Surgical and Radiologic Anatomy (2019) 41:469–476
https://doi.org/10.1007/s00276-018-2167-1

ORIGINAL ARTICLE

TMJ arthrosis: does the occlusal relationship really interfere? A comparison between cone beam computed tomography and dried skulls

Rafaela Scariot[1] · Paola Corso[1] · Briana Gonsar[2] · Navenett Gill[2] · Paula Cristina Trevillato[3] · Anitha Potluri[4] · Alexandre Rezende Vieira[2]

Received: 12 June 2018 / Accepted: 8 December 2018 / Published online: 14 December 2018

Abstract

The aim of this study was to investigate the association between condylar bone morphological characteristics with occlusal conditions. Besides the study will compare the tomography images with the real condition in 122 temporomandibular joints from 61 skulls. The occlusal conditions were evaluated by number of teeth missing, measurement of overjet and overbite, in millimeters, and presence or absence of crossbite, openbite and dental rotation. The condylar bone morphological conditions were classified in five types (normal, presence of erosion, presence of osteophytes, flattening and/or deformation). This classification was used in real skulls and in Cone Beam Computed tomography (CBCT) images. The data were submitted to statistical analysis with a level of significance of 0.05. Occlusal variables have no association to morphologic data ($p > 0.05$). Normal condylar bone was seen in 62 CBCT versus 53 in real skulls while morphological alterations were seen in 60 CBCT versus 67-real condyles. The clinical and tomographic measurements were compared, demonstrating an important difference in the classification demonstrating poor association between detection methods ($k - 0.3$, $p < 0.001$). The occlusal conditions appear to have no correlation with the morphological condyle conditions. The CBCT is a reliable diagnostic method, although it may present divergences of findings when compared with clinical raw examination to morphologic condylar conditions.

Keywords Dental occlusion · Mandibular condyle · Skull

Introduction

The mandibular condyle morphology is widely variable in both healthy subjects and in those with some form of temporomandibular disorders (TMD). There are numerous factors that can cause some kind of bone changes as hormonal and genetic factors, internal derangements, macro local trauma, parafunctional habits, facial types, growth pattern and among other unknown causes. Contradictorily, occlusal disharmonies have been discussed a lot in the literature as an influencer factor. Is known that occlusal alterations do not interfere on articular signs and symptoms; however, little is known if occlusal conditions interfere with morphological condyle alterations. Currently the studies correlate condylar alterations with orthodontic treatment in populations with dental malocclusion or with specific treatments such as mandibulectomy, condilectomy and orthognathic surgery [1–3].

In general, the adult condyle dimension presented the antero-posterior measurements (range from 8 to 10 mm) shorter than the medial–lateral (range from 15 to 20 mm)

Rafaela Scariot, Paola Corso, Briana Gonsar, Navenett Gill, Paula Cristina Trevillato, Anitha Potluri and Alexandre Rezende Vieira contributed equally to this work.

✉ Rafaela Scariot
rafaela_scariot@yahoo.com.br

[1] School of Health Science, Dentistry, Positivo University, 5300 Professor Pedro Viriato Parigot de Souza Street, Curitiba, PR 81280-330, Brazil

[2] Department of Oral Biology, University of Pittsburgh, 412 Salk Pavilion, Pittsburgh, PA 15261, USA

[3] School of Life Sciences, Pontifical Catholic University of Parana, 1155 Imaculada Conceição Street, Curitiba, PR 80215-901, Brazil

[4] Department of Diagnostic Sciences, University of Pittsburgh, Pittsburgh, PA, USA

in healthy individuals [4]. The articular surface is covered with an articular cartilage highly susceptible to remodeling by changes with great regenerative capacity. When articular surface is damaged there is an involvement of the mandibular condyle bone. The functional pattern can change the original features, leading to variations in articular surface in different degrees, which may have correlation with clinical symptoms or not [5, 6]. The Cone Beam Computed Tomography (CBCT) is one of the most realized exams of dental routine for overall assessment of TMJ, along with magnetic resonance, due to the high potential for clinical application and its accuracy. CBCT has contributed in treatment planning, diagnosis, therapeutic and prognosis of different diseases. It is well established that the CT images can promote up to 96% accuracy when bone components are measured [7].

The aims of this study were (1) to investigate the association between condylar bone morphological characteristics with occlusal conditions and (2) to compare tomographic images of the condylar morphology with raw clinical examination.

Materials and methods

Sixty-one adults' dried skulls, both sexes, were obtained from the University of Pittsburgh, School of Dental Medicines collection. Those individuals are likely to have lived in the northeast United States during the late nineteenth century and the early twentieth century. The skulls are in conservation period around the 1930s and were originally gathered by a former chair of orthodontics in the 1960s.

The ethnic group was determined from various markers on the skulls, which were predominantly composed by Whites, followed by Black, Asian and other ethnic groups. All of specimens of the collection were included in study except skulls with mixed dentition or edentulous, because of impossibility to evaluate occlusal parameters. The skulls with absence of upper and/or lower incisors central incisors were excluded too because of the impossibility to measure overbite, overjet, and anterior open bite. The University of Pittsburgh Institutional Review Board approved this study.

Occlusal variables

Occlusal aspects were evaluated as an etiologic factor of condylar bone morphological conditions. Number of teeth missing was evaluated by counting the teeth in the arches, excluding third molars. The overbite was measured from a pachymeter measuring the vertical distance from the edge of the upper and lower central incisors. The overjet was obtained by measuring the distance from the vestibular face of the lower central incisor to the palatal surface of the upper central incisor. The crossbite were evaluated in molars when the buccal cusp palatine surface of the maxillary teeth occluded lingually to the buccal cusp of the mandibular teeth. The open bite was considered when the distances of the incisal surfaces of the upper and lower incisors were greater than 0 mm. The presence of teeth rotation was compared to dental alignment in the arch. Trained and calibrated researchers (R. S., B. G., N. G.) blinded to each other, evaluated the skulls in two different times.

Morphology evaluation

Raw skull examination

At this stage, the same calibrated researches observed the skulls and checked the morphologic situation through the pre-established surface aspects, according to classification [8, 9] with minor modifications. Sclerosis and pseudocysts were allocated in other category called other deformation. The probable sex, age, and ethnicity of the skulls were determined using various markers. To determine the age, the eruption time of teeth were used only in estimating the age of teenage children. Ectocranial suture status, open versus closed, was used as an age estimator because most of the skulls were adults. Closed sutures are indicative of an individual greater than 40, whereas open sutures represent an individual less than 40 [10].

To distinguish the sex of the skeleton, general differences between the male and female skull were used. The male skull is generally larger, heavier, and less rounded (at the forehead). Also, muscular ridges, such as temporal lines, the frontal sinuses, the palate, the supra-orbital ridges and the teeth are often larger and more prominent in males. The mastoid process is more developed and the upper margin of the orbit is more rounded. The mandible is more robust and the ramus of the mandible is broader and longer in males with a better-developed coronoid process. The female skull tends to retain more of an adolescent form [11].

For determining ethnicity, various nasal features are commonly used by forensic anthropologists to determine ancestry. European descents usually have a narrow and tall nasal opening, high nasal bone, a more prominent chin, and greater brow-ridging. Asians commonly possess a medium and short nasal opening, low nasal bone, and more protruding jaw. Africans tend to have a wide and short nasal opening, medium nasal bone, and an oblong orbital shape [12].

Normal condyles were considered when the contour of the cortical bone was intact without alterations signals; erosion when there was an area with decreased density of the cortical bone and the adjacent subcortical bone; osteophytes were considered when there were marginal bony outgrowths on the condyle; flattening in the presence of flat bony contour deviating from the convex form; deformation for other major alterations that do not fit into another classification. The same condyle could be characterized by more than one type of classification.

Tomographic morphology

All the skulls underwent CT scan from the use of Iluma CBCT@ SN (0804168, Model 2520, Imtec LLC, Ardmore, OK, USA). The CBCT acquisition protocol was used 0.3 mm voxel size, 40 s, 120 kVp and 3.8 mA parameters. The skull was placed in an upright AP position on the positioning holder for model scans set 4 cm, height of arm set at 4 cm, and the skull set on a 3 cm sponge for height. The skull was positioned within the detector plate consistently, with the TMJ intersecting the positioning line. A scout image was taken before each scan to ensure consistent position of the skull. With the CBCT system, axial scans and multi-planar reconstructions were obtained and imported as DICOM files into Planmeca Romexis® version 4.3.0. (Roselle, NJ, USA). Condylar tomographic characteristics were classified in normal, erosion, presence of osteophytes, flattening, and deformation. It is possible to observe the pattern of each condylar type and obtained image, respectively in Figs. 1, 2, 3, 4 and 5.

Statistical analysis

Quantitative variables were described by average statistics, median, minimum, maximum, and standard deviation. Qualitative variables were summarized by frequencies and percentages. For the evaluation of the normality condition of quantitative variables, the Jarque–Bera test was considered. Kruskall–Wallis was used to compare non-parametric groups of occlusal variables with morphological condyle conditions. To evaluate the concordance between real ordinal measurements and measurements performed by the CBCT method, the Kappa concordance analysis was considered. *P* values less than 0.05 were considered statistically

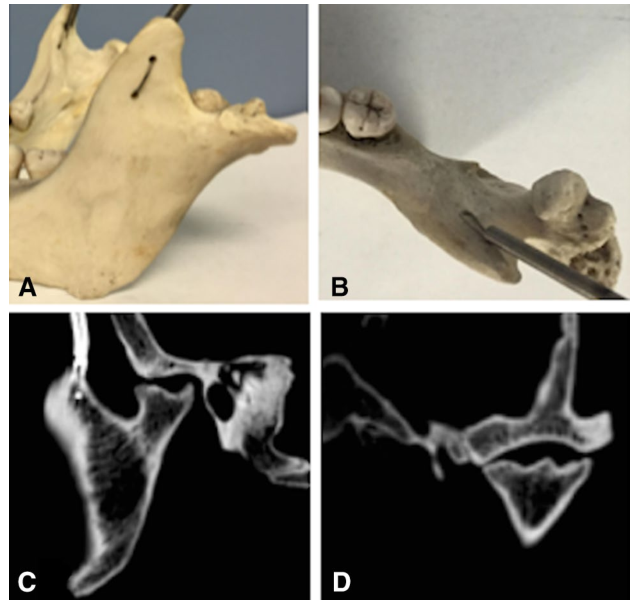

Fig. 2 Erosion: the lateral (**a**) and superior (**b**) views of condyle on dried skulls. Sagittal (**c**) and coronal (**d**) slices on CT images

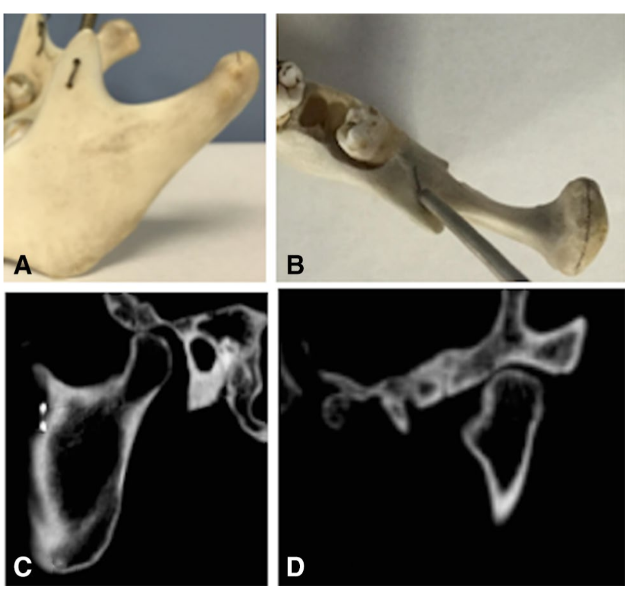

Fig. 1 Normal condition: the lateral (**a**) and superior (**b**) views of condyle on dried skulls. Sagittal (**c**) and coronal (**d**) slices on CT images

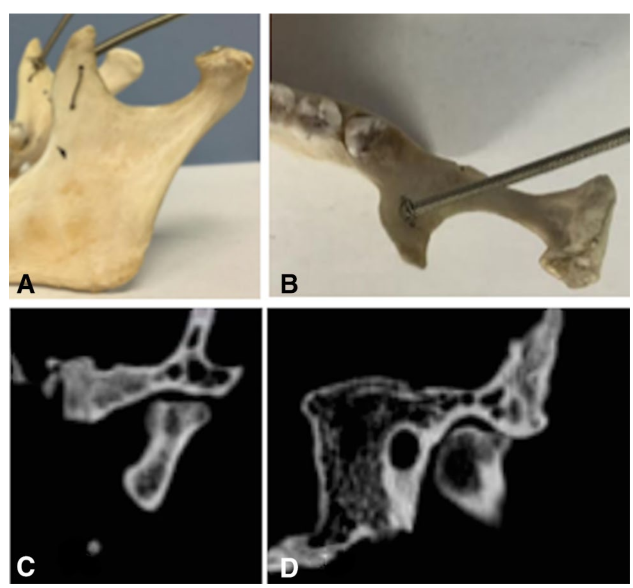

Fig. 3 Osteophytes: The lateral (**a**) and superior (**b**) views of condyle on dried skulls. Sagittal (**c**) and coronal (**d**) slices on CT images

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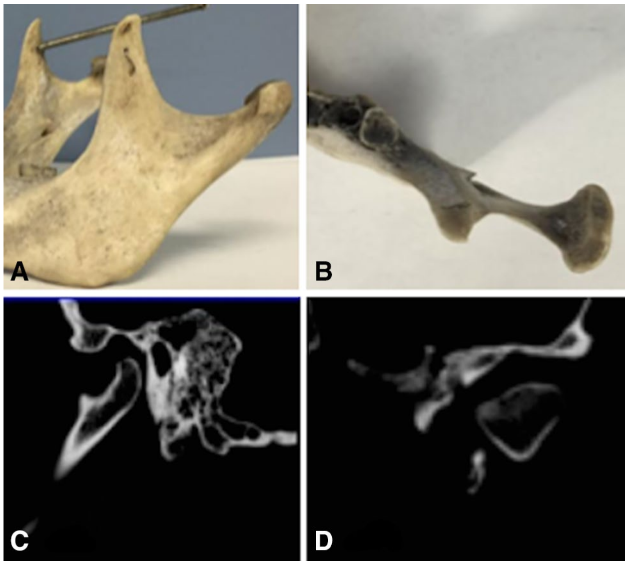

Fig. 4 Flattening: the lateral (**a**) and superior (**b**) views of condyle on dried skulls. Sagittal (**c**) and coronal (**d**) slices on CT images

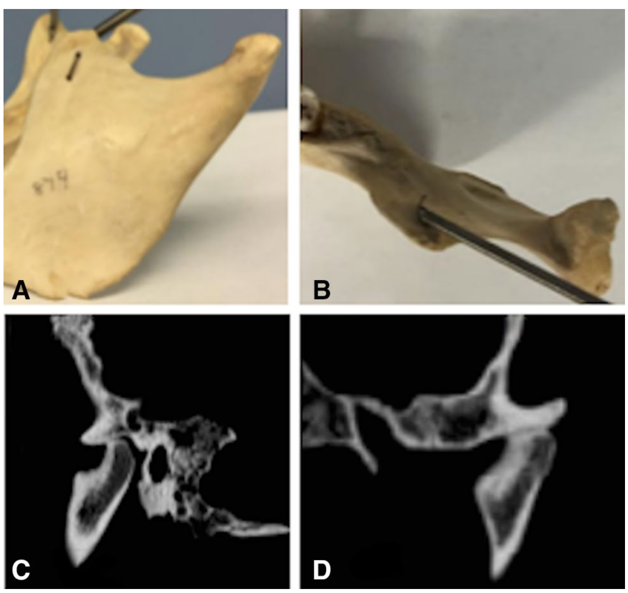

Fig. 5 Deformation: the lateral (**a**) and superior (**b**) views of condyle on dried skulls. Sagittal (**c**) and coronal (**d**) slices on CT images

significant. For data processing SPSS 20.0 Software was used(Statistical Package for the Social Sciences).

Results

No significant correlation between occlusal variables when compared with real morphologic alterations ($p > 0.05$). Data can be visualized in Tables 1 and 2.

With respect to the correlation of morphologic findings with CBCT images evaluation, 53 condyles were considered normal in a raw examination, while 62 were considered normal in CBCT analysis. Twenty-two condyles presented erosion on clinical versus 17 on tomographic evaluations. About presence of osteophytes, 15 condyles were considered in both real and CBCT measurements. A great difference also was observed in flattening and deformation characteristics. The Table 3 shows the entirety of the results. Based on results obtained in Table 3, it was evaluated whether there is an association between the clinical results and those of the CBCT evaluation versus the alternative hypothesis corresponding to the absence of association for both right and left sides. The result of the statistical test indicated rejection of the null hypothesis ($p < 0.001$). The estimated Kappa correlation coefficient was 0.33.

Discussion

The main findings of this work were the non-association between occlusal conditions and condylar bone morphological characteristics and the differences found in compared tomographic images of the condylar morphology with raw clinical examination. These two topics will be discussed below. We have some limitations in this study. One of this was the impossibility of comparing exactly the clinical situation with the dry skulls. The authors cannot be sure that the occlusion variables quantified do translate the actual in vivo situation, once all soft tissues are removed and the joint can articulate freely. Based on this, there is a risk of under/overestimation of the situation. Another limitation is the comparison between so-called normal morphology, considering no signs of arthrosis, and pathological modifications of the condyle.

As previously mentioned, much has already discussed in the literature about occlusal changes and it does not interfere on articular signs and symptoms in TMJ. However, a little is known if occlusal conditions interfere with morphological condyle alterations. With regard to some aspects of dental occlusion, we hypothesized that patients with dental malocclusion could present more condylar morphological alterations than patients without these alterations [13]. However, no statistically significant association between any of the analyzed variables was found.

We noted the difference of interpretation of tomographic images to the findings in the direct assessment in some alterations on dried skulls. On both sides, significant differences were present. We found 28 normal condyles in real measurements versus 34 in CBCT images on right side and 25 normal real condyles versus 26 CBCT normal images on left side. A change in this pattern was seen for morphological alterations with 31 condyles presenting some alteration

Table 1 Classification criteria of the skull examination according with teeth missing, overbite and overjet

Variable	Classification (*n* per group)	Median (min–max–range)	*p* value
Right side			
Teeth missing (number)	Normal (31)	1.0 (0.0–11.0)	0.561
	Erosion (12)	0.0 (0.0–9.0)	
	Osteophytes (9)	0.0 (0.0–6.0)	
	Flattening (11)	1.0 (0.0–15.0)	
	Deformation (3)	0.0 (0.0–9.0)	
Overbite (mm)	Normal (27)	2.0 (0.0–9.0)	0.436
	Erosion (10)	1.9 (0.0–4.0)	
	Osteophytes (8)	1.0 (0.0–3.0)	
	Flattening (10)	1.6 (0.0–8.0)	
	Deformation (1)[a]	4.0 (4.0–4.0)	
Overjet (mm)	Normal (27)	4.1 (0.0–8.0)	0.365
	Erosion (10)	1.4 (0.0–9.0)	
	Osteophytes (8)	1.6 (0.0–6.2)	
	Flattening (10)	2.9 (0.0–8.4)	
	Deformation (1)[a]	5.0 (5.0–5.0)	
Left side			
Teeth missing (number)	Normal (29)	0.0 (0.0–11.0)	0.619
	Erosion (12)	1.0 (0.0–5.0)	
	Osteophytes (7)	0.0 (0.0–5.0)	
	Flattening (12)	1.5 (0.0–15.0)	
	Deformation (6)	0.0 (0.0–4.0)	
Overbite (mm)	Normal (25)	1.0 (0.0–9.0)	0.908
	Erosion (10)	2.1 (0.1–4.0)	
	Osteophytes (7)	1.9 (0.0–4.1)	
	Flattening (9)	1.6 (0.0–8.0)	
	Deformation (5)	2.0 (0.0–4.0)	
Overjet (mm)	Normal (25)	2.0 (0.0–8.0)	0.781
	Erosion (10)	3.1 (0.3–9.0)	
	Osteophytes (7)	4.3 (0.0–6.2)	
	Flattening (9)	2.8 (0.0–8.4)	
	Deformation (5)	5.0 (0.4–6.0)	

Min minimum, *Max* maximum

*Kruskal–Wallis Test; $p < 0.05$

[a]It was not considered for the statistical test

on real measurements versus 27 on CBCT images on right side and 36-real measurements versus 33 CBCT images on left side. This fact shows us that we may be facing an overestimation of image interpretations when condyles are in a normal real situation, explained by a tendency to interpret more positive tomographic results (we interpreted tomographic images more normal than they really are). In contrast, in situations where there is some kind of bone change, there is a tendency to underestimate of the presence of morphological changes.

The osteophyte detection was equal in both evaluations, which leads us to think that this is an alteration more evident for the researchers and also in the tomographic image, and thus easier to be identified and reduced chances of divergence. On the other hand, deformation follows a different pattern of this last one, because there were many divergences of interpretation in both evaluations. The same situation occurred in erosion and flattening alterations. A speculation that can be cited, is the fact that when the tomographic images were seen, we separate it in slices, that could become a less apparent image of when compared to morphological analysis as a whole.

Some functional conditions have an influence on condyle shape. The clinical relevance of condylar changes is described by many authors in the literature, by applying significance is with respect to clinical symptomatology, diagnosis and treatment [13–15]. The importance of correct analysis of imaging studies is due to influence of the

Table 2 Skull examination according with crossbite, openbite, and teeth rotation

	Normal n (%)	Erosion n (%)	Osteophytes n (%)	Flattening n (%)	Deformation n (%)	*P value**
Right side						
Crossbite						
Presence	17 (54.8%)	6 (50.0%)	5 (55.6%)	5 (45.5%)	0 (0.0%)	0.737
Absence	14 (45.2%)	6 (50.0%)	4 (44.4%)	6 (54.5%)	3 (100.0%)	
Openbite						
Presence	10 (32.3%)	4 (33.3%)	4 (44.4%)	3 (27.3%)	1 (33.3%)	0.952
Absence	21 (67.7%)	8 (66.7%)	5 (55.6%)	8 (72.7%)	2 (66.7%)	
Teeth rotation						
Presence	22 (71.0%)	11 (91.7%)	9 (100.0%)	10 (90.9%)	3 (100.0%)	0.111
Absence	9 (29.0%)	1 (8.3%)	0 (0.0%)	1 (9.1%)	0 (0.0%)	
Left side						
Crossbite						
Presence	13 (44.8%)	7 (58.3%)	5 (71.4%)	6 (50.0%)	2 (33.3%)	0.628
Absence	16 (55.2%)	5 (41.7%)	2 (28.6%)	6 (50.0%)	4 (66.7%)	
Openbite						
Presence	9 (31.0%)	5 (41.7%)	3 (42.9%)	3 (25.0%)	2 (33.3%)	0.894
Absence	20 (69.0%)	7 (58.3%)	4 (57.1%)	9 (75.0%)	4 (66.7%)	
Teeth rotation						
Presence	26 (89.7%)	9 (75.0%)	4 (57.1%)	11 (91.7%)	5 (83.3%)	0.240
Absence	3 (10.3%)	3 (25.0%)	3 (42.9%)	1 (8.3%)	1 (16.7%)	
Crossbite						
Presence	13 (44.8%)	7 (58.3%)	5 (71.4%)	6 (50.0%)	2 (33.3%)	0.628
Absence	16 (55.2%)	5 (41.7%)	2 (28.6%)	6 (50.0%)	4 (66.7%)	
Right + left side						
Openbite						
Presence	6 (31.6%)	6 (42.9%)	6 (40.0%)	3 (25.0%)	2 (28.6%)	0.730
Absence	13 (68.4%)	8 (57.1%)	9 (60.0%)	9 (75.0%)	5 (71.4%)	
Teeth rotation						
Presence	17 (89.5%)	13 (92.9%)	12 (80.0%)	11 (91.7%)	6 (85.7%)	0.751
Absence	2 (10.5%)	1 (7.1%)	3 (20.0%)	1 (8.3%)	1 (14.73%)	
Crossbite						
Presence	9 (47.4%)	7 (50.0%)	10 (66.7%)	6 (50.0%)	2 (28.6%)	0.848
Absence	10 (52.6)	7 (50.0%)	5 (33.3%)	6 (50.0%)	5 (71.4%)	

*Kruskal–Wallis Test; $p < 0.05$

choice of treatment and prognosis prospects. In this study it is possible that we have some skulls with history of temporomandibular disorders and because of this some morphologic alteration in condyle. But it is impossible to determine the relation of this cause and effect. Our main finding that malocclusion does not associate with condyle morphology is intriguing. One hand, the study done in dried skulls can be seen as a limitation, since no functional clinical information could be gathered. One the other hand, the ability to directly visualize the condyle structures and the directly observe the dentition and how it occluded is very unique and there is no reason to believe that inferences cannot be made regarding the condyle anatomical changes given the occlusal and skeletal patterns.

We must remember that there are also other important risk factors and aggravation to change the condylar surface, such as an association of the genetic polymorphism (*COL1A1* gene) in patients with osteoporosis, demonstrated in a recent study [16]. This fact leads us to believe that there are a variety of factors that may be associated with an increase of propensity, beginning, aggravation and perpetuation of degenerative diseases, and we could not account for all possible factors at once. However, we can think in contributing to find individual factors that could increase the incidence of some form of TMJ disorders.

Creating a link of tomographic under and overestimation we can consider a critical analysis of the CT findings in patients with malocclusion, where there is a greater tendency

Table 3 Prevalence of condylar characteristics in CBCT versus raw examination separated by side in 61 dried skulls

CBCT evaluation *n* (%)	Skull examination *n* (%)					
	Normal	Erosion	Osteophytes	Flattening	Deformation	Total
Right condyles						
Normal	24 (39.3%)	3 (4.9%)	3 (4.9%)	3 (4.9%)	1 (1.6%)	34 (55.7%)
Erosion	0 (0.0%)	4 (6.6%)	2 (3.3%)	2 (3.3%)	0 (0.0%)	8 (13.1%)
Osteophytes	3 (4.9%)	2 (3.3%)	1 (1.6%)	2 (3.3%)	0 (0.0%)	8 (13.1%)
Flattening	1 (1.6%)	0 (0.0%)	1 (1.6%)	3 (4.9%)	1 (1.6%)	6 (9.8%)
Deformation	0 (0.0%)	2 (3.3%)	1 (1.6%)	1 (1.6%)	1 (1.6%)	5 (8.2%)
Total	28 (45.9%)	11(18.0%)	8 (13.1%)	11 (18.0%)	3 (4.9%)	61 (100%)
Left condyles						
Normal	16 (28.2%)	4 (6.6%)	2 (3.3%)	4 (6.6%)	2 (3.3%)	28 (45.9%)
Erosion	0 (0.0%)	7 (11.5%)	0 (0.0%)	2 (3.3%)	0 (0.0%)	9 (14.8%)
Osteophytes	3 (4.9%)	0 (0.0%)	2 (3.3%)	1 (1.6%)	1 (1.6%)	7 (11.5%)
Flattening	1 (1.6%)	0 (0.0%)	1 (1.6%)	3 (4.9%)	0 (0.0%)	5 (8.2%)
Deformation	5 (8.2%)	0 (0.0%)	2 (3.3%)	2 (3.3%)	3 (4.9%)	12 (19.7%)
Total	25 (41.0%)	11(18.0%)	7 (11.5%)	12 (19.7%)	6 (9.8%)	61 (100%)

in a clinical evaluation to find normal images of possibly altered condyles (in an initial stage or not). This can be one of the reasons for excluding the possibility of the malocclusion be a beginner factor of TMJ disorders.

Conclusion

The occlusal conditions appear to have no correlation with the morphological condyle conditions. The CBCT is a reliable diagnostic method, although it may present divergences of findings when compared with clinical raw examination to verify morphologic condylar conditions and should be considered with limitation if it is not associated with the clinical aspects.

Compliance with ethical standards

Ethical approval All applicable institutional guidelines for the care and use of skulls were followed.

Informed consent For this type of study, formal consent is not required.

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