 DOI: 10.21608/adjalexu.2023.169349.1322

ASSESSMENT OF CONE BEAM COMPUTED TOMOGRAPHY SCANS REFERRAL REASONS AND ITS IMPACT ON MODIFYING TREATMENT PLAN IN ENDODONTICS

Shereen F.Elsaid[1*] BDS, Hassan M. Aboulkheir[2] PhD,
Rania A. Fahmy[3] PhD, Salma M. Genena[4] PhD

ABSTRACT

BACKGROUND: Radiographs taken intra-orally are essential for planning a diagnosis; however the resulting two-dimensional images require thorough interpretation. Cone beam computed Tomographic (CBCT) imaging offers a more precise, three-dimensional image that could aid in proper diagnosis and treatment planning in endodontic and endo-periodontal cases.

OBJECTIVES: Assessment of CBCT referral reasons to private radiology centers, and its impact on modifying treatment plan in endodontic and endo-periodontal related cases.

MATERIALS AND METHODS: This cross-sectional study comprised a total of 131 patients, who visited private radiology centers in Alexandria, seeking CBCT scans, from July 2021to June 2022: All scans were inspected for assessing referral reasons; referring dentists were asked about their reason for CBCT acquisition, and its effect on their diagnosis and treatment plan. Assessed cases were categorized into either a group of teeth with solitary endodontic-related problem or teeth with an endodontic-periodontal - related problem.

RESULTS: The number of teeth found with endo-periodontal radiographic problems in the CBCT scans was significantly lower than solitary endodontic cases (n=14, 8.4%,n=152, 91.5% respectively). Also, a significant difference was detected between those referred cases with endodontic-Periodontal lesions that were not previously root canal treated and those endodontic related cases that received earlier endodontic treatment (p=0.004*) , CBCT had a positive effect on changing the endodontists' diagnosis and treatment plan, especially in endodontic-periodontal cases (p<0.01*).

CONCLUSION: CBCT is considered crucial for detection and proper diagnosis of endo-perio lesions. For all endodontic cases with missed canals, calcified canals and inflammatory resorptive defects, CBCT is deemed necessary.

KEYWORDS: Cone Beam Computed Tomography, Endodontic-Periodontal Lesion, Endodontic Lesion, Referral Reasons, Treatment Planning.

1-BDS, Resident of Oral Medicine, Periodontology, ,Oral diagnosis and Oral Radiology Department, Faculty of Dentistry, Alexandria University, Egypt.
2-Professor of Oral Medicine, Periodontology, Oral Diagnosis and Radiology Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
3-Assisstant Professor of Oral Medicine, Periodontology, Oral Diagnosis and Radiology Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.
4-Lecturer of Endodontic, Faculty of Dentistry, Alexandria University, Alexandria, Egypt.

Corresponding author:
Shereen16082016@gmail.com

INTRODUCTION

The integration of both clinical inspection and diagnostic imaging forms the basis for endodontic diagnosis, decision- making, treatment planning, and outcome assessment (1).

Even though periapical radiographs continue to be the imaging method of choice in endodontics, a significant leap has occurred in the use of CBCT in recent years (1, 2) rendering it a predicting diagnostic tool in endodontics (1). This is due to its ability to portray the intricate anatomy of root canal systems (3), root resorptive defects whether internal or external (4). Furthermore, it aids in detection and locating separated instruments, missed canals and other foreign body materials, prior to retreatment (1, 5). Thus, in difficult endodontic instances where standard radiography is insufficient, CBCT may be helpful (6, 7), as its 3D views can be used to convey extra information (8, 9).

Moreover, CBCT may provide an accurate analysis of periodontal defect morphology, compared with conventional two-dimensional radiographic measurement (10, 11). This includes identifying and determining the location and size of apical

periodontitis, assessing trauma including; root and alveolar bone fracture (1, 5); information obtained regarding the lamina dura, periodontal ligament tissue, and periapical tissue (10). The literature has confirmed that morphometric analysis of periodontal diseases by CBCT was as precise as direct measurements using a periodontal probe (12).

Endodontic-periodontal lesions (EPLs) are clinical conditions affecting the pulp and periodontium.The details of the lesions and adjacent structures can be revealed via CBCT, such as the relation to anatomic structures (maxillary sinus, mental foramen and the mandibular canal),and also assessment of postoperative treatment of EPLs such as buccal bone regeneration (13,14).

In 2017, a new classification of EPLs was developed, where the authors in the consensus report of workgroup 2 of the 2017 world workshop divided EPLs into two groups: EPLs with root damage and others without root damage (in periodontitis patient or non-periodontitis patient) (15). This new concept has changed the clinical approach, because the primary source endodontic or periodontal is not relevant to treatment (16). The diagnosis of an EPL must answer whether to preserve/remove the tooth in question (14).

However, CBCT higher effective dosage of ionizing radiation continues to be one of the key drawbacks compared to conventional periapical radiographs (17,18). The official instructions of the American Associations of Endodontists (AAE) and the European Society of End odontology (ESE) joint statement emphasize the importance of appropriate CBCT use, as part of clinical practice (3,5).However, it should be used selectively, always weighing the advantages and drawbacks of subjecting the patient to ionizing radiation (5).

The joint statement also suggested using intra-oral radiography for initial evaluation (19). When the information produced by intra-oral radiography is conflicting with clinical information, CBCT is then recommended (19). A small field of a view (FOV), small voxel sizes, low MA setting (depending on the size of patient), short exposure time, and pulsed exposure mode of acquisition are recommendations to be considered (19).

Therefore, the purpose of the study was to ascertain whether CBCT imaging can deliver more useful information that can be used to improve endodontic treatment planning.

The null hypothesis of this research was that CBCT would have no impact on diagnosis and treatment planning of endodontic and EPLs.

MATERIALS AND METHODS

Study Population

This analytical cross-sectional study was carried out on 5×5 scan images of teeth from 131 patients referred from endodontic clinics to private CBCT radiology centers in Alexandria, from 01/07/2021 to 30/6/2022.

Inclusion and Exclusion Criteria

CBCT images of adult patients 18-60 years old seeking endodontic treatment were selected. Scans with small field of view (FOV), 5 ×5cm were included; whereas large or medium FOV were not clear for radiographic interpretation, thus were excluded from the study.

Ethical Approval

This research study was carried out in compliance with the principles of the modified Helsiniki Declaration Guidelines for Human Research (20) and approved by the Ethics Committee of the Faculty of Dentistry, Alexandria University. (IRB No: 00010556 – IORG: 0008839). The purpose and nature of the study were explained to the patients, and their informed consent was obtained.

Sample size estimation

Based on the following assumptions the sample size was estimated: a confidence level of=95% and study power=80%. The prevalence of the need for cone beam computed tomography in diagnosis and treatment planning of endodontic cases was found to be 62.2% (18). The minimum required sample was 131.

Data collection and Imaging Protocol

All CBCT scans were taken at a three different radiology centers in Alexandria which have vatech-PAX-i3D machine (Vatech, Vatech s&c Co., Ltd South Korea). Depending on the primary diagnostic purpose, the protocol of imaging was chosen. The imaging protocol had the following exposure parameters: current setting was determined in an automatic way by the x-ray unit and the software, physically fitting the patients and varied from 3mA to 7mA, while voltage was fixed at 90 kVp.

Total time of examination was 17sec with an exposure time of 9sec, as x-ray unit uses a pulsed exposure. Isotropic voxels with a size of 0.08mm for 50×50mm was used. Image reconstruction was performed in axial, sagittal and coronal views (5). The data was gathered and teeth categorized into an Excel sheet based on the presence of either solitary Endodontic or Endodontic –periodontal lesion radiographic findings, following the most recent Endodontic-Periodontal classification (15).

Image evaluation

The CBCT images were evaluated; zoom, brightness and contrast tools were available during image evaluation. All images were viewed on a 15.6 inch FHD LED monitor with a resolution of 1920×1080. By carefully scrolling downward across the image, the on-demand tool bar was used to examine the teeth between the pulp chamber's and apex, to determine the number of roots, the number of root canals and the structure of the canal in the axial tomographic slices.

The center of view of the rebuilt slices was changed by selecting the image, and moving the

cursor in three orthogonal planes Tomographic slices of 1mm or even less (0.5mm) in the axial, coronal and sagittal planes were produced. Figure (1) Axial and cross-sectional images (coronal and sagittal images) were transmitted to a personal computer in the digital imaging and communications in medicine (DICOM) format into the on-Demand 3D™ version 1.0.10.4304 software (by cyber med Inc.) and reconstructed into multi-planner images that have been rebuilt using the dicom viewer. These views were used to examine the root canal systems. Figure (1)

The Following anatomic observations were inspected: Presence of (a) endodontic related problems: Root resorption (external, internal and cervical), Dento-Alveolar trauma (vertical root fracture, alveolar fracture and tissue displacement), root canal system abnormalities (anomalies, accessory canals and root curvature), periapical pathology (endodontic, non-endodontic or anatomical superimposition), post endodontic treatment complications (over-extension, separated root canal instrument, calcified canals, perforation, short obturation, missed canal) and (b) EPLs (15). The data was gathered and categorized into two groups (Endodontic or Endo-perio) based on the findings of CBCT images, and Group I (endodontic-related) further subdivided according to endodontic problem detected. Group II (endo-perio related problem) was subcategorized into either endo-perio with root damage or endo-perio without root damage.

By returning to the endodontist who referred the patients and inquiring about how CBCT has affected their diagnosis and course of therapy, all data were gathered and processed for statistical analysis. Figure (2)

Statistical Analysis

Data with categories were presented as frequencies and percentages, comparative analysis and descriptive statistics were analyzed to present the sample's standard features. Chi-square test to compare categorical variables across various groupings, and Fisher's exact tests were used for correction of chi-square when more than 20% of the cells' expected count was less than 5. Crude and Multivariable two-level mixed effects models of logistic regression were built to identify the effect of tooth-level (i.e., tooth type and previous endodontic therapy) characteristics of referral causes (i.e., Endodontic lesion, Endodontic-periodontal lesion). In addition, Crude and multivariable two-level mixed effects logistic regression models were built to identify the effect of referral reason on variation in diagnosis outcomes. The computer was fed with data analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp.) .Qualitative data were described using number and percentage.

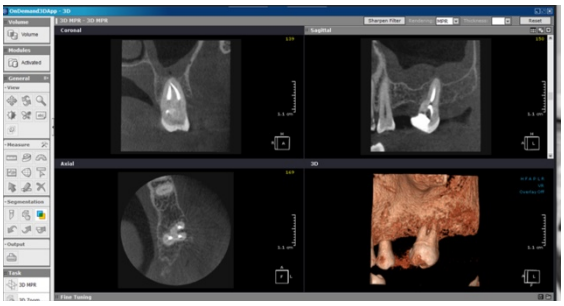

Figure 1: Axial, coronal, sagittal &3D view of upper left 7 with Endo-periodontal lesion.

Assessment Sheet of Endo-periodontal lesions in CBCT

Patient ID: Case #:

Patient Gender: Patient Age:

Region of interest (ROI): location of Endo/perio. lesion:

A) Endodontic Lesions:

1	Root resorption		
2	Dento-Alveolar Trauma		
3	R.C. System Abnormalities		
4	Periapical pathology		
5	Pre-surgical case planning.		
6	Post -endodontic Treatment Complications		
7	Others		

- **Root Resorption:** (External/ Internal/ Cervical).
- **Dento-Alveolar Trauma:**(Vert. Root Fracture/ Alveolar fracture/ T. Displacement.)
- **Root Canal System Abnormalities**: (Anomalies/ Accessory C./ Root curvature).
- **Periapical pathology:** Endodontic / Non-endodontic/anatomical superimposition).
- **Pre-surgical case planning:** (Exact location of Root apex/ Proximity to anatomical structure/Implant assessment).
- **Post-endodontic Treatment Complications:**(Overextension/ Separated R.C. Instrument/Calcified canals / Perforation).

B) Endo- periodontal Lesions:

With Root Damage		
Perforation	Root Resorption	Vertical Root Fracture

Without Root Damage	
Periodontitis Patient	
Non-Periodontitis Patient	

C) Referral Reasons for CBCT Scanning:

Referral Reasons for CBCT Scanning	Patients	Teeth
1. Surgical treatment planning		
2. Endodontic diagnosis-nonsurgical treatment planning		
3. Endodontic diagnosis-assessment of procedural complications		
4. Endodontic diagnosis-possible detection of vertical root fracture		
5. Evaluation of inflammatory resorptive defects		
6. Preoperative anatomy assessment		
Total		

Figure 2: Assessment sheet of Endo-periodontal lesion in CBCT.

RESULTS

A total of 131 patients contributing 137 teeth were referred to CBCT scans for endodontic purposes, with a slight predominance of female patients (90/131; 68.70%) compared to males (41/131;31.30%).The average age of the patients was 26.9, with a minimum age of 18 and a maximum of 60 years old.

In Table (2) the causes for CBCT referrals for all teeth (some teeth displayed more than one endo/endo-perio cause) were categorized to either solely endodontic cases (n=152, 91.5%) or endo-perio cases (n=14, 8.4%). The majority of referral was found to be endodonticlly related. (n=152, 91.5%) and was formulated as follows: root resorption (n=4, 2.4%), dento-alveolar trauma (n=6, 3.6%), root canal system abnormalities (n=22, 13.3%), periapical pathology (n=50, 30.1%), pre-operative tracing of canals (n=11, 6.6%), post–endodontic treatment complications (n=59, 35.5%). While referral for endo-perio problems were only

detected in 8.4% (n=14), and it was in non–periodontitis patients and without root damage cases according to the new periodontitis classification (15). As we found some teeth with more than one reason for referral so the total findings were 166.

In Table (3) most of the teeth found with endodontic- related problems were previously endodontically treated (n=76/137, 61.8%), whereas teeth with EPLs did not receive previous root canal treatment (n=11/14, 78.6%); p<0.004, Table (3). Most cases inspected with endodontic related problems showed no post CBCT changes in diagnosis related to the original endodontists' diagnosis (n=111/123, 90.2%); but teeth referred with EPLs exhibited a change in diagnosis, following inspection of the CBCT images (n=10, 71.4%) (p<0.001).

In Table (3) according to type of teeth (incisors, canines and posterior teeth); posterior teeth were the significantly most prevalent for CBCT referral (n=118, 86.1%).

Inter and Intra-examiner Reliability Results

Calibration on the method of assessment was done for the three observers all Ph.D. graduates; an oral radiologist, an endodontist, and a periodontist. Intra-examiner reliability was checked by re-evaluating 10% of the scans after two weeks with chi square test for association among various categories (statistically significant at P≤0.05) and the percentage of agreement was 92.3%. Inter-examiner reliability was calculated; the chi square test was computed to be 0.001 (no significant difference) revealing a very good percentage of agreement.

Table (2): Assessment of Endodontic-related problem &Endo-periodontal lesions in CBCT

Endodontic-related problem	Number	Percentage
Root resorption	4	2.4
Dento-Alveolar Trauma	6	3.6
R.C. System Abnormalities	22	13.3
Anomalies	5	22.7
Accessory canals	2	9.1
Root Curvature	15	68.2
Periapical pathology	50	30.1
Pre-operative tracing of canals	11	6.6
Post -endodontic Treatment Complications	59	35.5
Missed canals	9	15.3
Over extension	10	16.9
Separated instruments	20	33.9
Calcified canals	3	5.1
Perforation	5	8.5
Short obturation	12	20.3
Endo-perio lesions		
With Root Damage	0	0
Without Root Damage	14	8.4
Total	166	

Table (3): The frequency distribution of several predictors at tooth level such as tooth type, endodontic therapy, lesion and change in diagnosis

Categories	Reason For Referral						P-Value
	Endodontic		Endo-perio		Total		
	No.	%	No.	%	No.	%	
Tooth Type							
Anterior	16	13	3	21.4	19	13.9	FEp=0.413
Posterior	107	87	11	78.6	118	86.1	
Endodontic Therapy							
No	47	38.2	11	78.6	58	42.3	0.004*
Yes	76	61.8	3	21.4	79	57.7	
Change in Diagnosis							
No	111	90.2	4	28.6	115	83.9	FEp<0.001*
Yes	12	9.8	10	71.4	22	16.1	

DISCUSSION

The execution of CBCT as a regimen scanning technique in different dental fields has increased significantly over the past ten years (21,22). Its use for hard tissue assessment is well established, and numerous investigations have shown its accuracy's (23,24).CBCT has a lot of attractive prospective benefits for treating dento- alveolar disease as endodontics and periodontics (11) and CBCT images were found to be statistically superior to 2D modalities in terms of diagnostic precision, sensitivity and both positive and negative predictive values (11, 13, 25).

The current study primary goal was to inspect the referred cases from endodontists for presence of endodontic related problems or endo-periodontal lesions. This objective was supported by the studies that demonstrated the actual need for CBCT referral and its impact on planning for diagnosis and treatment (2, 5, 18). Our current work showed that in 71.4% of EPLs referred cases there was a change in diagnosis and course of treatment (either for tooth hemi sectioning or referral for tooth extraction) but in endodontic- related problem cases only 9.8% change in diagnosis and treatment planning was documented. In addition, in 2008, Tyndall and Rathore (11) examined CBCT applications in dentistry. They focused on

endodontic and periodontal lesions and stated that CBCT was a promising technology for bone topography and lesion framework visualization, but was not accurate in bone height assessment as the restoration in the teeth may obscure the vision of alveolar crest.

In the current research, the most frequent reason for referral in endodontic cases was post-operative complications (n=59, 35.5%) [separated instrument (n=20), over extension (n=10), calcified canals (n=3), perforation (n=5), missed canals (n=9), short obturation (n=11)].The second most frequent reason was to assess periapical pathology) (n=50,30.1%), These findings were in agreement with the result in 2022 by Boquete-Castro et al (26) ,who reported that CBCT was recommended to accurately assess the results of endodontic treatment and post-treatment complications, and was capable of detecting periapical radiolucent areas before they were obvious on conventional radiographs and revealing the presence of previously undiagnosed pathology; whereas in conventional radiographs, the lesions can only be detected when lingual and buccal cortical bone are involved, producing distinct bone loss (30%-50%) and area of rarefaction (26). Thus CBCT is crucial in endodontics, as supported by the study in 2012 by Durak and Patel (27).which showed that early detection of apical periodontitis improves endodontic prognosis, with CBCT being a valuable tool.

The most frequent referral reason in endo-perio cases was pre-surgical assessment of EPLs in non- periodontitis patient without root damage. This is in accordance with the results in 2014 by Mota de Almeida et al (28), who listed pre-surgical aid as the second most frequent cause of referral. Furthermore, several studies confirmed CBCT's significance in assessing pre-surgical cases (29,30). As in surgical fields, especially in lateral lesions; to provide the clinician with more information, a three- dimensional view is necessary to access the lesions with little invasion (5).It also helps to raise the level of diagnostic assurance of endodontists to reach the best treatment plan, as it was noted in 2020 by Wanzeler et al (19). Furthermore, extraction as a treatment option significantly increased among endodontists after CBCT analysis, as reported in 2017 by Rodriquez et al (2).

In 12 cases of the current research that were referred with endodontic related problems (missed canals & calcified canals) ,CBCT interpretations were needed to set a final diagnosis, this is in agreement with Chogle et al, who reported the ability of CBCT to recognize missed or calcified canals and complex morphology (18,31), To get the ultimate diagnosis, CBCT interpretation was needed, as the initial diagnosis was modified as a result of the CBCT interpretation; in 9.8% of the endodontic cases, there was a change in diagnosis, which is in agreement with Kakavetsos et al, who reported in 2020 that the surgical and conventional therapy plans both underwent notable alterations in the course of treatment, such as anatomy that was missing and later confirmed in CBCT, most frequently, MB2 canal in upper molars (5). Furthermore, for 10 cases of our current research that were referred with endo-periodontal lesions, CBCT interpretation resulted in modification of initial diagnosis, which corresponds to percentage of 71.4% of all endo-periodontal cases. By using CBCT imaging, it would be more helpful for clinicians to check out the bone resorption of the involved teeth in a three -dimensional view (32). In only 16.1% of the whole cases, there was a change in the initial diagnosis. This frequency is consistent with the rate reported by Kakavetsos VD et al, who stated that 17.3% of the cases required CBCT examination to reach a definitive diagnosis (5). Based on these findings, we highly advise clinicians when determining the severity of the cases, to make sure they follow precise criteria, and only refer patients for CBCT scans, when they are confident that the treatment strategy will change (5).

Practitioners need to be aware that CBCT employs ionizing radiation, so it should be handled with awareness, not as standard procedure. Most cases should be restricted to conventional radiography, when needed following the current guidelines recommended by ESE AAE/AAOOMR joint position statement (33, 34).

Qualification and experience of the endodontist have a significant relationship in managing cases with obvious endodontic difficulties (2,18,35), it has been found that compared to general practitioners, endodontists change their treatment plan in fewer situations (36).A second explanation may be the presence/absence of CBCT imaging system in the clinic. This could have an impact on the clinician's choice, especially in cases where referral questionable (35,37). Accessibility to CBCT may be a concern, financial factors may also sometimes inhibit the practitioner from proposing CBCT scanning to the patient (5).

CONCLUSIONS

CBCT is necessary for treatment planning of all endo-perio cases and certain endodontic cases especially, missed and calcified canals. CBCT significantly aids in modifying and establishing the ultimate diagnosis especially in complex endodontic cases. CBCT scans referral should strictly adhere to the AAE/AAOMR joint statement recommendations.

CONFLICT OF INTEREST

We affirm having no economic or personal benefit conflicts.

FUNDING STATEMENT

No definite funding.

REFERENCES

1. Svetlozarova S, Borisova-Papancheva T. Cone Beam Computed Tomography as a Diagnostic Tool in Endodontics-A Review of the Literature. ADOH. 2019;11:80-5.
2. Rodríguez G, Abella F, Durán-Sindreu F, Patel S, Roig M. Influence of cone-beam computed tomography in clinical decision making among specialists. J Endod. 2017;43:194-9.
3. Patel S, Brown J, Pimentel T, Kelly R, Abella F, Durack C. Cone beam computed tomography in Endodontics–a review of the literature. Int Endod J. 2019;52:1138-52.
4. Lima T, Gamba TdO, Zaia AA, Soares AdJ. Evaluation of cone beam computed tomography and periapical radiography in the diagnosis of root resorption. Aust Dent J. 2016;61:425-31.
5. Kakavetsos VD, Markou ME, Tzanetakis GN. Assessment of Cone-beam Computed Tomographic Referral Reasons and the Impact of Cone-beam Computed Tomographic Evaluation on Decision Treatment Planning Procedure in Endodontics. J Endod. 2020;46:1414-9.
6. Fewins J. Selection Criteria and Referral Patterns of Clinicians Utilizing CBCT at UCONN Health Center. UCONN Library. 2017.
7. Khanna AB. Applications of cone beam computed tomography in endodontics. Evid Based Dent. 2020;5:1-16.
8. Portelli M, Militi A, Lo Giudice A, Lo Giudice R, Rustico L, Fastuca R, et al. 3D assessment of endodontic lesions with a low-dose CBCT protocol. J Dent. 2020;8:51.
9. Patil S, Prasad BK, Shashikala K. Cone beam computed tomography: Adding three dimensions to endodontics. IDMJAR. 2015;1:1-6.
10. Du Bois A, Kardachi B, Bartold P. Is there a role for the use of volumetric cone beam computed tomography in periodontics? Aust Dent J. 2012;57:103-8.
11. Tyndall DA, Rathore S. Cone-beam CT diagnostic applications: caries, periodontal bone assessment, and endodontic applications. Dent Clin N Am. 2008;52:825-41.
12. Palkovics D, Mangano FG, Nagy K, Windisch P. Digital three-dimensional visualization of intrabony periodontal defects for regenerative surgical treatment planning. BMC Oral Health. 2020;20:351.
13. Grimard BA, Hoidal MJ, Mills MP, Mellonig JT, Nummikoski PV, Mealey BL. Comparison of clinical, periapical radiograph, and cone-beam volume tomography measurement techniques for assessing bone level changes following regenerative periodontal therapy. J Periodontol. 2009;80:48-55.
14. Parmar PD, Kaur R, Singh N. Surgical Management of combined apico-marginal and through & through peri-radicular lesion with GTR using bio-resorbable membrane, microscope and cone beam computed tomography: a case report. J Adv Med Dent Scie Res. 2018;6:42.
15. Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, et al. Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol. 2018;89:S173-S82.
16. Al-Fouzan KS. A new classification of endodontic-periodontal lesions. Int J Dent. 2014;2014:919173.
17. Al-Okshi A, Lindh C, Salé H, Gunnarsson M, Rohlin M. Effective dose of cone beam CT (CBCT) of the facial skeleton: a systematic review. Br J Radiol. 2015;88:20140658.
18. Chogle S, Zuaitar M, Sarkis R, Saadoun M, Mecham A, Zhao Y. The recommendation of cone-beam computed tomography and its effect on endodontic diagnosis and treatment planning. J Endod. 2020;46:162-8.
19. Wanzeler AMV, Montagner F, Vieira HT, da Silveira HLD, Arús NA, Vizzotto MB. Can cone-beam computed tomography change endodontists' level of confidence in diagnosis and treatment planning? A before and after study. J Endod. 2020;46:283-8.
20. Association WM. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. Bull World Health Organ. 2001;79:373-4.
21. American Dental Association Council on Scientific Affairs. The use of cone-beam computed tomography in dentistry: an advisory statement from the American Dental Association Council on Scientific Affairs. J Am Dent Assoc. 2012;143:899-902.
22. Horner K, O'Malley L, Taylor K, Glenny AM. Guidelines for clinical use of CBCT: a review. Dentomaxillofac Radiol. 2015;44:20140225.
23. Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;113:817-26.
24. Schulze R, Drage N. Cone-beam computed tomography and its applications in dental and maxillofacial radiology. Clin Radiol. 2020;75:647-57.
25. Ee J, Fayad MI, Johnson BR. Comparison of endodontic diagnosis and treatment planning decisions using cone-beam volumetric tomography versus periapical radiography. J Endod. 2014;40:910-6.
26. Boquete-Castro A, Lopez AP, Martins AS, Lorenzo AS, Perez PR. Applications and advantages of the use of cone-beam computed

tomography in endodontics: An updated literature review. Saudi Endod J. 2022;12:168-174.
27. Durack C, Patel S. Cone beam computed tomography in endodontics. Braz Dent J. 2012;23:179-91.
28. Mota de Almeida FJ, Knutsson K, Flygare L. The effect of cone beam CT (CBCT) on therapeutic decision-making in endodontics. Dentomaxillofac Radiol. 2014;43:20130137.
29. Suebnukarn S, Rhienmora P, Haddawy P. The use of cone-beam computed tomography and virtual reality simulation for pre-surgical practice in endodontic microsurgery. Int Endod J. 2012;45:627-32.
30. Fan Y, Glickman GN, Umorin M, Nair MK, Jalali P. A novel prefabricated grid for guided endodontic microsurgery. J Endod. 2019;45:606-10.
31. Parker JM, Mol A, Rivera EM, Tawil PZ. Cone-beam computed tomography uses in clinical endodontics: observer variability in detecting periapical lesions. J Endod. 2017;43:184-7.
32. Fan X, Xu X, Yu S, Liu P, Chen C, Pan Y, et al. Prognostic factors of grade 2-3 endo-periodontal lesions treated nonsurgically in patients with periodontitis: a retrospective case-control study. Biomed Res Int. 2020;2020:1592910.
33. Fayad MI, Nair M, Levin MD, Benavides E, Rubinstein RA, Barghan S, et al. AAE and AAOMR joint position statement: use of cone beam computed tomography in endodontics 2015 update. Oral surg Oral Med Oral Pathol Oral radiol. 2015;120:508-12.
34. Patel S, Brown J, Semper M, Abella F, Mannocci F. European Society of Endodontology position statement: use of cone beam computed tomography in Endodontics: European Society of Endodontology (ESE) developed by. Int Endod J. 2019;52:1675-8.
35. Krug R, Connert T, Beinicke A, Soliman S, Schubert A, Kiefner P, et al. When and how do endodontic specialists use cone-beam computed tomography? Aust Endod J. 2019;45:365-72.
36. Rodríguez G, Patel S, Durán-Sindreu F, Roig M, Abella F. Influence of cone-beam computed tomography on endodontic retreatment strategies among general dental practitioners and endodontists. J Endod. 2017;43:1433-7.
37. Setzer FC, Hinckley N, Kohli MR, Karabucak B. A survey of cone-beam computed tomographic use among endodontic practitioners in the United States. J Endod. 2017;43:699-704.