 20°).

Meso-arch normo-diagonal, brachy-arch macro-diagonal and dolicho-arch macrodiagonal arches were attributed to the mesotrusion type of arches. Anterior teeth protrusion was typical of dolich-arch types with macro- and normodiagonal dimensions, and was to be observed in case of meso-arch macrodiagonal types of dental arches. Retrusion was typical of brachy-arches with normo- and microdiagonal, as well as of meso-arch macrodiagonal types (Fig. 1).

In view of the circle geometry patterns, the anterior segment determined the radius of the circle where the front teeth sat. The radius was calculated as the ratio of the sum of the segment half-width square and the segment depth square to the segment double-depth.

For the quantitative distribution of constitution types, somatometric measurements were performed relying on a basic set of anthropometric tools, which had undergone metrological verification subject to generally accepted methods. The obtained outcomes were recorded in individual protocols. In order to ensure objective description of the physical constitution type and the physique proportions, the constitutional morphology index was employed (L. Rees – H. J. Eisenk). The L. Rees-H. J. Eisenk index = L × 100 / transverse chest diameter × 6; where L is body length (cm). Interpretation: picnical constitution — males (under 96.2), females (under 95.9); normosthenic constitution — males (96.2–104.8), females (95.9–104.3); asthenic constitution — males (beyond 104.8), females (beyond 104.3). The data processing was performed using the Microsoft Excel 2013 software as well as the SPSS Statistics statistical software package (Version 22). The critical level of the possible zero statistical hypothesis was set at 0.05.

RESULTS AND DISCUSSION

The results of the quantitative distribution of somatotypes by proportion and body constitution (L. Rees-H. J. Eisenk index) reveal that the picnical constitution was observed in 9 males and 6 females (23.7% and 12.2%, respectively), normosthenic constitution — in 21 males and 16 females (55.3% and 32.6%, respectively), whereas another for 8 males and

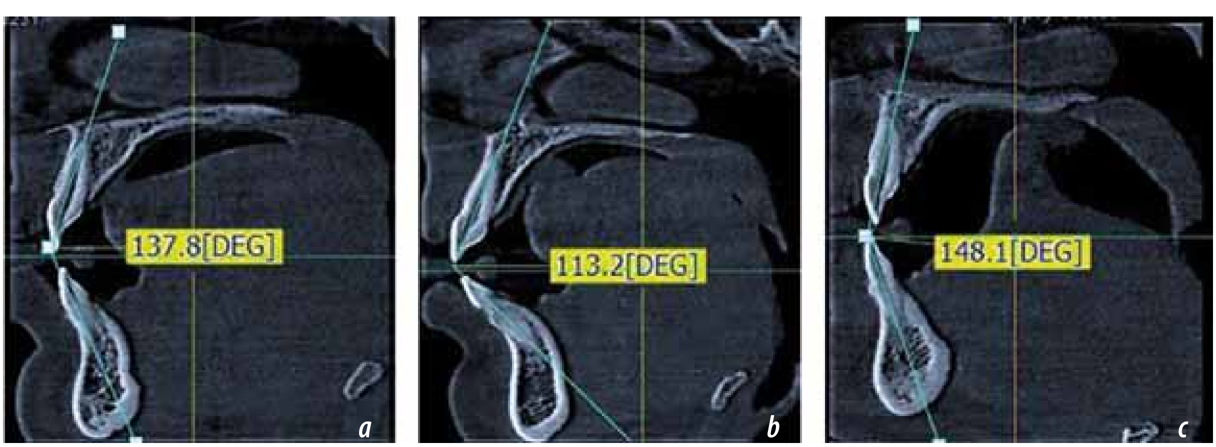

Fig. 1. Variants of the location of the medial incisors on the CBCT images: a — mesotrusion type of dental arches; b — protrusion type of dental arches; c — retrusion type of dental arches

27 females featured the asthenic constitution — 21.0% and 55.2%, respectively).

The alveolar arch measurements laid the basis for constructing the alveolar triangle, whose sides are the arch diagonal, while the base is the alveolar arch width. The mental triangle construction was based on detecting the location of the central interincisal point, which depends on the dental arch type. The distance between the ind – inal points for the retrusion type made up 1.5 mm, for the mesotrusion type — 2.5 mm, and for the protrusion type — 3.5 mm (Fig. 2).

apart from the interincisal point at a distance equal to the calculated depth of the anterior dental arch, while the position of the canines tearing tubercles is determined by the diagonal size, which is set with a compass from interincisal point to the junction with the base of the triangle on both sides, and is marked as cd. The alveolar and dental triangles are joined for further construction of the artificial dental arch template (Fig. 4).

The circle passes through the points that correspond to the location of the canines tearing tubercles and the interincisal point.

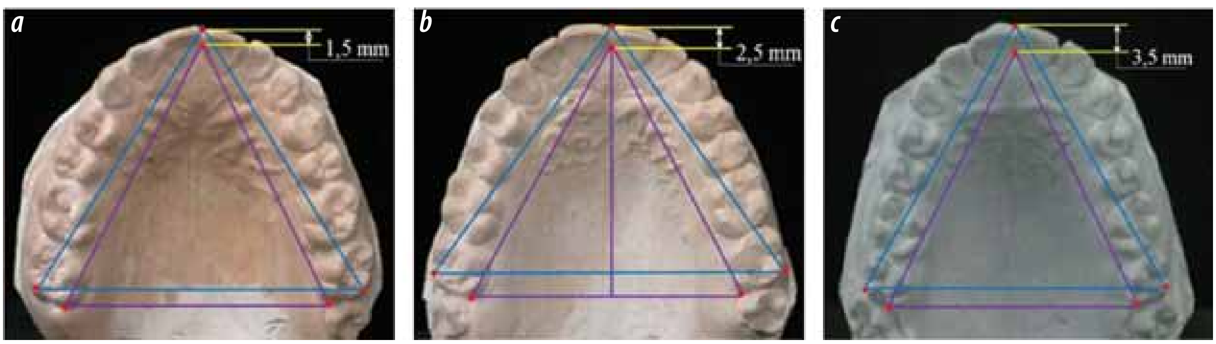

Fig. 2. Mutual position of dental and alveolar triangles for retrusion (a), mesotrusion (b) and protrusion arches (c)

The dental triangle base, which is the width of the dental arch, is separated from interincisal point at a distance equal to the calculated depth of the dental arch, whereas the position of the vestibular distal tubercles of the second molars is determined by the size of the diagonal, which is to be set with a compass from the interincisal point to the junction with the triangle base on both sides and is marked as md. The procedure above serves to identify the location of the second molars, which are the key teeth within the designed dental arch (Fig. 3).

The anterior triangle determines the position of the canines, which are the key teeth for the anterior segment of the artificial dental arch. The front triangle base, which is the width of the dental arch anterior segment, stands

When systematized, the obtained data reveal that when treating patients with compete adentia, it is reasonable to use the size of the alveolar arches thus to identify the key reference points, in order to forecast the size and shape of the artificial dental arch, which should be taken into consideration at the stage of designing the artificial dental arch through prosthetic treatment.

CONCLUSIONS

1. Clinical and morphometric grounds for the proportion of the main parameters of the upper jaw alveolar and dental arches allowed developing, explaining and testing a method for constructing an upper

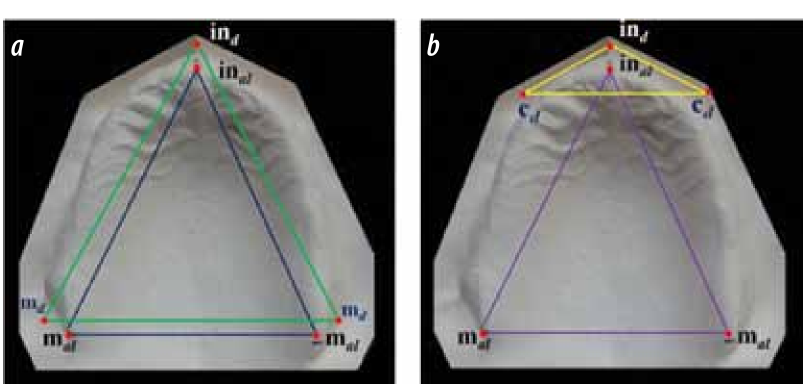

Fig. 3. Cast model of the upper jaw with applied reference points and the construction of the alveolar and dental triangles (a) and the alveolar and anterior dental triangles (b)

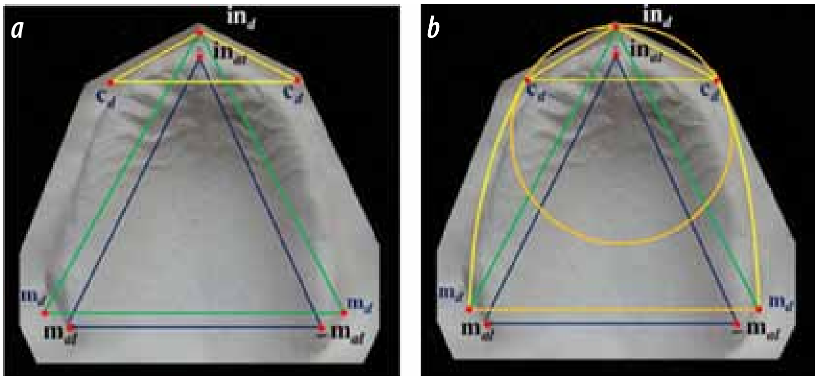

Fig. 4. Cast model of the upper jaw with applied reference points showing the key teeth location (a) and the construction of an artificial dental arch template (b)

dental arch of a forecasted shape based on the size of the toothless jaws alveolar processes in people with complete adentia and featuring various types of the body constitution. The following points were used as stable anatomical references that are most resistant to atrophy: retromolar points (m_{al}) located in the mucous mandibular tubercles of the retromolar triangles and maxillary alveolar tubercles; central points (in_{al}) located in the middle of the incisor papilla on the upper jaw hard palate.

2. The total index of the diagonal dimensions between the central (in_{al}) and the retromolar (m_{al}) points on the right and left sides in people with complete adentia, which falls within the reference intervals of 103–112 mm, points at the normodiagonal type of the alveolar arch. The total diagonal value of in_{al}–m_{al} below 103 mm indicates the microdiagonal type, while more than 112 mm means we are dealing with a macrodiagonal alveolar arch.

3. The arch index value taken as the ratio of the arch width to the sum of the diagonals in case of meso-arch, ranges between 0,46 and 0,5. The dimensional features of the arch index exceeding 0.5 are indicative of the brachi-arch type, whereas the same index below 0.46 points at the dolicho-arch type of the alveolar arches.

4. The value of the incisor-canine angle sine of the front segment for mesotrusion normodiagonal arches is 0.42 (angle — 25°), for protrusion arch — 0.5 (angle — 30°), for retrusion arch — 0.4 (angle — 20°).

5. The mesotrophic type of the dental arches includes meso-arch normodiagonal, brachy-arch macrodiagonal, and dolicho-arch macrodiagonal ones. The protrusion type of dental arches is diagnosed in dolicho-arch cases with macro- and normodiagonal dimensions, as well as in meso-arch macrodiagonal cases. The retrusion type of the dental arches features brachy-arch types with normo- and microdiagonal size as well as in case of meso-arch macrodiagonal types.

6. Due to complete loss of teeth, atrophy of the alveolar process and jaw bone tissue affects the shape and the size of the alveolar arches. Applying the limits of the alveolar arches reference intervals as reference points, when designing the dentition, may allow reproducing the volume and the nature of the structure available prior to the teeth loss and bone atrophy of the alveolar processes and jaws, which will finally allow designing a prosthesis to meet both the functional and the aesthetic requirements.

7. The individual-centered approach employed for the quantitative identification of the constitution types reveals that the normosthenic constitution prevails among elderly and old males, while the asthenic constitution prevails among females belonging to the same age group.

8. Rational prosthetic treatment can be improved through expanding the aesthetic aspects of modeling artificial teeth (Nelson's triad) with the size values and ratios identified for the alveolar arches of the upper jaw. Graphical identification of the key reference topography would not only allow forecasting the optimal shape and size of the artificial dental arch as well as arriving at a proper balance between the shapes of the teeth and the alveolar arches, yet would also help designing a well-balanced articulatory relationship, thus ensuring optimal functional and aesthetic outcomes.

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