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Digital image filters are not necessarily related to improvement in diagnostic of degenerative bone changes in the temporomandibular joint on cone beam computed tomography

Filtros de imagem digital não estão necessariamente relacionados à melhoria no diagnóstico de alterações ósseas degenerativas na articulação temporomandibular na tomografia computadorizada de feixe cônico

Los filtros de imágenes digitales no están necesariamente relacionados con la mejora en el diagnóstico de cambios óseos degenerativos en la articulación temporomandibular en la tomografía computarizada de haz cónico

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Abstract

This study assessed whether the use of digital image filters influences the detection of temporomandibular joint (TMJ) bone changes on cone beam computed tomography (CBCT). Two radiologists evaluated the TMJ images of CBCT scans to verify the presence of osteophytes, erosions, pseudocysts, bone sclerosis and flattening, using the software XoranCAT®; each image of the TMJ was assessed with and without the use of the following filters: Angio Sharpen 3x3 and Angio Sharpen 5x5. Kruskal-Wallis' test was used to assess whether the application of filters influenced the scores assigned to the degenerative bone changes in the condyle. Flattening was present in 15 cases (51.72%), followed by osteophytes in six cases (20.69%), sclerosis in three cases (10.34%), and erosion in three cases (10.34%), with pseudocyst found in two cases (6.90%). No statistically significant difference was found in the scores (P = 0.786) regarding the original images and those treated with both filters. Digital image filters used in our study did not influence the diagnosis of degenerative bone changes in the TMJ on CBCT images.

Keywords: Cone beam computed tomography; Temporomandibular joint; Diagnosis.

Resumo
Este estudo avaliou se o uso de filtros de imagem digital influenciam na detecção de alterações ósseas da articulação temporomandibular (ATM) na tomografia computadorizada de feixe cônico (TCFC). Dois radiologistas avaliaram as imagens da ATM de TCFC para verificar a presença de osteófitos, erosões, pseudocistos, esclerose óssea e achatamento, utilizando o software XoranCAT®; cada imagem da ATM foi avaliada com e sem o uso dos seguintes filtros: Angio Sharpen 3x3 e Angio Sharpen 5x5. O teste de Kruskal-Wallis foi usado para avaliar se a aplicação de filtros influenciou os escores atribuídos às alterações ósseas degenerativas no côndilo. O achatamento esteve presente em 15 casos (51,72%), seguido por osteófitos em seis casos (20,69%), esclerose em três casos (10,34%) e erosão em três casos (10,34%), com pseudocisto encontrado em dois casos (6,90%). Nenhuma diferença estatisticamente significativa foi encontrada nos escores (P = 0,786) em relação às imagens originais e aquelas tratadas com os dois filtros. Os filtros de imagens digitais usados em nosso estudo não influenciaram no diagnóstico de alterações ósseas degenerativas da ATM em imagens de TCFC.
Palavras-chave: Tomografia computadorizada de feixe cônico; Articulação temporomandibular; Diagnóstico.

Resumen
Este estudio evaluó si el uso de filtros de imagen digital influye en la detección de cambios óseos de la articulación temporomandibular (ATM) en la tomografía computarizada de haz cónico (TCHC). Dos radiólogos evaluaron las imágenes de ATM de las exploraciones CBHT para verificar la presencia de osteofitos, erosiones, pseudoquistes, esclerosis ósea y aplanamiento, utilizando el software XoranCAT®; cada imagen de la ATM se evaluó con y sin el uso de los siguientes filtros: Angio Sharpen 3x3 y Angio Sharpen 5x5. Se utilizó la prueba de Kruskal-Wallis para evaluar si la aplicación de filtros influyó en las puntuaciones asignadas a los cambios óseos degenerativos en el cóndilo. El aplanamiento estuvo presente en 15 casos (51,72%), seguido de osteofitos en seis casos (20,69%), esclerosis en tres casos (10,34%) y erosión en tres casos (10,34%), encontrándose pseudoquiste en dos casos (6,90%). No se encontraron diferencias estadísticamente significativas en las puntuaciones (P = 0,786) con respecto a las imágenes originales y las tratadas con ambos filtros. Los filtros de imágenes digitales utilizados en nuestro estudio no influyeron en el diagnóstico de cambios óseos degenerativos en la ATM en las imágenes de TCHC.
Palabras clave: Tomografía computarizada de haz cónico; Articulación temporomandibular; Diagnóstico.

1. Introduction

Degenerative bone changes, also known as osteoarthrosis, are a deteriorating, progressive, chronic condition defined as being a gradual deterioration of the bone surface, affecting more women and elderly individuals. They are significantly more frequent in the condyle than in the joint eminence, being characterised by the development of radiographic signs such as osteophytes, erosions, pseudocysts, bone sclerosis and faceting (Al-Ekrish, et al. 2015; Al-Shwaikh et al., 2016; Oliveira et al., 2020; Simon, Longis & Passuti, 2017; Urtane et al., 2018).

Digital filters for image enhancement are an alternative approach used to improve images, thus facilitating the evaluation of temporomandibular joint (TMJ) changes, in which specific software allows several valuable image manipulations for soft or bony tissues. The application of these filters can strongly influence the image quality depending on the type of filter used, as one can reduce artifacts, reduce image noise, soften gray tones and detect and increase edges (Carvalho et al., 2017; Eliášová & Dostálová, 2017).

The use of digital filters can improve images of poor quality as a result of artifacts, metallic restorations or high noise levels at low radiation dose as well as the detection of large amounts of diffused radiation. Other factors such as voxel size, tension peak, milliamperage, exposure time, FOV size, and rotation degree are also involved (Carvalho et al., 2017; García-Sanz et al., 2017) filters minimize the image noise by using mathematical algorithms in order to reduce or increase a specific characteristic (Eliášová & Dostálová, 2017; Soares et al., 2021; Verner et al., 2017).

Today, there are several types of cone beam computed tomography (CBCT) systems and a variety of image reconstruction softwares to study regions of interest and to improve images by means of tools such as brightness, color, contrast and application of digital filters.

There are a few studies (Carvalho et al., 2017; De Sousa et al., 2017; Eliášová & Dostálová, 2017; García-Sanz et al.,

2017) assessing the influence of filters on the quality of images and on the diagnostic capacity for condyle changes. Therefore, the present work aimed to study the influence of digital filters on the diagnostic of degenerative bone changes in the TMJ.

2. Methodology

The human research ethics committee of the São Leopoldo Mandic Institute and Research Center, Campinas (SP), approved all procedures involving the images in this study, according to protocol number CAAE 53665516.6.00005374. The sample size was defined based on the total of CBCT available in a private clinic, all taken for evaluation of the TMJ in both men and women. Low-quality images were excluded, including those of patients with tumor lesions and injuries in the buccomaxillofacial complex as well as aplasias or malformation of the TMJ area.

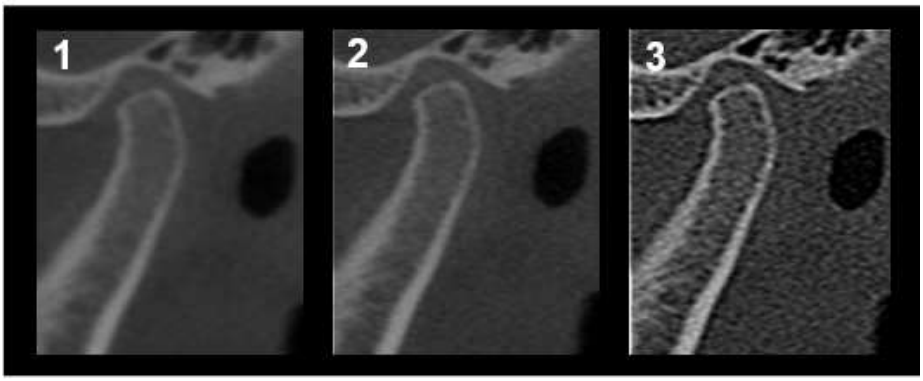
The selected examinations were obtained by the same operator, who used an i-CAT CBCT device (Imaging Sciences International, Inc, Hatfield, PA, USA) operating at 120 kVp, 36 mAs and 14-bit resolution.

The images were obtained with patients in maximum intercuspation and maximum mouth opening. The first reconstruction (i.e. raw data) was restricted to the region of TMJ (i.e. about 1 cm above the mandibular fossa and 1 cm below the cervix of the mandibular condyle), thus allowing a series of 0.25-mm thickness axial slices to be automatically generated. An axial section of the condyle was obtained by using the TMJ software tool (i.e. temporomandibular joint) in the axial view, from which sagittal and coronal sections were also generated. The thickness of the slices was 1 mm and the distance between them for sagittal image reconstruction was 1 mm as well.

Image reconstruction was performed by using the software of the CBCT device (XoranCAT®, version 3.1.62, Xoran Technologies Inc. 2005) and a 17-inch LCD flat screen (Model 5000:1, LG, Seoul, Korea) with resolution of 1280 x 1024 pixels and maximum colour quality (12 bits) under reduced light condition. All images were examined without filter (original images) and with the following filters: Angio Sharpen 3x3 and Angio Sharpen 5x5 (Figure 1).

Patient data regarding age, gender, side and bone changes in the condyle were gathered and tabulated into Excel spreadsheet (Microsoft, Seattle, USA).

Figure 1. Sagittal section of the same TMJ showing the application of the image filters.

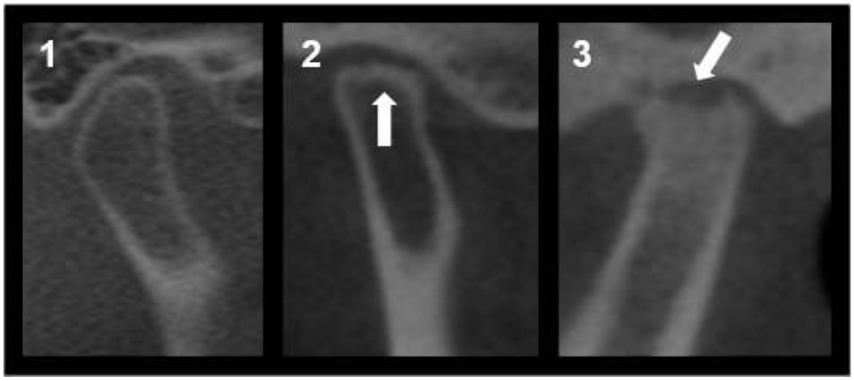


Notes: 1) No filter; 2) Angio Sharpen 3x3; 3) Angio Sharpen 5x5. Source: Authors.

The scans images evaluated according methodology of dos Anjos Pontual et al. (2012) with some modifications. The scan images were randomly arranged and masked by the main researcher, who did not perform as an observer in the study. Two radiologists, with three years of experience in CBCT imaging, assessed the images twice at a 15-day interval. Instructions and standardized sheets were given to the radiologists in order to record their observations on degenerative bone changes (Figures 2 and 3) according to the following scoring system: 1 – No change (2-1); 2 – Flattening: a flat contour of the condyle

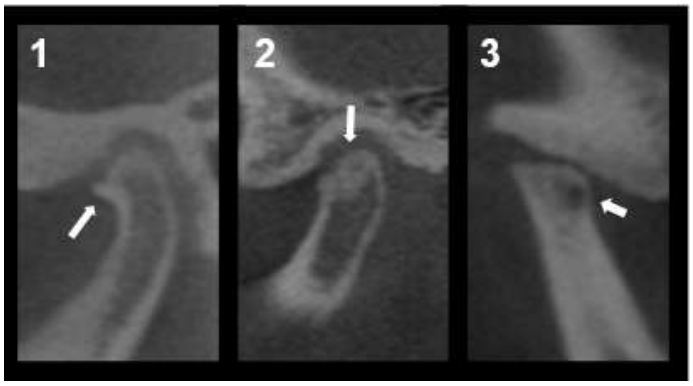
deviating from its convex shape (2-2); 3 – Erosion: area of decreased density in the cortical and adjacent sub-cortical bones (2-3); 4 – Osteophytes: marginal bony excrescence in the condyle (3-1); 5 – Sclerosis: area of increased density in the cortical bone extending to the bone marrow (3-2); 6 – Pseudocyst: a well-circumscribed osteolytic area near to the region of sub-cortical bone without cortical destruction (3-3).

Figure 2. Sagittal sections of the TMJ in maximum intercuspation showing bone changes in the condyle.



Notes: 1) No changes; 2) Flattening (white arrow) 3) Erosion (white arrow). Source: Authors.

Figure 3. Sagittal sections of the TMJ in maximum intercuspation showing bone changes in the condyle.



Notes: 1) Osteophytes (white arrow); 2) Sclerosis (white arrow); 3) Pseudocyst (white arrow). Source: Authors.

Statistical Analysis

Gender and age group of the patients whose examinations were used in the present study have been descriptively reported. Kappa statistics was used to evaluate the intra-examiner and inter-examiner reproducibility, whereas Kruskal-Wallis' test was used to assess whether the application of image filters (Angio Sharpen 3x3 and Angio Sharpen 5x5) influenced the score assigned to degenerative bone changes in the condyle. For statistical calculation, the SPSS software version 23 (SPSS Inc., Chicago, IL, USA) was used at a significance level of 5%.

3. Results

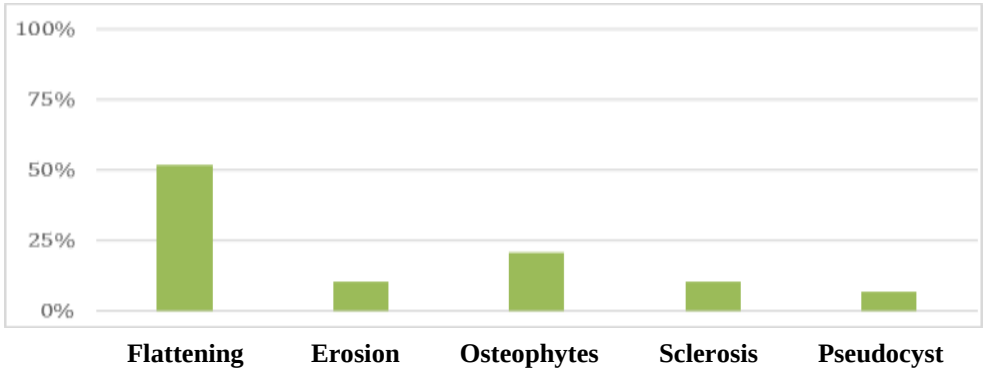
The CBCT images used in this work belonged to 91 patients, where 17 were male (18.7%) and 74 female (81.3%). Minimum age among the patients was 15 years old and maximum age was 86 years, with the mean age of 46.0 years and standard deviation of 16.7 years.

Kappa statistics revealed that intra-examiner reproducibility was excellent for both radiologists (0.919 and 0.889) regarding the degenerative bone changes, whereas Kappa statistics showed good reproducibility between the examiners (0.0764).

In the 91 CBCT, 62 (68.13%) were not shown to have degenerative changes in the condyle, whereas the presence of degenerative processes was found in the remaining 29 tomographs, thus indicating that the prevalence rate was 31.87% in our sample.

Among these 29 TMJ scans showing degenerative bone changes, flattening was present in 15 cases (51.72%), followed by osteophytes in six cases (20.69%), sclerosis in three cases (10.34%), and erosion in three cases (10.34%), with pseudocyst being the least frequent alteration, that is, appearing in only two cases (6.90%). Graph 1 shows the prevalence rate of osteoarthrosis in this study.

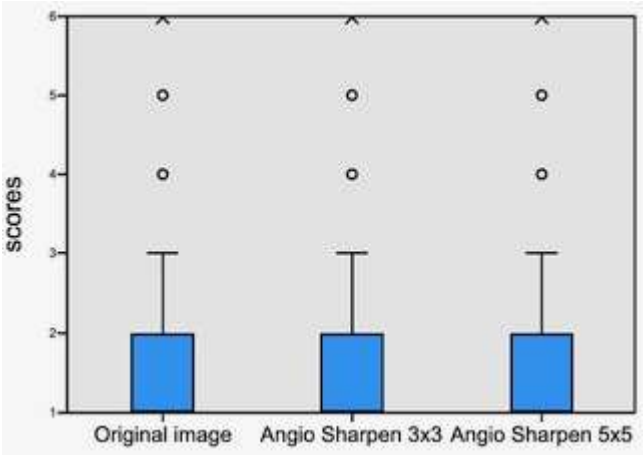
Graph 1. The prevalence rate of degenerative bone changes in the condyle.



Source: Authors.

Kruskal-Wallis' test demonstrated that there was no statistically significant difference in the scores assigned to degenerative bone changes in the condyle when original images were compared to those treated with filters (P = 0.786), as shown in Graph 2.

Graph 2. Box diagram of the scores attributed to degenerative bone changes in the condyle according to application of image filters.



Source: Authors.

4. Discussion

Image manipulation filters, which are software resources aimed to modify image characteristics, are an alternative approach used to improve and facilitate the evaluation of TMJ changes. Its application can strongly influence the image quality, since it can reduce artifacts, minimize image noise, attenuate gray tones, detect and increase edges, be depending on the image filter used (Carvalho et al., 2017; Eliášová & Dostálová, 2017).

Nowadays, there are several types of CBCT devices as well as a broad variety of image reconstruction software enabling to study the region of interest and to enrich the image quality by means of tools such as brightness, color, contrast and application of digital filters. Studies have investigated several pathological conditions of TMJ by using different tomography devices, image software, and image reconstruction protocols (Al-Ekrish et al., 2015; Bertram et al., 2018; De Sousa et al., 2017; García-Sanz et al., 2017; Liang et al., 2017; Oliveira et al., 2020; Pallaver & Honigmann, 2019).

In the present work, we have investigated the use of image filters Angio Sharpen 3x3 and Angio Sharpen 5x5 and their influence on the diagnosis of degenerative bone changes in the TMJ. Both filters enhance the image contrast, with the former making the contour of the structures more defined and letting the gray tones more uniform, whereas the latter lets the image far more granulated. One can observe that the use of image filters did not influence the diagnosis with this methodology P = 0.786), a finding, however, not corroborated by Monteiro et al. (2012), Bastos et al. (2013) and Verner et al. (2017).

Bastos et al. (2013) assessed the influence of image filters on the detection of bone changes in the condyle by using the same CBCT device as ours, but their results were different from those reported by us. This may have occurred due to artificially produced bone defects, which might be more highlighted and thus more easily identified. In addition, we have used a voxel size greater than that of Bastos et al. (i.e. 1.0 mm vs 0.25 mm), indicating that this parameter difference may have resulted in discrepant findings.

Although Monteiro et al. (2012) and Verner et al. (2017) have also used in their studies the same CBCT device and image software as ours, both reported different results. Therefore, this again indicates that voxel size can strongly influence the diagnosis as those authors used a voxel size of 0.25 mm, which is much smaller than that used in our study, i.e., 1.0 mm. Besides the voxel size, other factors such as type of image filter and image assessment method may explain the discrepancies in the results, with Monteiro et al. (2012) assessing the influence of other filters in their study (i.e. hard and very sharp). Although Verner et al. (2017) have studied the same image filters as in our study, that is, Angio Sharpen 3x3 and Angio Sharpen 5x5, they concluded that the latter filter worsens the diagnosis for sclerosis and the former has a better performance compared to non-filtered images. The methodology used may have influenced the results: Verner et al. (2017) used a 21-inch LCD monitor with 32-bit resolution for image assessment, whereas we have a 17-inch LCD monitor with 12-bit resolution; and when there was any discrepancy the examiners re-made their assessment based on a consensus regarding the images – a practice not performed in our study.

Studies investigating the effect of digital filters on several pathological conditions are still rare (Bastos et al., 2013; Monteiro et al., 2012; Verner et al., 2017). The reviewed literature describes the prevalence of degenerative changes, but without reporting the use of image filters (Al-Ekrish et al., 2017; Oliveira et al., 2020; Pallaver & Honigmann, 2019; Sun et al., 2018; Urtane et al., 2018).

Among the 91 TMJ images assessed, degenerative processes were found in 29 cases (31.87%) and the other 62 images (68.13%) showed no such changes. Moreover, section thickness, voxel size, image quality, software, and monitor resolution may have influenced the results.

With regard to the degenerative bone changes, faceting was the most frequently found in our study (51.72%), a finding also reported by Alkhader, Al-Sadhan & Al-Shawaf (2012), Al-Shwaikh et al. (2016), De Azevedo Vaz et al. (2012), Dos Anjos Pontual et al. (2012), Cömert Kiliç Kiliç & Sümbüllü (2015) and Ladeira, Cruz & Almeida (2015). Osteophyte was

the second most frequently found (20.69%), followed by erosion (10.34%) and sclerosis (10.34%), whereas pseudocyst was the least frequent change (6.90%).

Librizzi et al. (2011) studied bone defects in condyles by scanning them with a Hitachi CB MercuRay device operating with different voxel sizes (i.e. 0.2 mm, 0.3 mm and 0.4 mm), fields of view and types of detector, although all the images had been re-constructed by using the same software (Dental CT software, Hitachi Medical, Twinsburgh, Ohio, USA).

Verner et al. (2015), Ladeira et al. (2015), and Al-Shwaikh et al. (2016) investigated the diagnosis of pathological TMJ conditions by examining tomographic images, which were obtained with an i-CAT scanner (Imaging Sciences International, Inc, Hatfield, PA, USA) and re-constructed with own software (Xoran Technologies Inc. Ann Arbor, Michigan, USA, 2005). However, the authors used different voxel sizes, respectively, 0.25 mm, 0.4 mm and 0.25 mm. Although only Verner et al. (2015) had used image filters, the other two studies found that faceting was the most prevalent change, and like our study, it is possible that such an alteration depends less on the voxel size.

Degenerative bone changes in the condyle were also investigated by Alkhader, Al-Sadhan & Al-Shawaf (2012) and Al-Ekrish et al. (2015), who used different voxel sizes (i.e. 0.3 mm and 0.29 mm, respectively) and no image filter at all. By using images re-constructed with software provided by the CBCT device (Iluma Device, lmtek Imaging, 3M Company, St. Paul, MN, USA), Al-Ekrish et al. (2015) concluded that erosion was the most frequent change, whereas Alkhader, Al-Sadhan & Al-Shawaf (2012) found that faceting was more prevalent despite using no filter, which corroborates our results. Subtle changes, such as small cortical erosions, are better visualized at a higher spatial resolution and this might have led Al-Ekrish et al. (2015) to conclude that erosion was the most prevalent change.

Chen et al. (2015) studied the prevalence of osteoarthritic changes in the TMJ on non-filtered images re-constructed with software provided by the SCT Pro scanner (Vatech, Seoul, Korea). Although they had used a CBCT device different from that used in our study, faceting was the most prevalent bone change, thus indicating that different equipment may equally influence the diagnosis.

Cömert Kiliç Kiliç & Sümbüllü (2015) used a NewTom 900 CBCT device (QR s. r. l., Verona, Italy) for acquiring images of the TMJ before re-constructing them with own software. The examiners used image tools such as contrast, brightness and zoom, but they applied no filter. The study found that faceting was the most prevalent change, which also corroborates our results.

Studies have assessed the prevalence of bone changes in the TMJ by using several parameters: different CBCT devices, application or not of image filters, voxels of different sizes, different image re-construction software, and different image assessment methods (Al-Ekrish et al., 2017; Choudhary et al., 2020; Derwich, Mitus-Kenig & Pawlowska, 2020; Hou et al., 2020; Miller et al., 2018; Oliveira et al., 2020; Sun et al., 2018; Urtane et al., 2018). Even so, it is possible to state that the majority of these studies found that faceting was the most prevalent change.

5. Conclusion

Due to the great number of CBCT devices with different voxel sizes and fields of view, different types of sensors and different software for image acquisition and re-construction, further studies should be conducted so that some of the numerous questions regarding CBCT can be answered.

The use of image filters did not influence the diagnosis of degenerative bone changes in the TMJ on CBCT.

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