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Assessment of temporomandibular joint morphology of bifid mandibular condyles: a cone beam computed tomography study

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ABSTRACT

Background: Bifid mandibular condyle (BMC) is an extremely rare condition characterized by dublicity of the head of the mandibular condyle. Knowledge about the morphology of BMC may help to understand the development course of condyle and differential diagnosis of fractures or tumors in condylar area. The aim of this study was to examine temporomandibular joint (TMJ) hard tissue morphology of BMCs.

Materials and methods: 1900 cone beam computed tomography (CBCT) scans of the mandibular condylar heads examined for the presence of bifidity. When BMC were identified, morphological assessment and measurements of bone components of TMJ were done.

Results: 69 BMC were detected in 56 patients (3%). It was observed that 43 (76.8%) patients presented unilateral and 13 (23.2%) patients presented bilateral BMCs. 59.4% of condyles were mostly seen in mediolateral (ML) orientation and 40.6% of them were both ML and anteroposterior (AP) orientation. 46.4% of cases showed wide and shallow groove; 53.6% had deep and narrow groove on coronal images. 60 BMCs had osteoarthritic changes.

Conclusions: CBCT is an excellent imaging modality for accurate imaging of the bony components of TMJ. Due to the widespread use of CBCT, the prevalence of BMC is likely to

be higher than has been previously reported and reported new cases in literature could be useful for dentists for improving their knowledge about this variation.

Keywords: temporomandibular joint, bifid mandibular condyle, multiheaded mandibular condyle, CBCT

INTRODUCTION

Bifid mandibular condyle (BMC) is an anatomical malformation characterized by a vertical depression, notch, or deep cleft in the center of the condylar head, resulting in the appearance of a “double” condylar head [29]. The prevalence is controversial as it widely ranges from 0.3% to 5.84% [4, 15, 16, 21, 25]. BMCs might have coincidentally been diagnosed with a panoramic radiography during a routine exam [4]. The use of cone beam computed tomography (CBCT), computed tomography (CT), and magnetic resonance imaging (MRI), has led to an increase in the number of cases reported [4, 21].

BMC may play a role in some temporomandibular joint dysfunctions and can be misinterpreted as fractures or tumors in condylar area. Knowledge about the morpholoy of BMC may help to understand the development course of condyle and differential diagnosis of fractures or tumors in condylar area.

The aim of this study was to evaluate the incidence and detailed radiological characteristics of TMJ hard tissue morphology of BMCs using CBCT.

MATERIALS AND METHODS

This retrospective study investigated 1900 patients who applied to Department of Dentomaxillofacial Radiology. A retrospective analysis was carried out of using CBCT images taken either due to patient complaints or prior to implant surgery planning.

The study protocol was approved by the Ondokuz Mayıs University Institutional Review Board (KAEK no: 2022/231).

CBCT images were taken with GALILEOS Comfort Plus CBCT unit (Sirona Dental Systems, Bensheim, Germany), operating at 98 kVp, 15–30 mA. Voxel and Field of View (FOV) sizes were 0.25 mm^3 and 15 × 15 cm. Exposure time of 2–6 seconds and scanning time was 14 seconds. Measurements were performed in 1 mm thickness slices by using “distance tool bar” feature of the SIDEXIS XG 2.56 (Sirona Dental Inc., Bensheim, Germany) image analysis program. All examinations and measurements were performed under light illumination at 3.7 MP, 68 cm, 2560 × 1440 resolution, 27-inch color LCD display (The RadiForce MX270W, Eizo Nanao Corporation, Ishikawa, Japan). The CBCT evaluation was carried out in the axial, coronal, sagittal, cross-sectional, and tangential views using a standardized approach in viewing the CBCT scans (distance of 40 cm, dimly-lit room).

Patients who had a CBCT with adequate diagnostic image quality and the cases in whom, both condyles were within the FOV of CBCT scans were included. Presence of space occupying lesions within the TMJ area and low-quality CBCT images with motion blurring or imaging artifacts that could adversely affect the evaluation were excluded in the study.

20 year experienced radiologist examined the CBCT scans of the left and right condylar heads for the presence of bifidity separately. Radiologically depression or notch on superior condylar surface or duplication of condylar head with continuous cortex on CBCT images was considered as BMC [18]. Measurements were done twice with a 2-week interval to quantify intra observer agreement.

The radiologic characteristics of BMCs were evaluated as follows:

- Localization: uni-bilateral orientation and right-left condyle.
- Type of of BMC:
    - Mediolateral bifidity was assessed using coronal images parallel to the long axis of the condyle, mediolateral cases appears as “heart” shape in coronal images (Fig. 1A);
    - Anteroposterior bifidity was assessed using lateral images perpendicular to the long axis of the condyle. Anteroposterior case appears as two condyles, one anterior to other, in sagittal reformat [18];
    - Multiheaded: The formation of more than two condyles can be named multi-headed condyles (MHC) [12].
- The comparison of mediolateral width of the sides: The width of the medial (M) and lateral (L) sides of BMCs were compared by measuring widths that starts from middle of sulcus or notch. And noted as L > M, L = M, M > L.
- The shape of glenoid fossa: It was assessed from the two sagittal slices that show medial and lateral parts of the bifid condylar head separately. Fossa shapes were classified as oval, triangular, angled, trapezoidal (Fig. 1):
    - Fossa shape 1: from medial side of BMC in sagittal view;
    - Fossa shape 2: from lateral side of BMC in sagittal view.

- Fracture mark: hipo- or hyperdens linear fracture mark on BMC (Fig. 2a).
- Remodelling of glenoid fossa: Mandibular fossa may remodel to accommodate altered condylar morphology [18] (Fig. 2b).

- Presence of foramen tympanicum: This foramen is located at the antero-inferior aspect of the external auditory canal, posteromedial to the TMJ [19]. We identified the foramina on axial images and confirmed their existence on coronal and sagittal images.
- Presence of pneumatization.
- The type of groove: the BMC divided into two parts by sulcus with variable depth. This splitting can range from shallow groove (Type 1) to deep groove (Type 2) [12] (Fig 3).
- The BMC depth (Fig. 4a).
- The condylar width and anteroposterior dimension: horizontal angulation of each condyle were determined by measuring the angle between the long axis of the condyle in the axial cross-section with the largest ML dimension and an imaginary horizontal line [16].
- The depth of glenoid fossa.
- The glenoid fossa divergence angle was the angle measured between two lines known as the posterior eminence line (PEL) and anterior tympanic line (ATL) in the obtained sagittal views.
- The width of glenoid fossa.
- The thickness of the glenoid fossa (Fig. 4b).
- The articular eminence (AE) divergence angle: The eminence inclination was measured using two complementary methods:
    - Angle of AE1: The best-fit line method measures the angle between PEL and basal line;
    - Angle of AE2: The top-roof line method measures the angle between EF line (that passing through points E and F; F maximum point of fossa, E minimum point of AE), and basal line.
- The superior joint spaces from coronal images: It was a distance measured from glenoid fossa to the most superior point on medial, middle (deep point of groove) and lateral parts of the the condylar head in the coronal view.
- Osteoartritic changes in the condylar head: Each BMC was evaluated for the presence and localization (medial-middle-lateral sides of the BMC) of osteoartritic changes.

SPSS software version 23.0 (IBM Corp., Armank, NY, USA) was used to analyze the data. According to the Kolmogorov–Smirnov test, the nonparametric Wilcoxon test was performed to evaluate and compare the mean values. Paired sample t-test was used to compare the data that were normally distributed. Intra-class correlation coefficient (ICC) was used to examine the agreement between quantitave data. Kappa test was used to assess intraobserver agreement. Analysis results were presented as frequency (percentage) for categorical data, and as mean ± standart deviation, and median (minimum — maximum). Significance level was taken as $p < 0.05$.

RESULTS

In this study, 1900 CBCT images were evaluated and 69 BMCs were diagnosed in 56 patients. (Prevalens: 3%; mean age: 48.1 ± 14.3; age range 18–84) 30 patients were male and 26 were female.

It was observed that 43 (76.8%) patients presented unilateral and 13 (23.2%) patients presented bilateral BMCs (36 (52.2%) on the right side, 33 (47.8%) on the left side). 59.4% of condyles were mostly seen in ML orientation and 40.6 % of them were both ML and AP orientation (multiheaded).

The intraobserver agreement was found to be excellent by kappa statistics (0.90–1.00) Frequency distribution of variables and descriptive statistics is presented in Table 1.

A statistically significant difference was found between glenoid fossa shape 1 (sagittal view from lateral part of BMC) and fossa shape 2 (sagittal view from medial part of BMC) values ($p < 0.001$). In fossa shape 1, the highest rate belongs to triangular with 34.8%. The highest rate in fossa shape 2 belongs to trapezoidal with 40.6%.

A statistically significant difference was found between the median values of lateral, middle and medial joint spaces from the coronal images ($p < 0.001$). All measurements differ from each other. The mean value of the lateral joint space measurement was obtained the least (1 mm) and, the mean value of the middle joint space was the largest (5.6 mm). Descriptive statistics of quantitative variables is presented in Table 2.

Of 69 BMCs, 9 (13%) were normal (without bone changes) and 60 (87%) had osteoarthritic changes. Of these, 31 were observed in the right and 29 in the left condyle. There was no statistically significant difference between the distribution of osteoarthritic values according to the side of BMC ($p = 0.110$). Osteoarthritic changes in bifid condyles is presented in Table 3.

DISCUSSION

BMC is a rare entity, characterized by duplicity of the head of the mandibular condyle [2, 4]. The use of panoramic radiographs and especially CBCT examination, the number of reported BMC cases increased [20]. In a literature review of reported cases in living patients, Borras-Ferreres et al. [3] found 216 patients with 270 BMC. In the present study, CBCT was used as an imaging tool for diagnosis and analyzing BMC to prevent misinterpretation [4].

Many epidemiologic studies have been conducted to estimate the incidence of BMC with a wide variability in results [15, 16, 21, 25]. Radiologic technique, race and sample size may have influenced the study results. Miloğlu et al. [21] reported 0.3% BMC cases diagnosed on panoramic radiograph and Sahman et al. [25] reported 1.82% cases using CBCT. Khajastepour et al. [16] reported a prevalence of 4.5% for BMC and mentioned that compared to panoramic images, CT records showed a higher rate for BMC. Kendirci et al. [15] reported the prevalence of multiheaded mandibular condyles 5.84%. This study showed an incidence of 3% BMC which was slightly higher than that in previous reports [21, 25] and is lower than Khojastepour et al. [16] and Kendirci et al. [15] studies.

Unilateral involvement was the most prevalent although there was a remarkable proportion of bilateral BMC reaching the 25%. [3, 25]. In this study, the ratio of unilateral/bilateral cases was 3.3:1 which is close to those previously reported in the literature [4, 5, 21].

The orientation of bifid condyle was classified as anteroposterior (AP) and mediolateral (ML) [6]. ML orientation of the BMC supports the developmental origin theory whereas an AP orientation supports traumatic origin [20]. However, ML orientation of the mandibular condyles can also result from traumatic events [6, 20]. In the present study, most of BMC were found ML orientation and the others were multiheaded.

The division of the mandibular condyle varies from a shallow groove in the sagittal or coronal plane to a deep notch forming 2 discernible condylar heads with a ML or AP orientation [8, 28]. In this study, while 46.4% of cases showed wide and shallow groove; 53.6% of cases had deep and narrow groove on coronal images. In patients with developmental BMC there is a separate mandibular fossa for each of the 2 parts, whereas in traumatic BMC there is only 1 mandibular fossa [23, 26]. In this study, 21.7% of cases showed glenoid fossa remodelling according to mandibular condyle shape that forms two mandibular fossa from coronal views.

Derwish et al. [9] evaluated TMJ morphology in 105 patients and found that the most common shape of the glenoid fossa was oval with 62%. In the present study, the shape of fossa showed differences for medial and lateral side for BMC. For lateral side of BMC, triangular and oval shaped; and for medial side trapezoidal and angled shaped were most frequently observed in saggital views.

The etiology of BMC is still uncertain; it could be developmental anomaly or traumatic [3]. History of trauma in childhood is a common observation in many cases [1, 2, 13, 20]. Minor trauma of the condylar growth center might cause condylar bifidism or insufficient remodeling of the condylar bony fragment might give rise to the bifid condylar formation [2]. The margins of fracture planes usually appear as sharply defined radiolucent lines of separation that are confined to the structure of the mandible. Occasionally the margins of the adjacent fracture fragments overlap, resulting in an area of increased radiopacity at the fracture site [29]. In this study, 13 BMCs showed fracture mark on coronal images that supports etiology of trauma.

The foramen tympanicum is an osseous dehiscence of the temporal bone and located posteromedial to the TMJ and anteroinferior of the external auditory canal. It may predispose individuals to TMJ pathology [19]. In normal TMJ, it ranges from 4.6% to 23.2% foramen tympanicum may persist throughout life [7, 19]. In the present study, high values compared to other studies was found for foramen tympanicum in BMC cases that should be supported future studies.

The mandibular condyle is approximately 20 mm in width mediolaterally and 8 to 10 mm in dimension, anteroposteriorly [29]. In this study, mean width of BMC was found 20.7 mm and mean A-P dimension was found 7.9 mm. It can be concluded that ML dimension of BMC was slightly higher than normal condyles' may be because of increasing condyle volume.

Miloğlu et al. [22] reported a prevalence of 8% pneumatization of the articular eminence on 514 patients using CBCT that is higher than has been previously reported prevalence to be between 1% and 2.6% on panoramic radiographs. In the present study, very high values compared to other studies was found for articular eminence and glenoid fossa pneumatization in BMC patients that should be supported future studies.

Osteoarthritic changes have an effect on glenoid fossa but glenoid fossa thickness is unaffected by the coronal condyle head morphology. Condyle with osteoarthrosis had a higher glenoid fossa thickness than the without osteoarthrosis category [10]. The thickness of the roof of the glenoid fossa has been varied between 0.2 mm and 1.5 mm with an average of 0.61 mm. [14]. In Ejima et al. [10] study the mean value of the glenoid fossa thickness for normal condyles were ranged from 0.53–1.2 mm. However, the roof of the glenoid fossa was significantly larger in joints with osteoarthritis and perforation [14]. In the present study, the mean value was 2.18 mm ranged from 0.2–6.9 mm for BMCs. An increase in the thickness of the roof of the glenoid fossa in BMCs could be a response of the joint to maintain a proper function and due to altered function or osteoarthritic changes [10, 14].

Osseous changes in the form of remodeling or osteoarthrosis were important factors influencing the steepness of the eminence [24]. TMJ disorders can lead to a decrease in the inclination of articular eminence over time by remodeling [27]. Various methods have been used to measure the inclination of the posterior slope of the articular eminence. Two different methods were used to evaluate the articular eminence inclination in this study; the best-fit line method and the top-roof line method. According to Yasa and Akgul's [30] study the mean eminence inclination was found 60.78 and 38.85 in asemptomatic patients, 58.94 and 37.89 in temporomandibular joint disorder patients in best-fit line method and the top-roof line method respectively. In the present study, the mean eminence inclination was found high both in two methods. Additionally, the median depth of glenoid fossa (9.5 mm) was found lower however fossa length (23.52 mm) and fossa divergence angle (62.69°) was found higher than Derwichs et al. [9] study which was applied in normal condyles.

CBCT provides information about the osseous component and various bony changes of TMJ. Koç [17] found a prevalence of 67.3% osseous changes in TMJ in patients with the initial diagnosis of a TMJ disease and reported that condylar flattening was the most frequent finding. Derwich et al. [9] reported that articular flattening was the most common osseous change in both groups with and without reciprocal clicking followed by surface erosion, subcortical sclerosis and osteophyte. Cho and Jung [4] found that flattening was more common on the BMCs than the normally shaped condyles. In the present study, 87% of BMC showed osteoarthritic changes and osteophyte was the predominant finding following by erosion and flattening. We speculated that the high prevalence of osteophytes and the low prevalence of flattening on the BMC side might be attributed to the morphological features of BMCs. Grooving tended to make the condyle flat and lack to potential to form osteophytes [4].

Sahman et al. [25] found the angles between the axis of the BMC and the transverse plane differed from 0° to 25° in a tomographic study. In Khojastepour et al. [16] study, the mean horizontal angulations of the condyles in normal individual were calculated to be 22.6° versus 24.02° in BMC cases. In the present study, the mean horizontal angulation value was 17.16° in axial images.

The limitation of this study was owing to the lack of clinical symptoms and soft tissue examination of TMJ of BMC. The radiological examination was based on only bone components. Although BMC is usually asymptomatic, there have been reports of pain associated with temporo mandibular clicks or sounds and, less frequently, temporomandibular ankylosis [11]. Future studies should be focus on patients with BMC where clinical findings and soft tissue characteristics are also evaluated. In addition, there have been few studies for BMC to compare and discuss the morphologic values obtained from this study.

CONCLUSIONS

CBCT is an excellent imaging modality for accurate imaging of the bony components of TMJ. Due to the widespread use of CBCT, the prevalence of BMC is likely to be higher than has been previously reported and reported new cases in literature could be useful for dentists for improving their knowledge about this variation. BMC should be evaluated and assessed as a separate entity prior to any treatment. In surgical procedure and orthodontic management, anatomical dimensional variabilities can be significant. According to our knowledge the present study is a unique one, analyzing bifid condyles and their TMJ morphology in great detail using CBCT.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

The study protocol was approved by the University Institutional Review Board. OMU KAEK: 2022/231.

Author contributions

Ayse Zeynep Zengin: study design, data collection, analysis, manuscript revising. **Tuna Sumer:** analysis, interpretation of data, manuscript writing/editing. **Kübra Cam:** interpretation of data, manuscript writing.

Conflict of interest

The authors declare that there is no conflict of interest.

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Table 1. Frequency distribution of variables and descriptive statistics.

	N	%
Comparison of lateral and medial sides of BMC*		
L = M	26	37.7
L > M	35	50.7
M > L	8	11.6
Glenoid Fossa shape 1**		

Angled	18	26.1
Oval	23	33.3
Trapezoidal	4	5.8
Triangular	24	34.8
Glenoid Fossa shape 2**		
Angled	19	27.5
Oval	15	21.7
Trapezoidal	28	40.6
Triangular	7	10.1
Remodelling of glenoid fossa	15	21.7
Fracture mark in BMC*		
No	56	81.2
Yes	13	18.8
Groove*		
Type 1	32	46.4
Type 2	37	53.6
Foramen tympanicum		
No	36	52.2
Yes	33	47.8
Pneumatization		
No	35	50.7
Yes	34	49.3
AE	16	23.2
AE + glenoid fossa	15	21.7
glenoid fossa	3	11.4

*From coronal images; **From sagittal images. AE — articular eminens; AP — anteroposterior; BMC — bifid mandibular condyle, L — lateral; M — medial; ML — mesiolateral.

Table 2. Descriptive statistics of quantitative variables.

	Mean ± SD [mm]	Median (min–max) [mm]
Depth of BMC	2.0 ± 0.92	1.8 (0.7–5)
Width of BMC	20.7 ± 2.46	20.9 (14–27.8)
Anteroposterior dimension of BMC	7.9 ± 1.85	7.8 (3.2–12.8)
Horizontal angle of BMC	17.2 ± 9.2	18.6 (–18.6 to 34.5)
Depth of fossa	9.4 ± 1.48	9.5 (5.3–12.8)
Angle of fossa	62.7 ± 13.92	63 (7.2–102)
Thickness of fossa	2.2 ± 1.81	1.5 (0.2–6.9)
Width of fossa	23.5 ± 22.65	21 (14.6–208)
Angle of AE 1	62.8 ± 11.74	61 (42–102)
Angle of AE 2	44.3 ± 7.94	43 (27–82.3)

Joint spaces from the coronal		
Lateral	1.1 ± 0.92	1 (0–4.6)
Middle	6 ± 2.94	5.6 (0.5–12.9)
Medial	4.3 ± 2.14	4 (0–9.5)

Mean ± SD; Median (min–max). AE — articular eminens. BMC — bifid mandibular condyle; SD — standard deviation.

Table 3. Osteoarthritic changes in bifid mandibular condyles.

	Frequency (N)	%
Osteoarthritic changes		
Condylar flattening	12	13.5
Condylar erosion	27	30.3
Loose body	3	3.4
Condylar osteophytes	29	32.6
Condylar sclerosis	7	7.9
Subchondral cyst	11	12.4
Localization of osteoarthritic changes		
Lateral side	37	37.8
Medial side	34	34.7
Middle side	92	93.9

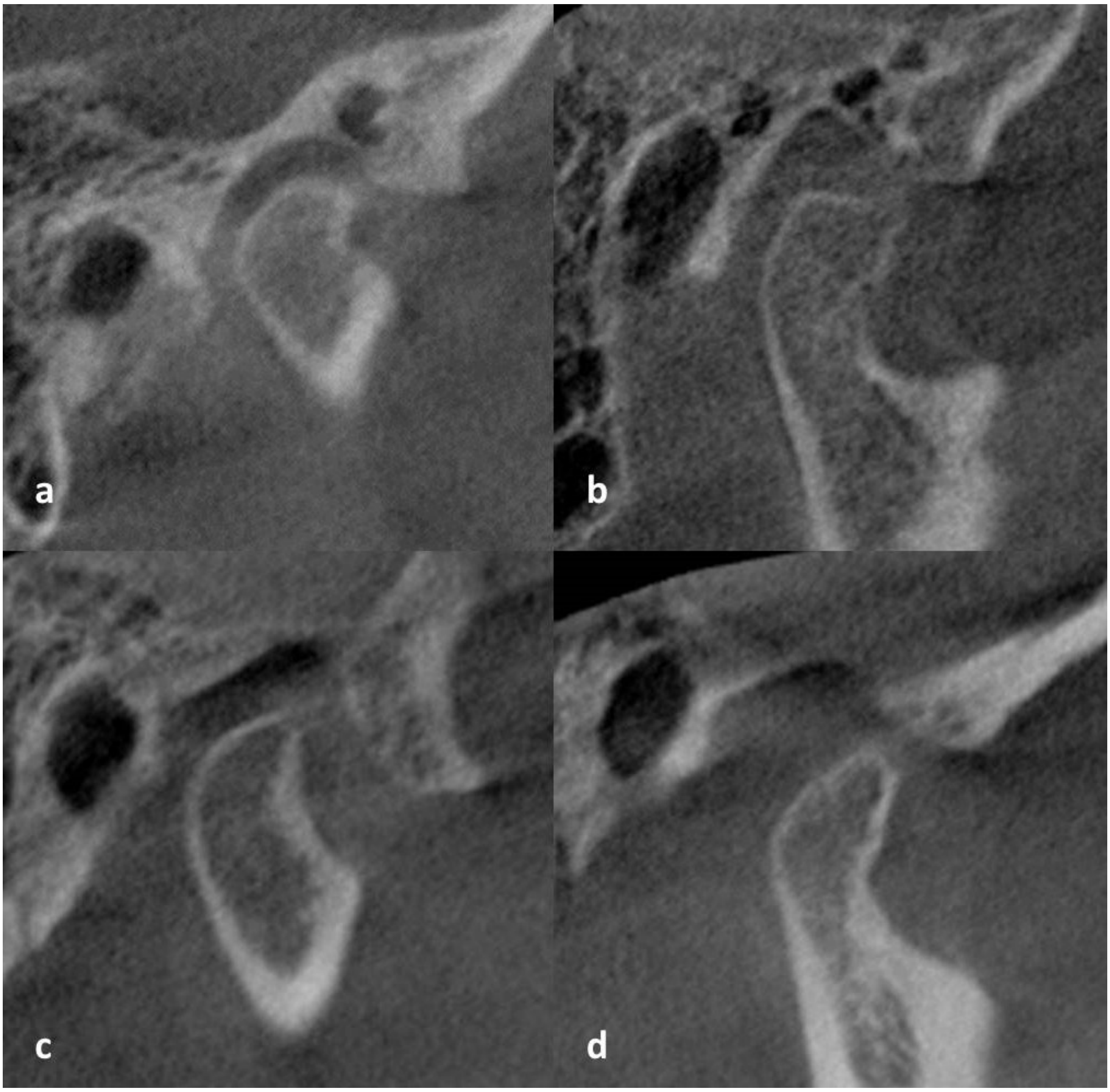

Figure 1. The shape of glenoid fossa: **A.** Oval; **B.** Triangular; **C.** Angled; **D.** Trapezoidal.

Figure 2A. Heart shape bilateral BMC with linear fracture marks (blue arrows); B. Remodelling of glenoid fossa.

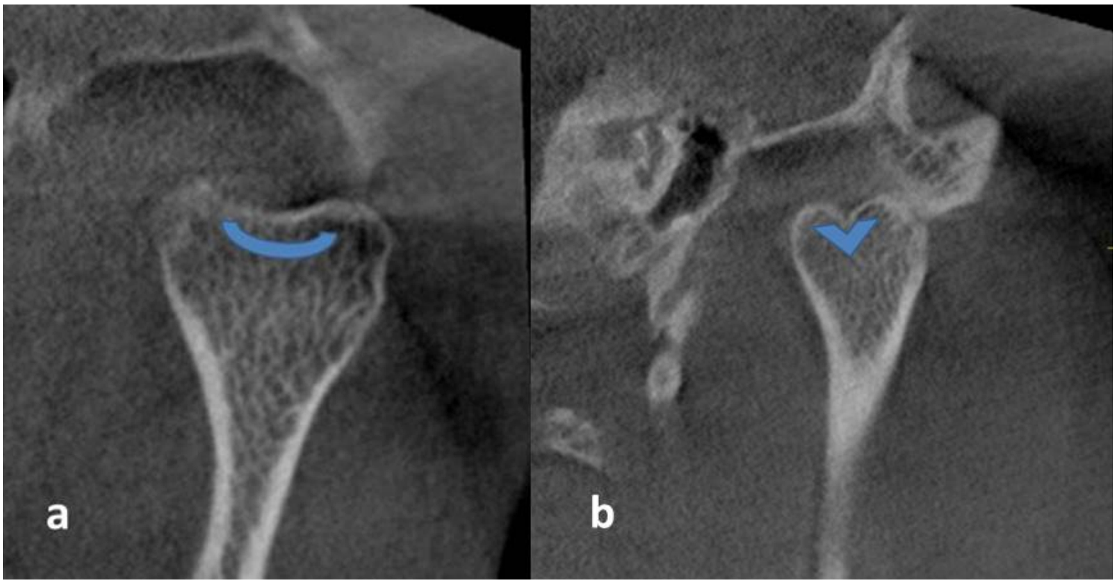

Figure 3. BMC with wide and shallow groove (**A**) and with deep and narrow groove (**B**).

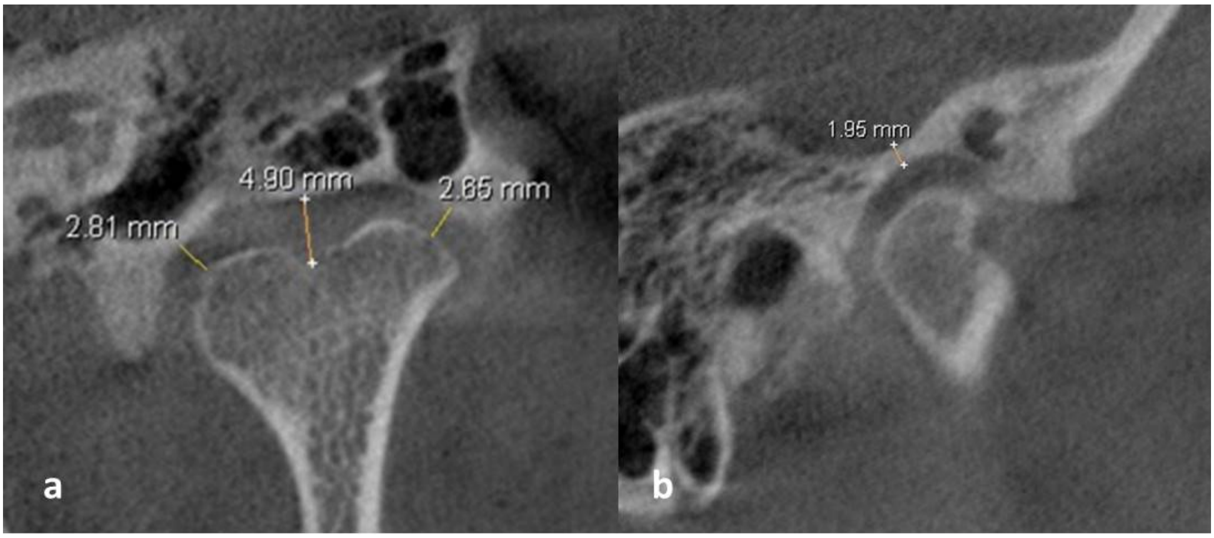

Figure 4. Measurement of the depth of BMC (**A**) and the thickness of the glenoid fossa (**B**).