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Cone beam computed tomography study of osteoarthritic alterations in the osseous components of temporomandibular joints in asymptomatic patients according to skeletal pattern, gender, and age

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Objective. The aim of this study was to evaluate the prevalence of osteoarthritic alterations in the osseous components of the temporomandibular joint (TMJ) in asymptomatic patients with different skeletal patterns, gender, and age groups with cone beam computed tomography (CBCT) images.

Study Design. CBCT images of 213 asymptomatic patients were assessed for the presence of any degenerative changes in the condyle and fossa/eminence complex. Each TMJ was evaluated separately and was classified as normal, indeterminate for osteoarthritis, or affected by osteoarthritis. Differences were tested by using the χ^2 and Fisher's exact tests ($P < .05$).

Results. In total, 52.3% of the joints presented some visible alteration in the osseous components. Abnormalities were detected in 32.6% of the condyles and 31.5% of the articular fossae/eminences, and flattening was the most prevalent alteration in all classes. There was no statistically significant difference in the prevalence of alterations in either the condyle or the articular fossa/eminence among the skeletal groups for the entire sample or for the gender and age subsets.

Conclusions. There are no differences in degenerative TMJ changes in patients with or without skeletal jaw discrepancies. No differences were found when gender and age were considered. (Oral Surg Oral Med Oral Pathol Oral Radiol 2019;128:70−77)

Temporomandibular disorders (TMD) are a complex group of pathoses involving the masticatory muscles, the temporomandibular joint (TMJ), and its associated structures.[1] These disorders have a multifactorial etiology and occur in response to mechanical and biologic events.[2] They have the potential to affect the morphology of the hard tissue components of the TMJ (condyle and articular and fossa/eminence),[3] in the form of osteoarthritis (also referred to as *degenerative joint disease*), which can be observed in imaging examinations.[4]

The Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD),[4,5] a system proposed in 1992 and widely used for the diagnosis of TMDs,[4] describes, among other things, the image analysis criteria for osteoarthritis based on computed tomography (CT) images, which indicate remodeling or degenerative changes of the bone. These osteoarthritic features include condylar flattening, osteophyte formation or loose bodies, erosion, deviation in form, subcortical sclerosis or general sclerosis, subcortical cysts, hyperplasia or hypoplasia of the condylar head, and bony ankylosis. Changes in the articular fossa/eminence include flattening, erosion, and subcortical sclerosis. On the basis of this assessment, TMJ is classified as normal, indeterminate, or affected by osteoarthritis.[4−6] These features, although asymptomatic, may indicate the type of bone remodeling that is occurring, which may be functional (morphologic changes not associated with significant functional or occlusal alterations) or dysfunctional (disturbed function of TMJ and unstable occlusion).[6,7]

TMJ osteoarthritis is more frequently observed in the condyle.[8] The anatomic condylar location is altered by continuous repositioning of the mandible during craniofacial growth and adaptive remodeling of the TMJ.[9] In patients with skeletal jaw discrepancies, TMJ osteoarthritis and other joint disorders are more common,[1,6] suggesting an association between degenerative alterations and the skeletal pattern. However, available studies are based on a single-factor design, not taking into account the complexity of biologic and mechanical models.[1] There is a need for investigations involving the most representative populations possible,

Statement of Clinical Relevance

The diagnosis of temporomandibular disorders is based on findings regarding temporomandibular joint osteoarthritis. This study was based on a design of multiple factors and addressed both the condyle and the articular fossa/eminence, which is unprecedented. Degenerative temporomandibular joint changes did not differ among groups based on skeletal patterns, age, and gender.

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comprising different age and gender groups.[1] Moreover, there is lack of information regarding changes in the articular fossa and eminence. Thus, the aim of this study was to evaluate the prevalence of osteoarthritic alterations in the osseous components of the TMJ in asymptomatic patients with different skeletal patterns, gender, and age groups by using the RDC/TMD and cone beam computed tomography (CBCT) images. The null hypothesis stated that there were no significant differences in the manifestations of osseous alterations on the basis of skeletal patterns, gender, or age.

MATERIALS AND METHODS

This retrospective and observational study, developed according to the Strengthening the Reporting of Observational Studies in Epidemiology initiative,[10] was approved by the Ethics Committee (CAAE: 34328214.3.0000.0104).

Sample

This study included CBCT examinations of 213 asymptomatic patients, who underwent CBCT for several reasons at the Oral Radiologic Clinic at (LIPC/UEM) (Laboratório de Imagens em Pesquisa Clínica - Laboratory of Images in Clinical Research) for (Universidade Estadual de Maringá - State University of Maringá). The cases were selected from an archive of 1002 CBCT scans based on our inclusion and exclusion criteria. Scans were included if they depicted the condyle and articular fossa/eminence bilaterally, in maximum intercuspation. Patients younger than 18 years of age, edentulous patients, and individuals with congenital craniofacial syndromes, a history of dentofacial trauma, orthognathic surgery or known TMD, orofacial pain or mandibular dysfunction, remarkable parafunction, rheumatoid arthritis, or other degenerative joint disease were excluded.

Skeletal pattern was classified as Class I ($0^\circ <$ A point, nasion, B point [ANB] $< 4^\circ$; n = 62), Class II (ANB $\geq 4^\circ$; n = 71), and Class III (ANB $\leq 0^\circ$; n = 80).[11,12] The study patients were divided according to gender (97 males and 116 females) and age (patients younger than 40 years [n = 116] and 40 years and older [n = 97]). Each TMJ was considered individually, resulting in a total of 426 examinations, divided into 12 groups.

Images

All of the CBCT scans were obtained by using the Next Generation i-CAT (Imaging Sciences International, Hatfield, PA) device, with a standardized scanning protocol (120 kVp, 38 mA, 0.3-mm isometric voxel, 1 mm-thickness). The same experienced radiologist performed all examinations.

Images were examined by using the scanner's proprietary software (Xoran 3.1.62 version, Xoran Technologies, Ann Arbor, MI), and the ANB angle measurements were performed in the InVesalius 3.0.0 software (Centro de Tecnologia da Informação Renato Archer, Campinas, SP, Brazil). After CBCT acquisition, the orthogonal reformatting planes were rotated such that the axial plane was aligned with the Frankfort horizontal plane (in the sagittal image window), the coronal reformatting plane was aligned with the transporionic plane (in the axial image window), and the sagittal reformatting plane was aligned with the midsagittal plane (in the coronal image window). To perform the angular measurements, the midsagittal plane was determined in the sagittal plane window. The angle tool was then used to select 3 points: "point A" (landmark located in the greater concavity of the maxilla subjacent to the anterior nasal spine); "point N" (nasion − angle vertex, in the anterior point of the frontonasal suture; and "point B" (the deepest point in the concavity of the mandible at the mental symphysis) (Figure 1).

Data collection

The right and left TMJs of each patient were evaluated from reconstructed axial, paracoronal, and parasagittal slices (TMJ window). The observers first examined the entire TMJ in the axial plane. From the largest diameter slice of the condyle in this plane, axial, paracoronal, and parasagittal slices were reconstructed with 1 mm thickness. According to the RDC/TMD, the condyles were examined for the presence or absence of flattening, osteophyte formation or loose joint bodies, erosion, deviation in form, subcortical sclerosis or generalized sclerosis, subcortical cysts, hyperplasia or hypoplasia of the condylar head, and bony ankylosis (Figure 2). In cases of condylar hypoplasia or hyperplasia, the condylar morphology is normal, but its size is smaller or larger, respectively. The deviation in form is defined as an alteration from normal shape not attributable to flattening, erosive changes, osteophytes, or hyper- or hypoplasia.[4] For the articular fossa/eminence the presence or absence of articular surface flattening, erosion, and subcortical sclerosis.[4,5] were analyzed (see Figure 2). To validate the presence of these features, hard tissue changes had to be observed in at least 2 consecutive slices.

On the basis of this analysis, the TMJ was classified as normal (normal relative size of the condyle; and absence of articular surface flattening, osteophytes or loose bodies, subcortical or generalized sclerosis, and subcortical cysts); indeterminate for osteoarthritis (normal relative size of the condyle; and articular surface flattening with or without subcortical sclerosis, or subcortical sclerosis with or without articular surface flattening; and absence of osteophytes, surface erosion, generalized sclerosis, and subcortical cysts); and affected by osteoarthritis (osteophytes, surface erosion, generalized sclerosis, or subcortical cysts).[4–6]

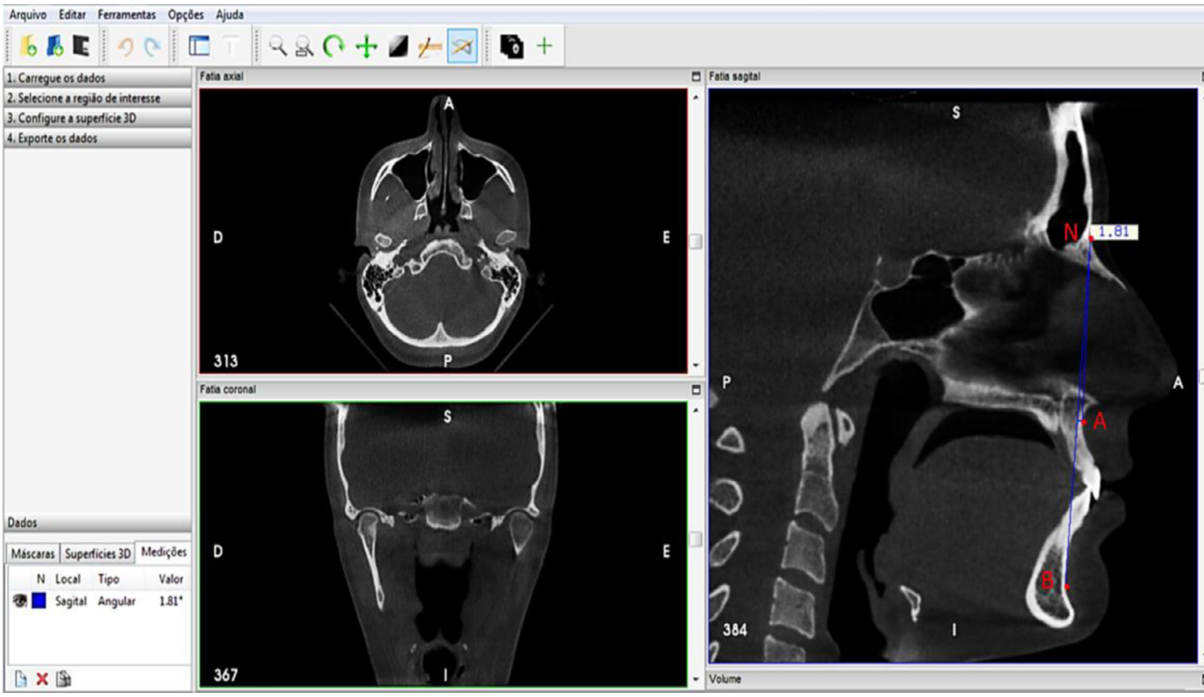

Fig. 1. ANB (A point, nasion, B point) measures analyzed with InVesalius 3.0 software.

Two independent examiners (radiology and dental imaging specialists with at least 5 years of experience with CBCT, calibrated with 10% of the sample) assessed the examinations and recorded the presence or absence of the osteoarthritic alterations in each TMJ. The assessments were performed in duplicate with a 2-week interval, and only 10 examinations were evaluated per day to avoid eye fatigue. The examiners were allowed to change the brightness and contrast of the images to obtain ideal visual conditions for the diagnosis.

Statistical analysis

All the qualitative variables were described in percentage and analyzed on R software version 3.1.1 (R Development Core Team, 2014). The prevalence and the number of changes observed by class, gender, and age were assessed by using frequency tables, and differences were tested by using the χ^2 test and Fisher's exact test. The level of intra- and interobserver agreement was assessed by kappa statistics. P values $< .05$ were considered significant.

RESULTS

CBCT scans of 213 patients were selected from an archive of 1002 CBCT examinations based on our inclusion criteria. The following cases were excluded: 294 examinations of patients after orthognathic surgery; 64 symptomatic patients referred with previous diagnosis of TMD; 12 patients with history of dentofacial trauma; 9 syndromic patients; 87 patients younger than 18 years of age; and 323 scans that did not completely cover both TMJ.

Because the kappa value for intra- and interobserver agreement was perfect (1.00), there was no need to reach consensus for subsequent data analysis. Table I shows the homogeneity among the groups with regard to sample distribution according to skeletal pattern, gender, and age.

Overall, 223 TMJs (52.3%) presented some visible alteration in the osseous components (Table II). In total, 139 condyles (32.6%) were affected by any of the TMD features. Among these patients, 25 condyles presented 2 alterations at the same time, totaling 165 condylar alterations: Flattening (n = 53; 12.4%), osteophyte (n = 35; 8.2%), erosion (n = 24; 5.6%), deviation in form (n = 18; 4.2%), subcortical sclerosis (n = 16; 3.8%), subchondral cyst (n = 11; 2.6%), and hypoplasia (n = 8; 1.9%). In total, 134 articular fossae/eminences (31.5%) were affected by osseous alterations, of which one presented 2 alterations. The alterations found in articular fossa/eminence were flattening (n = 105; 24.6%), erosion in the eminence (n = 14; 3.3%), and subcortical sclerosis (n = 15; 3.5%). None of the patients presented with generalized sclerosis, loose joint bodies, hyperplasia, or bony ankylosis.

The most prevalent alterations in Class I were flattening in the articular fossa/eminence (n = 24; 34.8%) and in the condyle (n = 22; 31.8%). In Class II, 14.4% (n = 16) of the patients presented condylar flattening and 14.4% (n = 16) osteophytes, and 30.4% (n = 34) showed flattening in the articular fossa/eminence. In Class III,

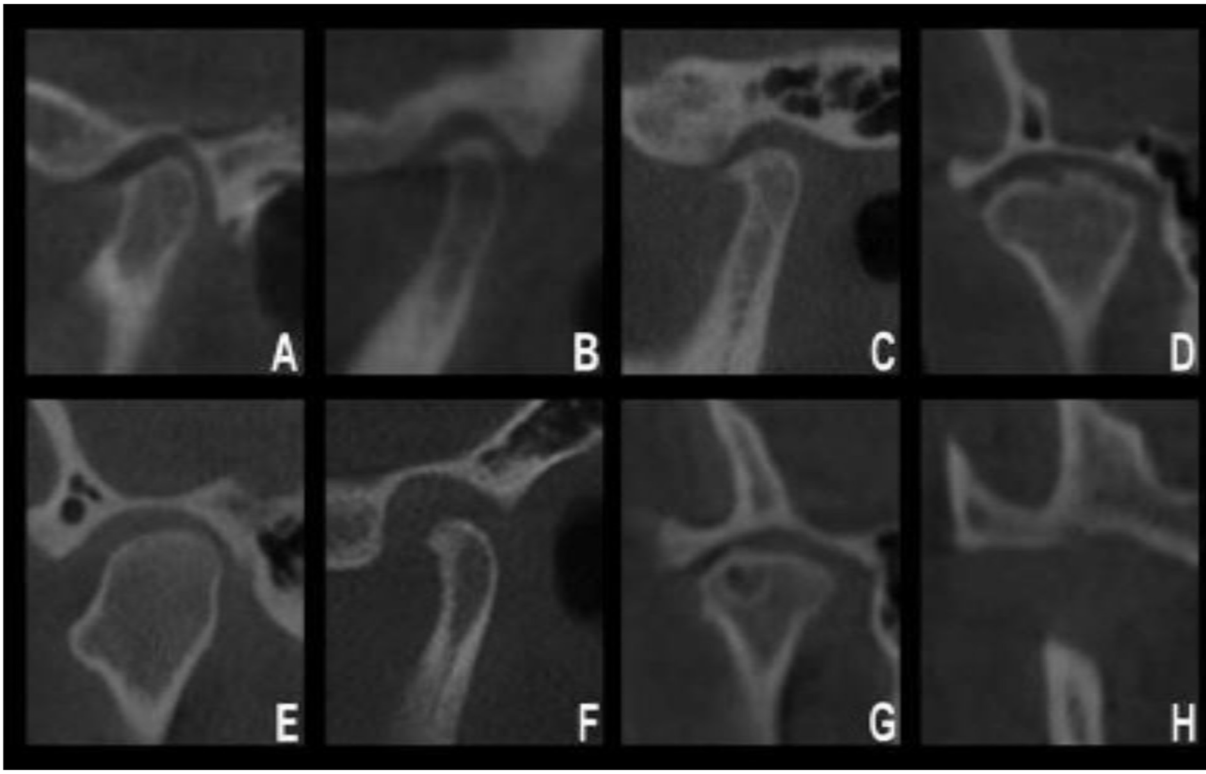

Fig. 2. **A**, Condylar flattening (parasagittal reconstruction). **B**, Condyle with an osteophyte and flattening in the articular fossa and eminence (parasagittal reconstruction). **C**, Condyle with an osteophyte and subcortical sclerosis in the articular fossa and eminence (parasagittal reconstruction). **D**, Condylar erosion (paracoronal reconstruction). **E**, Deviation in form in the condyle (paracoronal reconstruction). **F**, Condylar subcortical sclerosis (parasagittal reconstruction). **G**, Condylar subcortical cyst (paracoronal reconstruction). **H**, Articular fossa and eminence erosion (paracoronal reconstruction). No examples of loose bodies, condylar hyperplasia, or bony ankylosis were found in this study.

40.2% (n = 47) presented flattening in the articular fossa/eminence and 12.9% (n = 15) in the condyle.

Patients of all skeletal groups with alterations in the condyle and/or articular fossa/eminence did not present a statistically significant difference, and there were no significant differences for the gender and age subsets. When osseous alterations were absent, a statistically significant difference ($P = .0055$) was found between males and females with Class II skeletal patterns (Table III).

Table I. Distribution of the sample according to skeletal pattern, gender, and age

	Class			*Total*	
	I	*II*	*III*		
	n	*n*	*n*	*P value*	*n*
Gender					
Male	60	64	70	.7318	194
Female	64	78	90		232
Age					
<40 years	60	78	94	.2183	232
≥40 years	64	64	66		194

P value not significant (χ^2 test considering significance level of 5%).
n, number of joints.

Table IV lists the distribution of osseous diagnoses in the study population grouped according to the RDC/TMD for no osteoarthritis, indeterminate for osteoarthritis, and arthritis. No statistically significant difference was found among the groups ($P = .2685$).

DISCUSSION

In the present study, patients with all skeletal patterns showed alterations in the condyle and the articular fossa/eminence, with 32.6% and 31.5% of cases, respectively. This represents a very similar prevalence of osteoarthritic alterations in those structures. Although some authors have demonstrated the relevance of the condyle, because it presents osseous changes more commonly,[8,13−17] the temporal bone component of the TMJ should be considered because radiographic alterations detected in CBCT images may suggest a diagnosis of osteoarthritis. All hard tissue components of the TMJ are continuously subjected to a remodeling process, which could affect their volume and shape.[18] It is known that the biology of the condyle is significantly modified in response to environmental changes.[9] Alterations in the biophysical environment of the TMJ by forward mandibular positioning can

Table II. Distribution of osteoarthritic features in the condyle and articular fossa/eminence according to skeletal pattern, gender, and age

		Class I			*Class II*			*Class III*		
Features	*Age*	*Male n*	*Female n*	*P value*	*Male n*	*Female n*	*P value*	*Male n*	*Female n*	*P value*
Condyle										
Flattening	<40 years	0	5	.1348	5	4	.3575	3	7	.9999
	≥40 years	7	10		2	5		1	4	
Osteophyte	<40 years	0	1	.9999	3	6	.5846	1	1	.9999
	≥40 years	2	5		1	6		4	5	
Erosion	<40 years	1	1	.9999	2	3	.9999	3	1	.1905
	≥40 years	1	0		3	3		1	5	
Deviation in Form	<40 years	1	1	.9999	3	0	.4000	5	1	.9999
	≥40 years	1	0		1	1		3	1	
Subcortical sclerosis	<40 years	0	0	.9999	0	2	.9999	0	5	.2857
	≥40 years	0	1		2	4		1	1	
Subcortical cyst	<40 years	0	0	.9999	0	2	.9999	2	1	.9999
	≥40 years	1	0		1	2		1	1	
Hypoplasia	<40 years	1	0	.9999	2	1	.9999	0	1	.9999
	≥40 years	0	0		1	1		1	0	
Articular fossa/eminence										
Flattening	<40 years	8	4	.2203	13	7	.296	14	15	.3739
	≥40 years	4	8		6	8		6	12	
Erosion	<40 years	0	1	.9999	0	5	.2857	3	2	.9999
	≥40 years	1	0		1	1		0	0	
Sclerosis	<40 years	0	0	.9999	0	1	.9999	1	1	.9999
	≥40 years	2	2		2	2		2	2	

P value not significant (Fisher's exact test considering significance level of 5%).

cause the release of regulatory factors that can lead to osteogenesis as well as a change in condylar morphology.[1] In addition, the articular fossa may alter its shape and position in response to these environmental changes and undergo compensatory remodeling.[1] Corroborating other studies in asymptomatic patients[6] and in patients with rheumatoid arthritis,[16] the most prevalent alterations in all classes were articular surface flattening, which is a sign of remodeling or a physiologic response to increased loading, and subcortical sclerosis.[6]

Some studies have indicated that asymptomatic patients may present with bone remodeling[6,8] or that there are no significant differences in the prevalence of osteoarthritic alterations when asymptomatic and painful conditions are compared.[19] In the present study, a high percentage (52.3%) of the TMJs presented some visible change in the osseous components, in the absence of such symptoms as pain. In other words, the absence of symptoms does not necessarily indicate that the patient does not have osteoarthritic characteristics. Several studies revealed that there is a poor correlation between osseous changes observed in imaging examinations and pain or other clinical signs and symptoms of TMJ osteoarthritis.[20,21] A previous study[6] also found a relatively high prevalence (42.7%) of TMJs with visible changes in the osseous components among asymptomatic patients, similar to the findings in the present investigation. The fact that there are overt osseous changes in TMJ skeletal structures on CBCT images, without any clinical complaints of pain or malfunction of the joint, is in accordance with Okeson's theory that morphologic alterations are usually a long-term

Table III. Distribution of the presence and absence of alterations according to skeletal pattern, gender, and age

		Class I			*Class II*			*Class III*		
Alteration	*Age*	*Male n*	*Female n*	*P value*	*Male n*	*Female n*	*P value*	*Male n*	*Female n*	*P value*
Present	<40 years	11	12	**.7833**	16	24	**.9999**	25	27	**.5203**
Present	≥40 years	13	19		15	23		15	23	
Absent	<40 years	19	18	**.9999**	14	24	**.0055***	15	27	**.1503**
Absent	≥40 years	17	15		19	7		15	13	

*Significant difference between males and females with Class II skeletal pattern without temporomandibular joint (TMJ) alterations (χ^2 test considering significance level of 5%).

Table IV. Distribution of osseous diagnosis in each class

Class	No osteoarthritis n	Indeterminate for osteoarthritis n	Osteoarthritis n	Total N	P value
I	69	39	16	124	.2685
II	64	51	27	142	
III	71	64	25	160	

P value not significant (χ^2 test considering significance level of 5%).
n, number of joints.

dysfunction that may not present as a painful condition.[22] We speculate that although all patients included in the study were asymptomatic, the presence of osteoarthritic alterations or indeterminate results on imaging examinations does not exclude the possibility of development of a dysfunction.

This study assessed temporomandibular osseous changes according to the RDC/TMD in patients with skeletal Class I, Class II, and Class III jaw relationships. The influence of the malocclusion and skeletal pattern on the relation between the articular fossa and the condyle has been studied in recent years,[1,6] but available studies are based on a single-factor design. For this reason, we also considered other potential risk factors for TMDs, such as gender and age.

Considering that the variations in TMJ structures are related to a particular type of skeletal pattern, we could infer that the correction of dentofacial deformity by orthodontic and/or orthognathic treatment could have a beneficial effect on the TMJ.[23] However, we found no statistically significant association between the presence of osteoarthritic alterations and the skeletal patterns. A combination of features that corresponded to a diagnosis of osteoarthritis was observed in 12.9% of Class I, 19% of Class II, and 15.6% of Class III patients. In a similar study, Krisjane et al.[6] evaluated the skeletal morphology of the TMJ in patients with severe skeletal malocclusions and found that the degenerative changes of the TMJ were more common in patients with skeletal jaw discrepancies but that wide interindividual variations could be observed even in patients with clinically similar malocclusions. The authors did not consider the gender or age of the patients.

Although no significant differences were found among the class groups, joints with a diagnosis indeterminate for osteoarthritis were more common in the Class III group (41.6%) than in Class I (25.3%) or Class II (33.1%) joints. This finding corroborates those of other studies,[6,17] which suggest that in cases of mandibular prognathism, the condyles may develop TMDs. However, alterations, such as flattening and/or subcortical sclerosis (considered indeterminate results for degenerative joint disease), may represent only normal variations, aging response, remodeling, or a physiologic response to increased orthopedic load.[6] These alterations are not necessarily precursors of degenerative articular diseases. Therefore, we speculate that the remodeling over the years in Class III patients may represent adaptation, rather than progression to osteoarthritis or other TMJ diseases.

Some studies showed that females are more susceptible to TMDs compared with males.[2,13,3] Estrogen deficiencies and postmenopausal hormone decline may contribute to condylar resorption.[14] Nevertheless, we found no statistically significant difference between males and females in the prevalence of alterations. A statistically significant difference was found between males and females with Class II skeletal patterns, but only when osseous alterations were absent.

In this investigation, there was no significant difference among the age groups, although a relationship between osteoarthritis and age has been reported in the literature.[13,3] Some authors[6] have reported that the disease mainly manifests in the fourth and fifth decades of life; others have suggested that the disease is more common in adolescents and young adults.[2,24] Al-Ekrish et al.[19] and Bae et al.[25] did not find associations between age and the prevalence of degenerative osseous changes. Moreover, a study performed in children and adolescents with or without TMJ symptoms did not find this association.[24] Because the TMJ and the craniofacial skeleton undergo a final maturation at about 18 years,[6] we did not include patients younger than 18 years of age in the sample. Doing so could have adversely influenced the data relating to the condyle−fossa relationship and the morphology of the osseous joint components. Also, it is possible that patients in their late 20s would not be expected to manifest features of osteoarthritis.[6]

As in other studies,[2,6,17,26] CBCT was used in the present investigation. Accurate assessment of the TMJ on conventional radiography is difficult because of the overlapping of anatomic structures. CBCT provides accurate and undistorted 3-dimensional images[8] of the osseous components, at a lower radiation dose and cost, compared with conventional CT.[26] According to Barghan et al.[7] CBCT should be considered the imaging modality of choice to evaluate the osseous components of the TMJ. Some studies have shown that CBCT was superior to magnetic resonance imaging in detecting osteoarthritis and osseous alterations.[26–28] Moreover, available CBCT software provides detailed images,[2] improving the identification of some alterations. It should be emphasized that the diagnostic information obtained on CBCT is limited to the morphology of the osseous TMJ components, cortical bone integrity, and subcortical osseous abnormalities. For the assessment of inflammatory activity and soft tissue abnormalities in patients with TMDs, magnetic resonance imaging is the method of choice.[26]

Considering that the early diagnosis of osteoarthritis may prevent occlusal and emotional disturbances, headaches, changes in sleep quality, and other factors that affect the patients' quality of life,[3,29,30] the recognition of these alterations in imaging examinations is important, even in asymptomatic patients. In clinical practice, CBCT is a reliable tool for the diagnosis of osteoarthritic alterations in the TMJ. The cases where osteoarthritic alterations were found on CBCT examinations in this study were the result of nonphysiologic loading or overloading of the joint not related to a specific skeletal discrepancy. Other factors, such as corresponding mastication, emotional and parafunctional conditions, balance, and muscle strength, should be considered.

CONCLUSIONS

Although 52.3% of the TMJs presented some visible alteration in the osseous components, no differences were found among skeletal patterns. Articular flattening was the most commonly observed feature in all groups. Patients of all skeletal groups with alterations in both the condyle and articular fossa/eminence did not present a statistically significant difference when gender and age were considered.

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