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Morphometry and Morphology of the Articular Surfaces of the Medial Region of the Temporomandibular Joint in the *Felis Catus* (Domestic cat) - A Cone Beam Computed Tomography Study

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Abstract

The articular surfaces of the temporomandibular joint (TMJ) in the cat consist of the articular head of the condylar process of the ramus of the mandible and the mandibular fossa of the petrous part of the temporal bone. Anatomic conformation of the TMJ articular surfaces can vary; however, this has not been studied in the cat. Thus, the aim of this study was to characterize the conformation of the medial region of the TMJ in mesocephalic adult cats as well as to determine the articular relationship by measurement of the degree of coverage of the mandibular fossa over the articular head. This was accomplished by assessing 60 TMJs from 30 mesocephalic adult cats by means of cone-beam computed tomography (CBCT). The width and depth of the mandibular fossa, and the degree of coverage of the mandibular fossa were evaluated using parasagittal reconstructions of the medial aspect of the TMJ by two observers. No statistically significant difference was observed during the intra and interobserver evaluation of the mandibular fossa width and depth and the degree of coverage of the mandibular fossa over the articular head. P-values for the studied variables were greater than 0.05. The resulting measurements demonstrated a concave mandibular fossa with a prominent retroarticular process and a poorly developed articular eminence; a well-defined rounded articular surface, and a high degree of coverage (171°) of the mandibular fossa over the articular head. In conclusion, the articular surfaces at the medial aspect of the TMJ displayed elevated geometric similarity, with an articular head of the condylar process deeply seated in the mandibular fossa.

Keywords

morphometry, morphology, temporomandibular joint, cat, cone beam computed tomography

Introduction

The temporomandibular joint (TMJ) in the cat is a synovial joint comprised of two articular surfaces: the articular head of the condylar process of the ramus of the mandible and the mandibular fossa of the squamous portion of the temporal bone.[1,2] The retroarticular process and the articular eminence are bony elongations located at the medial ventrocaudal and lateral dorsorostral aspects of the mandibular fossa respectively. The bony elongations prevent the displacement of the condylar

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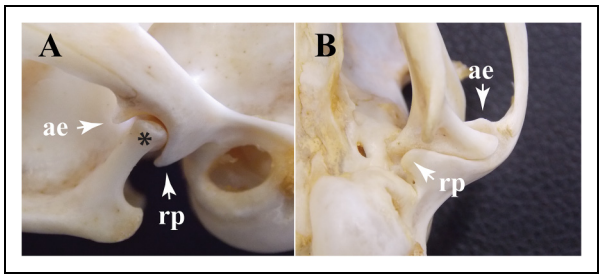

Figure 1. Lateral (A) and ventral (B) views of the left TMJ of an adult cat skull. Articular eminence (ae). Retroarticular process (rp). Articular head of the condylar process (*).

process in a caudal or rostral direction (Figure 1). A fibrocartilaginous articular disk located between the articular surfaces divides the joint space into two separate compartments (dorsal and ventral) containing synovial fluid.[1,2]

In the cat, the articular surfaces are stabilized by the lateral pterygoid muscle and the articular capsule, which in turn is reinforced at its lateral and caudal aspect. The lateral and caudal reinforcements of the joint capsule have been considered analogous to the lateral and caudal ligaments in the horse.[3,4] Great congruence between the articular surfaces of the TMJ has been reported in sagittal sections in a previous study that showed that the rostrolateral articular surface of the articular head of the condylar process was more developed at the point that articulates with the articular eminence of the mandibular fossa, while the ventromedial articular surface of the articular head was more prominent at the area that articulates with the retroarticular process.[3,4]

Although shape and integrity of the TMJ have been routinely assessed in the veterinary field by general practitioners by means of radiography, diagnosis of TMJ alterations using this technique remains a challenge due to the superimposition of the joint with adjacent structures of the calvarium.[5,6] Advancements in diagnostic imaging techniques such as computed tomography (CT), magnetic resonance imaging (MRI), and, more recently, cone beam computed tomography (CBCT) have been used in veterinary medicine to obtain high-quality images while eliminating superimposition of soft and bony components over the joint.[5–10] In human medicine, these advanced diagnostic imaging techniques are considered standard for evaluation of disorders of the TMJ, enabling very detailed images of cortical and trabecular patterns and of articular surface morphology.[11,12]

Although the TMJ morphology and congruence in the cat may be affected by several disorders such as fractures, osteoarthritis, dysplasia, or ankylosis,[13] changes in the anatomic conformation and the relationship between the articular surfaces may also be related to the normal anatomic conformation of a specific breed or skull conformation as previously reported in other species.[14] From a clinical viewpoint, joint congruence has been defined as how the articular surfaces meet each other from a geometrical perspective. Joint congruence has been used as a tool to evaluate the capability of a joint to distribute a load over the articular surfaces.[15] Knowledge of the normal conformation and the congruence of the articular surfaces of the feline TMJ can improve the ability to diagnose underlying conditions that may decrease the range of motion of the mandibles, and cause oral discomfort and dysphagia.

In humans, the contour of the TMJ articular surfaces, the joint space, and its congruence have been assessed by semiautomated 3-dimensional analysis of images obtained by means of CBCT. This technique uses specialized imaging software for mapping the opposing joint surfaces by means of placement of homologous pairs of landmarks on both articular surfaces. The distance between the homologous landmarks allows for evaluating the shape and the joint space from a 3-dimensional perspective.[12] In the veterinary field, a CT study performed in the dog demonstrated three different configurations for the TMJ. In that study, CT parasagittal images of the medial aspect of the joint were used for assessment of the shape of the articular surfaces and their relationship.[14]

Although the morphologic features and diagnosis of dental and TMJ abnormalities in veterinary patients have been evaluated with cross-sectional imaging techniques such as CT and CBCT,[13,14,16] studies focused on the typical morphology and establishment of the relationship between the articular surfaces of the TMJ in the cat are lacking. The aim of the present study was to establish the morphology of the TMJ in adult mesocephalic cats, as well as to propose a measurement for quantification of the 'articular congruence' at the medial aspect of the TMJ, the area where the articular surfaces display the greatest articular relationship.

Materials and Methods

Pilot Study

A preliminary CBCT study using three cat cadaver heads established where the TMJ mandibular fossa displayed its deepest area, and consequently, where there was the greatest relationship between the articular head of the condylar process and the mandibular fossa. Measurements from this region were used to calculate the variables studied in the 60 TMJs. Imaging acquisition was performed using a CBCT unit[a]. For the acquisition of tomographic images, the heads were placed in a cylindrical plastic container, with the mandibles parallel to the horizontal plane. The tomographic technique used 120 kVp, 37.7 mA, and a 27 s acquisition time with a matrix size of 512 × 512 and voxel resolution of 0.25mm. Multiplanar reformation (MPR) using a bone window for the TMJs was performed using a dedicated DICOM viewer software (window level - 400 - 600 HU/window width 2000–5000 HU)[b].

Following the initial transverse reconstruction, multiplanar reformation (MPR) was performed to create two-dimensional symmetrical images of the TMJs on transverse, parasagittal and dorsal planes. Measurements were made at the mandibular fossa depth at its lateral, middle, and medial regions on parasagittal images for establishment of the deepest area. The depth of the mandibular fossa was established by the measurement between the external surface of the subchondral bone of the mandibular fossa and a line drawn between the caudoventral and rostrodorsal margins of the fossa (Figure 2). The deepest region of the mandibular fossa corresponded to its medial portion (Figure 3).

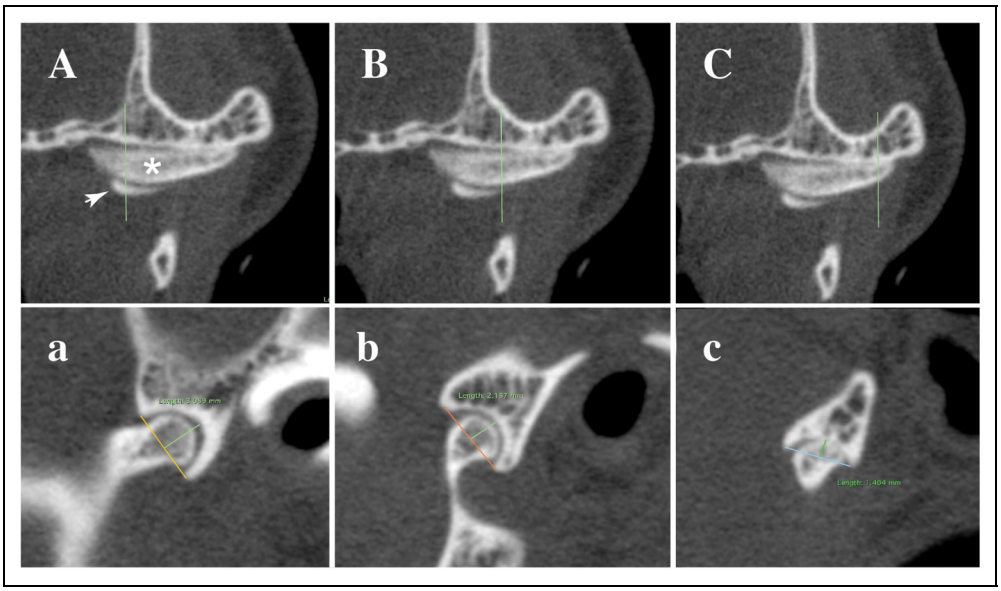

Figure 2. CBCT transverse (A, B, C) and parasagittal (a, b, c) multiplanar rendering of the left TMJ region in an adult cat head using bone algorithm reconstruction, showing how the temporomandibular fossa depth was obtained at the medial (Aa), middle (Bb) and lateral (Cc) regions. The depth corresponded to the measurement between the external surface of the subchondral bone of the mandibular fossa and a line drawn between the caudoventral and rostrodorsal margins of the fossa. Articular head of the condylar process (*). Retroarticular process (arrowhead).

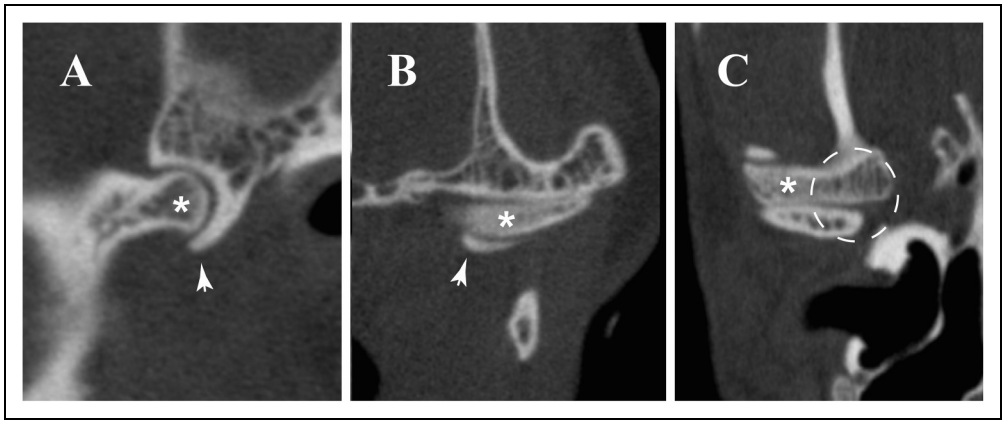

Figure 3. CBCT parasagittal (A), transverse (B) and dorsal (C) multiplanar rendering of the left TMJ region in an adult cat head using bone algorithm reconstruction. Articular head of the condylar process (*). Retroarticular process (arrowhead). The medial aspect of the TMJ, where the retroarticular process reaches its maximum extension, is demarcated (dashed circle).

The relationship of the TMJ articular surface of the mandibular fossa with the articular head of the condylar process at its deepest area was also assessed in an open versus closed mouth position. Using reformatted CBCT images, the joint space was assessed qualitatively by visual inspection to identify a possible widening of the articular space in the medial region of the TMJ. Narrowing or widening of the joint space was linked with a change in the articular relationship between the condylar process and the mandibular fossa. No relevant differences were associated with the position of the condylar process in relation to the mandibular fossa, therefore the main study was performed using the closed mouth position.

As proposed in previous research performed in the dog,[14] the following anatomic landmarks were suggested on parasagittal reconstructions of the medial aspect of the TMJ in the present study: (1) the mandibular fossa, (2) the ventral border of the retroarticular process, (3) the articular eminence of the mandibular fossa and (4) the estimated axis of rotation (EAR) of the articular head of the condylar process (Figure 4). The EAR was obtained by fitting part of a circle drawn over the articular surface of the articular head, and then adding two perpendicular lines, one in a horizontal plane and another in a vertical plane, dividing the circle into four equal quadrants. The intersection point between the lines was considered as the EAR of the articular head of the condylar process (Figure 5).

Main Study

Using the landmarks and technique established during the pilot study, 60 TMJs from 30 cadavers of mesocephalic domestic shorthair cats donated by the owners for research and teaching purposes were evaluated by CBCT. No brachycephalic or dolichocephalic cats were used in this study due to a shortage of specimens at the time of the investigation. Heads from cats euthanized for reasons related to head trauma, and with evidence of ear or TMJ disease on gross examination, were excluded from this study. Sex and weight were not available. This study was approved by the ethics committee of the School of Veterinary Medicine and Animal Science of the University of São Paulo (USP).

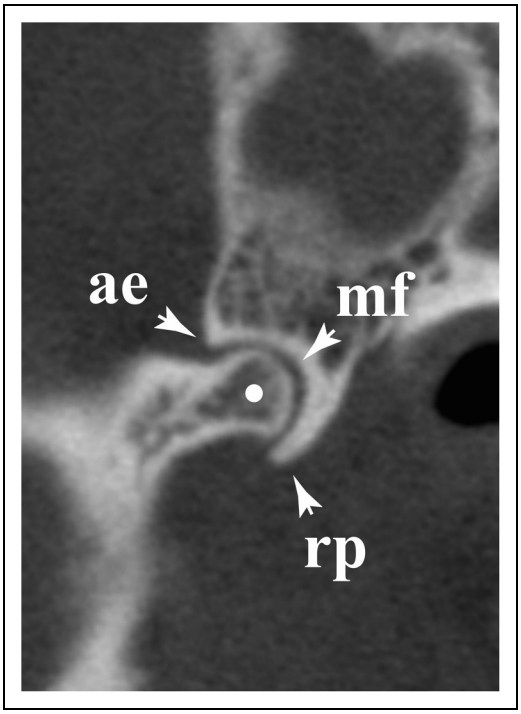

Figure 4. CBCT parasagittal rendering of the medial aspect of the TMJ of a mesocephalic adult head cat showing the anatomic landmarks used for the morphometric study. Articular eminence (ae). Mandibular fossa (mf). Retroarticular process (rp). Estimated axis of rotation of the articular head of the condylar process (dot).

Based on anatomic landmarks, the following measurements were performed at the medial aspect of the joint in a close mouth position: (1) the width, (2) depth of the mandibular fossa, and (3) the degree of coverage of the mandibular fossa over the articular head of the condylar process. The width was the distance in a straight line extending from the margin of the articular eminence to the ventral border of the retroarticular process of the mandibular fossa. The depth of the mandibular fossa was the distance between the external surface of the subchondral bone of the mandibular fossa at its deepest area, and the line used for measuring the width (Figure 6). The degree of coverage of the mandibular fossa over the articular head quantifies the relationship between the articular head of the condylar process of the ramus of the mandible and the mandibular fossa at the medial aspect of the joint. The degree of coverage of the mandibular fossa was composed of vectors connecting the margin of the articular eminence to the EAR of the articular head, and then to the ventral border of the retroarticular process (Figure 7). The morphology of the surface of the articular head at the medial aspect of the condylar process was classified as either regular, if its contour was rounded and easily delineated by the circle used for the establishment of the EAR of the condylar process, or irregular, if the contour of the articular head was not uniformly delineated by the circle.

Thirty right TMJs and 30 left TMJs were independently evaluated using a dedicated image diagnostic software[b] by two certified veterinary dentists (MSR and LAV) at one-week intervals. The landmarks and measurements were obtained at the area where the retroarticular process of the mandibular

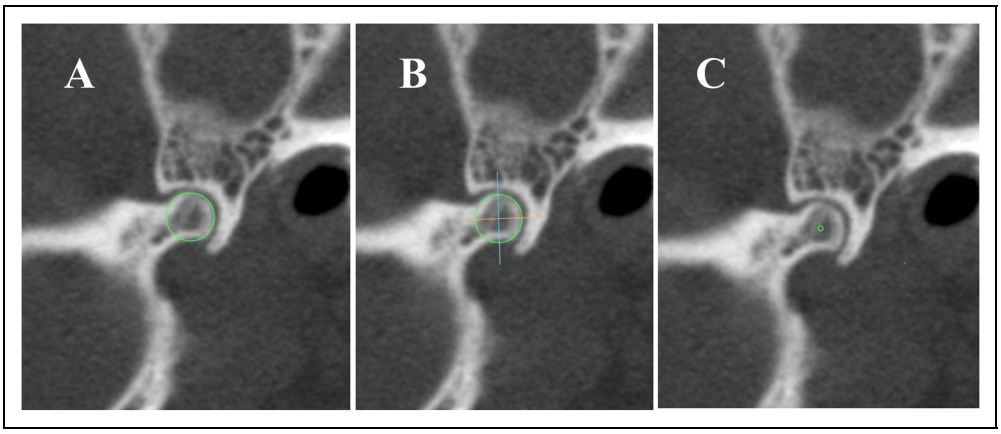

Figure 5. CBCT sagittal reconstructions of the medial aspect of the TMJ of a mesocephalic adult head cat showing how the estimated axis of rotation of the articular head was obtained using a DICOM imaging software. A circle was matched to the articular surface of the articular head contour (A). The circle's center was established by drawing a vertical and horizontal line dividing the circle into four equal parts (B). The interjection point between the lines (small circle) was the estimated axis of rotation of the articular head of the condylar process (C).

fossa displayed its maximum ventral extension. The measurements were performed at the same location or as near as possible to the medial aspect of each joint. The measurements for the width, depth, and degree of coverage were performed three times during each evaluation, and their means were calculated for statistical purposes. Intraobserver comparison was performed between the right and left mean values for the width, depth, and degree of coverage of the mandibular fossa to establish if the joints were symmetric.

Subsequently, interobserver reliability was evaluated for the degree of coverage of the mandibular fossa, which was the parameter in this study proposed to quantify the extent of the relationship between the articular surfaces at the medial aspect of the joint. The minimum and maximum values and respective means were calculated on each side (left and right TMJ) using statistical 'R' software (version 3.5.1)[c]. Descriptive analysis was used to identify potential measurement errors (anomalous values or values that were too different from the other measurements). The paired *t*-test was used to compare the results. Significance was defined as $P < 0.05$.

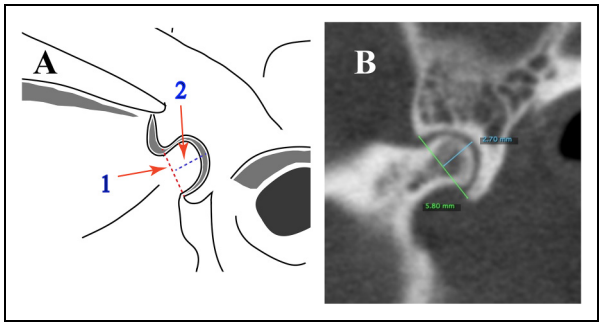

Figure 6. Illustration of the medial aspect of the TMJ region in a cat (A) and CBCT parasagittal rendering of the TMJ of a mesocephalic adult cat (B) showing how the width and depth were obtained. (1) Mandibular fossa width: measurement between the articular eminence and the ventral border of the retroarticular process; (2) mandibular fossa depth: measurement between the subchondral bone of the mandibular fossa and the line used for getting the width.

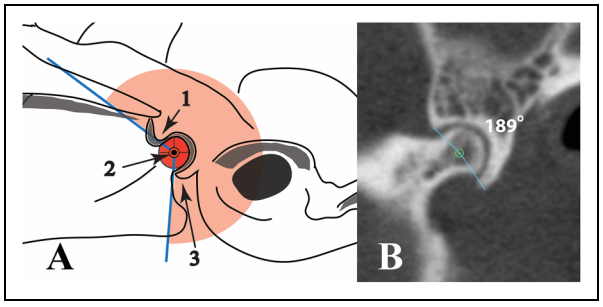

Figure 7. Illustration of the medial aspect of the TMJ region in a cat (A). The landmarks used for the angle measurement were: (1) articular eminence, (2) estimated axis of rotation, and (3) ventral border of the retroarticular process. CBCT parasagittal rendering of the TMJ of a mesocephalic adult cat showing how the degree of coverage (189°) of the mandibular fossa over the articular head (shaded area in A) was obtained (B).

Results

The pilot study determined that the deepest area of the mandibular fossa corresponded to the medial aspect of the temporomandibular joint, the region where the retroarticular process showed its greatest caudoventral extension. The range and mean values for the lateral, middle, and medial portions of the TMJ deep were between 0.89 - 1.01 mm (mean = 0.93 mm), 1.77 - 1.90 (mean = 1.83 mm), and 2.0 - 2.38 mm (mean = 2.22 mm) respectively. On visual inspection of the tomographic images, no gross articular space widening or narrowing was associated with mouth positioning (open/closed).

In parasagittal reformatted images of the medial aspect of the TMJ, the articular head surface of the condylar process was observed as a well-defined circumscribed bony structure cupped ventrocaudally by the retroarticular process of the mandibular fossa. At the lateral aspect, parasagittal reformatted images showed a less prominent semicircular surface on the dorsorostral aspect of the articular head, articulating with the articular eminence of the mandibular fossa. The articular surface of the articular head was more prominent at the medial region of the joint, presenting its maximum diameter and the maximum articular relationship with the mandibular fossa. The morphology of the surface of the articular head at the medial aspect of the condylar process in parasagittal reformatted CBCT images corresponded to a well-defined rounded bony structure in 96.6% (58/60 TMJs), while 3.4% (2/60 TMJs) presented a moderate irregular contour (Figure 8).

Parasagittal images of the medial aspect of the mandibular fossa showed a concave articular surface with a well-defined retroarticular process located at its ventrocaudal aspect. The articular eminence of the mandibular fossa appeared as a less

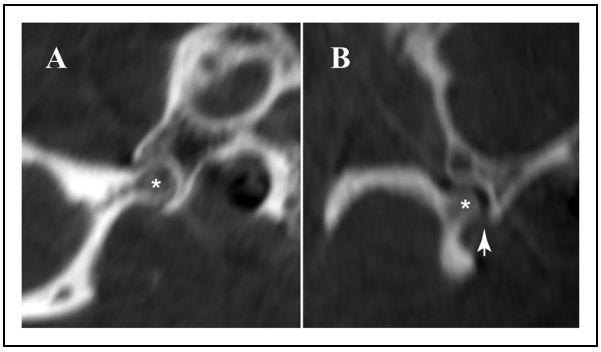

Figure 8. CBCT. Parasagittal rendering images of the medial aspect of TMJs of two mesocephalic adult cats. (A) Congruent joint formed by a well-defined rounded articular head (*) fitted in a deep mandibular fossa. The joint space appears as a uniform hypoattenuating line. This TMJ anatomic conformation was observed in 96.6% (58/60 TMJs). (B) Two TMJs from one cat (3.4%) were less congruent, showing an irregular articular head contour, a shallow mandibular fossa and an increased and non-uniform joint space (arrow).

prominent bony projection located at the rostrodorsal aspect at the lateral region of the mandibular fossa (Figure 9).

No statistically significant difference was observed between the measurements of the right and left TMJs for either observer for the three proposed variables (width, depth and degree of coverage of the mandibular fossa over the articular head). When comparing the observers by means of the paired *t*-test, no statistically significant difference was observed for the degree of coverage of the mandibular fossa over the articular head. Tables 1 and 2 display the minimum, maximum, mean, and p-values for the right and left TMJ width and depth for each observer. Table 3 displays the minimum, maximum, mean, and p-values between both observers for the degree of coverage of the mandibular fossa over the articular head.

The overall mean for the width and depth of the mandibular fossa were 6.1 and 2.0 millimeters, respectively, and the mean for the degree of coverage of the mandibular fossa over the articular head at the medial aspect of the joint was 171°. Based on the width, depth, and degree of coverage of the mandibular fossa overall mean values, the medial region of the TMJs in this study showed congruent articular surfaces with concaved mandibular fossa, well-developed retroarticular processes and rounded articular head surfaces (Figure 10).

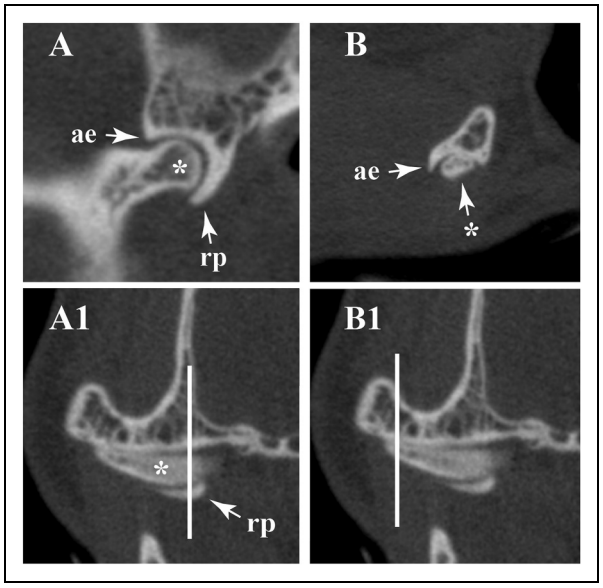

Figure 9. CBCT multiplanar rendering of the TMJ region in a mesocephalic adult cat. (A) Parasagittal reconstruction of the medial aspect of the TMJ showing a concave mandibular fossa with a prominent retroarticular process (rp) located at its ventrocaudal aspect. The articular eminence (ae) is poorly developed at the medial aspect of the joint. The articular head appears as a well-defined rounded bony structure (*). (B) Parasagittal reconstruction of the lateral aspect of the joint. In this region, the articular eminence located at the rostrodorsal aspect of the articular head of the condylar process (*) was more prominent. Lines displayed on the transversal reconstructions on A1 and B1 show where the parasagittal reconstructions were performed on A and B, respectively.

Discussion

The morphometric assessment in this study was consistent with previous studies, which assessed the dentoalveolar and maxillofacial structures in the dog and the cat.[9,17,18] The CBCT multiplanar reformation (MPR) allowed identification, without superimposition of other structures of the calvarium, of the proposed anatomic landmarks and articular surfaces. Parasagittal MPR showed the TMJ as a condylar joint, comprised of two articular surfaces: 'the articular head of the condylar process of the ramus of the mandible' and a reciprocal depression 'the mandibular fossa of the petrous part of the temporal bone'.[1,2,19,20]

As previously described in the dog,[4,14] the articular surface of the condylar process at the medial aspect of the joint in 96.6% of specimens was observed as a well-defined circumscribed bony structure cupped medially and ventrocaudally by the retroarticular process of the mandibular fossa. At the medial aspect of the joint, the articular head was more prominent, presenting its maximum diameter, and the maximum articular relationship with the mandibular fossa, which corresponded to a concaved articular surface which also presented its deepest area at the medial region of the joint, as reported previously in an anatomic study.[4] Two TMJs were less congruent than the rest of the other

Table 1. Maximum and Minimum Values in Millimeters with Their Respective Means in Parenthesis for Observer 1. P-Values > 0.05 Shows no Differences Between the Right and Left TMJs for the Three Variables Assessed by Observer 1 (Width and Depth of the Mandibular Fossa, and Degree of Coverage of the Mandibular Fossa Over the Articular Head).

	Observer 1		
	Right TMJ	Left TMJ	p-value
MFW	4.6–6.9 (5.8) mm	4.3–7.4 (5.9) mm	0.68
MFD	1.5–2.6 (2.0) mm	1.5–2.8 (2.1) mm	0.071
DCMF	129°-200° (173°)	137°-203° (173°)	0.764

Abbreviations: MFW = mandibular fossa width; MFD = mandibular fossa depth; DCMF = degree of coverage of the mandibular fossa over the articular head; mm = millimeters.

Table 2. Maximum and Minimum Values in Millimeters with Their Respective Means in Parenthesis for Observer 2. P-Values > 0.05 Shows no Differences Between the Right and Left TMJs for the Three Variables Assessed by Observer 2 (Width and Depth of the Mandibular fossa, and Degree of Coverage of the Mandibular fossa Over the Articular Head).

	Observer 2		
	Right TMJ	Left TMJ	p-value
MFW	5.4–7.5 (6.4) mm	4.8–8.0 (6.3) mm	0.41
MFD	0.9–2.7 (1.9) mm	0.9–3.0 (1.9) mm	0.649
DCMF	136°-193° (169°)	132°-203° (169°)	0.865

Abbreviations: MFW = mandibular fossa width; MFD = mandibular fossa depth; DCMF = degree of coverage of the mandibular fossa over the articular head; mm = millimeters.

Table 3. Degree of Coverage of the Mandibular fossa Over the Articular Head - Maximum and Minimum Values with Their Respective Means in Parenthesis for Both Observers. P-Value > 0.05 Shows no Difference Between Observers.

	Observer 1	Observer 2	p-value
DCMF	129°-203° (173°)	132°-203° (169°)	0.169

Abbreviation: DCMF = degree of coverage of the mandibular fossa over the articular head.

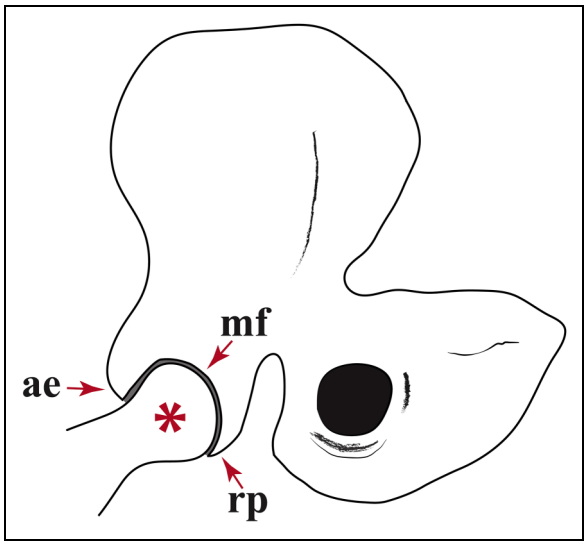

Figure 10. Parasagittal plane illustration of the anatomic conformation of the medial region of the TMJs of the cats used in the current study. The anatomic conformation was consistent in most of the cast in this study (96.6%), with a concave mandibular fossa (mf) having a prominent retroarticular process (rp), and well-defined rounded articular head surface of the condylar process (*).

TMJs in this study, and they were from the same cat. This finding could be related to real anatomic alteration of the joint, or it could be associated with postmortem contraction of soft tissue.

Consistent with previous studies, the mandibular fossa consisted of a concave articular surface, which is mainly enlarged at its caudomedial region by the retroarticular process, and to a lesser degree by the rostrodorsal articular eminence at its lateral aspect.[1,4,20] Both the articular eminence and the retroarticular process prevent the rostrodorsal or caudoventral dislocation of the joint, respectively, by increasing approximation between the articular head and the mandibular fossa.[4,21,22]

The retroarticular process and the articular eminence of the mandibular fossa were easily identified on the CBCT images in this study. Agreeing with previous reports, these bony extensions enhance the articular relationship between the mandibular fossa and the articular head.[4,21] The concave format of the mandibular fossa and the well-rounded shape of the articular head of the condylar process at the medial region of the joint were associated with high levels of articular relationship, with an overall mean value of 171°. Degree of coverage of the mandibular fossa near 180° would demonstrate that the estimated axis of rotation of the articular head would be at the same level as the line used for measuring the depth; specifically, almost half of the articular surface of the condylar process may be situated on the mandibular fossa at its deeper region. In a similar study performed in dogs, an angle of 96.5° was associated with shallow mandibular fossae, small or absent retroarticular process and irregular articular head joint surface.[14]

The articular relationship displayed between the articular surfaces of the medial region of TMJ reported in this study, along with the supporting TMJ soft tissue structures described in a previous report, may be associated with the masticatory biomechanics in the cat, in which the ability to perform rotational or lateral movements is limited or absent.[4,21,23] As a strict carnivore, the TMJ congruence in the cat and the transversal disposition of the articular head into the mandibular fossa result in restricted movements of the mandibles in the sagittal plane, which allows cutting of food into small pieces before swallowing. Thus, the congruence of the TMJ may avoid dislocation of the condylar process from the mandibular fossa during the grasping of prey, as observed in other predatory felids.[4,21,23–26]

Concurring with previous literature, CBCT did not allow the evaluation of the articular or periarticular soft tissue structures such as the articular disk, articular capsule, or periarticular muscles.[10,27] When compared to conventional CT scanners, the current CBCT machines display noticeably less soft-tissue contrast, with this disadvantage being attributed to the CBCT geometry, low radiation dose, flat-panel technology and algorithms used for image reconstruction.[10,11,27] The joint space was observed during the pilot study as a homogeneous hypoattenuating linear image between the articular head and the mandibular fossa on the tomographic images. Widening of joint spaces, presence of abnormal periarticular or articular bony projections such as enthesophytes and osteophytes, or presence of cystic lesions at the subchondral bone as well as the morphology and articular relationship between the joint surfaces must be included in further studies to rule out the presence of TMJ disorders.[13]

Contrary to the results of a similar study performed in dogs, where three TMJ anatomic conformations were described,[14] only one anatomic conformation for the articular surfaces of the articular head and mandibular fossa was observed at the medial aspect of the TMJ in most of the specimens. This finding may be related to the fact that only heads from mesocephalic adult cats with no history of TMJ disorders were evaluated. Inclusion of a different skull conformation (eg brachycephalic) or inclusion of other ages (eg kitten) may show more distinct TMJ morphologies.

The results of this study describe the shape of the articular surfaces of the joint and its articular relationship at the medial aspect of the TMJ. Overall, these findings are in accordance with findings reported in the dog, where tomographic images allowed for morphologic assessment of the articular surfaces.[14] Even though this study did not aim to compare CBCT with other diagnostic imaging techniques, such as conventional

CT, the CBCT imaging technique did demonstrate to be a suitable diagnostic technique for assessment of the bony structures of the TMJ in the cat.[9]

The morphometric and morphologic assessment described in this study provided the basis for a more detailed and objective anatomical description of the TMJ in the cat. The primary intent of the intraobserver assessment of the three variables was to establish if the articular surfaces at the medial aspect of both right and left TMJs were symmetrical, and since there was no statistically significant difference for the intraobserver assessment, this hypothesis was confirmed.

The degree of coverage of the mandibular fossa over the articular head of the condylar process was a reliable and consistent measurement for evaluating the relationship between the articular surfaces at the medial region of the joint. This measurement was easily obtained, with no difficulties reported by the observers in the identification of landmarks or in performing the measurements.

Even though no statistical differences were observed for the degree of coverage during the intra and interobserver evaluation, further research will be necessary using the degree of coverage through the middle and lateral regions of the joint to establish reliability in these areas. New clinical studies must be conducted, including patients with temporomandibular disorders or different skull conformation, since the present study used heads from mesocephalic cats with no gross anatomic alterations of the temporomandibular joint.

One limitation of this study was the determination of the articular relationship of a 3-dimensional structure using 2-dimensional images. A more accurate assessment of the joint surfaces would include a 3-dimensional evaluation of the articular surfaces and the joint space using specialized imaging software, as performed in humans.[12] Although a 3-dimensional assessment was not performed, the measurements proposed in the present study may serve as a reference for the initial assessment in a clinical setting as well as for further studies of the TMJ in the cat.

In conclusion, the proposed measurements at the medial region of the TMJ demonstrated a concave mandibular fossa with a prominent retroarticular process and a poorly developed articular eminence; a well-defined rounded articular head surface; and a high degree of coverage (171°) of the mandibular fossa over the articular head. The results indicated that the articular surfaces at the medial aspect of the TMJ displayed constant geometric similarity, with the articular head of the condylar process deeply seated in the mandibular fossa.

Materials

(a) Veraviewepocs 3D cone-beam CT, MORITA Corp, Osaka, Japan
(b) Osirix, DICOM Software, version 11.0.2, Pixmeo SARL, Geneva, Switzerland
(c) R' software (version 3.5.1), Free Software Foundation, Boston, USA

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