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MODERN X-RAY DIAGNOSTICS POTENTIAL IN STUDYING MORPHOLOGICAL FEATURES OF THE TEMPORAL BONE MANDIBULAR FOSSA

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ABSTRACT — Based on the data obtained through panoramic radiograph analysis and cone-beam computed tomograms involving 213 patients (21–35 y.o.) featuring physiological occlusion and various gnathic and dental types of dental arches, a method has been developed to allow identifying the index of temporomandibular joints' articular fossae, taken as the ratio of the sagittal and the vertical sizes. The study revealed that in case of physiological occlusion there are three major types of the temporal bone articular fossa to be identified: dolichotemporal — *short* and *high*; brachytemporal — *long* and *low*; mesotemporal — *proportional*. It has been proven that with different physiological occlusions, the average type of the articular fossa is typical of those with mesognathic normodontic, brachygnathic macrodontic, and dolichognathic microdontic dental arches, while the articular fossa index is 1.84±0.21, 1.74±0.13 and 1.82±0.24, respectively. The systematization of the data from morphometric studies suggests that in case of physiological retrusion, the articular fossa value index is significantly lower compared to the average type of the articular fossa, whereas it is statistically higher in case we observe protrusion.

KEYWORDS — temporomandibular joint, temporal bone articular fossa, cone-beam computed tomography, front teeth physiological protrusion, front teeth physiological retrusion, dental arches.

INTRODUCTION

Subject to epidemiological studies held by the World Health Organization in more than twenty economically prosperous countries of Europe, Asia and America, there is a very high incidence of temporomandibular joint (TMJ) issues in people of mature age. Clinical TMJ pathologies combined with chewing muscles parafunction, reduce significantly the patients' life quality due to the disabling effect they work on the chewing apparatus, and reveal low efficiency when treated through conservative methods [10, 35, 42, 51]. The temporomandibular joint dysfunction shows significant prevalence, polyetiology, progressive course, as well as a high relapse rate. The combination of the features typical of this disease places it among a number of urgent issues of higher significance in general medical, while the diversity of concepts and approaches to analyzing the TMJ dysfunction etiopathogenesis stirs a lot of interest among those committed to search for highly reliable diagnostic methods, specifically when it comes to the preclinical manifestations stage [17, 41, 68].

Difficulties in diagnosing and treating TMJ diseases are due to not only the lack of a clear understanding of etiopathogenesis, yet could be also accounted for by the extremely diverse clinical image of dysfunctional disorders [2, 16, 36, 50, 54].

Diagnostic issues are taken separately from the holistic view on the status of the dentofacial system as a whole, where TMJ is one of the major elements [3, 14, 30, 49, 61].

The quality and the long-term positive effect of treating dentition issues are the main goal of applied dentistry. The current progress stage in certain areas of clinical dentistry reveals a significant increase in the role of anthropometric, morphological, genetic and functional research methods. When talking about solving priority research and practical problems, we can hardly overestimate the role of the concept implying combined use of diagnostic methods as the basis of an integrated population strategy, which involves a detailed study of the TMJ functional pathology [5–7, 13, 22–24, 29, 32, 38–40].

The TMJ morphology gets quite serious attention in clinical orthodontics and prosthetic dentistry [15, 19, 45, 52]. The location of the joint bone elements is decisive for the lower jaw biomechanics, proof to that being data from various morphometric and functional studies [9, 37, 56, 60].

Currently, it is clinical, instrumental, radiological, graphical, and functional methods that are employed to diagnose TMJ dysfunction, whereas the most reliable of the methods in question include the axiography system, electromyography, computed tomography and magnetic resonance imaging [64, 69].

When examining the TMJ in patients undergoing orthodontic treatment for certain teeth and dentition issues, no pronounced structural changes were detected. At the same time, there was an obvious need for the joint X-ray examination in each case, since some pathology symptoms may manifest at the stage of treatment [20, 26–28, 55, 66].

It is worth noting the works by experts talking about the effect that the front teeth location (protrusive or retrusive) has on the TMJ morphology, as well as on the dependence that the front teeth topography has on the type of dental arches in people with physiological occlusion [8, 18, 33, 47, 58, 63, 65].

There have been signs of sexual dimorphism in teeth and dental arches identified for various physiological and pathological occlusions [11, 31, 46, 57, 62].

A key role in the etiopathogenesis of TMJ issues is assigned to anomalies, maxillofacial deformations [4, 21, 53, 67].

When deciphering teleroentgenograms of patients with TMJ dysfunction, the following indicators are mandatory: the facial and inclinational angles (by Schwartz); the occlusal plane inclination angle; the incisors inclinational angles; the angles showing the chin position and the apical bases of the jaws; the lower jaw head inclination angle in the sagittal plane; the ratio of the lower jaw branches and body size [43].

Based on the teleroentgenogram analysis in the lateral projection, the authors mention the following as the predictors of violated articulation of the lower jaw: prominent sagittal occlusal Spee curve, a multidirectional change in the upper and lower occlusal angles, a tendency to *zeroing* the difference between the angles of the sagittal articular and incisal sagittal angles [34, 44].

The authors note the features of the mandibular joint in people with defects in dental arches of various lengths, including full adentia, as well as the reason for graphic reproduction of dental arches taking into account individual TMJ features, as well as those of the craniofacial unit as a whole [1, 12, 25, 48, 59].

The available research literature offers no data on the TMJ articular fossa morphology in patients with various dental arches and the front teeth position (protrusion, retrusion), which constituted the aim of this study.

Aim of study:
to identify the linear parameters, the index values of the TMJ articular fossae in people with various physiological occlusions, and reveal the dependence of the articular fossa shape on the type of dental arch.

MATERIALS AND METHODS

Cone-beam computed tomography was employed for a morphometric study of TMJ in 213 patients (97 males, 116 females; median 29.3 ± 3.4) aged 21–35 years featuring various types of physiological occlusion with no sign of muscle & articular dysfunction. Computed tomography was performed on a Planmeca ProMax® 3D Plus cone-beam computed tomograph with a cephalostat. The data were processed using the Romexis Viewer software package, which allows obtaining, processing, storing, and export 2D and 3D images in the conventional medical universal DICOM file formats. Scanning parameters: voxel size — 200 microns; pixel size — 200 microns; 3D exposure time — 9–33 sec; reconstruction time in 3D mode — 2-30 sec; focal spot size — 0.5 mm; rotation step — 1 mm; step through the slice reconstruction — 1 mm; slice — 0.2 mm.

Physiological occlusion was identified in case of detecting six *Andrews* occlusion keys. The dental arch type (dental, gnathic) was identified in view of the modern classifications. The dental index was determined through the length of the dental arch, which was calculated as the sum of the crown widths (mesial-distal diameters) of 14 teeth (not taking into account the variable third permanent molars) (Fig. 1).

The sum of the crown widths of the 14 upper teeth lying within the range of 111–118 mm revealed the normodontia dental arch type. An arch length below 111 mm revealed microdontia, while macrodontia was observed in case the value went above 118 mm. Thus, the major dental types of the upper dental arches were determined as normodontia, macrodontia and microdontia (Fig. 2).

To determine the gnathic type of the dental arch, two main and relatively stable indicators were used — the size of the teeth and the width of the upper dental arch between the second molars. The measuring points of the second molars were located on the vertices of the vestibular distal tubercles near the occlusal contour of the crowns (Fig. 3).

The ratio of the crown widths half-sum of the 14 teeth to the width of the upper dental arch was indicative of the dental index of the arch, which determined its gnathic type. In case of index values within 0.9–0.97, the type of the dental arches was referred to as mesognathic. The index value below 0.9 was attributed to the brachygnathic type, while a value above 0.97 — to the dolichognathic type of dental arches (Fig. 4).

The morphometric study of TMJ used tomograms of the right and left sides with subsequent data analysis. For convenience, we used a technique for identifying the vertical and the sagittal size selecting three major types of the articular fossa.

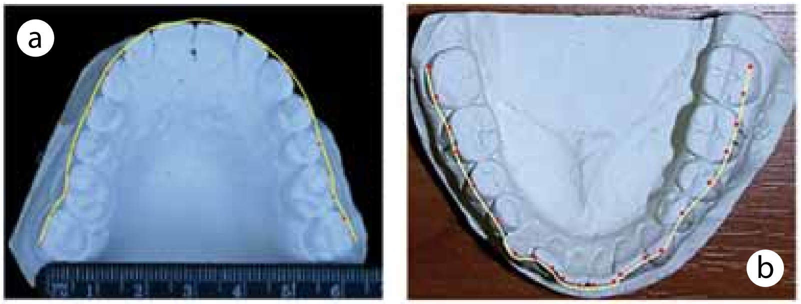

Fig. 1. Photographs of plaster models of the upper jaw (a) and lower jaw (b) with plotted contours of the tooth vestibular arc

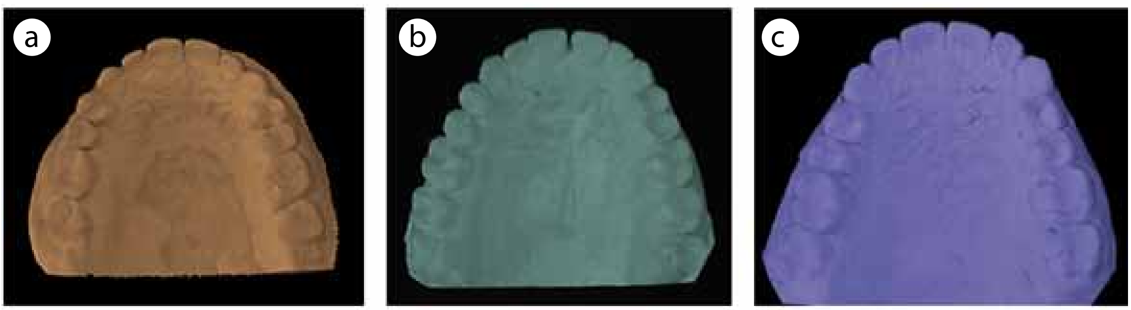

Fig. 2. Upper jaw cast model images featuring microdontism (a), normodontism (b) and macrodontism (c)

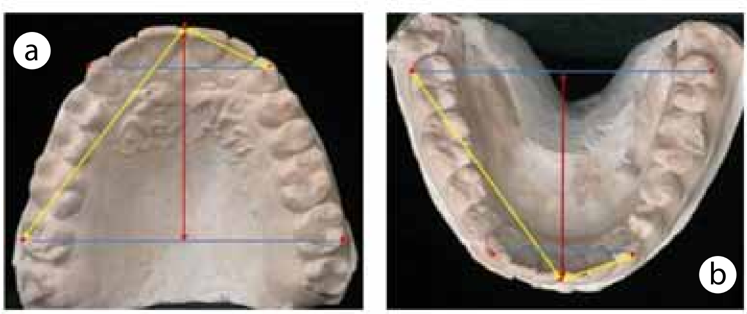

Fig. 3. Width, depth and diagonal of the dental arches of the maxilla (a) and lower (b) jaw

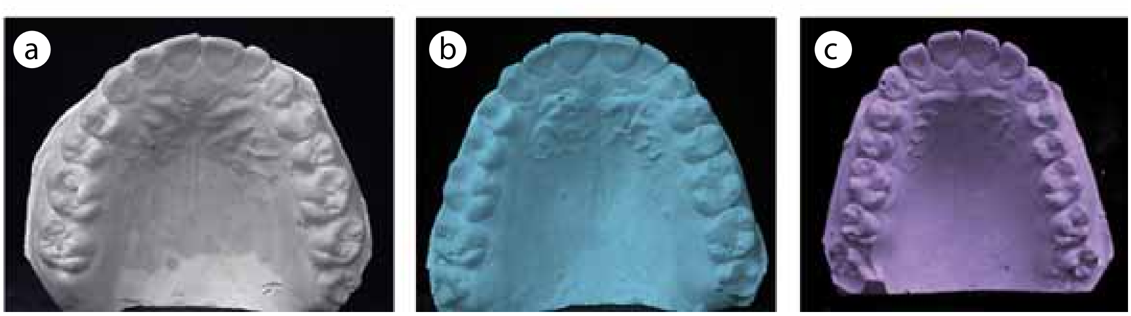

Fig. 4. Upper jaw cast model images with brachygnathic (a), mesognathic (b) and dolichognathic (c) dental arches

Morphometric study methods

The major anthropometric points were placed on the TMJ tomograms in the sagittal projection: A was a point on the lower edge of the external auditory canal; B was the point located on the articular tubercle slope; C was the top point of the articular fossa. Further, the lines were constructed: a horizontal line connecting the lower edge of the external auditory meatus (A) with the point located on the articular tubercle slope (B); a vertical line (CD), running down from the articular fossa top (C) perpendicular to the horizontal AB line. The sagittal (EB) and vertical (CD) sizes of the articular fossa were measured, followed with identifying the articular fossa index taken as the ratio of the sagittal size to the vertical one (Fig. 5).

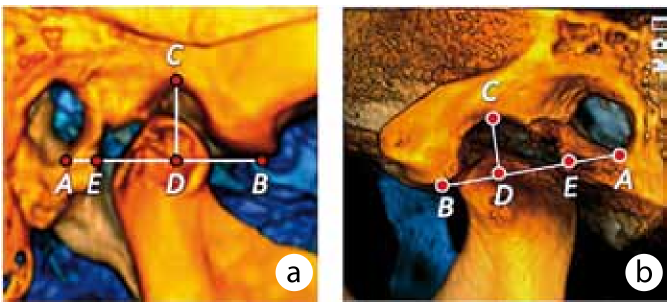

***Fig. 5.** The major reference points for measuring the linear parameters of the temporomandibular joint articular fossa on a CT scan: a — on the right, b — on the left.*

The shape of the mandibular (articular) fossa of the temporal bone was identified through the index value: dolichotemporal — *short* and *high*; brachytemporal — *long* and *low*; *mesotemporal — proportional*.

For statistical processing of the obtained data, the software products STATISTICA 8.0 and SPSS 22.0 (StatSoft, USA) were used. For each feature, the arithmetic mean value and the arithmetic mean error were identified. When establishing the significance difference between the average values from the counter-lateral sides, the Student t-test was identified. To identify the difference significance between the average parameters through comparing variances, we employed analysis of variance (ANOVA). The value of $p \leq 0.05$ was taken as the critical significance level.

RESULTS AND DISCUSSION

The sagittal dimensions of the articular fossa of people with different physiological occlusions varied from 15.70 mm to 20.74 mm, while the articular fossa height was less susceptible to fluctuations, and the values ranged from 8.12 mm to 10.04 mm. The data obtained allowed calculating the articular fossa index for the mesotemporal type — 48.59 ± 1.82%. A decrease in the sagittal (less than 15.70 mm) sizes and an increase in the fossa height (beyond 10.04 mm) were considered as the dolichotemporal (*short* and *high*) type of the articular fossa (index value — 56.65 ± 2.12%). At the same time, an increase in the anteroposterior size exceeding 20.74 mm and a decrease in its height below 8.12 mm was defined as the brachytemporal (*long* and *low*) articular fossa (index value — 35.29 ± 1.74 %).

Table 1 offers a view on the morphometric parameters of the mandibular (articular) fossa of the temporal bone for various types of (dental, gnathic) dental arches.

Morphometric studies showed that people with normodont dental arches had the variability of the articular fossa size both in the sagittal and vertical planes. The smallest sagittal sizes were observed in people with brachygnathia (14.79 ± 1.37 mm), while the largest ones – in dolichognathia cases (22.12 ± 1.19 mm, $p \leq 0.05$). The vertical parameters had differences, too, and people with dolichognathia had a height of the articular fossa (8.93 ± 0.76 mm) that was significantly smaller than in cases with brachygnathia (12.53 ± 0.49 mm). The obtained data makes it obvious that the dental arch type affects the shape of the articular fossa. However, no such regularity was revealed through the analysis of the indicated gnathic types with macro-, normo-, and microdontism. People with macrodontism, for instance, had no difference in the sagittal sizes in cases of meso- and dolichognathia. This applies to the vertical dimensional parameters of the articular fossa as well. In case of microdental dental arches, a similar pattern was revealed with brachy- and mesognathia. No attempt to detect a link between the articular fossa shape and the gnathic types of dental arches (taking into account odontometric indicators) yielded any fruit.

Despite the numerous gnathic and dental types of dental arches, we have shown a certain pattern, which is due to the front teeth location. The research data indicate that the magnitude of the inter-incisal angle for different types of (dental, gnathic) dental arches is not the same. The incisors protrusive position and a decrease in the incisal angle are observed in people with mesognathy and macrodontism, and can also be found in patients falling into the group of dolichognathic dental arches with normo- and macrodontism. There is every reason to note that the shape of the articular fossa for these types of (dental, gnathic) dental arches is *long* and *low*, whereas the articular fossa index (the ratio of the sagittal to the vertical size) was 2.40 ± 0.22 for the mesognathic macrodont type; in case of the dolichognathic normodont type — 2.48 ± 0.27; for the dolichognathic macrodont type — 2.41 ± 0.19 (Fig. 6).

We have found that people with the retrusive position of the incisors and increased sizes of the incisal angle, the articular fossa shape in the sagittal direction is *short* and *high*, and therefore, the articular fossa index is significantly lower than in people with the protrusive position of the front group teeth. In case of the brachygnathic normodont type of dental arches, for instance, the articular fossa index was 1.18 ± 0.16,

Table 1. *Morphometric parameters of the temporal bone articular fossa for various types of (dental, gnathic) dental arches, (M ± m), (mm), (p ≤ 0.05)*

Physiological options for dental arches	Parameters of the articular fossa:		
	Sagittal parameters	Vertical parameters	Ratio
Mesognathia, normodontism	18,34±1,26	9,96±0,58	1,84±0,21
Brachygnathia, normodontism	14,79±1,37	12,53±0,49	1,18±0,16
Dolichognathia, normodontism	22,12±1,19	8,93±0,76	2,48±0,27
Mesognathia, macrodontism	21,28±1,14	8,87±0,36	2,40±0,22
Brachygnathia, macrodontism	18,59±1,13	10,67±0,88	1,74±0,13
Dolichognathia, macrodontism	21,71±1,23	9,01±0,74	2,41±0,19
Mesognathia, microdontism	15,03±1,02	13,07±1,04	1,15±0,19
Brachygnathia, microdontism	15,21±1,12	12,28±0,64	1,24±0,11
Dolichognathia, microdontism	17,96±1,08	9,87±0,89	1,82±0,24

in the case of the brachygnathic microdont type — 1.24 ± 0.11, and in the mesognathic microdont type — 1.15 ± 0.19 (Fig. 7).

The study outcomes show that in case of the incisors protrusive position, the shape of the articular fossa is significantly different from the articular fossa shape with the front teeth retrusion.

Note to be made that the incisors position affects the lower jaw biomechanics, and is reflected in the morphology of the temporomandibular joint major elements. Patients with averaged values of the incisal angle, for instance, had the ratio of sagittal sizes to the articular fossa height for the mesognathic normodont dental arches equal to 1.84 ± 0.21, for the brachygnathic macrodont type — 1.74 ± 0.13, and in case of the dolichognathic microdont type — 1.82 ± 0.24 (Fig. 8).

Systematizing morphometric data from the TMJ computed tomograms of patients with physiological occlusion and various types (dental, gnathic) dental arches allows distinguishing three major shapes of the mandibular (articular) fossa of the temporal bone: *dolichotemporal — short* and *high*; *brachytemporal — long* and *low*; *mesotemporal – proportional* (Fig. 9).

The above-described examination of the temporomandibular joint based on modern methods of X-ray should be mandatory in a clinic for orthopedic dentistry and orthodontics involving comprehensive examination, selecting the treatment tactics in patients with dentofacial anomalies, as well as evaluating the effectiveness of the dental treatment (rehabilitation).

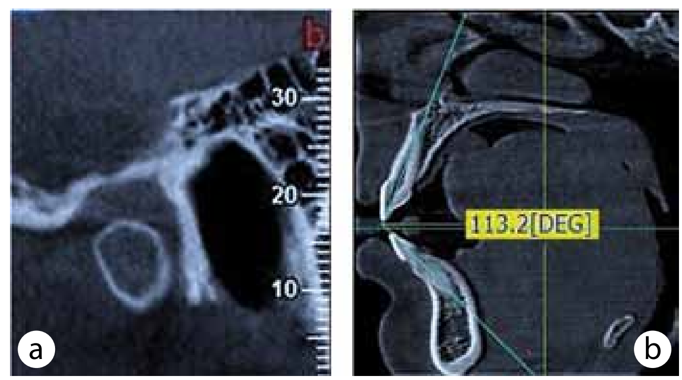

Fig. 6. *Brachytemporal articular fossa (a) tomograms in the protrusive position (b) of the medial incisors*

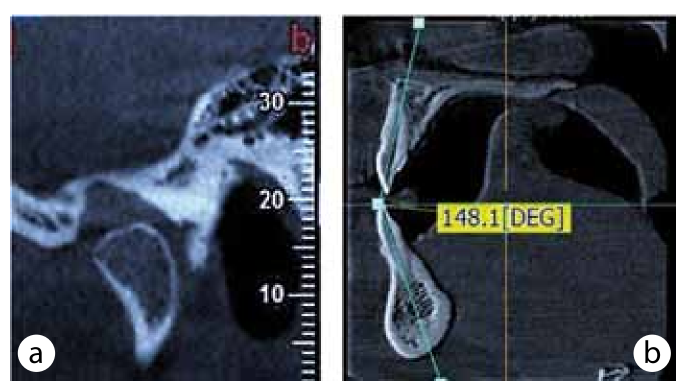

Fig. 7. *Dolichotemporal articular fossa (a) tomograms in the retrusive position (b) of the medial incisors*

CONCLUSIONS

1. The obtained results prove a link between the temporal bone mandibular (articular) fossa shape and various types of (gnathic, dental) dental arches. The type (brachy-, meso-, dolichotemporal) of the temporomandibular joint articular fossa is expressed as index values through the ratio of the sagittal and vertical size values.

2. A decrease in the interdental angle size at physiological protrusion of the front teeth is associated with

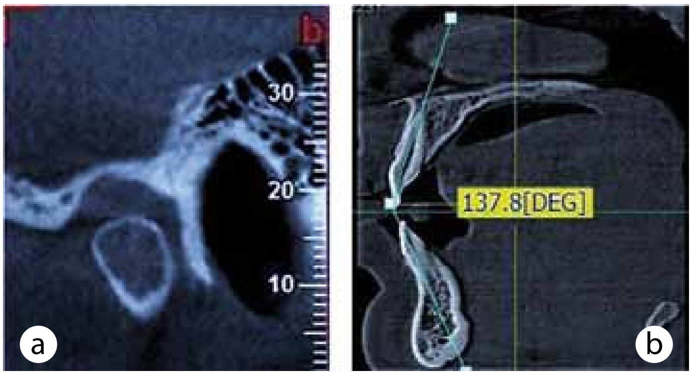

Fig. 8. Mesotemporal articular fossa (a) tomogram with the mesotrusive position (b) of the medial incisors.

a significant dominance of the sagittal sizes over the vertical ones, which determines the articular fossa shape (in terms of the visual expression) as *long* and *low*. The brachytemporal type of the articular fossa is to be observed in people with mesognathia and macrodontism, as well as in patients with dolichognathic dental arches with normo- and macrodontism.

3. Increased interdental angle with the retrusive front teeth is associated by a decrease in the articular fossa index, if compared with the protrusive incisors indicators, thus visually setting the articular fossa shape as *short* and *high*. The dolichotemporal type of the articular fossa is predominant in people with mesognathy and microdontism, as well as in patients with brachygnathic types of dental arches with normo- and microdontism.

4. The averaged inter-incisal angle values in the mesotrusive position of the front teeth visualize the shape of the articular fossa as *proportional*. The mesotemporal type of the articular fossa can be observed in people with mesognathy and normodontism, as well as in patients with the brachygnathic macrodont and dolichognathic microdont dental arches.

5. Cone-beam computed tomography, which features its own specifics, high sensitivity, and low radiation exposure, allows obtaining the most comprehensive diagnostic data regarding the morphostructural status of the temporomandibular joint hard tissues. Improving the algorithms for visualization and analysis of the temporomandibular joint bone structures, taking into account the patient's individual features, would allow standardizing dental research methods as well as modifying the conventional systems for analyz-

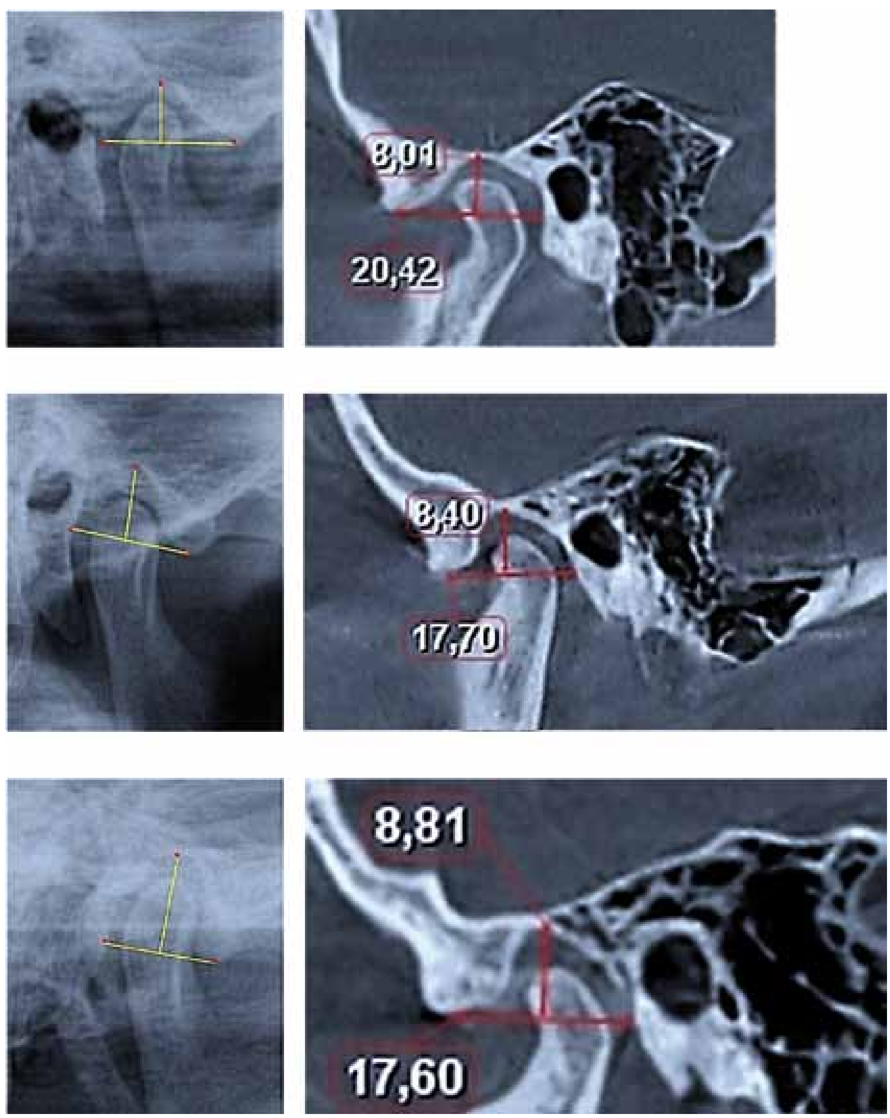

Fig. 9. X-ray image (a, c, e) and tomogram (b, d, f) of the TMJ in people with physiological occlusion and protrusive (a-b), mesotrusive (c-d) and retrusive (e-f) position of the front teeth

ing and interpreting data obtained for the reliable diagnostics of patients revealing dentoalveolar anomalies and deformations.

6. The inclusion of the averaged index values of the temporal bone articular fossa for various types of dental arches in people with physiological occlusion in the *Clinical protocols for diagnostics and orthodontic treatment of dentoalveolar anomalies in outpatient settings* would reduce significantly the time orthodontist has to spend through clinical examination and setting the diagnosis, achieve a stable long-term treatment result, increase the efficiency of occlusal disorders diagnostics, identify the presence (absence) of maxillofacial gnathic pathology, and minimize the risk of complications.

7. The potential of further detailed investigation into the etiopathogenetic mechanisms of the temporomandibular joint dysfunction can be explained by the research-proven range of diagnostic capacities of modern dentistry, as well as by the development of highly reliable digital diagnostics technologies.

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