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EVALUATION OF MAXILLARY BONES USING CONE BEAM COMPUTED TOMOGRAPHY: A SYSTEMATIC REVIEW

AVALIAÇÃO DOS OSSOS MAXILARES POR MEIO DA TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO: UMA REVISÃO SISTEMÁTICA

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ABSTRACT

Purpose: Cone beam computed tomography is widely used in dentistry, due to its easy accessibility, low cost and better accuracy compared to medical tomography. The present study aims to conduct a systematic review of the literature on the evaluation of jaw bones using cone beam computed tomography. A bibliographic search was performed in the electronic databases PubMed, Scopus, Embase and Web of Science. At the end of the analysis, 10 articles published between 1998 and 2015 were included. Cone beam computed tomography is a precise and fast method, used to evaluate digital images in high resolution, with sharpness, precision. In addition, the acquisition of these images is essential to measure bone elements, in quantity and quality. It should also be noted that the forecast of bone strength will depend on several factors, such as bone density and microarchitecture. Thus, the professional and reduces the likelihood of making mistakes, which interfere with the prognosis of dental treatment.

Key words: Cone beam computed tomography, Bone density, Jaw, Dentistry.

RESUMO

A tomografia computadorizada de feixe cônico é amplamente utilizada na odontologia, devido a sua fácil acessibilidade, baixo custo e melhor precisão em comparação à tomografia médica. O presente estudo tem como objetivo realizar uma revisão sistemática da literatura acerca da avaliação dos ossos maxilares utilizando tomografias computadorizadas de feixe cônico. Foi realizada uma pesquisa bibliográfica nas bases de dados eletrônicas PubMed, Scopus, Embase e Web of Science. Ao final das análises, foram incluídos 10 artigos publicados entre 1998 e 2015. A tomografia computadorizada de feixe cônico é um método preciso e rápido, utilizado para avaliar imagens digitais em alta resolução, com nitidez, precisão. Além disso, é fundamental a aquisição dessas imagens para mensuração de elementos ósseos, em quantidade e qualidade. Deve-se ressaltar ainda que a previsão da resistência óssea vai depender de diversos fatores, como a densidade e microarquitetura óssea. Dessa forma, o profissional e reduz a probabilidade de cometer erros, os quais interferem no prognóstico do tratamento odontológico.

Descritores: Tomografia computadorizada de feixe cônico, Arcada osseodentária, odontologia**.**

INTRODUCTION

In medical imaging, conventional radiographs, such as panoramic, use techniques based on two-dimensional (2D) representation of bone structures[1]. However, to obtain a volumetric evaluation of bone tissue, it is necessary to use imaging tests that provide visualization in three-dimensional format (3D), in this context, computed tomography has been used in order to reconstruct the information collected by the equipment, through the analysis of cuts in different planes of the human body. This technology allows 3D reconstruction and image manipulation to take place using computerized software at full scale (1:1)[2].

Cone beam computed tomography is widely used in dentistry, due to its easy accessibility, low cost and better accuracy compared to medical tomography. In addition, this exam offers a higher resolution, providing an increase in the quality of the images, in addition to producing a lower radiation dose when compared to fan beam tomography. Another important factor is the lower production of technical artifacts in relation to metallic objects1,2. Coronal, sagittal and oblique images are formed from the axial slices originated through the software, thus building the volume of the region and incorporating the reference lines making the location of the slices simple[2].

In the planning of surgeries and maxillomandibular reconstructions, the cone beam computed tomography becomes a useful tool in the preoperative evaluation and surgical planning, having a greater accuracy in the diagnosis when compared with other methods. The accuracy of bone measurements is related to the sharpness and resolution of the image, taking into account important aspects, such as thickness, height

and bone quality[3,4,5,6]. However, there is a difference in the reproducibility of measurements between the anterior and posterior lower teeth, because the thickness of the bone plates in the anterior region of the mandible is less than the thickness of the plates in the posterior region. Therefore, the thinner the bone board, the less sharp the image, which can hamper the accuracy of linear measurements3.

Another characteristic that contributes to the use of computed tomography is the patronized code of images obtained in the DICOM (Digital Imaging and Communications in Medicine) format. Manufacturers of devices that perform cone beam computed tomography have the option to convert the outcome images in a DICOM file exportable via software. With this, it is possible to export sections or images in different software, making it possible to use specific measurements, thus contributing to the increase in tools that visualize, measure and record three-dimensional images5. Therefore, the objective of this study is to conduct a systematic review of the literature on the evaluation of maxillary bones using cone beam computed tomography..

METHODS

Search strategies

This systematic review was registered in PROSPERO 2020 under protocol nº CDR42020203677 and conducted following the PRISMA statement6. A bibliographic search was performed in the electronic databases PubMed, Scopus, Embase and Web of Science, locating published studies regardless of the source language and date of publication. All stages and reviews of the research were evaluated by two reviewers with experience in developing systematic review protocols (JCP, LAMS). The search strategy was based on combinations of the following keywords: "computed tomography" [MeSH] AND "cone beam computed tomography" [MeSH] AND "jaw bones" [MeSH] AND "outcome" [MeSH]). A manual search of the articles was also carried out using the references of the studies with potential for inclusion in the systematic review.

Studies selection

For this search, the PICO methodology was used in order to establish the guiding question of bibliographic research. Thus, the central question established in the present systematic review was: What is the importance of cone beam computed tomography to assess maxillary bones?

The studies were selected regardless of language or year of publication. Randomized clinical trials, animal model studies, in vitro studies, review articles and case reports that evaluated maxillary bones using cone beam computed tomography were included. The exclusion criteria were studies that did not correspond to the elucidated theme. Articles that do not meet the eligibility criteria and duplicate articles were removed from the study. A first step in the selection of works was carried out based on the analysis of titles and abstracts. Subsequently, all studies whose titles or abstracts are

deemed relevant to the topic were obtained in full and analyzed in full. At the end, the articles analyzed and selected by the evaluator were included in the systematization of the data. Reference management software was used to control the analyzed articles and remove duplicates (EndNote; Thomson Reuters, Philadelphia, PA, USA). In addition, the following information from the studies evaluated was collected: authors, year of publication, country, bone measurement site (maxilla and/or mandible), tomographic sections analyzed and relevant results.

Risk of bias

Methodologically, the authors evaluated all included studies according to a checklist based on the Meta-Analysis of Statistics and Review Instrument (MAStARI)7. Two reviewers (JCP, LAMS) answered 9 questions for descriptive studies: Q1- Is the study based on a random or pseudo-random sample?; Q2- Are the criteria for inclusion in the sample clearly defined?; Q3- Are confounding factors identified and strategies for dealing with them declared?; Q4- Are results evaluated using objective criteria?; Q5- If comparisons are being made, was there a sufficient description of the groups?; Q6- Is the monitoring carried out for a sufficient period of time?; Q7- Are the results of the people who left are described and included in the analysis?; Q8- Are results measured reliably?; Q9- Is appropriate statistical analysis used?

Y was used for "yes", N for "no" and NA for "non applicable". Subsequently, the risk of bias was classified as high when the study reached up to 49% of a "yes" score, moderate when the study reached 50% to 69% of a "yes" score and low when the study reached more than 70% of a "yes" score. The differences were resolved by the discussion between the two authors (JCP, LAMS).

RESULTS

Studies selection

The search strategy developed in this systematic review resulted in a total of 60 studies located in the evaluated databases. After screening the titles and abstracts, 17 studies were considered potentially eligible and were read in full by 2 independent evaluators (JCP, LAMS). At the end of the analyzes, 10 articles published between 1998 and 2015 met all the inclusion criteria and were selected for this systematic review as shown in Figure 1.

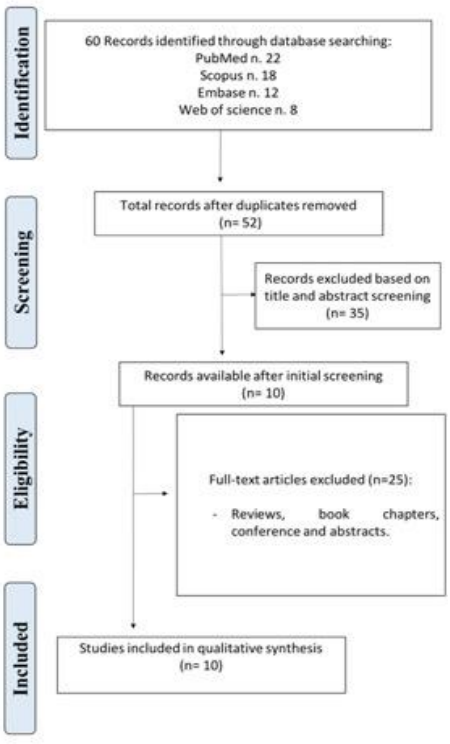

Figure 1 - Selection of studies based on the inclusion criteria

Risk of bias

According to the analysis by the two authors (JCP, LAMS), the articles included in the review and evaluated by MAStARI, presented a low risk of bias, observing 70% of the "yes" score (Table 1).

Table 1 - Analysis of the risk of bias in the articles included in the review was carried out with the MAStARI (Meta-Analysis of Statistics and Review Instrument) critical assessment tool.

Author (Year)	Questions*									Yes(%)	RB*
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	87.5	L
Mozzo et al. (1998)[9]	NA	Y	Y	Y	Y	N	Y	Y	Y	87.5	L
Norton (2001)[14]	NA	Y	Y	Y	Y	N	Y	Y	Y	87.5	L
Hua et al. (2009)[20]	NA	Y	Y	Y	Y	N	Y	Y	Y	100.0	L
Georgescu et al. (2010)[19]	NA	Y	Y	Y	Y	Y	Y	Y	Y	100.0	L
Menezes et al. (2010)[3]	NA	Y	Y	Y	Y	Y	Y	Y	Y	87.5	L
Hohlweg et al. (2011)[11]	NA	Y	Y	Y	Y	N	Y	Y	Y	87.5	L
Hohlweg et al. (2011)[13]	NA	Y	Y	N	Y	Y	Y	Y	Y	75.0	L
Nackaerts et al. (2014)[21]	NA	Y	Y	N	Y	N	Y	Y	Y	87.5	L
Kim et al. (2015)[10]	NA	Y	Y	Y	Y	N	Y	Y	Y	87.5	L
Vasconcelos et al. (2015)[5]	NA	Y	Y	Y	Y	N	Y	Y	Y	87.5	L

Methodological characteristics

The 10 studies eligible for this work bring in their methodological characteristics aspects related to the use of cone beam computed tomography in the maxilla and/or in the mandible. Such aspects can be seen in Table 2.

Table 2 – Summary of the descriptive characteristics of the included studies (n = 10)

Author (year)	**Country**	**Bone measurement site (maxilla and / or mandible)**	**Tomographic sections analyzed**
Mozzo et al. (1998)[9]	Italy	Maxilla e mandible	- Paraaxial oblique images of the complete maxilla; - Paraaxial oblique images of the complete mandible;
Norton (2001)[14]	England	Maxilla e mandible	32 scans of different patients were performed, totaling 139 sites. Of which: 25 anterior mandibular, 42 anterior and 27 posterior jaws.
Hua et al. (2009)[20]	Belgium	Mandible	19 specimens were analyzed, on the mandible section.
Georgescu et al. (2010)[19]	Romania	Mandible	Analysis of 51 patients, of the alveolar crest of anterior lower teeth.
Menezes et al. (2010)[3]	Brazil	Mandible	12 jaws. Sections were selected, which showed the mental foramen.

Author (year)	Country	Bone measurement site (maxilla and / or mandible)	Tomographic sections analyzed
Hohlweg et al. (2011)[11]	Germany	Mandible	60 jaws were used and divided into hemi-arches; Only one hemi-arch was used. The sections focused on the teeth and the retromolar region.
Hohlweg et al. (2011)[13]	Germany	Mandible	6 cylinders containing cortical and trabecular bone were analyzed. The analyzed sections involved the bony part and in some cases, the apex of the teeth.
Nakaerts et al. (2014)[21]	England	Maxilla e mandible	Four jaws and mandibles (2 of each) were selected. The sections were obtained in order to segment the trabecular bone.
Kim et al. (2015)[10]	South Korea	Maxilla e mandible	68 specimens were trabecular bone (cut in the para-sagittal plane), from 4 pairs of maxilla and mandible.
Vasconcelos et al. (2015)[5]	Brazil	Mandible	Eight jaws were selected, the selected areas correspond to the regions of teeth: incisors, canines, premolars and first molars.

Source: Authors.

Relevant results of the studies analyzed

Cone beam computed tomography has been shown to be more effective for evaluating images of dento-maxillofacial structures, when compared to more traditional models, panoramic radiographs and traditional fan tomographic techniques[8]. The images are obtained based on several two-dimensional sections, which allow the reconstruction of a three-dimensional volume, done through software. Many benefits are related to the use of this cone beam tomography, among them, the low cost, ease of use, fast scanning, excellent performance, low radiation dose and large-scale use stand out[8,9]. Measurements are a crucial factor in the choice for cone beam computed tomography, all images can be printed on a 1:18 scale.

The study by Mozzo et al. (1998)[9], evaluated the geometric precision of the mandibular bone, performing three measurements at different points, the result of the numerical values of the measurements were very close to the real numbers, showing the precision and, consequently, reliability that this method has, thus helping the planning in several areas of dentistry, such as implantology.

Another work that expresses this reliability was that of Vasconcelos et al. (2015)5, in it the authors made a comparison between several measurement softwares. Cone beam tomography images were obtained using i-CAT Next Generation and bone measurements were performed using three software packages: XoranCat®, OnDemand3D® and KDIS3D®, all capable of evaluating DICOM images. At the end of the study, the authors concluded that regardless of the program used, the measurement accuracy is high and reliable, since all of them presented this result.

The work carried out by Menezes et al. (2010)[3], evaluated and compared the reproducibility of the buccal and lingual bone plate thickness, using measurements on CBCT images, varying the image acquisition protocols, as well as changing the dimensions of the voxel. Reproducibility was observed in the three protocols used and was shown to have good accuracy for the dimensions used, however, he observed that the reproducibility of the measurements of the anterior region of the mandible was critical when compared to the posterior region. Structural indices are commonly determined by means of two-dimensional histological sections and obtained non-destructively through several sections in one of the three directions, allowing a comprehensive description of structural variation within a specimen[8].

The study by Kim et al. (2015)10, sought to evaluate the potential of cone beam computed tomography in the evaluation of the microarchitecture of the trabecular bone of the maxilla and mandible. The authors realized that this method offers reliability and easy access to the microarchitecture of the trabecular bone, especially when it comes to dental implants, guaranteeing the quantity and quality of bone observed in cone beam computed tomography.

In addition, two studies by Hohlweg et al. (2011)[11] evaluated aspects related to bone quantity. The first investigated this quantity in different methods of image acquisition of cone beam computed tomography. For this, several measures were recorded in pig mandibles in the retromolar region, and the authors realized that this method is very good for analyzing bone mass in the quantitative aspect. However, they did not obtain any information about bone quality. In their second study, the authors carried out a methodology similar to the first, aiming to determine the quantity or quality of bone by means of cone beam computed tomography and reached the same conclusion as the first study.

Thus, however possible to evaluate bone density using computed tomography using a cone beam, aspects related to bone stability are inaccurate using only cone beam computed tomography. That is why, today, 3D reconstructions in software are used. In addition, currently, cone beam computed tomography has high contrast structures that allow analyzing only bone tissue, however, soft tissues are not visualized[11,12].

Such aspects mentioned above are favorable to the use of cone beam computed tomography for the rehabilitation treatment with dental implants, since they are subject

to variable masticatory loads, requiring a good density and bone quality to be fixed. Therefore, the type and architecture of the bone influence the implant's ability to withstand occlusal efforts[13]. The results of an analysis of computed tomography scans used by Norton et al. (2001)[14], demonstrates that density measurements, performed prior to implant placement, are fundamental to the treatment prognosis, as well as preventing iatrogenesis, preventing the placement of these implants in regions with little bone quantity and quality.

DISCUSSION

Cone beam computed tomography has been used in order to be able to view a 2D image in 3D. With this, it is possible to obtain three-dimensional images quickly and easily, when compared to conventional tomography. Many benefits are related to the use of this method, among them, the presence of sharp images without distortions, the ability of directing the x-rays to the desired area, more accurate images, reduction of radiation dose, reduction of artifacts. In addition, cone beam computed tomography can be evaluated on computers, using software, which allows the enlargement of images and even the possibility of sharing information with professional colleagues and assisting in the planning of dental treatment[14,15].

Cone beam computed tomography allows reformatting images in the axial, coronal and sagittal planes. They are indicated for evaluating jaws in the placement of implants, surgeries, orthodontic planning, measuring the proximity of the third molar with the mandibular canal, dental fractures, bone evaluation considering cysts and tumors[15]. In addition, cone beam computed tomography currently allows evaluations of the quality and quantity of the buccal and lingual bone boards[14].

Several computerized studies have shown that the thinner the bone plate, the greater the risk of dehiscence during gyroversion or vestibularization in orthodontic treatments. Therefore, thickness must be taken into account in orthodontic planning[15]. An important aspect in which cone beam computed tomography assists in dental planning is in relation to measurement accuracy. Measurability can bring together image quality and the usefulness of an image method. It allows to add the visual gradation analysis of the images, commonly used to assess the image quality, since it requires the evaluator to perform a clinically relevant task. Accuracy is a very important parameter to be evaluated and is related to the effectiveness of diagnostic methods, as well as planning, generating reliability in what is being operated in order to reduce errors[16].

In the study by Okshi et al. (2019)[17], conical beam computed tomography and panoramic radiographs of teenagers with permanent teeth, dental crowding and displacement, which were in the process of placing orthodontic appliances, were evaluated. After making the comparison, they realized that the precision and reliability

were higher in the cone beam computed tomography when they analyzed the measurements of root length and marginal bone level.

In the case of surgeries for implant placement, in addition to the high measurability and reliability, it is important to evaluate the trabecular bone microstructure, thus guaranteeing the success of the procedure and the clinical longevity of dental implants. It is worth noting this, because the quantity and quality of the trabecular bone has important effects on the stability of the implant[17]. The study by Muhammad et al. (2020)[18], evaluated the measurements of trabecular bone microstructure with different size of reconstruction voxel, however, these parameters did not compromise the trabecular structure, even with the change in the size of the voxel.

It is up to the dentist to understand the anatomy, so that it reaches its goal of rehabilitating the patient in form and function. Even in cases of implants, cone beam computed tomography assists in obtaining planning of surgical guides, which allow the professional to acquire a model similar to that of surgery, thereby minimizing surgical errors, reducing clinical time and enables greater precision of results[17].

Nogueira et al. (2012)[15], reported in his studies that by measuring bone height, width and thickness, it made it easier to choose the type of implant to be installed for each patient, as well as to better visualize the anatomical sites of installation in order to to minimize the risks of iatrogenesis, in addition to providing an early diagnosis of complications resulting from inadequate facilities, when compared to two-dimensional radiographs.

CONCLUSION

Cone beam computed tomography is widely used in dentistry, mainly in the planning of surgeries, implants and orthodontic movement, considering that it makes it possible to view an image in volume. This is a precise and fast method, used to evaluate digital images in high resolution, with sharpness and precision. In addition, the acquisition of these images is essential to measure bone elements, in quantity and quality. It should also be noted that the forecast of bone strength will depend on several factors, such as bone density, bone microarchitecture and mechanical properties, which must be considered. Thus, the professional saves clinical time and reduces the likelihood of making mistakes, which interfere with the treatment prognosis.

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