USE OF TELERADIOGRAPHY AND CONE-BEAM COMPUTERIZED TOMOGRAPHY FOR CEPHALOMETRIC ANALYSIS: LITERATURE REVIEW

Uso da telerradiografia e tomografia computadorizada de feixe cônico para análise cefalométrica: revisão de literatura

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ABSTRACT

Introduction: *tomographic images produced by conical beam tomography (CBCT) may replace conventional radiographic images, since the use of this tomographic resource resides in the reproduction as close as possible to the three-dimensional craniofacial morphology.* **Objective***: to provide information to orthodontists about the types of 3D and 2D cephalometric analysis that can be applied in orthodontic planning, its evolution and applicability. Since the use of cephalometric methods, mainly 3D, has been little used by orthodontists, it was collected as much* *information related to the types of tomography together with the cephalometric analyzes as possible*. **Material and Methods***: a review of 38 articles in the literature on 3D and 2D cephalometric analyzes was carried out to evaluate if three-dimensional cephalometric analyzes are a more efficient diagnostic method than two-dimensional cephalometric analyzes and, if it can contribute to elucidation of the diagnosis with accuracy, for the correct orthodontic treatment planning.* **Results***: regarding the types of cephalometric analysis employed, the 3D techniques of cone beam were highlighted.* **Conclusion***: based on the information collected in the literature, it was concluded that the value of the cephalometric analysis depends on the accuracy of the technique because the errors can lead to an incorrect diagnosis and planning.*

Keywords*: Orthodontics. Tomography. Diagnosis.*

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RESUMO

Introdução: imagens tomográficas produzidas por tomógrafos de feixe cônico (TCFC) podem substituir imagens radiográficas convencionais, uma vez que o uso desse recurso tomográfico reside na reprodução o mais próximo possível da morfologia craniofacial tridimensional. **Objetivo**: fornecer informações aos ortodontistas sobre os tipos de análises cefalométricas 3D e 2D que podem ser aplicadas no planejamento na ortodontia, sua evolução e aplicabilidade. Visto que o método de análise cefalométrica, principalmente a 3D, tem sido pouco utilizado pelos ortodontistas, procurou-se colher o máximo de informações relacionadas aos tipos de tomografia juntamente com as análises cefalométricas. **Material e Métodos**: foi realizada uma revisão de 38 artigos na literatura acerca das análises cefalométricas 3D e 2D para avaliar se as análises cefalométricas tridimensionais são um método de diagnóstico mais eficiente que as análises cefalométricas bidimensionais e, se pode contribuir na elucidação do diagnóstico com maior precisão para o correto planejamento do tratamento ortodôntico. **Resultados**: quanto aos tipos de análises cefalométricas empregadas, se destacaram as técnicas 3D de tomografia de feixe cônico. **Conclusão**: diante das informações colhidas na literatura, conclui-se que o valor da análise cefalométrica depende da precisão da técnica porque os erros podem levar a um incorreto diagnóstico e planejamento.

Palavras-chave: Ortodontia. Tomografia. Diagnóstico

INTRODUCTION

2D cephalometry has been used as an important auxiliary tool in orthodontic diagnosis since the introduction of the cephalostat by Broadbent in the early 1930s and has persisted to date as a clinical tool; determination of craniofacial morphology and growth; in the diagnosis of anomalies; in the planning of orthodontic cases and in post-treatment follow-up (BAUMRIND; FRANTZ, 1971; HALAZONETIS, 2005; KUMAR et al., 2007; KUMAR et al., 2008; NALÇALCI et al., 2010; JACQUET et al., 2010; COUCEIRO; VILELLA, 2010; ZAMORA et al., 2011; KAPILA et al., 2011; GATENO et al., 2011; NERVINA, 2012; NAVARRO et al., 2013; DURÃO et al., 2013; KARATAS; TOY, 2014).

However, the cephalograms have limitations, such as image enlargement, distortion in the lateral structures, inaccurate location of the reference points due to overlap of structures of the craniofacial complex (BAUMRIND; FRANTZ, 1971; ZAMORA et al., 2011; GATENO et al., 2011; NAVARRO et al., 2013). Positioning of the patient's head is another relevant factor which may lead to a false diagnosis (NERVINA, 2012). Finally, the execution of radiographic cephalometry is made difficult by the facial asymmetry found in many patients (ADAMS et al., 2004; OZ et al., 2011; PARK et al., 2012; FARRONATO et al., 2014).

In an attempt to compensate for the limitations of two-dimensional measurements, several authors suggest that tomographic images produced by conical beam tomography (CBCT) may replace conventional radiographic images, since the use of this tomographic resource resides in the reproduction as close as possible to the three-dimensional craniofacial morphology (JACQUET et al., 2010; NALÇALCI et al., 2010; NERVINA, 2012; DURÃO et al., 2013). This fact is in accordance with the study of Adams et al that showed to be the 3D method four to five times more accurate than the 2D. Thus, the expectation is that the CBCT changes concepts and paradigms, redefining goals and therapeutic plans in orthodontics. Thus, this literature review aims to provide information on the types of 3D and 2D cephalometric analysis that can be applied in orthodontic planning, its evolution and applicability.

MATERIAL AND METHODS

The present study deals with a narrative literature review that has as approach: to provide information about the reference values *of the 3D cephalometric analyzes in order to validate these measures as a standard for daily clinical use. The selected literature covers articles from 2004 to 2016, including classic articles (1930 to 2000) available in the database.*

During the bibliographic survey, the exclusion criteria were: articles in duplicate; articles that did not address the proposed theme. The review consisted of searching for articles with the descriptors: cephalometric analysis, tomography and orthodontics. The selection was obtained by checking the PubMed and Bireme database, for a total of 38 scientific papers.

LITERATURE REVIEW

Orthodontic diagnosis and planning, over the years, has been based on a number of technological tools. The use of these resources resides in the reproduction as close as possible to the craniofacial morphology of the patients, in the three dimensions of space, in a static and dynamic way, just as it presents itself in nature.

Currently, it is known that the obtaining of cephalometric lateral cephalometric radiographs for orthodontic analysis can be divided into two main means: conventional and can be digitized tomographic by volumetric acquisition.

2D CEFALOMETRIC METHOD

Over the years, 2D cephalometric examinations obtained through lateral cephalometric radiographs were the result of the evolution of anthropometric and archaeological studies, due to the need for standardization of bone measurements. This method is also used to understand normal skull growth, diagnosis of malocclusions, other facial anomalies and also to quantify the effects of orthodontic, orthopedic and surgical interventions (HALAZONETIS, 2005; JACQUET et al., 2010; NALÇALCI et al., 2010; KAPILA et al., 2011; NERVINA, 2012; DURÃO et al., 2013; KARATAS; TOY, 2014).

Although 2D cephalometry is a widely used tool for the orthodontic treatment plan, among other applications, it has limitations and the large number of existing analyzes demonstrates the difficulty of standardizing the measurements (BAUMRIND; FRANTZ, 1971; GATENO et al., 2011; NAVARRO et al., 2013).

Errors in the identification of cephalometric points are considered to be the main source of trajectory failures performed on conventional cephalometric radiographs which are influenced by several factors, such as radiographic image quality, spot location accuracy and operator ability (NALÇALCI et al., 2010; JACQUET et al., 2010; NERVINA, 2012; DURÃO et al., 2013).

2D teleradiography presents angular and linear distortions because it is a two-dimensional image of a three-dimensional structure. Many points used in this analysis are situated in the median sagittal plane, which generates varied distortions in the projection of these images due to the depth of the craniofacial complex (NALÇALCI et al., 2010; JACQUET et al., 2010; NERVINA, 2012; DURÃO et al., 2013). Thus, these distortions known as magnifications, as well as the appearance of double images, in the case of bilateral structures, represent a loss in the detection of anomalies or even in the correct positioning of some anatomical structures, thus hindering a correct cephalometric analysis (HALAZONETIS, 2005; KAPILA et al., 2011; OZ et al., 2011; PARK et al., 2012; FARRONATO et al., 2014).

In view of the above, the constant technological developments in the area of radiology and computer science have allowed the emergence of new imaging techniques, such as computed tomography that gives its examiners a clearer visualization of structures, reducing the limitations that occur in two-dimensional examinations.

3D IMAGE METHODS

With the objective of overcoming the problems observed in the images obtained through conventional techniques, new technological resources were developed to perform the cephalometric analysis.

In the 1970s, computerized tomography was invented with the achievement of the desired third dimension with clarity (HOUNSFIELD, 1973; DAMSTRA et al., 2012; LIEDKE et al., 2012). The technique was developed in England, exactly in 1972 by Hounsfield, which represented one of the greatest scientific revolutions today, consecrating it with the Nobel Prize of Medicine in 1979.

In general, CT scans can be classified into two types: conventional tomography and computed tomography (HOUNSFIELD, 1973; DAMSTRA et al., 2012; KIM et al., 2012; LIEDKE et al., 2012; KARATAS; TOY, 2014). The latter can be classified according to the format of the X-ray beam used: Fan- Beam) and conical beam volumetric computed tomography (Cone-Beam).

The image obtained by the CBCT allows to evaluate the patient's hard and soft tissues in three dimensions, with minimal distortion, without overlapping of structures and with a lower dose of radiation (HALAZONETIS, 2005; KAPILA et al., 2011; KARATAS; TOY, 2014). Moreover, with the help of specific software, undesirable portions are eliminated, such as the cervical and occipital columns, avoiding the overlapping of images (HOUNSFIELD, 1973; KATSUMATA et al., 2005; LAGRAVERE; MAJOR, 2005; LAGRAVERE et al., 2006, LIEDKE et al., 2012; KIM et al., 2012) presenting features similar to conventional radiographs, such as profile teleradiographs, panoramic radiography, periapical radiographs, among others. Obtaining these secondary reconstructions prevents the patient from being exposed to radiation again. Thus, from a single examination, complementary images can be obtained. In these, measurements such as those performed on radiographs can be performed and, thus, help in the diagnosis, planning and evaluation of treatments (LAGRAVERE et al., 2006; GRAUER et al., 2009; DAMSTRA et al., 2012).

However, to establish the image from the CBCT as a common auxiliary means in orthodontic diagnosis, it is necessary to evaluate the accuracy of the identification of reference points routinely used in 2D cephalograms for orthodontic diagnosis. This has already been verified for the measurements performed in conventional cephalometry, but not for the same measurements performed on cephalometrics obtained from the CBCT.

3D CEPHALOMETRIC ANALYSIS

3D reconstruction via computer graphics has been studied with the improvement of image quality, efficiency and versatility in different applications involving the craniofacial complex. CT-specific programs have some limitations, which justify the use of specific programs for 3D-CT reconstruction and analysis of 3D cephalometric measures (NALÇALCI et al., 2010; NERVINA, 2012; DURÃO et al., 2013). However, the use of specific programs for the analysis of cephalometric 3D- CT scans should be compared with conventional cephalometric analyzes (LAGRAVERE et al., 2006; GHORBANIZADEH et al., 2016; VAN VLIJMEN et al., 2009) because there is no specific method of standardization of 3D cephalometric analysis (HASSAN et al., 2009; GRAUER et al., 2009; MIRANDA et al., 2013; PARK et al., 2015).

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Junqueira (2007) points out that, in order to obtain more reliable 3D cephalometric analysis, the same evaluation program must be used. Jacquet et al (2010), Lagravère e Major (2005) and Lagravère et al (2006) proposed the use of a new standardization system for 3D cephalometric analysis. These new methods suffer little influence from craniofacial growth and the position of the patient's head during imaging, thus allowing cephalometrics without screening, avoiding the inherent error of reference points and the imprecise influence of operators.

Of the methods for 3D cephalometric analysis, Cattaneo et al (2008) report that the RayCast technique (sum of voxels) is superior to MIP (maximum intensity projection). On the other hand, Moshiri et al (2007) observed a greater precision for linear measurements (SN, Ba-N, MN, ANS-N, ANS-PNS, Pog-Go, Go-M, Po-Or, and GoCo) 2D images of the TCFC in Ray-Sum methods (volumetric reconstruction overlapping several sagittal sections to form a thicker and brighter image) and Base Image (taken laterally to the patient's head), except for Pog-Go and Go-M measurements.

Kumar et al (2008), Zamora et al (2011), Van Vlijmen et al (2009) observed high reliability for angular and linear measurements performed with the CBCT, except for the Na-Ans distance (using NemoCeph 3D), and the Ans-Me distance (using InVivo5). The authors also recommend not using frontal 3D images in longitudinal studies, where the previous images are conventional frontal (2D) radiographs. Already Kumar et al. (2008) observed that measurements made on lateral sections of the CBCT using the orthogonal projection presented better accuracy in the median measurements than the prospective projection of the CBCT and the conventional cephalometric. At the same time, Periago et al (2008) found mean differences between 3D images and dry skulls, except for the measurements in the sagittal plane Na-A (nasal point of the front-nasal suture to the maxilla point A).

Analyzing the influence of the position of the patient's head during image acquisition on the measurement result, Hassan et al (2009) verified only a statistically significant difference for measurements in 2D images between the ideal position of the patient's head (Frankfurt plane parallel to the ground) and the position rotated horizontally.

Couceiro and Vilella (2010) affirm that the three-dimensional images are more reliable for the identification of some cephalometric points, such as pório (Po), orbitário (Or), subspinhal (A), supramental (B) and násio (N) points. As well as being easier to identify the lower edge of the jaw. However, Grauer et al (2009) report that the marking of the cephalometric points in the volumetric (3D) images for all *programs still do not have specific standardization. Likewise, other factors may make it difficult to mark the points such as: the presence of metallic artifacts, patient movement during image acquisition and image noise due to the use of a poorly applied filter by the operator.*

Damstra et al (2012) observed that the median points of the skulls are the ones that suffer the least possibility of deformity. Oz et al (2011) have found difficulty in locating the Go-Me and Condilio-Gnátio points (Co-Gn), and may be associated with the fact of identifying reference points on curved surfaces, even when using the information 3D. Also, Farronato et al (2014) observed a particular difference in measurements of the sagittal dimension of the mandible and anterior and posterior nasal spines, which may occur in possible errors when evaluating reference planes and linear measurements.

Park et al (2015) observed that the mandible head and morphology vary according to vertical facial morphology, and this relationship should be considered to predict and establish a suitable treatment plan for temporomandibular diseases during orthodontic treatment. Miranda et al (2013) also report that the anterior distance from the condyle to the articular eminence and the height of the eminence presented significant differences when compared to class I with Class II and Class III groups in 3D images.

DISCUSSION

According to the literature, the use of three-dimensional 3D images is becoming increasingly popular and has opened up new possibilities for orthodontic diagnosis and treatment analysis.

In view of this, 3D Craniometry can promote a more accurate planning, mainly because there is no overlap of images (ADAMS et al., 2004; OZ et al., 2011; NERVINA, 2012; PARK et al., 2012; LIEDKE et al., 2012; KIM et al., 2012; KARATAS; TOY, 2014; FARRONATO et al., 2014). Some software such as Dolphin 10.5 and Nemotec allow to go beyond planning, showing the evolution of the treatment, predicting the orthodontic movement and even the repositioning of the jaws in orthognathic surgeries. Despite the advantages, there are also some disadvantages that must be considered.

Among them, the highest cost for the examination and the greater amount of radiation that the individual receives when compared to conventional radiographic examinations (HASSAN et al., 2009; KIM et al., 2012; FARRONATO et al., 2014; PARK et al., 2015). In relation to patients with fixed orthodontic appliances, Katsumata et al (2005) point out that although the CBCT reduces the presence of *image artifacts caused when in the medical CT, they still exist due to the presence of radiopaque materials such as metals, gutta-percha and sealing cements.*

Although the superiority of 3D computed tomography images on 2D radiography is known, it is necessary that the measurements obtained in 3D images are real. Thus, linear measures in CBCT have been studied and craniometric analyzes proposed, but the anatomical structures and criteria for the treatment plan need to be defined.

Hassan et al (2009) verified that, since the CBCT examination acquires the full head volume, the positioning of the head does not modify the spatial location (X, Y, and Z coordinates) of the anatomical structures.

However, the operator may interfere significantly with the systematic effects of 3D cephalometric analyzes, affecting the reproducibility of cephalometric values. Operator calibration is a method of error control in the replication of cephalometric measurements and should therefore be included in any scientific experiment (ADAMS et al., 2004; NERVINA, 2012). According to Oliveira et al (2009) the calibration of the cephalometric points in the three planes of space, during the performance of the experiment, it increases the reliability and ease of precise marking of these references by the operators. However, it is observed that in some studies this was not followed, not providing a detailed definition of the points in the three planes of space.

Image thickness, image sharpness, anatomical complexity, soft and hard tissue overlap and experience in locating a particular point are important factors that may also influence the identification of cephalometric points (NALÇALCI et al., 2010; NERVINA, 2012; DURÃO et al., 2013). Several scientific articles evaluated the reliability of the identification of craniometric points in CBCT images and stated that the three-dimensional marking of these points in CBCT images is reproducible and consistent (HALAZONETIS, 2005; LAGRAVERE et al., 2006; HASSAN et al., 2009; FARRONATO et al., 2014; PARK et al., 2015). Therefore, it can be said that CBCT favors images for cephalometric analysis.

Computer graphics programs are well established as an important aid in the segmentation of 3D images, in the identification and marking of craniometric points (HOUNSFIELD, 1973; DAMSTRA et al., 2012; KARATAS; TOY, 2014) in order to obtain quantitative measurements (LAGRAVERE et al., 2006; LIEDKE et al., 2012; KIM et al., 2012). However, reconstruction is not simultaneous to acquisition and 3D images still follow reconstruction by surface *technique. Consequently, the quantitative analysis for application in the craniofacial region is of concern (PARK et al., 2015).*

Thus, computerized tomography, because it is intrinsically a three-dimensional method, generates a volumetric acquisition that does not present the same problems of the conventional cephalometric technique, but according to several authors, CT is subject to other variations such as: type of tomographic technique employed (Conventional TC and TC cone beam); type of reconstruction technique of 3D images (software that employs volume technique or surface technique); the cost; dose of radiation used and the logistics for the routine patient (HASSAN et al., 2009; KIM et al., 2012; FARRONATO et al., 2014; GHORBANIZADEH et al., 2016).

At the same time, the structures in the midline of the skull are the ones that suffer the least possibility of deformities. However, although the saddle point (S) is on the median line, this reference is a virtual point with no definite anatomical orientation and its transfer to a CT scan is not a simple procedure, which could incorporate a lack of accuracy in the location dimensional study (NERVINA, 2012; FARRONATO et al., 2014). In the study by Periago et al (2008), the saddle point was marked between the anterior Clinic Processes in the sagittal plane. Already Halazonetis (2005) propose the use of new anatomical points for 3D cephalometry and cites the use of the TS point (saddle tuber) because it is a point located in the bone structure and is a more accurate point compared to the S point.

A pattern that suffers the greatest variability is found in several studies. Certain points such as Go (Gón), Gn (Gnátio), Pog (Pogonio), N (Násio), Me (Mento) have a great depth variability in their location. This seems to be very acceptable since the location of the point in a structure without a striking anatomical detail can induce these variations (VAN VLIJMEN et al., 2009; KAPILA et al., 2011; FARRONATO et al., 2014). The variability of the N-point seems to be related to the applied contrast and brightness difference, which often causes the suture to appear deeper (HASSAN et al., 2009; GRAUER et al., 2009; PARK et al., 2015).

Baurimd and Franz (1971) also report that reference points located on a prominence or curvature, such as Gn, present greater variability of identification when compared to points in defined and flat positions.

The points marked on the condyle, in general, presented low reliability in both reconstructions, because it is a rounded and irregular structure, the condylar anatomy makes difficult the marking of points, which can interfere in the results of the studies.

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The greater imprecision was also observed in the Pório point. The definition of this as the "highest point of the external acoustic meatus" is problematic in 3D views, as it is not reliable for cephalometric radiographic studies (HASSAN et al., 2009; KIM et al., 2012; MIRANDA et al., 2013).

Zamora et al (2011), Naçalci et al (2010) and Durão et al (2013) found high reliability in the marking of maxillary and central incisors, whereas the tuberosity region presented the greatest marking error. The difficulty in locating these anatomical points can be caused by the lack of practice in the identification, since they are not frequently used in conventional cephalometry.

Thus, studies by Lagravère et al (2006), Oliveira et al (2009), Gateno et al (2011) are one of the few in the literature to propose reference points and standard plans for three-dimensional cephalometry. Thus, it is perceived that further studies and evidences are still necessary, since the measures studied were selected based on discussion between the authors and non-systematic consultation of the literature. Meanwhile, cephalometry can be done in a traditional way, manually or computed, in 2D images of CBCT, similar to conventional cephalometric radiography, which has results at least equal to those of cephalometry in cephalometric radiographs. The 2D images of TCFC similar to teleradiographs can be manipulated by computer programs, with equal dimension on the left and right sides, different from the teleradiographs that has enlargement, mainly on the side of the farthest face of the film, that is the side that is first reached by X-rays (usually the right), in addition to the overlapping of bilateral structures (NERVINA, 2012; PARK et al., 2015). At the same time, Van Vlijmen et al (2009) report that the cephalometric analyzes performed by conventional teleradiography are significantly different when performed by computerized scanning. The findings of Lamichane et al (2009) and Kumar et al (2008) also confirm some variables related to conventional lateral cephalometry. The variables that have been adopted are related to the mandibular plane and the Frankfurt plane, which are difficult to mark due to the overlap of images in the region.

To the detriment of the studies, it is evident that 3D cephalometric comparisons still have to occur, especially when using CBTC volumetric acquisition technology. Thus, studies proving the accuracy and accuracy of CBCT are scarce and further clarification for the elaboration of new cephalometric standards in 3D is still required.

CONCLUSION

The cephalometric analysis is based on the identification of anatomical points, which can be difficult to define in the conventional radiographs. Thus, cephalometric quantities depend on the accuracy of the technique because the errors can lead to incorrect diagnosis and planning. With the advent of technological resources, it is possible to minimize errors using specific programs, through the TCFC, since this provides reliable images for the cephalometric analysis. However, the use of conventional cephalometric radiographs remains feasible because of their cost-effectiveness and access by orthodontists.

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REFERENCES

ADAMS, G. L.; GANSKY, S. A.; MILLER, A. J.; HARELL JR, W. E.; HATCHER, D. C. Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. **American Journal of Orthodontics and Dentofacial Orthopedics.** St. Louis, v. 26, n. 10, p. 397-408, 2004.

BAUMRIND, S.; FRANTZ, R. C. The reliability of head film measurements. 1-Landmark identification. **Am J Orthod Dentofacial Orthop**. St. Louis, v. 60, n. 2, p. 111-27, 1971.

BROADBENT, H. B. A new X-ray technique and its application to orthodontia. **Angle Orthodont.** Appletown**,** v. 2, p. 45-66, 1931.

CATTANEO, P. M.; BLOCH, C. B.; CALMAR, D.; HJORTSHOJ, M.; MELSEN, B. Comparison between conventional and cone-beam computed tomography – generated cephalograms. **American Journal of Orthodontics and Dentofacial Orthopedics.** St. Louis, v. 134, n. 10, p. 798-802, 2008.

COUCEIRO, C. P.; VILELLA, O.V. Imagens em 2D e 3D geradas pela TC Cone-Beam e radiografias convencionais: qual a mais confiável? **Dental Press J. Orthod.** Maringá**,** v. 15, n. 5, p. 1-8, 2010.

DAMSTRA, J.; FOURIE, Z.; DEWIT, M.; REN, Y. A three-dimensional comparison of a morphometric and conventional cephalometric midsagittal planes for craniofacial asymmetry. **Clin Oral Invest.,** Heidelberg, v. 16, p. 285–294, 2012.

DURÃO, A. R.; PITTAYAPAT, P.; ROCKENBACH, M. I. B.; OLSZEWSKI, R.; SUK, N. G.; FERREIRA, A. P. Validity of 2D lateral cephalometry in orthodontics: a systematic review. **Progress in Orthodontics**. Copenhagen, n. 14, p. 31-35, 2013.

FARRONATO, G.; SALVADORI, S.; NOLET, F.; ZOIA, A.; FARRONATO, D. Assessment of inter- and intra-operator cephalometric tracings on cone beam CT radiographs: comparison of the precision of the cone beam CT versus the latero-lateral radiograph tracing. **Progress in Orthodontics**. Copenhagen, v. 15, p. 1-8, 2014.

GATENO, J.; XIA, J. J.; TEICHGRAEBER, J. F. A New Three-Dimensional Cephalometric Analysis for Orthognathic Surgery. **J Oral Maxillofac Surg**. Copenhagen, v. 69, n. 3, p. 606–622, 2011.

GHORBANIZADEH, S.; ABDINIAN, M.; FAGHIHIAN, R.; GOROOHI, H. Comparing the accuracy of linear measurements in different image views of Galileos cone-beam computed tomography unit. **Journal of Research in Dental Sciences.** Thousand Oaks, v. 7, n. 2, p. 58-63, 2016.

GRAUER, D.; CEVIDANES, L. S. H.; PROFFIT, W. R. Working with DICOM craniofacial images. **American Journal of Orthodontics and Dentofacial Orthopedics**. St. Louis, v. 136, n. 3, p. 460-70, 2009.

HALAZONETIS, D. J. From 2-dimensional cephalograms to 3-dimensional computed tomography scans. **American Journal of Orthodontics and Dentofacial Orthopedics**. St. Louis, v. 127, n. 5, p. 627-37, 2005.

HASSAN, B.; VANDERSTELT, P. V.; SANDERINK, G. Accuracy of three-dimensional measurements obtained from cone beam computed tomography surface-rendered for cephalometric analysis: influence of patient scanning position. **European Journal of Orthodontics**. London, v. 31, n. 2, p. 129-34, 2009.

HOUNSFIELD, G. N. Computerized transverse axial scanning (tomography).1. Description of system. **British Journal of Radiology**. London, v. 56, n. 12, p. 1016-22, 1973.

JACQUET, W.; NYSSEN, E.; BOTTENBERG, P.; GROEN, P.; VANDE VANNET, B. Novel information theory-based method for superimposition of lateral head radiographs and cone beam computed tomography images. **Dentomaxillofacial Radiology.** Erlangen, n. 39, p. 191–198, 2010.

JUNQUEIRA, J. L. C. **Avaliação comparativa entre as telerradiografias cefalométricas laterais convencional, digital e geradas por tomografia computadorizada por aquisição volumétrica Cone Beam.** 2007. 148f. Tese (Doutorado em Ortodontia). Universidade Estadual Paulista, Faculdade de Odontologia, Programa de Pós-graduação em Odontologia, Departamento de Ortodontia, 2007.

KAPILA, S.; CONLEY, R. S.; HARRELL JR, W. E. The current status of cone beam computed tomography imaging in Orthodontics. **Dentomaxillofacial Radiology**. Erlangen, v. 40, p. 24–34, 2011.

KARATAS, O. H.; TOY, E. Three-dimensional imaging techniques: A literature review. **European Journal of Dentistry**. Ankara, v. 8, n. 1, p. 132-140, 2014.

KATSUMATA, A.; FUJISHITA, M.; MAEDA, M.; ARIJI, Y.; ARIJI, E.; LANGLAIS, R. P. 3D-CT evaluation of facial asymmetry. **Oral Surg Oral Med Oral Pathol Oral Radiol Endod**. St. Louis, v. 99, n. 2, p. 212-20, 2005.

MARANHÃO, Pablo de Melo, REIS, Cássio de Souza e MARANHÃO, Kalena Melo. *Use of teleradiography and cone-beam computerized tomography for cephalometric analysis: literature review. SALUSVITA*, Bauru, v. 37, n. 3, p. 731-747, 2018.

MARANHÃO, Pablo de Melo, REIS, Cássio de Souza e MARANHÃO, Kalena Melo. *Use of teleradiographyand cone-beam computerized tomography for cephalometric analysis: literature review. SALUSVITA*, Bauru, v. 37, n. 3, p. 731-747, 2018.

KIM, M.; HUH, K. H.; YI, W. J.; HEO, M. S.; LEE, S. S.; CHOI, S. C. Evaluation of accuracy of 3D reconstruction images using multi--detector CT and cone-beam CT Imaging. **Science in Dentistry**. Seoul, v. 42, p. 25-33, 2012.

KUMAR, V.; LUDLOW, J.; MOL, A.; CEVIDANES, L. H. S. Comparison of conventional and cone beam CT synthesized cephalograms. **Dentomaxillofacial Radiology**. Erlangen, v. 36, n. 5, p. 263-9, 2007.

KUMAR, V.; LUDLOW, J.; MOL, A.; CEVIDANES, L. H. S. In Vivo comparison of conventional and cone beam CT synthesized cephalograms. **Angle Orthodontist**. Appletown, v. 78, n. 5, p. 873-79, 2008.

LAGRAVERE, M. O, HANSEN, L.; HARZER, W.; MAJOR, P. W. Plane orientation for standardization in 3-dimensional cephalometric analysis with computerized tomography imaging. **American Journal of Orthodontics and Dentofacial Orthopedics**. St. Louis, v. 129, n. 5, p. 601-4, 2006.

LAGRAVERE, M. O.; MAJOR, P. W. Proposed reference point for 3-dimensional cephalometric analysis with cone-beam computed tomography. **American Journal of Orthodontics and Dentofacial Orthopedics**. St. Louis, v. 128, p. 11, p. 657-60, 2005.

LAMICHANE, M.; ANDERSON, N. K.; RIGALI, P. H.; SELDIN, E. B.; WILL, L. A. Accuracy of reconstructed images from cone--beam computed tomography scans. **American Journal of Orthodontics and Dentofacial Orthopedics**. St. Louis, v. 136, n. 2, p. 156-7, 2009.

LIEDKE, G. S.; DELAMARE, E. L.; VIZZOTTO, M. B.; SILVEIRA, H. L. D.; PRIETSH, J. R.; DUTRA, V. Comparative study between conventional and cone beam CT-synthesized half and total skull cephalograms. **Dentomaxillofacial Radiology**. Erlangen, v. 41, p. 136-42, 2012.

MIRANDA, J. M. A.; VALENCIA, M. S.; FLORES, C.; SAMPEN, N. A. P.; ARRIOLA-GUILLEN, L. E. Spatial analysis of condyle position according to sagittal skeletal relationship, assessed by cone beam computed tomography. **Progress in Orthodontics**. Copenhagen, v. 14, p. 36-40, 2013.

MOSHIRI, M.; SCARFE, W. C.; HILGERS, M. L.; SCHEETZ, J. P.; SILVEIRA, A. M.; FARMAN, A. G. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone beam tomography. **American Journal of Or-**

thodontics and Dentofacial Orthopedics. St. Louis, v. 132, n. 4, p. 550-60, 2007.

NALÇALCI, R.; OZTURK, F.; SOKUCU, O. A comparison of two--dimensional radiography and three-dimensional computed tomography in angular cephalometric measurements. **Dentomaxillofacial Radiology**. Erlangen, v. 39, p. 100–106, 2010.

NAVARRO, R. L.; OLTRAMARI-NAVARRO, P. V. P.; FERNANDES, T. M. F.; OLIVEIRA, G. F.; CONTI, A. C. C. F.; ALMEIDA, M. R. Comparison of manual, digital and lateral CBCT cephalometric analysis. **J Appl Oral Sci**. Bauru, v. 21, n. 2, p. 167-76, 2013.

NERVINA, J. M. Cone beam computed tomography use in orthodontics. **Australian Dental Journal**. Sydney, v. 57, n. 1, p. 95–102, 2012.

OLIVEIRA, A. E. F.; CEVIDANES, L. H. S.; PHILLIPS, C.; MOTTA, A.; BURKE, B.; TYNDALL, D. Observer reliability of tree--dimensional cephalometric landmark identification on cone-beam computerized tomography. **Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology**. St. Louis, v. 107, n. 2, p. 256-65, 2009.

OZ, U.; ORHAN, K.; ABE, N. Comparison of linear and angular measurements using two dimensional conventional methods and three-dimensional cone beam CT images reconstructed from a volumetric rendering program in vivo. **Dentomaxillofacial Radiology**. Erlangen, v. 40, p. 492–500, 2011.

PARK, C. S.; PARK, J. K.; KIM, H.; HAN, S. S.; JEONG, H. G.; PARK, H. Comparison of conventional lateral cephalograms with corresponding CBCT radiographs. **Imaging Science in Dentistry**. Seoul, v. 42, p. 201-5, 2012.

PARK, I. Y.; KIM, J. H.; PARK, Y. H. Three-dimensional cone--beam computed tomography-based comparison of condylar position and morphology according to the vertical skeletal pattern. **Korean J Orthod**. Seoul, v. 45, n. 2, p. 66-73, 2015.

PERIAGO, D. R.; SCARFE, W. C.; MOSHIRI, M.; SCHEETZ, J. P.; SILVEIRA, A. M.; FARMAN, A. G. Linear accuracy and reliability of cone beam CT derived 3D images constructed using an orthodontic volumetric rendering program. **Angle Orthodontist**. Appletown, v. 78, n. 3, p. 387-95, 2008.

VAN VLIJMEN, O. J. C.; BERGÉ, S. J.; SWENEN, G. R. J.; BRONKHOST, E. M.; KATSAROS, C.; KUIJPERS-JAGTMAN, A. M. Comparison of cephalometric radiograph obtained from cone-

MARANHÃO, Pablo de Melo, REIS, Cássio de Souza e MARANHÃO, Kalena Melo. *Use of teleradiography and cone-beam computerized tomography for cephalometric analysis: literature review. SALUSVITA*, Bauru, v. 37, n. 3, p. 731-747, 2018.

MARANHÃO, Pablo de Melo, REIS, Cássio de Souza e MARANHÃO, Kalena Melo. *Use of teleradiographyand cone-beam computerized tomography for cephalometric analysis: literature review*. *SALUSVITA*, Bauru, v. 37, n. 3, p. 731-747, 2018.

-beam computed tomography scan and conventional radiography. **European Journal of Oral Sciences**. Copenhagen, v. 117, n. 2, p. 300-5, 2009.

ZAMORA, N.; LLAMAS, J. M.; CIBRIÁN, R.; GANDIA, J. L.; PAREDES, V. Cephalometric measurements from 3D reconstructed images compared with conventional 2D images. **Angle Orthodontist**. Appletown, v. 81, n. 5, p. 856-64, 2011.