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CLINICAL TYPES OF HARD PALATAL VAULT IN PEOPLE WITH VARIOUS GNATHIC DENTAL ARCHES WITHIN PHYSIOLOGICALLY OPTIMAL NORM

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ABSTRACT — The study is based on an analysis of cone-beam computed tomograms and biometric examination of jaw cast models obtained from 68 people aged 21–35 with permanent teeth physiological occlusion. The findings were used to identify the relationship between the morphometric values (height, depth) of the palatal vault, and the linear parameters (length, width) of dental arches. In patients with mesognathic dental arches, the palatal vault index, taken as a ratio between the palate height to the alveolar part width, was 41.14 ± 2.87%, whereas the width indicators exceeded (by 2.43 times on average) the hard palate vault depth parameters. People with dolichognathic dental arches had the value of the palatal vault index reaching 51.75 ± 2.57%, while the width indicators exceeded the depth parameters of the hard palate vault by 1.93 times on average. In patients with brachygnathic dental arches, the palatal vault index was 28.29 ± 2.62%, with the width indicators exceeding the depth parameters by 3.53 times on average. There is evidence showing that mesognathic dental arches have mesopalatal (proportional) palatal vault matching them, while in case of dolichognathic dental arches, the match is dolichopalatal (high and narrow) type of vault. As for brachygnathic dental arches, then the match is brachypalatal, i.e. a low and wide vault. The obtained data can be used in clinical orthodontics, orthopedic dentistry, as well as maxillofacial surgery to assess the hard palate parameters, to diagnose palatal vault pathologies, and to select respective treatment approaches in view of the dental arches shape and size anomalies.

KEYWORDS — dental system; hard palate; cone-beam computed tomography; physiological occlusion; gnathic types of dental arches; biometrics of jaw cast models.

INTRODUCTION

Modern achievements in applied anatomy, focusing on the organ structure and their topography in normal cases as well as in pathologies, which serving the interest of various areas of clinical medicine, rely on advanced technologies for intravital study of various morphological structures belonging to the human support & motor system [6, 9, 15, 20, 29, 43, 55].

Methods employed for visualizing the face bone-based skeleton and its soft frame, especially in dentistry and maxillofacial surgery, have been given a specific development impetus [7, 14, 19, 24, 28, 34, 53].

Highly reliable, safe, non-invasive methods of X-ray diagnostics, which involve computer software, allow identifying the individual variability patterns within the structure of the facial skull bones [2, 10, 16, 30, 36, 45].

Continuous improvement of research technologies in this field contributes to enhancing the knowledge when applied to studying various aspects of the skull clinical anatomy, this entire activity facilitating the activities of dentists, maxillofacial surgeons, neurosurgeons, otorhinolaryngologists, ophthalmologists, etc. [3, 8, 11, 21, 37, 44, 54, 56].

One of the fundamental problems of morphology, which is of applied value, is a comprehensive study of the individual typological variability of the structures of the skull facial and cerebral parts, as well as the interconnection patterns of individual components in the skull system as a whole [12, 18, 23, 31, 38].

A detailed and thorough study of the facial and cerebral skull morphology, in view of individual typological features, will allow significant expansion of the scientific knowledge concerning the patterns pertaining to the structure of the craniofacial complex and its components, while obtaining valuable information related to variant anatomy [1, 4, 17, 22, 27, 33, 46].

The hard palate, which is a bone wall separating the oral cavity from the nasal cavity, is both the roof of the oral cavity and the bottom of the nasal cavity. The front section of the hard palate includes the palatal processes of the maxillary bones, whereas the posterior (distal) part is shaped by the horizontal plates of the palatal bones. The mucous membrane covering the hard palate is fused tightly with the periosteum, whereas there is a bone suture running along the hard palate middle line. The configuration of the palatal vault, depending on the individual typological variability, features significant variability [5, 25, 41, 48].

As far as measuring the hard palate is concerned, there were various devices and research methods proposed — from the classical symmetrograph of Korkhaus to computer 3D diagnostics. The proposed programs allow not only identifying the main parameters of the palatal vault, yet also matching them versus the average values falling within the norm, as well as archiving the study outcomes [13, 47].

Following expert recommendations, the length of the palatal vault is measured from the apex of the interstitial papilla to the line connecting the first permanent molars' distal surfaces. Vertically, the distance is measured from the deepest point (between the second premolars and the first molars) to the line connecting the interdental papillae. The transversal dimensions (the width of the palatal vault) are measured at the same spot. As for a criterion to evaluating the palate parameters, the authors here propose the palate height index, which is to be calculated as a ratio of the palate depth (height) to the palate width. The value of the index in question has been found to be 31–32% at a young age. Notable is that this study was caried out without taking into account the gnathic and the dental types of dental arches, which determine the major morphometric features of the dental system [26, 42, 49]. There is reliable data showing that people belonging to the brachygnathic type, have their upper dental arches wider transversally and shorter sagittally, if compared with mesognathic dental arches [35, 40, 50, 52, 58]. People with dolichognathic types, however, revealed something completely opposite — upper dental arches shorter in the transversal, and longer in the sagittal, plane, if matched against mesognathic dental arches [32, 39, 51, 57].

The available literature offers no data on the variability of the hard palate parameters for different types of dental arches, which explains the aim of this study.

Aim of study:
to identify the main parameters of the hard palate vault in people with different genetic types of dental arches within the physiologically optimal norm.

MATERIALS AND METHODS

A stratified, as well as a retrospective study was conducted focusing on the examination of cast models and CBCT images of 68 patients within their first adulthood stage (age — 21–35). All the patients were registered as featuring the physiological occlusal norm, and they were divided into 3 groups in view of the gnathic type their dental arches belonged to, namely, mesognathic (25 patients), dolichognathic (21 patients) and brachygnathic (22 patients). The type of the dental arch was identified relying on the ratio of the transversal measurement of the dental arch distal part (the width between the second molars' distal tubercles at the vestibular and occlusal surfaces border) to the sum of the crown width of 14 teeth (the dental arch length). Mesognathic arches included those where the arch index varied from 0.52 to 0.56. The gnathic index of the dental arch under 0.52 was considered typical of the dolichognathic type of dental arches, and that exceeding 0.56 — of the brachygnathic one (Fig. 1).

The position of the highest point of the hard palate vault in the sagittal plane (passing between the medial upper incisors) was identified based on the respective CBCT data, whereas the horizontal palatal line passed through the incisor papilla apex. The palatal vault height was measured from the top height to the horizontal papillary line. These landmarks were used to measure the palate width in the CBCT direct projection, as well as in the occlusal norm projection. As a rule, the deepest point was located between the second premolar and the first molar, which reflects respective data reported by most researchers (Fig. 2).

Apart from the CBCT analysis, these parameters were measured on jaw cast models. The measuring points were similar to the CBCT marks. The obtained linear parameters allowe1d identifying the *palatal vault index* as a ratio of the palate height (depth) to the width of the alveolar part. The index allowed selecting three groups — at an index of 35% to 45%, the palatal vault was attributed to the mesopalatal type. An increase in the index pointed at a palatal vault belonging to the deep (dolichopalatal) type, while a decrease in the index was indicative of the low (brachypalatal) type. In addition to the palatal vault index, the indicators of the palatal vault module were evaluated, taken as half the sum of the palate height and the width of its alveolar part.

The statistical processing of the obtained data was performed with Microsoft Excel 2013 software as well as the SPSS Statistics (Version 22) statistical software package. The critical level of a possible null statistical hypothesis was set at 0.05.

RESULTS AND DISCUSSION

A biometric study of jaw cast models revealed that the main parameters of dental arches and the palatal vault arch are determined by the gnathic types of dental arches (Table 1).

Fig. 1. *The major shape of dental arches: mesognathic (a), brachygnathic (b), dolichognathic (c)*

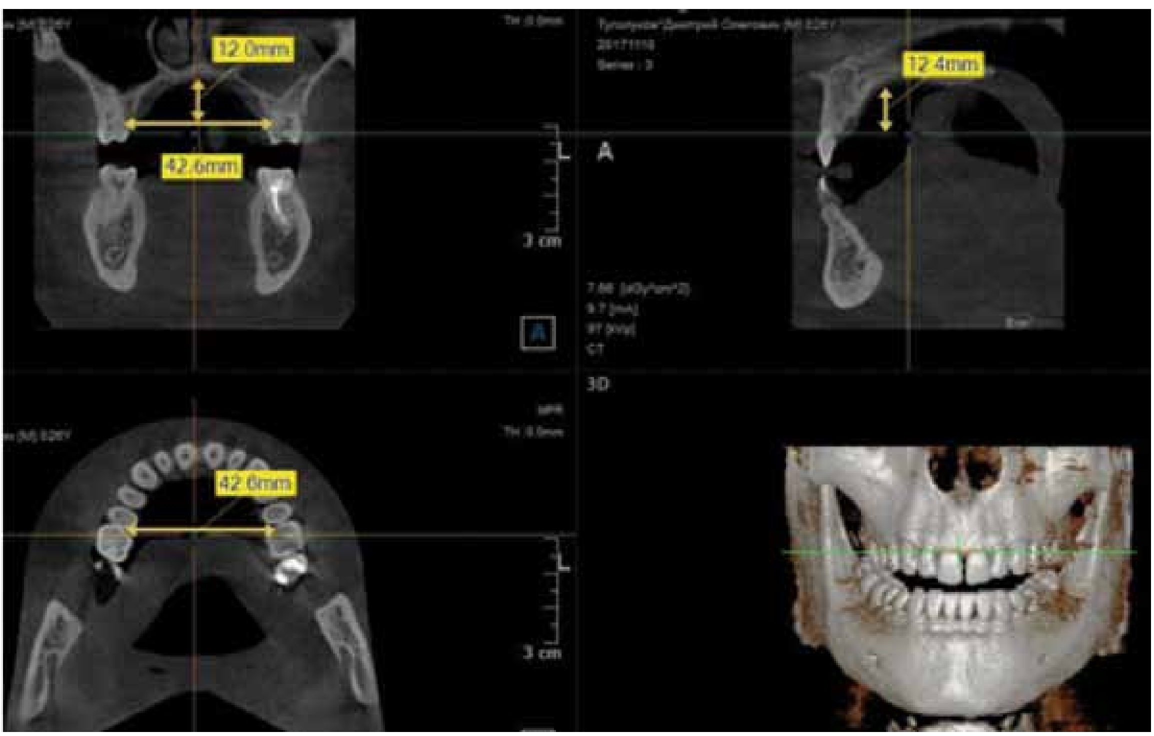

Fig. 2. *Reference marks for measuring the depth and the width of the hard palate vault on CBCT slices*

Table 1. *Outcomes of a biometric study focusing on dental arch parameters and on the hard palate vault, jaw cast models (M ±m) ($p \le 0.05$)*

Parameters	Size and index of dental arch		
	mesognathic	dolichognathic	brachygnathic
Arch length (mm)	112.72±1.25	113.23±1.59	109.05±1.96
Arch width (mm)	59.08±1.27	55.05±1.86	63.09±1.89
Palate width (mm)	39.14±1.18	36.61±1.32	43.12±1.25
Palate depth (mm)	15.24±0.21	19.36±0.48	12.53±0.19
Palatal vault index (%)	38.94±1.42	52.88±1.57	29.06±1.23
Palatal vault module (mm)	27.19±1.18	27.98±1.39	27.82±1.37

The gnathic type of dental arches was identified based on their length and width dimension parameters. The ratio of the transversal size between the second molars to the dental arch length in the mesognathic type of arches was 0.52 ± 0.02; in case of the dolichognathic type — 0.49± 0.02, whereas for the brachygnathic type the value was 0.58± 0.02, which fell well within the ranges to be found in respective research literature.

The transversal dimensions of the hard palate, as combined with its height (depth) served to identify the indices that characterized the type of the palatal vault as *deep*, *medium* or *low* (Fig. 3).

According to the CBCT data, patients with *mesognathic dental arches* had a palate width of 38.04±1.29 mm; the *palate depth* value was 15.65±1.01 mm; the *palatal vault index* was 41.14±2.87 %, the *palatal vault module* being 26.85±0.85 mm.

For patients with the *dolichognathic dental arches*, the palate transversal dimensions were 36.85±1.17 mm; the vertical parameters were 19.07±1.12, the *palatal vault index* reached 51.75±2.57 %, with the palatal vault module being 27.96 ±1.12 mm. An analysis of coronal tomograms obtained from patients with *dolichognathic dental arches* shows that the palatal vault dome is visualized as high and narrow (Fig. 4).

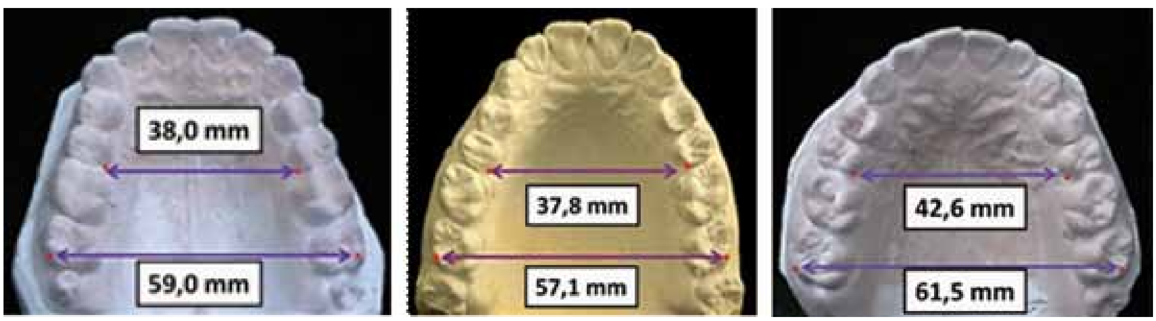

Fig. 3. *Cast models for cases of mesognathic (a), dolichognathic (b) and brachygnathic (c) dental arches*

As the biometric study of jaw cast models show, patients with *mesognathic dental arches* have a palate width of 39.14 ± 1.18 mm; a depth of 15.24± 0.21 mm, the value of the *palatal vault index* being 38.94± 1.42%, and the *palatal vault module* — 27.19±1.18 mm.

For patients with *dolichognathic dental arches*, the palate transversal dimensions were 36.61±1.32 mm; the vertical parameters were 19.36±0.48; the *palatal vault index* was 52.88± 1.57 %, while the *palatal vault module* was 27.98±1.39 mm. The *palatal vault index* in this category was found to feature statistically significant prevalence of such indicators over similar ones in people with mesognathic dental arches ($p<0.05$).

In patients with the *brachygnathic type of dental arches*, the width of the palate was 43.12±1.25 mm; the palate depth was 12.53±0.19 mm; the palatal vault index was 29.06±1.23 %, with the palatal vault module being 27.82±1.37 mm. The study revealed that in this category, the palatal vault index was reliably lower than similar parameters in people with *mesognathic* and *dolichognathic* type of dental arches ($p<0.05$).

An analysis of CBCT indicators revealed that the main parameters of the hard palate vault were close to the dimensions obtained through studying the jaw cast models, and were also determined by the types of dental arches (Table 2).

In people with brachygnathic dental arches, as the CBCT showed, the palate width was 43.16±1.32 mm; the depth was 12.21±0.85 mm; the palatal vault index was 28.29±2.62 %, while the palatal vault module was 27.68±1.11 mm. When visualizing coronal tomograms of patients with brachygnathic dental arches, it was obvious that the palatal vault dome visualized as *low* and *wide* (Fig. 4).

It is important to note that the hard palate vault module in patients with various genetic types of dental arches is stable, the limits of variability being not statistically significant ($p\geq0.05$).

This means that the morphometric parameters of the hard palate vault obtained through biometric study of jaw cast models and cone-beam computed tomograms reveal no statistically significant differences ($p\leq0.05$), and can be used in orthopedic dentistry and orthodontics for diagnostics, as well as for selecting tactics when dealing with patients featuring dental anomalies, and for evaluating the effectiveness of dental treatment.

CONCLUSION

1. CBCT data shows that patients with *mesognathic dental arches* have palatal vault index of 41.14 ± 2.87%, while the width indicators exceed the hard palate depth parameters — by 2.43 times on average.

Table 2. Parameters of hard palate vault based on CBCT data (M±m) (p ≤ 0.05)

Parameters	Size and index of palatal vault at the following dental arches:		
	Mesognathic	dolichognathic	brachygnathic
Palate width (mm)	38.04±1.29	36.85±1.17	43.16±1.32
Palate depth (mm)	15.65±1.01	19.07±1.12	12.21±0.85
Palatal vault index (%)	41.14±2.87	51.75±2.57	28.29±2.62
Palatal vault module (mm)	26.85±0.85	27.96±1.12	27.68±1.11

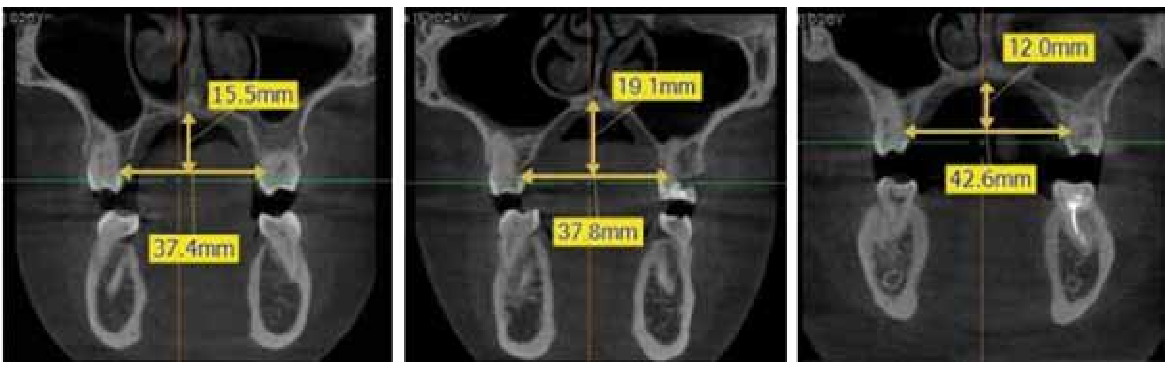

***Fig. 4.** CBCT of patients with mesognathic (a), dolichognathic (b) and brachygnathic (c) dental arches*

2. People with *dolichognathic dental arches*, according to CBCT data, have the palatal vault index reaching 51.75 ± 2.57%, while the width indicators are an average of 1.93 times those of the hard palate depth parameters, while a decrease in the hard palate vault width is accompanied by an increase in the height indicators.

3. CBCT data reveals that patients with *brachygnathic type of dental arches* have a value of the palatal vault index of 28.29 ± 2.62%, while the width indicators exceed the depth parameters of the hard palate vault by 3.53 times on average, whereas an increase in the palatal vault width comes combined with a decrease in the height indicators.

4. The palatal vault module, taken as the ratio of its height (depth) parameters half-sum to the width of the alveolar part, as is obvious from the respective CBCT data, is a constant value and: with *mesognathic* dental arches is 26.85 ± 0.85 mm, with *dolichognathic* dental arches is 27.96 ± 1.12 mm, while with *brachygnathic* dental arches it is 27.68 ± 1.11 mm.

5. When visualizing coronal tomograms at the second premolars level in patients with the *brachygnathic* type of dental arch, the palatal vault dome is visualized as *low* and *wide*, whereas in patients with the dolichognathic dental arches it is *high* and *narrow*.

6. The outcome of the individual-typological variability study focusing on the cranio-facial structures with physiologically normal occlusion, is identifying the relationships (patterns) between morphometric values (height, depth) of the palatal vault and the linear parameters (length, width) of dental arches. Patients with *mesognathic* dental arches correspond to the *mesopalatal* (proportional) type of the vault; those featuring the *dolichognathic* type of dental arches — to the *dolichopalatal* (high and narrow) type of the vault, whereas patients with *brachygnathic* dental arches matched the *brachypalatal* (low and wide) type of the palatal vault.

7. Cone-beam computed tomography, which is part of the standard X-ray examination protocol provides the most complete diagnostic information on the cranio-facial bone structures. Improving visualization algorithms of cranio-facial bone structures in regard to age, sex and individual variability facilitates standardization of dental research methods used for objective diagnostics of patients with congenital issues (cleft lip, alveolar process, hard and soft palate, dysplastic disorders), as well as occlusion anomalies and deformities in the sagittal and transversal planes.

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