Cone-beam Computed Tomography: Basics, Applications and Advantages in Periapical Lesions Diagnostics and Surgical Treatment Planning in the Posterior Mandible

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Abstract: ***Aim**: The aim of this review is to analyze and summarize the basics of CBCT technology and its specific application for detecting periapical lesions in posterior region of the mandible. **Materials and methods**: PubMed and Google Scholar databases were searched, in order to select articles, related to the topic. The review includes articles written in English language, published from 1973 to 2021. **Results**: CBCT enables three-dimensional examination of segments of the dentition, complete jawbones, facial bones or all of the above. The obtained images permit the study of objects in all possible projections, as well as for establishing the actual spatial relationships between them by elimination the distortion of the image and superimposition of adjacent structures, characteristic of conventional two-dimensional radiographs.The use of CBCT for preoperative diagnostics and examination in the posterior region of the mandible is determined to be most efficient in comparison to other imaging techniques. **Conclusion**: CBCT imaging surpassed the obstacles of 2D imaging, offering high quality, submillimeter resolution images, with short scanning time and low radiation dose. This makes it a method of choice in cases when conventional two-dimensional radiographs do not provide sufficient information to ensure an adequate treatment approach.*

Keywords: cone-beam, intraoral radiographs, periapical lesions, mandible, apical surgery

1. Introduction

Cone-beam computed tomography permits three-dimensional examination of segments of the dentition, complete jaws, facial bones or all of the aforementioned structures. The obtained images enable the examination of objects in all possible projections, as well as establishing the actual spatial relationships between them by eliminating the distortion of the image and superimposition of adjacent structures, characteristic of conventional two-dimensional radiographs. Namely because of these advantages, multiple contemporary studies establish a higher percentage of diagnosed periapical lesions with cone-beam computed tomography, compared to conventional radiography.

2. Materials and methods

PubMed and Google Scholar databases were searched, in order to select articles, related to the topic. The review includes articles written in English language, published from 1973 to 2021.

3. Results and Discussion

In the daily ambulatory surgicalpractice the most commonly performed interventions are related not only to the sound knowledge of anatomical objects, features of the oral structures and development of pathological processes, but also the possibilities for their visualization and further examination.

This is precisely why there is an enormous need for cone-beam computed tomography (CBCT) – in the diagnostics of periapical pathology and following up of healing processes, assessment of different types of cysts and tumors, diagnostics of fractures and inflammatory diseases of the jawbones, planning of the surgical extraction of third molars and impacted teeth, implant treatment, orthognathic surgery and many more.

Generally, conventional two-dimensional (2D) radiographyis still the most commonly applied method. In many casesit provides sufficient information, fulfilling the requirements of the daily clinical practice – images with good quality, wide accessibility of the devices, low price, fairy low radiation dose for the patient. Despite this, they exhibit many disadvantages, the most substantial of which are: superimposition of adjacent anatomical structures, lack of information regarding the ratios between the examined objects in the three dimensions, distortion and enlargement of the images.

The misinterpretation of data of these two-dimensional examinations can lead to misdiagnosis and inappropriate choice of treatment, as well as occurrence of intraoperative complications of different nature. All of this can compromise the outcome of the overall treatment.

The development of computed tomography (CT) in 1972 by Godfrey Hounsfield marks the beginning of the three-dimensional (3D) diagnostics in medicine (1). Despite its wide application in many clinical specialties, this equipment is still relatively high in cost, large in size and exposes the patients to a relatively high dose of ionizing radiation. The acquired images of the maxillofacial region are often difficult to interpret, which leads to a significant decrease in the use of CT in the dental practice (2).

Many of the disadvantages of two-dimensional radiographs, as well as those of conventional computed tomographies, have enforced the speedy implementation of cone-beam computed tomography in the daily surgical practice, regarded by many authors as "standard" in dental radiology (3, 4, 5, 6, 7).

CBCT enables the three-dimensional examination of segments of the dentition, complete jawbones, facial bones or all of the above (8, 9). The obtained images permit the study of objects in all possible projections, as well as for establishing the actual spatial relationships between them by elimination the distortion of the image and superimposition of adjacent structures, characteristic of conventional two-dimensional radiographs (5, 10, 11, 12, 13, 14, 15, 16, 17, 18).

All of these advantages of CBCT over the other radiological methods affirm its place in the diagnostics of maxillofacial pathology, its follow-up and treatment planning (19).

The image obtained by CBCT is comprised of isotropic voxels (volumetric pixels), which are analogical to the pixels of two-dimensional images. Isotropic voxels are of equal sizes in the three dimensions (x, y, z planes) and have submillimeter measurements – ranging from 0,4mm to 0,076mm. The quality of the final image depends directly on the size of the voxels. The smaller they are in size, the higher the resolution (20). This determines the immense role and high sensitivity of CBCT in the diagnostics of bone pathologies even in the early stages of their development. Alterations, the size of which is smaller than that of the voxels, cannot be visualized on the images.

For comparison, the voxels in conventional CT are anisotropic, which means they are equal in only two of the dimensions, but differ in the third (20). Although their superficial measurements can also be around 0,625 mm^2, in depth their size is usually between 1 and 2 mm, i.e. they have a lower resolution. This determines CBCT as a method of choicewhen planning surgical interventions, placement of dental implants, analyzing radiographs for orthodontic purposes, which require precise measurements with submillimeter accuracy (5, 21).

Depending on the type of device used, as well as the extent of the selected zone of interest, the values of the effective dose in CBCT can range between 29 and 477μSv, with mean values of 212 μSvat large field of view (FOV), 177 μSvat medium FOV and 84 μSv μSvat small FOV (22, 23, 24, 25, 26).In addition to this, up to 40% of these numbers can be reduced by changing the position of the patient (by tilting the chin) and with the use of a protective lead thyroid collar.

One of the major advantages of CBCT is the ability for selection of a smaller FOV, which reduces the radiation dose for the patient. This makes it possible to fulfill the individual requirements of the actual examination by reducing the diffusion of rays, respectively occurrence of artefacts (2, 27, 28).A small FOV is indicated when examining segments of one jaw, medium FOV – for scanning both jaws, large FOV – for visualization of the entire maxillofacial region and skull, most commonly applied in maxillofacial traumatology, orthognathic surgery and orthodontics (29).

All of this defines the radiation dose of a segmented scan as slightly larger than that of a panoramic x-ray, equivalent to that of a few segmented x-rays and comparable to the exposure to the natural radiation background between 3 and 48 days (29). Simultaneously, it is multiple times lower than the dose of conventional CT – from 1200 μSv and higher for each scan, depending on the selected field of view (30, 31, 32, 33, 34).

Another advantage of CBCT is the shorter scanning time – all images are taken with one rotation of the machine, during which the source of ionizing radiation and the detector rotate around the head of the patient. During this motion multiple consequent planar scans are registered, which are afterwards "stitched up" to one another through processing with special software (35). The obtained information is transferred to a computer, where it is reconstructed and stored in DICOM (Digital Imaging and Communications in Medicine) format. This allows for examination in the three planes, precise measurement and application of additional software if needed (36).

The average scanning time in the abovementioned technique is between 10 and 70 seconds, which reduces the risk of creating artefacts due to involuntary movements of the patient. Nevertheless, the occurrence of artefacts is still among the most substantial drawbacks of CBCT.

Defined as artefacts are distortions or defects in the acquired image, which cannot be observed in the actual object of examination (37).

They significantly affect the quality of the obtained images by reducing the contrast between the examined objects and can ultimately lead to making an inaccurate or wrongful diagnosis (38).

This is exactly why the methods of reducing artefacts are subject to intense investigation (39, 40, 41, 42, 43).

Application of CBCT in the diagnostics of periapical lesions

For the most part, periapical lesions progress asymptomatically and are usually discovered during routine radiographic examinations (44).

The gold standard in the diagnostics of periapical lesions is the histological examination, but due to its invasive character, the method cannot be regularly applied.

Conventional intraoral and panoramic x-rays present the lesions as 2D images. Although they allow for the visualization and assessment of the pathology in many cases, they rarely provide adequate information regarding its size and extension (45). The use of CBCT enables the acquisition of three-dimensional data, which provides the clinician with valuable information regarding the proximity of the lesion to important anatomical structures, as well as the bone resorption, sclerosis of the adjacent tissue, cortical expansion, internal and external calcification (46).

According to some authors,the buccolingual dimensions of periapical lesions are the largest(47). The lack of information about these dimensions on standard two-dimensional images can lead to underestimation of the clinical condition, selection of an inappropriate treatment method and ultimately to tooth loss.

Tsai et al. (48) compare the diagnostic possibilities of two- and three-dimensional examinations and conclude that 3D images provides more detailed data, regarding the size, location and extension of periapical lesions. They also permit the visualization of lesions with submillimeter dimensions, which cannot be accomplished with two-dimensional techniques. This facilitates the selection of an appropriate treatment method and improves the outcome for the patient (48).

Two-dimensional radiographs allow the differentiation of periapical lesions when there is advanced demineralization of at least 30%, due to the superimposition of the dense cortical plates. As a result, only half of the small and medium lesions are discovered on 2D x-rays (50-55%) (49).

Liang et al. (50) compare the sensitivity of periapical radiographs, panoramic x-rays and CBCT images in the diagnostics od periapical lesions. They find that the least sensitive are panoramic radiographs, followed by periapical and most sensitive are three-dimensional ones.

Multiple studies establish a higher percentage of diagnosed periapical lesions by cone-beam computed tomography, compared to conventional radiography (51, 52, 53, 54, 55). In many cases, after analyzing the data from CBCT, the previously determined treatment plan undergoes some changes (56).

An experimental study by Patel et al. (57) demonstrates the presence of artificially created defects in the cancellous bone with a diameter of 2 mm in 100% of CBCT images, whereas in periapical x-rays this percentage is four times smaller – 24,8%.

As the different types of periapical lesions often have an identical radiographic image, the precise diagnosis on a two-dimensional x-ray is practically impossible.

Guo et al. (58) assess the radiographic diagnosis of CBCT images, comparing it to the histological one of 36 teeth with existing periapical pathology. Based on this, they determine CBCT as a reliable method for diagnostics as they observe a coincidence in 87% of the examined cases (58).

Simon et al. (59) define CBCT as an even more reliable method for differentiation of periapical lesions, owing to the possibility of misinterpretation of the histological examination or a flaw in the surgical protocol when performing a biopsy.

Tyndall et al. (60) also point out the possibilities for distinguishing chronic localized periodontitis from radicular cysts on CBCT images,based on the contents of the lesion – dense granulation tissue in chronic periodontitis and liquidsubstance in the cystic cavity.

Many authors use cone-beam computed tomography as a diagnostic tool for different cystic formations (61, 62, 63, 64, 65).

Stoetzer et al. (66)use the data from CBCT to assess the volume of 71 cysts of the jaws. According to them, the information, obtained by these measurements, is sufficiently accurate and fulfills the requirements for precise preoperative planning, as well as shortening the diagnostic period. Another advantage of the method is the ability to reproduce the measurements non-invasively (66).

The results of previous studies of multiple authors also confirm the high accuracy and reproducibility of the measurements obtainedby CBCT (67, 68, 69).

Venskutonis et al. (70) review the literature on the need for CBCT when assessing periapical pathologies. After analyzing 1200 publications, they conclude that CBCT is a method of choice in the cases when conventional two-dimensional radiographs do not provide sufficient information to ensure an adequate treatment approach. According to them, CBCT has a potential to become a method of choice, especially as the technology progresses and theradiation doses are limited withcontemporary machines (70).

Application of CBCT in the preoperative planning of apical surgery

Apical surgery is one of the treatment modalities for periapical lesions, non-responsive to conservative treatment. The outcome of the surgical intervention is, however, directly related to the correct diagnosis, assessment of the extent of the lesion and the selection of surgical access.

After the incorporation of CBCT in the daily practice, the application of two-dimensional radiographs for planning of endodontic surgery is very limited (71). Reason for this are the multiple advantages of the 3D examination – volumetric visualization of structures without overlapping, distortion or amplification of images (71).

Performing apical surgery in the posterior regions of the mandible is often highly complicated, due to the risk of damaging the inferior alveolar nerve, located in the mandibular canal.Damage to the nerve can lead to several symptoms and functional disturbances that can persist for months and in rare cases may even be irreversible, which significantly decreases the quality of life of the affected patients (72).

The ability to prevent such severe complications is a major factor for enforcing CBCT as a treatment of choice and a standard in preoperative diagnostics for interventions, directly dependent on anatomical variations of the position of this nerve.

Zahedi et al. (73) examine 170 CBCT images of posterior teeth in the mandible, on which they perform some measurements: thickness of the root in medio-distal and buccolingual direction; thickness of the buccal and lingual bone, covering the roots; distance between the apices of the teeth and the mandibular canal; distance between the premolars and the mental foramen.

The authors find that the data regarding the thickness of the roots of the posterior teeth, the density of the buccal cortex and the distance between the roots of the teeth and the mandibular canal can guide the surgeon pre-, as well as intraoperatively (73).

The use of CBCT for preoperative diagnostics and examination of the distances between the mandibular canal and the apices, which are subject to resection, is determined to be much more efficient compared to 2D radiographs (74, 75).

However, in the molar region of the mandiblea higher percentage of failure of the apical surgeryis still observed. Defined as reasons for this are the close proximity of the roots to anatomically important structures such as the mandibular canal and the mandibular foramen, as well as the high density of the buccal cortical plate and the tendency for excessive enlargement of the bony window for the surgical access (74, 76, 77).

Application of CBCT for following up of the healing process

Many authors follow up the healing process after endodontic surgery, comparing the dataobtained from intraoral radiographs and CBCT. As a result they point out the higher sensitivity of CBCT for establishing the presence or lack of bone regeneration in the periapical region and acknowledge the significance of three-dimensional examination in these cases (78, 79, 80).

In their study Gouveia et al. (81) also follow up and compare the healing process after endodontic surgery on two-dimensional radiographs and CBCT. They, however, do not establish significant diagnostic differences between the methods, which they explain with the removal of a portion of the cortical plate while creating the surgical access. According to them, this eliminates one of the factors that decrease the diagnostic value of intraoral radiographs and this effect is maintained up to 8 months after the intervention (81).

Similar are the results of Balasundaram et al. (49).

Intraoperative application of CBCT

Also worth mentioning are the advantages of application of CBCT intraoperatively.

Many authors acknowledge the important role of the method when performing interventions for the removal of foreign bodies, bone fragments, dislocated roots, which can lead to life-threatening complications (82, 83).

4. Conclusion

CBCT imaging surpassed the obstacles of 2D imaging, offering high quality, submillimeter resolution images, with short scanning time and low radiation dose. This makes it a method of choice in cases when conventional two-dimensional radiographs do not provide sufficient information to ensure an adequate treatment approach.

References

[1] Hounsfield GN. Computerized transverse axial scanning (tomography): Part I. Description of system. 1973. Br J Radiol. 1995 Nov;68(815):H166-72.

[2] White SC, Scarfe WC, Schulze RKW, Lurie AG, Douglass JM, Farman AG, Law CS, Levin MD, Sauer RA, Valachovic RW, Zeller GG, Goske MJ, The Image Gently in Dentistry Campaign Promotion of Responsible Use of Maxillofacial Radiology in Dentistry for Children, Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology (2014), doi: 10.1016/j.oooo.2014.06.001.

[3] Farman AG. Image guidance: the present future of dental care. Practical Procedures & Aesthetic Dentistry. 2006; 18(6):342–344.

[4] Farman AG, Levato CM, Scarfe WC. A primer on cone beam computed tomography. Inside Dentistry. 2007; 3:90–92.

[5] Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. Journal of the Canadian Dental Association. 2006; 72(1):75–80.

[6] Scarfe WC, Farman AG. Cone beam computed tomography: a paradigm shift for clinical dentistry. Australasian Dental Practice. 2007:102–110.

[7] Hayakawa Y, Sano T, Sukovic P, Scarfe WC, Farman AG. Cone beam computed tomography: a paradigm shift for clinical dentistry. Nippon Dental Review. 2005; 65:125–132.

[8] Patel S, Durack C, Abella F, Lemberg K et al. Cone Beam Computed Tomography in Endodontics- A review. International Endodontic Journal. 2014; 48(1).

[9] AAE & AAOMR. Use of cone-beam computed tomography in endodontics Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial

Radiology. Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2011; 111:234-237.

[10] Meena N, Kowsky RD, Applications of Cone Beam Computed Tomography in Endodontics: A Review. Dentistry. 2014; 4:242.

[11] Durack C, Patel S. Cone beam computed tomography in endodontics. Braz Dent J. 2012;23(3):179-91.

[12] Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dental Clinics of North America. 2008; 52, 707–30.

[13] Iplikçioğlu H, Akça K, Cehreli MC. The use of computerized tomography for diagnosis and treatment planning in implant dentistry. J Oral Implantol. 2002;28(1):29-36.

[14] Sukovic P. Cone beam computed tomography in craniofacial imaging. OrthodCraniofac Res. 2003;6Suppl 1:31-6; discussion 179-82. doi: 10.1034/j.1600-0544.2003.259.x.

[15] Quereshy FA, Savell TA, Palomo JM. Applications of cone beam computed tomography in the practice of oral and maxillofacial surgery. J Oral Maxillofac Surg. 2008 Apr;66(4):791-6.

[16] Worthington P, Rubenstein J, Hatcher DC. The role of cone-beam computed tomography in the planning and placement of implants. J Am Dent Assoc. 2010 Oct;141Suppl 3:19S-24S.

[17] Arisan V, Karabuda ZC, Avsever H, Özdemir T. Conventional multi-slice computed tomography (CT) and cone-beam CT (CBCT) for computer-assisted implant placement. Part I: relationship of radiographic gray density and implant stability. Clin Implant Dent Relat Res. 2013 Dec;15(6):893-906.

[18] Cassetta M, Stefanelli LV, Pacifici A, Pacifici L, Barbato E. How accurate is CBCT in measuring bone density? A comparative CBCT-CT in vitro study. Clin Implant Dent Relat Res. 2014 Aug;16(4):471-8.

[19] Patel S, Durack C, Abella F, Lemberg K et al. European Society of Endodontology position statement: The use of CBCT in Endodontics. International Endodontic Journal. 2014; 47(6).

[20] Gomes LR, Gomes MR, Gonçalves JR, Ruellas ACO, Wolford LM, Paniagua B, Benavides E, Cevidanes LHS, CBCT versus MSCT-Based Models on Assessing Condylar Morphology, Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology (2015), doi: 10.1016/ j.oooo.2015.10.015.

[21] Razavi T, Palmer RM, Davies J, Wilson R, Palmer PJ. Accuracy of measuring the cortical bone thickness adjacent to dental implants using cone beam computed tomography. Clin Oral Implants Res. 2010 Jul;21(7):718-25.

[22] Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3cbct devices for oral and maxillofacial radiology: Cbmercuray, newtom 3g and i-cat. DentomaxillofacRadiol 2006;35(4):219-226.

[23] Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two extraoral direct digital imaging devices: Newtom cone beam ct and orthophos plus ds panoramic unit. DentomaxillofacRadiol 2003;32(4):229-234.

[24] Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E, Samuelson DB, Scheske MJ. Effective dose of dental CBCT-a meta analysis of published data and additional data for nine CBCT units. DentomaxillofacRadiol. 2015;44(1):20140197.

[25] Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Pathol Oral RadiolEndod 2003;96(4):508-513.

[26] Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. DentomaxillofacRadiol. 2004 Mar;33(2):83-86.

[27] Gutierrez D, Monnin P, Valley JF, Verdun FR. A strategy to qualify the performance of radiographic monitors. RadiatProtDosimetry. 2005;114(1-3):192-7.

[28] Palomo L, Palomo JM. Cone beam ct for diagnosis and treatment planning in trauma cases. Dent Clin North Am 2009;53(4):717-727, vi-vii.

[29] Venkatesh E, Elluru SV. Cone beam computed tomography: basics and applications in dentistry. J IstanbUnivFac Dent. 2017 Dec 2;51(3 Suppl 1):S102-S121. doi: 10.17096/jiufd.00289.

[30] Dula K, Benic GI, Bornstein M, Dagassan-Berndt D, Filippi A, Hicklin S, Kissling-Jeger F, Luebbers HT, Sculean A, Sequeira-Byron P, Walter C, Zehnder M. SADMFR Guidelines for the Use of Cone-Beam Computed Tomography/Digital Volume Tomography Swiss Dent J. 2015;125(9):945-53.

[31] Vandenberghe B, Luchsinger S, Hostens J, Dhoore E, Jacobs R; SEDENTEXCT Project Consortium The influence of exposure parameters on jawbone model accuracy using cone beam CT and multislice CT. DentomaxillofacRadiol. 2012 Sep;41(6):466-74.

[32] Estrela C, Bueno MR, Azevedo BC, Azevedo JR, Pécora JD. A new periapical index based on cone beam computed tomography. Journal of Endodontics. 2008; 34(11):1325–1331.

[33] Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Silveira AM, et al. Accuracy of linear measurements from imaging plate and lateral cephalometric images derived from cone-beam computed tomography. Am J OrthodDentofacialOrthop. 2007; 132: 550-560.

[34] Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral RadiolEndod. 2008 Jul;106(1):106-14.

[35] Abramovitch K, Rice DD. Basic principles of cone beam computed tomography. Dent Clin North Am. 2014 Jul;58(3):463-84. doi: 10.1016/j.cden.2014.03.002.

[36] Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. DentomaxillofacRadiol. 2015;44(1):20140224.

[37] Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a review. DentomaxillofacRadiol. 2011; 40:265-73.

[38] Helvacioglu-Yigit D, DemirturkKocasarac H, Bechara B, Noujeim M. Evaluation and Reduction of Artifacts Generated by 4 Different Root-end Filling Materials by Using Multiple Cone-beam Computed Tomography Imaging Settings. J Endod. 2016 Feb;42(2):307-14.
[39] Schulze RK, Berndt D, d'HoedtB.On cone-beam computed tomography artefacts induced by titanium implants. Clin Oral Implants Res. 2010; 21:100-7.
[40] Pauwels R, Stamatakis H, Bosmans H, Bogaerts R, Jacobs R, Horner K, Tsiklakis K; SEDENTEXCT Project Consortium. Quantification of metal artifacts on cone beam computed tomography images. Clin Oral Implants Res. 2013 Aug; 24Suppl A100:94-9.
[41] Spin-Neto R, Mudrak J, Matzen LH, Christensen J, Gotfredsen E, Wenzel A. Cone beam CT image artefacts related to head motion simulated by a robot skull: visual characteristics and impact on image quality. DentomaxillofacRadiol. 2013;42(2):32310645.
[42] Wang Q, Li L, Zhang L, Chen Z, Kang K. A novel metal artifact reducing method for cone-beam CT based on three approximately orthogonal projections. Phys Med Biol. 2013 Jan 7;58(1):1-17.
[43] Parsa A, Ibrahim N, Hassan B, Syriopoulos K, van der Stelt P. Assessment of metal artefact reduction around dental titanium implants in cone beam CT. DentomaxillofacRadiol. 2014;43(7):20140019.
[44] Karamifar K, Tondari A, Saghiri MA. Endodontic Periapical Lesion: An Overview on the Etiology, Diagnosis and Current Treatment Modalities. EurEndod J. 2020 Jul 14;5(2):54-67.
[45] Santos O, Pinhiero LR, Umetsubo OS, Cavalcanti MG. CBCT-based evaluation of integrity of cortical sinus close to periapical lesions. Braz Oral Res. 2015; 29.
[46] Kaneda T, Minami M, Kurabayashi T. Benign odontogenic tumours of the mandible and maxilla. Neuroimaging Clin N Am 2003;13:495–507.
[47] Schloss T, Sonntag D, Kohli MR, Setzer FC. A Comparison of 2- and 3-dimensional Healing Assessment after Endodontic Surgery Using Cone-beam Computed Tomographic Volumes or Periapical Radiographs. J Endod. 2017 Jul;43(7):1072-1079.
[48] Tsai P, Torabinejad M, Rice D, Azevedo B. Accuracy of cone-beam computed tomography and periapical radiography in detecting small periapical lesions. J Endod. 2012; 38(7):965–70.
[49] Balasundaram A, Shah P, Hoen MM, Wheater MA, Bringas JS, Gartner A, Geist JR. Comparison of cone-beam computed tomography and periapical radiography in predicting treatment decision for periapical lesions: a clinical study. Int J Dent. 2012;2012:920815. doi: 10.1155/2012/920815.
[50] Liang YH, Li G, Shemesh H, et al. The association between complete absence of posttreatment periapical lesion and quality of root canal filling. Clin Oral Invest. 2012; 16:1619-26.
[51] Campello AF, Gonçalves LS, Guedes FR, Marques FV. Cone-beam computed tomography versus digital periapical radiography in the detection of artificially created periapical lesions: A pilot study of the diagnostic accuracy of endodontists using both techniques. Imaging Sci Dent. 2017 Mar;47(1):25-31.
[52] Ramis-Alario A, Tarazona-Alvarez B, Cervera-Ballester J, Soto-Peñaloza D, Peñarrocha-Diago M, Peñarrocha-Oltra D, Peñarrocha-Diago M. Comparison of diagnostic accuracy between periapical and panoramic radiographs and cone beam computed tomography in measuring the periapical area of teeth scheduled for periapical surgery. A cross-sectional study. J ClinExp Dent. 2019 Aug 1;11(8):e732-e738.
[53] Estrela C, Reis Bueno M, Alencar AHG et al. Method to evaluate inflammatory root resorption by using cone beam computed tomography. Journal of Endodontics 35. 2009; 1491–7.
[54] Abella F, Patel S, Durán-Sindreu F, Mercadé M, Bueno R, et al. An evaluation of the periapical status of teeth with necrotic pulps using periapical radiography and cone-beam computed tomography. IntEndod J. 2014; 47: 387-396.
[55] Abella F, Patel S, Duran-Sindreu F, Mercadé M, Bueno R, et al. Evaluating the Periapical Status of Teeth with Irreversible Pulpitis by Using Cone-beam Computed Tomography Scanning and Periapical Radiographs. J Endod. 2012; 38: 1588-1591.
[56] Sheth K, Kapoor S, Daveshwar S. Comparison of Cone-beam Computed Tomography and Periapical Radiography to Determine the Proximity of Periapical Lesions to Anatomical Structures in Premaxillary Area prior to Surgical Endodontics: A Clinical Study. Int J ClinPediatr Dent. 2020 Jul-Aug;13(4):322-326.
[57] Patel S, Dawood A, Mannocci F, Wilson R, Pitt Ford T. Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. IntEndod J. 2009 Jun;42(6):507-15.
[58] Guo J, Simon JH, Sedghizadeh P, Soliman ON, Chapman T, Enciso R Evaluation of the reliability and accuracy of using cone-beam computed tomography for diagnosing periapical cysts from granulomas. J Endod. 2013 Dec;39(12):1485-90.
[59] Simon JH, Enciso R, Malfaz JM, et al. Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy. J Endod 2006; 32:833–7.
[60] Tyndall DA, Rathore S. Cone-beam CT diagnostic applications: caries, periodontal bone assessment, and endodontic applications. Dental Clinics of North America. 2008; 52(4):825–841.
[61] Wang X, Wei L, Li B, Li J, Li W, Wang F, Cheng Y. Clinical and Cone-Beam Computed Tomography Features of Orthokeratinized Odontogenic Cysts and Odontogenic Keratocysts in the Mandible. J Oral MaxillofacSurg. 2021 Jun;79(6):1255-1261.
[62] Bonavolontà P, Dell'AversanaOrabona G, Friscia M, Sani L, Abbate V, Iaconetta G, Califano L. Surgical Management of Large Odontogenic Cysts of the Mandible. J CraniofacSurg. 2019 Oct;30(7):e658-e661.
[63] Yilmaz B, Yalcin ED. Retrospective evaluation of cone-beam computed tomography findings of odontogenic

cysts in children and adolescents. Niger J ClinPract. 2021 Jan;24(1):93-99.

[64] Derindağ G, Miloğlu Ö, Sümbüllü MA. Buccal bifurcation cyst (paradental cyst) defined by ultrasonography and cone-beam computed tomography. Oral Radiol. 2019 Sep;35(3):315-320.

[65] Scarfe WC, Toghyani S, Azevedo B. Imaging of Benign Odontogenic Lesions. RadiolClinNorth Am. 2018 Jan;56(1):45-62.

[66] Stoetzer M, Nickel F, Rana M, Lemound J, Wenzel D, von See C, Gellrich NC. Advances in assessing the volume of odontogenic cysts and tumors in the mandible: a retrospective clinical trial. Head Face Med. 2013 Apr 20;9:14.

[67] Damstra J, Fourie Z, Huddleston Slater JJ, Ren Y. Accuracy of linear measurements from cone-beam computed tomography-derived surface models of different voxel sizes. Am J OrthodDentofacialOrthop. 2010 Jan;137(1):16.e1-6; discussion 16-7.

[68] Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL, Covell DA Jr. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. Am J OrthodDentofacialOrthop. 2011 Nov;140(5):734-44.

[69] Wood R, Sun Z, Chaudhry J, Tee BC, Kim DG, Leblebicioglu B, England G. Factors affecting the accuracy of buccal alveolar bone height measurements from cone-beam computed tomography images. Am J OrthodDentofacialOrthop. 2013 Mar;143(3):353-63.

[70] Venskutonis T, Plotino G, Juodzbalys G, Mickevičienė L. The importance of cone-beam computed tomography in the management of endodontic problems: a review of the literature. J Endod. 2014 Dec;40(12):1895-901

[71] Chandra A, Tikku AP, Verma P, Ansari RBA. Applications of CBCT in Surgical Endodontics A Case Series. ARRB, , 2017; 20(4): 1-6.

[72] Renton T, Yilmaz Z. Profiling of patients presenting with posttraumatic neuropathy of the trigeminal nerve. J Orofac Pain. 2011 Fall;25(4):333-44.

[73] Zahedi S, Mostafavi M, Lotfirikan N. Anatomic Study of Mandibular Posterior Teeth Using Cone-beam Computed Tomography for Endodontic Surgery. J Endod. 2018; 44(5):738-743.

[74] Kim TS, Caruso JM, Christensen H, Torabinejad M. A comparison of cone-beam computed tomography and direct measurement in the examination of the mandibular canal and adjacent structures. J Endod. 2010; 36: 1191-1194.

[75] Angelopoulos C, Thomas S, Hechler S, Parissis N, Hlavacek M. Comparison Between Digital Panoramic Radiography and Cone-Beam Computed Tomography for the Identification of the Mandibular Canal as Part of Presurgical Dental Implant Assessment. J Oral Maxillofac Surg. 2008; 66: 2130-2135.

[76] Von Arx T, Hanni S, Jensen SS. Correlation of bone defect dimensions with healing outcome one year after apical surgery. J Endod. 2007; 33:1044-8.

[77] Song M, Kim SG, Lee SJ, et al. Prognostic factors of clinical outcomes in endodontic microsurgery: a prospective study. J Endod. 2013; 39:1491-7.

[78] Tanomaru-FIlho M, Jorge ÉG, Guerreiro-Tanomaru JM, Reis JM, Spin-Neto R, Gonçalves M Two- and tridimensional analysis of periapical repair after endodontic surgery. Clin Oral Investig. 2015 Jan;19(1):17-25.

[79] von Arx T, Janner SF, Hänni S, Bornstein MM. Agreement between 2D and 3D radiographic outcome assessment one year after periapical surgery. IntEndod J. 2016 Oct;49(10):915-25.

[80] Bornstein MM, Seiffert C, Maestre-Ferrín L, Fodich I, Jacobs R, Buser D, von Arx T. An Analysis of Frequency, Morphology, and Locations of Maxillary Sinus Septa Using Cone Beam Computed Tomography. Int J Oral Maxillofac Implants. 2015 Oct 16. doi: 10.11607/jomi.4188.

[81] Gouveia Jorge EG, Mario Tanomaru-Filho M, Tanomaru JMG, Nunes Reis JMS, Spin-Neto R, Gonçalves M. Periapical Repair Following Endodontic Surgery: Two- and Three-Dimensional Imaging Evaluation Methods. Brazilian Dental Journal. 2015; 26(1): 69-74.

[82] Bensing JR, McElroy KE, Perez L Jr. Retrieval of Displaced Third Molar Into the Sublingual Space Using 3-Dimensional Navigation Assistance. J Oral Maxillofac Surg. 2021 Mar; 79(3):537.e1-537.e7.

[83] Shruthi TM, Shetty A, Imran M, Akash KS, Ahmed F, Ahmed N. Removal of Displaced Maxillary Third Molar Using Modified Gillie's Temporal Approach. Ann Maxillofac Surg. 2020 Jan-Jun;10(1):210-212.

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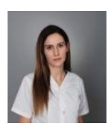

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