BS Brazilian Dental Science
Ciência Odontológica Brasileira
unesp UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE doi: 10.14295/bds.2016.v19i2.1243

Incidental findings of bone alterations in temporomandibular joints in cone-beam computed tomography scans for implants planning: the importance of total acquired volumeanalysis

Achados incidentais de alterações ósseas nas articulações tempormandibulares em exames de tomografia computadorizada de feixe cônico com indicação específica para implantodontia: a importância da análise do volume total adquirido

Sergio Lucio Pereira de Castro LOPES[1], Mari Eli Leonelli de MOARAES[1], Luiz Roberto Coutinho MANHÃES JÚNIOR[1], Afonso Celso Souza de ASSIS[1], Danielle Tallia GIOSA[1], Daniel Silveira URBANO[1]

1 – School of Dentistry - Department of Diagnosis and Surgery- Institute of Science and Technology – UNESP – Univ Estadual Paulista — São José dos Campos – SP – Brazil.

ABSTRACT

Objective: to evaluate the frequency of bone alterations in temporomandibular joints (TMJ) in cone beam computed tomography (CBCT) imagesfor dental implats planning. **Material and Methods:**148 CBCTscanswere selected from the files of the Radiology Clinics(ICT UNESP). All the imageswere performed by Next Generation i-CATscanner (Imaging Sciences Ltda, Hatfield, PA, USA), using voxel of 0.20/0.25 mm and FOV of 16.0 x 13.0 cm for dental implants planning. All the images shouldshow both (rigth and left) TMJ condyle. The TMJ condyle were reformated using TMJ protocol, with parasagittal cuts, perpendicular to the long axis of TMJ condyle, to study the presence of the following bone alterations: osteophytes, erosion, flatenning, bone sclerosis, and cortical thinning. **Results:** The results showed that 63.51% of the sample werefemale and 36.49% male. In addition, it was noted that the most frequent bone alterations in condyle were osteophytes (56.75%) and flattening (55.4%). The erosion was the alteration with lower frequency (0.67%). Mcnemar's testshowed that there was relationship between flattening and erosion, flattening and bone sclerosis, flattening and cortical thinning, erosion and osteophytes,bone sclerosis and cortical thinning ($p<0.0001$), in both sides. There was no relationship between flattening and osteophytes, erosion and bone sclerosis, erosion and cortical thinning ($p>0.01$). **Conclusion:** The hight frequency of bone alterations findings in TMJ condylewas an indicator of the importance of the analysis of all the structures present in the CBCT total acquired volume, regardless CBCT indication.

KEYWORDS

Cone-Beam computed tomography;Osteoarthritis; Temporomandibular joint.

RESUMO

Objetivo: Estudar a frequencia de alterações ósseas nas articulações temporomandibulares (ATM) em exames por imagem de tomografia computadorizada de feixe cônico (TCFC) com indicações específicas para planejamento de implantes. **Material e Métodos:** 148 exames de TCFC foram selecionados do arquivo da Clínica de Radiologia do ICT-UNESP. Todas as imagens foram adquiridas por meio do tomógrafo i-CAT Next Generation (Imaging Sciences Ltda, Hatfield, PA, USA), usando voxel de 0,20/0,25 mm e FOV de 16,0 x 13,0 cm com o objetivo de planejamento de implantes dentários. Todas as imagens deveriam exibir ambas (direita e esquerda) as cabeças da mandíbula das ATM. O estudo das cabeças da mandíbula foi realizado utilizando um protocolo para as ATM, com cortes parassagitais, perpendiculares aos longos eixos das mesmas, com o objetivo de se estudas as seguintes alterações ósseas: osteófitos, erosão, aplainamento, esclerose óssea, e adelgaçamento de corticais. **Resultados:** Os resultados evidenciaram que 63,51% da amostra pertecia ao sexo feminino e 36,49% ao sexo masculino. Adicionalmente, observou-se que a alteração óssea na cabeça da mandíbula mais frequente foi a presença de osteófitos (56,75%) e aplainamento (55,4%). A erosão foi a alteração de menor frequencia (0,67%). O teste estatístico de Mcnemar mostrou que houve relação entre: aplainamento e erosão, aplainamento e esclerose óssea, aplainamento e adelgaçamento de corticais, erosão e osteófitos, esclerose óssea e adelgaçamento de corticais ($p<0,0001$), em ambos os lados. Não houve relação entre aplainamento e osteófitos, erosão e esclerose óssea, erosão e adlegaçamento de corticais ($p>0,01$). **Conclusão:** A alta frequencia de alterações ósseas encontradas nas cabeças da mandíbulas nas ATM estudadasfoi um idicador da importância na análise de todas as estruturas presentes no FOV adquirido nos exames de TCFC, independentemente de sua indicação.

PALAVRAS-CHAVE

Tomografia computadorizada de feixe cônico;Osteoartrite; Articulação temporomandibular.

INTRODUCTION

Cone beam computed tomography (CBCT) is a imaging method with many advantages, among which the high level of spacial resolution of bone tissues; possibility of multiplanar cuts without superpositions; and obtainment of accurate measurements on the images with real distances between important anatomic structures of maxillofacial complex[1,2]. These aforementioned advantages justify CBCT large use in Dentistry, especially to plan osseointegrated implants[3,4].

The main CBCT characteristicis the principle for acquisition of images in which a volume of the face (usually cylindrical) is acquired by the device and then reconstructed by the computer and displayed in cuts or anatomical sections. This volume is referred to as Field of View (FOV)and may vary from device to device or even inside the device itself, according to the region of interest sought for study. In this context, many systems of different brands and characteristics have been available on the market with varying FOV. A larger FOV enables a broader analysis of the maxillofacial complex, but the irradiated area is increased and the patient will be subjected to a higher radiation dose [5].

Based on the aforementioned information, since certain volume is acquired by CBCT, the radiologist should mandatorily examine their structures and possible changes in detailed and comprehensive manner, regardless of particular interest region requested, thus justifying the exposure of the patient.

Many dentomaxilofacial radiologists, however, are not familiar with the anatomical interpretation of the structures or conditions, outside the area of primary examination interest (such as teeth and dental arches), a fact that often culminates in negleting the interpretation, limiting the analysisonly to specific areas requested, regardless of whether there are any other changes in acquired FOV. This is particularly evident when CBCT is requested for the study and planning of dental implants in restricted regions of the arches. It is noted an objectivity in studying and providing to the dentist only information requested on the examination, but without an overall volume analysis [6].

Some CBCT systems enable use of very limited FOV to the region of interest, thereby reducing the irradiated region and producing a smaller image volume. While others have fixed FOV or even a FOV allowing reduction also provide an irradiated volume greater than the regions of the dental arches, including structures such as upper respiratory tract, sinuses, and temporomandibular joints (TMJ), which are no longer often analyzed.

TMJs are structures subjected to a heterogeneous group of changes altogether, temporomandibular disorders (TMD) whose causes may originate in the muscles of mastication and / or joint components. Among the articular causes of TMD, there is internal disorders of articular disc (disc displacement), inflammatory disorders and degenerative articular disease (DAD). These latter involve TMJ bone components, as the condyle, fossa, and articular tubercle [6-8].

A large number of studies have been published concerning the role of CBCT in the diagnosis of TMJ bone changes, because of CBCT high degree of sensitivity in determining changes as flattening of the condyle, bone sclerosis, osteophytes formation, erosion, and reduction in joint spaces. Among these, the flattening (59%) and formation of osteophytes (29%) has been the most prevalent in cases of degenerative articular diseases (DAD) [8,9].

In a study conducted to evaluate the influence of FOV size on determining TMJ erosions [10],the authors demonstrated that smaller FOV provides images of superior performance than larger FOV in the diagnosis of this change, which does not contraindicate or even prevent that large FOVs are used

This study aimed to determine the prevalence of different incidental bone changes in the temporomandibular joints (TMJ) in CBCT examinations with strict indication for planning dental implants, to emphasize the importance of a comprehensive analysis of all listed structures, regardless of specific indication on examination.

MATERIALS AND METHODS

This study was submitted and approved by the Institutional Review Board regarding ethical aspects, under protocol CAAE no.#28002114.7.0000.0077. The initial sample comprised 300 CBCT examinations within the files of the Clinic of Radiology, School of Dentistry, Institute of Science and Technology of São Paulo State University Julio de Mesquita Filho (ICT-UNESP). All CBCT examinations were previously acquired in i-CAT Next Generation (imaging Sciences International, Hatfield, PA, USA) using voxel of 0.20/0.25 mm and FOV of 16.0 x 13.0 cm for dental implants planning. Of these, 148 CBCTs(74 TMJs)were selected for analysis because they met the following inclusion criteria:specific previous indication for planning of dental implants in the maxilla and / or mandible (checked on the record file of patients in the clinics) and to exhibit the mandible heads of both TMJ (right and left) totally and clearly. The age of patients ranged from 20 to 80 years of both sexes (94 female and 54 male). All images were evaluated by 02 examiners independently and previously trained to do so. The kappa test was used, with values greater than 0.60, indicating good to excellent intra and inter-examiner agreement index.

Analysis of the images–All examinations were assessed on their original image acquisition format (.xstd), on a computer (17-inch LCD screen),using XORAM software (Xoran Technologies, Ann Arbor, MI, USA),provided by the manufacturer of the scanner, following this protocol:

1) Multiplanar Reconstruction Screen (MRS): among the axial cuts, we determined those in which the mandible's head (MH) were much better visualized at the long axis(so-called standard axial cut or locator cut) (Figure 1A);2) We selected thesoftware's TMJ tool; next, we traced the long axis of the left and right MH by joining the medial and lateral poles (Figura 1B);3) Automatically, the parasagittal cuts were traced (perpendicular to the long axis) atlateral-medial direction, measuring 1.0mm thick each(Figura 1C), enabling to evaluate TMJs and bone components individually(Figure2). On these cuts, we searched for the following TMJs alterations(Figure3), corresponding to the signs of degenerative articular diseases: a) mandible head (MH) flattening – considerable loss of the convex aspect; b) MH erosions – loss of cortical;c) presence of MH osteophytes– hyperdense exophilic formations on MH edges, with"duckbill" aspect; d) bone sclerosis on MH – increasing in MH cortical thickness and densitiy; e) cortical thinning– considerable thinning of any region of MH bone cortical.

The evaluators had free access to system tools such as changing brightness and contrast, appling filters and zoom.

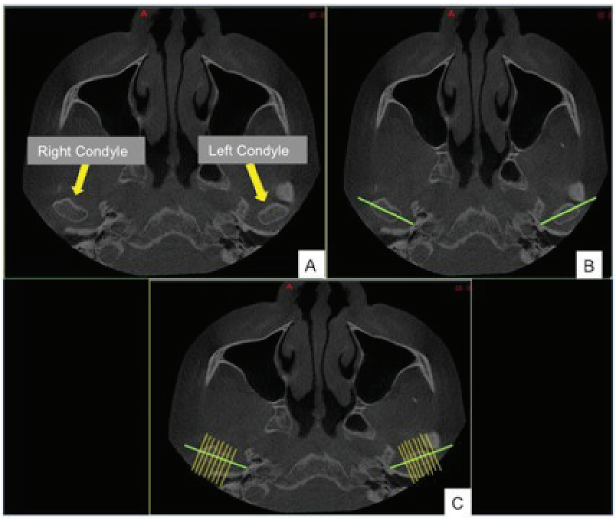

Figure 1 - CBCT standard axial cuts exhibiting: view of the mandible's head (A); Long axes tracing of the mandible's head (B); parasagittal cut at lateral-medial direction perpendicular to the long axes (C).

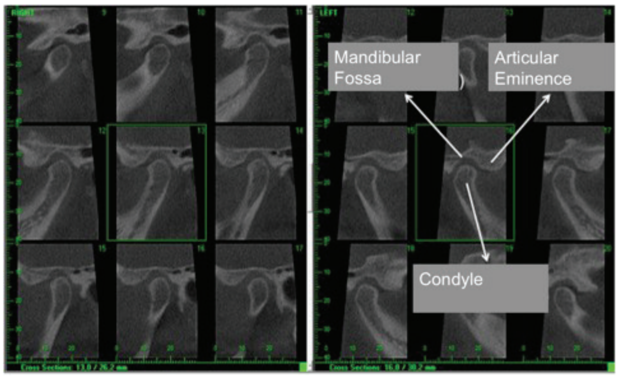

Figure 2 - CBCT parasagittal cuts, right and left TMJ exhibiting the bone structures: articular tubercle (AT), mandibular fossa (MF), and mandible's head (MH).

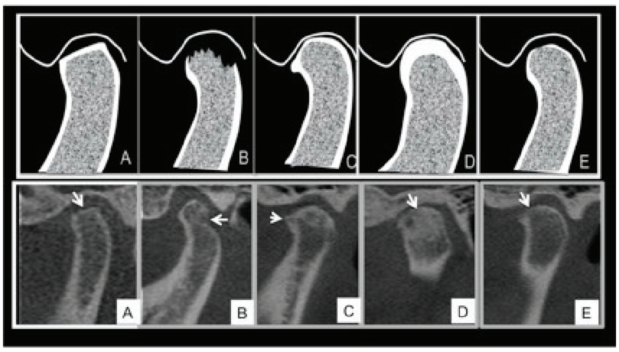

Figure 3 - Drawings (upper) and corresponding CBCT images (lower) of the alterations studied on the mandible's head: Flattening (A); Erosion (B); Osteophytes (C); Bone sclerosis (D); and Thinning of the bone cortical (E).

RESULTS

The sample frequence regarding to gender and age range distributions is seen in Tables IandII.

Table 1 - Frequence of individuals in relation to gender.

Gender	Number of individuals	Percentage (%)
Female	94	63.51
Male	54	36.49
Total	148	100

Table 2 - Frequence of individuals in relation to age range.

Age range	Number of individuals	Percentage (%)
20 - 30 years	12	8.01
31 - 40 years	27	18.25
41 - 50 years	35	23.66
51 - 60 years	45	30.4
61 - 70 years	20	13.6
71 - 80 years	9	6.08
Above 81 years	0	0
Total	148	100

TMJs were evaluated independently, considering the presence of the following bone alterations seen in CBCTs: flattening, erosion, osteophytes, bone sclerosis, and thinning of bone corticals. TableIIIevidences the frequence of these alterations, considering the distribution for right, left TMJ and total sample.

Table 3 - Frequence of individuals in relation to age range.

Alteration	right TMJ		leftTMJ		Total	
	N	%	N	%	N	%
flattening	38	25.67	44	29.73	82	55.4
erosion	0	0	1	0.67	1	0.67
osteophytes	45	30.4	39	26.35	84	56.75
bone sclerosis	4	2.7	6	4.05	10	6.75
Thinning	1	0.67	1	0.67	2	1.34

Aiming at verifying a possible relationship between each alteration type, Mcnemar's test with significance level of5% was appliedto evaluate the degree of discordance of two bone alterations on each side – right and left – in a same indiidual (Table IV).

Table 4 - Discordance of proportions of the results among the bone alterations on mandibular right and left condyles.

Association between bone alterations	Right	P value	Left	P value
	%		N	
Flattening X Erosion	40-0	< 0.0001*	40-0	< 0.0001*
Flattening X Osteophyte	27-34	0.4424	30-25	0.5896
Flattening X Sclerosis	37-3	< 0.0001*	42-4	< 0.0001*
Flattening X Thinning	37-0	< 0.0001*	44-1	< 0.0001*
Erosion X Osteophyte	0-45	< 0.0001*	1-39	< 0.0001*
Erosion X Sclerosis	0-4	0.1250	1-6	0.1250
Erosion X Thinning	0-1	1.0000	1-1	1.0000
Osteophyte X Sclerosis	44-3	< 0.0001*	37-4	< 0.0001*
Osteophyte X Thinning	45-1	< 0.0001*	39-1	< 0.0001*
Sclerosis x Osteophyte	4-1	0.3750	6-1	0.1250

P-Presence/A-absence

The results indicated that considering the presence of flattening, this was related with erosion ($p<0.001$), bone sclerosis ($p<0.0001$), and bone cortical thnninig($p<0.0001$), on both sides (right and left). No relation occurred between flattening and osteophytes, on right and left TMJs($p=0.4424$ and $p=0.5896$, respectively).

Concerning to the presence of erosion on MH, besides the aforementioned relationship with flattening, it was also related bilaterally with osteophytes($p<0.0001$). No relationship occurred with erosion and bone sclerosis on both sides($p=0.125$), as well as erosion and cortical thinning, on both sides($p=1.000$).

The presence of osteophytes were not related with flattening, but were related with erosion and bone sclerosis and bone cortical thinning($p<0.0001$). However, no relationship occurred between osteophyte presence and bone sclerosis.

DISCUSSION

This study, based on the possible presence of incidental imaging findings, beyond the regions of dental arches, examined the prevalence of major bone changes in temporomandibular joints (TMJ) in 148 CBCT examinations for planning implants. In addition, we studied the possible relationship between these changes.

We evaluated the presence of the following changes in the condyle: flattening, thinning of cortical bone erosion, bone sclerosis and osteophyte formation. These correspond to signals compatible with remodeling processes or degenerative articular disease (DAD), thus being of great significance to be identified, since the CBCT examination consists of a modality with 75% sensitivity and 100% specificity for detecting bone changes with a positive predictive value of 100% and negative predictive of 78% [10].

In this sample, 63.51% of the exams wereof female and 36.49% of males. Taking into account that the sample selection was performed in CBCTs with specific indication for implant dentistry, we believe that high female frequency can be explained by a greater concern with health care by women than men, taking also into account the aesthetic factor related to implantology. Additionally, it was noted that most individuals presented the age range from 50 to 60 years (45% and 35%), respectively. These would match those in which there is a greater need / demand for treatment by prosthesis and dental implants.

Considering the possible changes in MH, we observed the following frequencies in the sample: 56.75% of osteophytes, 55.4%of flatenning, 6.75%of bone sclerosis 1.34% of thinning of cortical, followed by 0.67% affected by erosion. In our study the most frequent finding was the presence of osteophytes.A study[11]on the prevalence of MH bone alterations on CBCTfound 8% of osteophytes. This finding differs from our results, but the sample studied by the author consisted of patients with temporomandibular disorders (TMD), which was not considered in our study, where no access to clinical data and medical history of patients was possible, only access to the exam indication: implantology. Our results corroborate those found by a study[12] analyzing the presence of degenerative bone alterations on the mandible head, and found that osteophytes were the most common. However, it is worth noting that this study [12] used images from magnetic resonance imaging (MRI)and not CBCT. CBCT images have greater sensitivity for bone alterations than RMI images.

Erosion was the least frequent finding in this study. Other study[13]analysing symptomatic and asymptomatic TMD found erosion as the most frequent alteration in DTM individuals (15.6% of the sample), different from our findings. This study, however, was conducted on younger patients (2nd life decade), with could be a dfferential in relation to the reaction of the mandible's head. Likely our results, erosion was one of the most findings, in other study[11] in TMD patientswith 29.3% of the sample.

In addition to erosion, bone sclerosis and cortical thinning were the least frequent findings in our study. These two changes can be understood as antagonistic reactions. While sclerosis reflects a low intensity stimulation and high capacity of reaction of the body at this higher functional demand (overload for example), the thinning of cortical is consistent with a more intense stimulus / frequency and a lower adaptive capacity of the body.

Considering the possible relationship between changes, it was observed that the flattening of condylar cortical was the finding that were most often related to the other studied changes, presenting bilateral relationship with the presence of: thinning, erosion, and sclerosis (all p=0.0001, bilateral). When this relationship is alnalyzed, we agree that there is a coherence between the high frequency of flattening found in this study and its relationship with thinning and cortical erosion. It can be even inferred that these are distinct phases of the same degenerative process, which starts with a wearresulting in flattening of the cortical, which would then be followed (or concurrently occur) by thinning the cortical, ending in a more advanced process: the cortical erosion. The association between the flattening and bone sclerosis can be explained as the first initial cortical wearing process that, eventually, due to the chronic nature of the stimulus and a high degree of individual's response, would lead to a periosteal reaction in the region, with bone production to preserve the underlying spinal cord.

However, no relationship occur between flatenning and osteophytes(p=0.4424 and p=0.5896, for right and left sides, respectively). These changes are actually interpreted as antagonistic process, because planning is the predominance of a wearign process, while the formation of osteophytes is a proliferative reaction. Likewise, antagonistically, we noted the relationship between the presence of erosion and formation of osteophytes (p=0.0001, bilateral),which normally is not expected, once the first is the bone lyisis exacebation; while the latter is a osteoblastic reaction.It is worth emphasize the locations of these changes within the edges of the condyle, since once a process of greater intensity and less exacerbated at different points in the same structure, could be occurring. This purpose was not the objective of our study, which was only to identify the processes.

The relationship found in this study between osteophytes and cortical thinning (p=0.0001, bilateral),also would follow the aforementioned rationale.But, the relationship between osteophytes and sclerosis (p=0.0001, bilateral) is in agreement with the concept of bone neoformation for both findidngs and completes each other.

It was noted that the high frequency, mainly related to the formation of osteophytes and flattening in the condyle, on the analyzed TMJ, we emphasize the importance of analyzing, meticulously, all anatomical structures, beyond the regions of the study objectives in

CBCT, which are included in the FOV used in acquisition. We encouraged, due to progressive and increasing use of dental CBCT in different specialties that emphasis should be given to obtain a volume restricted to the region indicated in the examination, aiming at reducing the patient dosage and compliance with the principle of ALARA (*As Low As Reasonably Achievable*), which advocates that the dose of radiation should be as low as reasonably possible in exams for diagnostic purposes. CBCTshows unique possibilities for diagnosis of maxillofacial complex, but theprofessionals should be adequately trained, both in the acquisition process and the interpretation of the images, not to mention the selection and indication of the cases, so that to search the ultimate goal of CTBC as a complementary exam.

CONCLUSION

Based on our results, it was concluded that:

It was observed the presence of all bone changes studied and the presence of osteophytes and condyle flattening were the most common frequent and erosion less the least frequent.

A relationship occurs between flattening and thinning, erosion and bone sclerosis; the presence of osteophytes and thinning and sclerosis.

Due to the frequency of incidental findings on TMJ, we emphasize the importance of the analysis of all the structures in the total volume acquired on the CBCT, regardless of the indication.

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Sergio Lucio Pereira de Castro Lopes
(Corresponding address)
Avenida Engenheiro Francisco José Longo, 777. São Dimas. São José dos Campos/SP
CEP:12245000.

Date submitted: 2016 Feb 05
Accept submission: 2016 Mar 07