Health Evidence Review Commission's Oral Health Advisory Panel

October 5, 2020

9:00 AM - 11:00 AM

Virtual

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Section 1.0

Call to Order

AGENDA
ORAL HEALTH ADVISORY PANEL (OHAP)
October 5, 2020
9:00-11:00 a.m.
Virtual Meeting
https://www.zoomgov.com/j/1618226299?pwd=dUFPSWV1NUJWVEJ0WlBCdjd2QkRsQT09

(All agenda items are subject to change and times listed are approximate)

#	Time	Item	Presenter
1	9:00	Call to Order, Review of Minutes	Gary Allen
2	9:05	New Codes 1) 2021 CDT code placement	Ariel Smits
3	10:00	New Discussion Items 1) Straightforward CDT code changes 2) Guideline for dental implant removal 3) Cone beam computed tomography	All
4	10:45	Other Business	Gary Allen/staff
5	10:55	Public Comment	
6	11:00	Adjournment	Gary Allen

MINUTES

Health Evidence Review Commission's
Oral Health Advisory Panel (OHAP)

Clackamas Community College
Wilsonville Training Center, Room 155
October 11, 2018
9:00-11:00 a.m.

Members Present: Gary Allen, DMD, Chair; Bruce Austin, DMD; Alison Noble (via phone); Laura McKeane; DDS; Deborah Loy.

Members Absent: Eli Schwarz, DDS, MPH, PhD; Len Barozzini; Karen Nolon.

Staff Present: Darren Coffman; Ariel Smits, MD, MPH.

Also Attending: Kellie Skenandore (OHA), Dayna Steringer (Willamette Dental).

Roll Call/Minutes Approval/Staff Report

The meeting was called to order at 9:00 am and roll was called. Minutes from September 18, 2017 were reviewed and no changes were suggested.

- **Topic:**

2019 CDT Codes

1) D0412: The dental board is reviewing whether glucose testing is in the scope of practice of dentistry. Blood stick glucose meters would make a dental office a lab for legal purposes. This is an integration issue. No issue with code being diagnostic. Scope of practice is beyond the purview of the OHAP or HERC.
2) D1516-D1527, D5282-D5283: just split existing codes into more specific new codes.
3) D5876: Used to strengthen dentures. Already being done in certain cases in dental practice. Adds cost up front but may save cost in repairs downstream. OHA could make rules about when this procedure is covered. Decision was to place on line 451 DENTAL CONDITIONS (E.G., MISSING TEETH, PROSTHESIS FAILURE) and have OHP All Plans Dental Group look at rules around this procedure.
4) D9130: Austin reports that specific massage can be effective, but no way to determine if this code is being used for actual effective massage. TMJ is historically non-covered. Adding a service for TMJ would require HERC to re-evaluate the prioritization of TMJ as a condition. Decision was line 547 TMJ DISORDER.

5) D9613: cannot be used for short acting local anesthetic. May be used for dental blocks. Question about whether this could be used in the ED for dental pain. Question about whether to cover separately from the procedure. Concern that this might be abused. These are not expensive drugs. Discussion about covering long-acting anesthetic rather than corticosteroids. Many private plans roll this into the procedure as a bundle. Concern with unbundling and increasing cost. OHAP wanted to get further input from commercial plans to see how they are handling this code. OHAP needs information on whether this is bundled with the procedure. Also, need input on whether this could be billed as a second visit if a patient returns later for the injection. Return visit might also be bundled with the procedure, so concern for extra cost as a separate code. Concern that this should be done when appropriate, and already being done without extra payment now. Medicaid already pays high fees for oral surgery; concern for adding cost. Currently, D9610 is being used for this type of injection, which is on line 54 DENTAL CONDITIONS (E.G., INFECTION, PAIN, TRAUMA). Input from Karen Nolan indicated that commercial plans are not covering this as a separate procedure unless a group requires it in its contract. If it is in a contract, it will only be paid on the date of service and when paired with dental extraction codes (D7220-D7241). Decision was Excluded File.
6) D9944-D9946: no discussion
7) D9961: this is standard of care, but rules exclude payment. Will make Excluded and will change to covered in the future if OHA rules change.
8) D9990: this should be covered, but unclear how OHA will cover it. It is bundled for CCOs. T1013 is the medical equivalent code, which was on the Exempt File (which no longer exists). Decision was to make Ancillary and have OHA work on rules.

<u>Update on orthodontia and craniofacial anomalies</u>

Skenandore reported that further discussion is needed between the HERC and OHA leadership on incidence of these abnormalities. Dr. Garfinkle should be consulted about how often these craniofacial abnormalities are needing treatment under OHP. Need this data prior to being able to calculate cost. HERC staff will do a data search to see number of unique claims for patients with these types of diagnoses, as these patients should already be getting services for medical issues, surgeries, etc. HERC staff will reach out to Dr. Garfinkle to better determine incidence as well. Once incidence is determined, then this data needs to be taken to actuarial services to determine if any changes in rates is required. Skenandore reported that cleft lip and cleft palate are now both being covered with a temporary rule. A permanent rule is in the works.

<u>Other business</u>:

Tori removal coverage will be effective November 1, 2018. The codes are already loaded into the OHA billing system per Skenandore.

- **Public Comment:**
  No public comment was received.

- **Issues for next meeting:**
  HERC staff will accept issues from members and other stakeholders as they arise over the year and bring them to the next OHAP meeting, along with 2020 CDT code changes.

- **Next meeting:**
  - TBD

DRAFT

Section 2.0

New Codes

Code	Descriptor	Suggested Placement	Comments	Additional Information
D0604	Antigen testing for a public health related pathogen, including coronavirus	Diagnostic Procedure File		
D0605	Antibody testing for a public health related pathogen, including coronavirus	Excluded File	Antibody testing is restricted to only hospital work up of MIS-C, which would not be done in the dental setting. Will need to revisit if antibody testing is expanded	DIAGNOSTIC GUIDELINE D27, SARS-COV-2 (COVID-19) TESTING Testing for SARS-CoV-2 (COVID-19) virus RNA or viral antigen is a covered diagnostic service. Antibody testing for SARS-CoV-2 (COVID-19; CPT 86408, 86409, 86328 or 86769) is covered as diagnostic only when such testing meets the following criteria: A) Testing is done using tests that have FDA Emergency Use Authorization (EUA) or FDA approval; AND B) Testing is used as part of the diagnostic work up of multisystem inflammatory syndrome in children (MIS-C) for hospitalized persons under the age of 21.
D0701	Panoramic radiographic image – image capture only	Diagnostic Procedure File		
D0702	2-D cephalometric radiographic image – image capture only	Diagnostic Procedure File		
D0703	2-D oral/facial photographic image obtained intra-orally or extra-orally – image capture only	Diagnostic Procedure File		
D0704	3-D photographic image – image capture only	Diagnostic Procedure File		
D0705	Extra-oral posterior dental radiographic image – image capture only	Diagnostic Procedure File		
D0706	Intraoral – occlusal radiographic image – image capture only	Diagnostic Procedure File		
D0707	Intraoral – periapical radiographic image – image capture only	Diagnostic Procedure File		
D0708	Intraoral – bitewing radiographic image – image capture only	Diagnostic Procedure File		
D0709	Intraoral – complete series of radiographic images – image capture only	Diagnostic Procedure File		
D1321	Counseling for the control and prevention of adverse oral, behavioral, and systemic health effects associated with high-risk substance use	53 PREVENTIVE DENTAL SERVICES		
D1355	Caries preventive medicament application – per tooth	53 PREVENTIVE DENTAL SERVICES		
D2928	Prefabricated porcelain/ceramic crown – permanent tooth	Excluded File		
D3471	Surgical repair of root resorption - anterior	646 DENTAL CONDITIONS WHERE TREATMENT RESULTS IN MARGINAL IMPROVEMENT	Replaces D3427 (Periradicular surgery without apicoectomy) on line 646	

Code	Descriptor	Suggested Placement	Comments	Additional Information
D3472	Surgical repair of root resorption – premolar	646	See D3471	
D3473	Surgical repair of root resorption – molar	646	See D3471	
D3501	Surgical exposure of root surface without apicoectomy or repair of root resorption – anterior	646	See D3471	
D3502	Surgical exposure of root surface without apicoectomy or repair of root resorption – premolar	646	See D3471	
D3503	Surgical exposure of root surface without apicoectomy or repair of root resorption – molar	646	See D3471	
D5995	Periodontal medicament carrier with peripheral seal – laboratory processed – maxillary	646 DENTAL CONDITIONS WHERE TREATMENT RESULTS IN MARGINAL IMPROVEMENT	Replaces D5994 (Peridontal medicament carrier with peripheral seal - laboratory processed) on line 646	
D5996	Periodontal medicament carrier with peripheral seal – laboratory processed – mandibular	646	See D5995	
D6191	Semi-precision abutment – placement	619 DENTAL CONDITIONS (E.G., MISSING TEETH)	Implants are on line 619	
D6192	Semi-precision attachment – placement	619	Implants are on line 619	
D7961	Buccal / labial frenectomy (frenulectomy)	344 DENTAL CONDITIONS (E.G., SEVERE CARIES, INFECTION)	Replaces D7960 (Frenulectomy - also known as frenectomy or frenotomy - separate procedure not incidental to another procedure) which was on lines 18,344	
D7962	Lingual frenectomy (frenulectomy)	18 FEEDING PROBLEMS IN NEWBORNS 344 DENTAL CONDITIONS (E.G., SEVERE CARIES, INFECTION)	Replaces D7960 (Frenulectomy - also known as frenectomy or frenotomy - separate procedure not incidental to another procedure) which was on lines 18,344. Current covered CPT code in GN139 is for lingual frenectomy; previous review did not find evidence to support coverage of labial frenectomy	GUIDELINE NOTE 139, FRENOTOMY FOR TONGUE TIE IN NEWBORNS Lines 18,596 Ankyloglossia (ICD-10-CM Q38.1 is included on Line 18 for pairing with frenotomy (CPT 41010, CDT D7962 ~~D7960~~) only when it interferes with breastfeeding. Otherwise, Q38.1 and CPT 41010 are included on Line 596
D7993	Surgical placement of craniofacial implant – extra oral	Excluded File		
D7994	Surgical placement: zygomatic implant	Excluded File		

Section 3.0

New Discussion Items

Straightforward CDT Code Changes

Code	Code Description	Line(s) Involved	Issue	Recommendation(s)
D0320	Temporomandibular joint arthrogram, including injection	643 TMJ DISORDERS	TMJ conditions are only included on an uncovered line. D0320 is currently on the Diagnostic Procedures File	Add D0320 to line 643 Advise HSD to remove D0320 from the DIAGNOSTIC PROCEDURES file
D0321	Other temporomandibular joint radiographic images, by report	643 TMJ DISORDERS	See above	Add D0321 to line 643 Advise HSD to remove D0321 from the DIAGNOSTIC PROCEDURES file

Dental Implant Removal

Question: Should a guideline be added to the Prioritized List regarding dental implant removal?

Question source: Gary Allen, DMD; DCOs

Issue: As part of the 2018 Biennial Review, dental implant removal (CDT D6100) was added to a covered line and kept on an uncovered line. The intent was to cover for situations in which the implant is infected or otherwise impacting the health of the patient. HERC staff was directed to work with Dr. Allen to devise a guideline regarding D6100. However, for reasons unclear in the minutes, such a guideline was never put forward. Dr. Allen and dental directors of the DCOs feel that such a guideline should be added to the Prioritized List.

Current Prioritized List status
D6100 (Implant removal, by report) is on lines 344 DENTAL CONDITIONS (E.G., SEVERE CARIES, INFECTION) and 619 DENTAL CONDITIONS (E.G., MISSING TEETH)

HERC staff recommendation:

1) Adopt the following new guideline note

GUIDELINE NOTE XXX DENTAL IMPLANT REMOVAL
Lines 344, 619
Removal of dental implants (D6100) is included on line 344 only when there is advanced peri-implantitis with bone loss and mobility, abscess or implant fracture. Otherwise, this procedure is included on line 619.

Cone Beam Computed Tomography

Question: Should the indications for cone bean computed tomography (CBCT) be expanded on the Prioritized List?

Question source: DCO dental directors

Issue: CBCT was not a covered service for many years. In 2017, limited coverage was added for surgical planning for repair of craniofacial anomalies. The DCOs have had many requests for coverage from dentists and oral surgeons and would like clarification of when the evidence supports use of CBCT. From Dr. Allen: "We get pressure from oral surgeons and endodontists that the standard of care requires CBCT imaging for selected conditions."

Cone-beam computed tomography systems (CBCT) are a variation of traditional CT systems. The CBCT systems used by dental professionals rotate around the patient, capturing data using a cone-shaped X-ray beam. These data are used to reconstruct a three-dimensional (3D) image of the following regions of the patient's anatomy: dental (teeth); oral and maxillofacial region (mouth, jaw, and neck); and ears, nose, and throat. Dental CBCT systems are increasingly used by radiologists and dental professionals for various clinical applications including dental implant planning, visualization of abnormal teeth, evaluation of the jaws and face, cleft palate assessment, diagnosis of dental caries (cavities), endodontic (root canal) diagnosis, and diagnosis of dental trauma. CBCT involves considerably more radiation exposure then traditional x-rays.

From the FDA: Dental CBCT should be performed only when necessary to provide clinical information that cannot be provided using other imaging modalities.

Current Prioritized List status

CDT code	Code description	Current line(s)
D0354	Cone beam CT capture and interpretation with limited field of view less than one whole jaw	256 DEFORMITIES OF HEAD
D0365	Cone beam CT capture and interpretation with field of view of one full dental arch - mandible	256 DEFORMITIES OF HEAD
D0366	Cone beam CT capture and interpretation with field of view one full dental arch – maxilla with or without cranium	256 DEFORMITIES OF HEAD
D0367	Cone beam CT capture and interpretation with field of view of both jaws with or without cranium	256 DEFORMITIES OF HEAD

CDT code	Code description	Current line(s)
D0368	Cone beam CT capture and interpretation for tmj series including two or more exposures	EXCLUDED FILE
D0380	Cone beam CT image capture with limited field of view - less than one whole jaw	EXCLUDED FILE
D0381	Cone beam CT image capture with field of view of one full dental arch - mandible	EXCLUDED FILE
D0382	Cone beam CT image capture with field of view of one full dental arch - maxilla, with or without cranium	EXCLUDED FILE
D0383	Cone beam CT image capture with field of view of both jaws, with or without cranium	EXCLUDED FILE
D0384	Cone beam CT image capture for tmj series including two or more exposures	EXCLUDED FILE

GUIDELINE NOTE 169, ORTHODONTICS AND CRANIOFACIAL SURGERY FOR CRANIOFACIAL ANOMALIES

Line 256

Orthodontics and craniofacial surgery are included on this line only for pairing with craniofacial anomaly diagnoses when there is significant malocclusion expected to result in difficulty with mastication, speech, or other oral function. Advanced dental imaging is included on this line only when required for surgical planning for repair of craniofacial anomalies.

Evidence

1) **Weiss 2019,** evidenced based review of cone beam computed tomography
    a. Impacted or supernumerary teeth: 3-dimensional imaging by way of CBCT can provide an increased visualization and enhance diagnostic capability but does not increase sensitivity and specificity when compared to plain PA and PANO radiographs when evaluating mandibular third molars. On the contrary, evidence exists demonstrating an increase in diagnostic capability of CBCT during the evaluation of maxillary third molars. However, while clinically relevant for added diagnostic capability, the additional information provided by CBCT led to a change in the treatment plan only in respect to impacted canines. Clinical outcome and reduction in the number of complications, while addressed in few articles, were undetermined.
    b. Dental implants: Limited data has quantified the ability of CBCT to affect clinical outcome or complication rates.
    c. Soft tissue and osseous pathology: PANO and CBCT both provide sufficient imaging for most odontogenic osseous lesions. CT or MRI is indicated if there is evidence of extraosseous soft tissue involvement or suspicion of malignant potential
    d. Inflammation and infection: CBCT has proven to be superior to PANO in the diagnosis of hard tissue inflammatory change or infection, such as osteomyelitis, offering a quicker diagnosis and more accurately staging the disease. However, in the context of soft tissue, CT and the added benefit of contrast media remains far better in visualization and diagnosis than CBCT. Changes in treatment plan and complications were not explored in any of the studies and clinical outcome could not be determined based on the current literature.
    e. Orthognathic surgery: Advantages of CBCT for its indications in orthognathic surgery include an accurate and reliable analysis, especially when considering facial asymmetry, occlusal cants, translational discrepancies, and certain developmental disorders. Soft tissue analysis was proven to be comparable to traditional cephalometric tracing predictions. Critical landmarks of orthognathic surgery are identified equivalently with CBCT and CT imaging. Of the numerous articles implementing the use of CBCT in the evaluation of orthognathic surgery, few articles addressed the alteration of treatment and complications. Regarding surgical outcome, CBCT was found to be equivalent to CT for VSP post-surgical comparison.
2) **Patel 2018**, systematic review of CBCT in endodontics
    a. Periapical lesions
        i. Due to the limitations of conventional radiography, the size of periapical lesions is underestimated when compared to CBCT;
        ii. Current evidence suggests that CBCT has a higher sensitivity than periapical radiography (PR) for the detection of periapical lesions;
        iii. Cone beam computed tomography may be indicated to aid the diagnosis of (non-)odontogenic pain when clinical examination and conventional radiographic assessment are not clear;

iv. Cone beam computed tomography may be considered when (in)direct pulp capping or pulpotomy is being planned in extensively carious teeth where PR does not reveal anything untoward.

b. CBCT is recommended for
   i. Complex surgical cases (i.e. multi-rooted teeth and complex anatomy);
   ii. When the root apices are in close proximity to important anatomical structures or where these structures cannot be accurately assessed with PR

c. Cone beam computed tomography should be considered in dental trauma:
   i. When the diagnosis from clinical and PR assessment is inconclusive;
   ii. When there are severe injuries to multiple teeth; When DTI results in it being impossible to acquire PR due to patient discomfort and/or limited mouth opening;
   iii. Thought should be given to using CBCT as the tool of choice in reviewing traumatically injured teeth to allow earlier detection of complications (e.g. resorption).

d. There is insufficient evidence to advocate the use of CBCT for detection of vertical root fracture

e. Cone beam computed tomography imaging may be indicated to obtain information about the nature of complex root canal anatomy.

f. Diagnostic CBCT may provide additional information when compared to PR, which may an impact on the treatment planning of complex endodontic retreatment cases.

3) **Chang 2016**, systematic review of CBCT for evaluation of vertical root fractures in endodontically treated teeth
   a. N=4 studies (130 patients)
   b. The reported ranges of values were 40%–90% for vertical root fracture (VRF) prevalence, 84% (0.64–0.95) to 100% (0.83–1.00) for sensitivity, 64% (0.35–0.87) to 100% (0.03–1.00) for specificity, 71% (0.51–0.87) to 100% (0.63–1.00) for positive predictive value, and 50% (0.01–0.99) to 100% (0.84–1.00) for negative predictive value. All 4 studies revealed multiple items at high risk or unclear risk of bias.
   c. Conclusions: Because of the significant imprecision in the range of reported estimates and the biases observed in the included studies, there is currently insufficient evidence to suggest that CBCT is a reliable test in detecting VRFs in endodontically treated teeth

<u>Specialty Society Recommendations</u>:

1) **AAE and AAOMR Joint Position Statement 2016**: Use of Cone Beam Computed Tomography in Endodontics
   a. Recommendation 1: Intraoral radiographs should be considered the imaging modality of choice in the evaluation of the endodontic patient.
   b. Recommendation 2: Limited FOV CBCT should be considered the imaging modality of choice for diagnosis in patients who present with contradictory or

nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth.

c. Recommendation 3: Limited FOV CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology, such as mandibular anterior teeth, and maxillary and mandibular premolars and molars, and dental anomalies
d. Recommendation 4: If a preoperative CBCT has not been taken, limited FOV CBCT should be considered as the imaging modality of choice for intra-appointment identification and localization of calcified canals.
e. Recommendation 5: Intraoral radiographs should be considered the imaging modality of choice for immediate postoperative imaging
f. Recommendation 6: Limited FOV CBCT should be considered the imaging modality of choice if clinical examination and 2-D intraoral radiography are inconclusive in the detection of vertical root fracture
g. Recommendation 7: Limited FOV CBCT should be the imaging modality of choice when evaluating the nonhealing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical or extraction.
h. Recommendation 8: Limited FOV CBCT should be the imaging modality of choice for nonsurgical retreatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.
i. Recommendation 9: Limited FOV CBCT should be considered as the imaging modality of choice for presurgical treatment planning to localize root apex/apices and to evaluate the proximity to adjacent anatomical structures
j. Recommendation 10: Limited FOV CBCT should be considered as the imaging modality of choice for surgical placement of implants
k. Recommendation 11: Limited FOV CBCT should be considered the imaging modality of choice for diagnosis and management of limited dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures, in the absence of other maxillofacial or soft tissue injury that may require other advanced imaging modalities
l. Recommendation 12: Limited FOV CBCT is the imaging modality of choice in the localization and differentiation of external and internal resorptive defects and the determination of appropriate treatment and prognosis
m. Recommendation 13: In the absence of clinical signs or symptoms, intraoral radiographs should be considered the imaging modality of choice for the evaluation of healing following nonsurgical and surgical endodontic treatment.
n. Recommendation 14: In the absence of signs and symptoms, if limited FOV CBCT was the imaging modality of choice at the time of evaluation and treatment, it may be the modality of choice for follow-up evaluation. In the presence of signs and symptoms, refer to Recommendation #7.

2) **European Union 2011**, evidence-based guideline on cone beam CT on dental and maxillofacial radiology http://sedentexct.eu/files/radiation_protection_172.pdf

a. CBCT may be indicated for the localized assessment of an impacted tooth (including consideration of resorption of an adjacent tooth) where the current imaging method of choice is conventional dental radiography and the information cannot be obtained adequately by lower dose conventional (traditional) radiography [level of evidence: C]
b. Large volume CBCT should not be used routinely for orthodontic diagnosis [level of evidence: D]
c. For complex cases of skeletal abnormality, particularly those requiring combined orthodontic/surgical management, large volume CBCT may be justified in planning the definitive procedure [level of evidence: good practice]
d. CBCT is not indicated as a method of caries detection and diagnosis [level of evidence: B]
e. CBCT is not indicated as a routine method of imaging periodontal bone support [level of evidence: C]
f. Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management [level of evidence: C]
g. CBCT is not indicated as a standard method for identification of periapical pathosis [level of evidence: good practice]
h. CBCT is not indicated as a standard method for demonstration of root canal anatomy. Limited volume, high resolution CBCT may be indicated, for selected cases where conventional intraoral radiographs provide information on root canal anatomy with is equivocal or inadequate for planning treatment, most probably in multi-rooted teeth [level of evidence: good practice]
i. Limited volume, high resolution CBCT may be indicated in selected cases of suspected, or established, inflammatory root resorption or internal resorption, where three-dimensional information is likely to alter the management and prognosis of the tooth. [level of evidence D]
j. Limited volume, high resolution CBCT may be justifiable for selected cases, where endodontic treatment is complicated by concurrent factors, such as resorption lesions, combined periodontal/endodontic lesions, perforations, and atypical pulp anatomy [level of evidence C]
k. Limited volume, high resolution CBCT is indicated in the assessment of dental trauma (suspected root fracture) in selected cases, where conventional intraoral radiographs provide inadequate information for treatment planning [level of evidence B]
l. Where conventional radiographs suggest a direct inter-relationship between a mandibular third molar and the mandibular canal, and when a decision to perform surgical removal has been made, CBCT may be indicated [level of evidence C]
m. CBCT is indicated where bone information is required, in orthognathic surgery planning, for obtaining three-dimensional datasets of the craniofacial skeleton [level of evidence C]

HERC staff summary

Evidence based reviews and guidelines consistently agree that CBCT is indicated in the evaluation of complex surgical cases, such as multi-rooted teeth, complex anatomy, and dental anomalies. Limited CBCT is also indicated for the diagnosis and management of limited dento-alveolar trauma, luxation, and/or displacement of teeth and localized alveolar fractures, in the absence of other maxillofacial or soft tissue injury that may require other advanced imaging modalities.

There is insufficient evidence for the use of CBCT in detection of vertical root fracture. The evidence for use of CBCT for evaluation of impacted teeth finds that CBCT does not change management. Other imaging modalities, such as CT or MRI, are superior for evaluation of possible osseous or soft tissue infection or malignancy. CBCT is not indicated for routine evaluation of periodontal bone support, diagnoses of caries, or evaluation of periapical pathosis.

HERC staff recommendations

1) Continue to include CBCT for pre-surgical evaluation of complex craniofacial anomalies
2) Do not add additional indications for CBCT
    a. Select cases, such as complex dental trauma, can be reviewed as exceptions

dentistry journal

MDPI

Review

Cone Beam Computed Tomography in Oral and Maxillofacial Surgery: An Evidence-Based Review

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Abstract: Cone Beam Computed Tomography (CBCT) is a valuable imaging technique in oral and maxillofacial surgery (OMS) that can help direct a surgeon's approach to a variety of conditions. A 3-dimensional analysis of head and neck anatomy allows practitioners to plan appropriately, operate with confidence, and assess results post-operatively. CBCT imaging has clear indications and limitations. CBCT offers the clinician 3-dimensional and multi-planar views for a more accurate diagnosis and treatment without the financial burden and radiation exposure of conventional computed tomography (CT) scans. Furthermore, CBCT overcomes certain limitations of 2-dimensional imaging, such as distortion, magnification, and superimposition. However, CBCT lacks the detailed depiction of soft tissue conditions for evaluation of pathologic conditions, head and neck infections, and temporomandibular joint (TMJ) disc evaluation. This review evaluates the evidence-based research supporting the application of CBCT in the various fields of oral and maxillofacial surgery, including dentoalveolar surgery, dental implants, TMJ, orthognathic surgery, trauma, and pathology, and will assess the value of CBCT in pre-operative assessment, surgical planning, and post-operative analysis when applicable. Additionally, the significant limitations of CBCT and potential areas for future research will be discussed.

Keywords: cone beam computed tomography (CBCT); evidence-based; oral and maxillofacial surgery

1. Introduction

Many critical functions in oral and maxillofacial surgery (OMS) are served by 3-dimensional imaging. Clinicians frequently operate in areas of the face and jaws, which cannot be directly observed prior to a procedure, consequently risking damage to critical structures, such as nerves and blood vessels. Furthermore, complex surgical procedures, such as orthognathic surgery and treatment of traumatic injuries require meticulous preoperative planning. Therefore, it is important to utilize imaging modalities that provide detailed information that can ensure accurate diagnosis and good clinical outcomes.

Cone beam computed tomography (CBCT) has become a mainstay in oral and maxillofacial surgery, and many surgeons have a CBCT machine available in the office. CBCT offers the clinician 3-dimensional and multi-planar views for a more accurate diagnosis and treatment without the financial burden and radiation exposure of conventional computed tomography (CT) scans. Furthermore, CBCT overcomes certain limitations of 2-dimensional imaging, such as distortion, magnification, and superimposition.

While CBCT is used for many purposes, including routine OMS procedures, such as removal of impacted teeth and placement of dental implants, the quality of literature supporting its use and demonstrating superiority over other imaging methods is quite varied.

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REVIEW

Cone beam computed tomography in Endodontics – a review of the literature

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Abstract

Patel S, Brown J, Pimentel T, Kelly RD, Abella F, Durack C. Cone beam computed tomography in Endodontics – a review of the literature. *International Endodontic Journal*, **52**, 1138–1152, 2019.

The use of cone beam computed tomography (CBCT) in the diagnosis and/or management of endodontic problems is increasing and is reflected in the exponential rise in publications on this topic in the last two decades. The aim of this paper is to: (i) Review current literature on the endodontic applications of CBCT; (ii) Based on current evidence make recommendations for the use of CBCT in Endodontics; (iii) Highlight the areas in which more research is required.

Keywords: cone beam computed tomography, endodontic diagnosis, management of endodontic problems, radiography.

Received 12 December 2018; accepted 11 March 2019

Introduction

The three-dimensional radiographic assessment of teeth and their surrounding structures with cone beam computed tomography (CBCT) is desirable for aiding diagnosis and/or management of complex endodontic problems (Rodríguez *et al.* 2017a,b).

The use of CBCT in Endodontics is increasing rapidly worldwide, and this is reflected in position statements being published by several specialist societies (European Society of Endodontology 2014, American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology CBCT position statement 2015).

The limitations of conventional radiography are well established. The diagnostic yield of the two-dimensional images generated (Brynolf 1967, Velvart *et al.* 2001) is impaired, to varying degrees, by anatomical noise masking the area of interest (Bender & Seltzer 1961, Paurazas *et al.* 2000) and geometric distortion (Forsberg & Halse 1994). The three-dimensional nature of CBCT overcomes some of these limitations (Patel *et al.* 2015).

There are insufficient data within meta-analyses or systematic reviews assessing the use of CBCT in Endodontics. Therefore, the aim of this review is to present the most relevant literature highlighting the relative advantages and also disadvantages of CBCT in the various aspects of Endodontics.

Radiological aspects of CBCT

Cone beam computed tomography is a modification of the computed tomography (CT) concept, involving the single rotation of an X-ray source around the dental subject.

The data are analysed and reconstructed using a CT-based algorithm to create a volume of data, which can be viewed in three conventional planes (axial, sagittal and coronal) and multiple alternative planes on manipulation of the data set.

Image acquisition is rapid and uses technology, which is becoming relatively affordable. A three-dimensional visualization of the region of interest is obtained in sufficient detail to localize teeth and

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adjacent anatomy in a manner, which is simply not achievable with conventional, 2D, plain dental film imaging.

Dosages, their reduction and optimization

The potential benefits of CBCT must be balanced with the comparatively higher levels of risk from radiation exposure, compared to conventional imaging.

Mean effective doses for large, medium and small field of views (FOV) CBCT scans have been measured to be 212, 177 and 84 μSv, respectively (Ludlow *et al.* 2015). The range for a small field of view is 5 – 146 μSv, but many machines achieve a reasonable exposure of around 30 μSv on manufacturer's default settings. For comparison, a panoramic radiograph is normally between 16 and 20 μSv (Ludlow *et al.* 2015).

Dose reduction is therefore focused on optimizing exposure parameters on an individual basis (Table 1). Each examination should be tailored to the individual patient and their diagnostic needs, rather than just assuming manufacturer's default settings are the most appropriate ones. Every attempt should be made to understand and maximize the capability of the CBCT unit to generate diagnostically suitable images to enhance endodontic diagnosis and management.

Training and education

Cone beam computed tomography is sufficiently new to have been given little exposure in undergraduate dental training to date, and so there is a need for both newly qualified and established dentists to learn about this new technique so that they can employ it effectively and use it safely.

Table 1 The dose (in μSv) will be increased by:

Exposures that include the salivary glands in the FOV (e.g. posterior mandible > anterior maxilla)
Larger FOVs
Higher kV
Higher mA
Higher exposure time (e.g. full rotation vs half rotation, or more versus reduced number of basis images, or continuous versus pulsed X-ray beam)
Smaller voxel size (not an automatic dose increase, but often the manufacturers compensate for the greater noise in small-voxel images by increasing exposure)

Article 18 of the EURATOM 2013 directive requires that individuals are 'adequately trained' for any role they play in the radiographic imaging of a patient. The legislation makes general requirements for training in radiation protection but does not generally define what specific 'adequate training' should be for any particular radiographic technique or modality. As such, it falls to specialist and expert bodies to draw up guidelines that define what training would be appropriate. Cone beam computed tomography training needs to familiarize the user with the principles of CBCT imaging and highlight how it differs from conventional dental imaging so that it can be applied correctly. Crucially, the user needs to be aware of the very specific advantages and disadvantages of this technique over other dental imaging and be able to balance the potential benefits with the possible detrimental effects of increased radiation exposure.

Two levels of training are to be recommended by the European Academy of Dentomaxillofacial Radiology (Brown *et al.* 2014) and by Public Health England in the UK. A 'core course' (level 1 training) is to be undertaken by those prescribing CBCT scans. An 'advanced training' (level 2 training) is recommended for those interpreting CBCT scans. The training should ideally take place over 12 h and through a variety of methods: lectures, seminars, hands-on and face-to-face exercises, case-based discussions, group tutorials, distance learning and online teaching (Brown *et al.* 2014).

Specific requirements for endodontics

Cone beam computed tomography imaging in Endodontics requires exceptionally high detail and resolution to appreciate the intricacies of the root canal system and periodontium. High image resolution comes at the cost of higher patient radiation exposure.

Only small FOV CBCT scans are recommended for the diagnosis and management of endodontic problems. A small FOV scan reduces the volume of exposed tissue, and therefore, the effective radiation dose, but, favourably, this also reduces scatter, which improves image quality. The generated images may be easily degraded by subtle patient movement; the most suitable machines for maintaining patient stability are where the patient sits, or even lies down, rather than stands (Spin-Neto *et al.* 2015). This is an important consideration when using CBCT imaging, as the dedicated CBCT units are often designed for a

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seated or supine patient whilst hybrid panoramic/CBCT units usually have the patient standing. The trend for hybrid panoramic/CBCT units appears to be the predominant growth area in CBCT imaging currently, most probably because these units are cheaper yet multifunctional. However, it must be recognized that image quality is at risk of being lower.

Limitations

The presence of metallic restorations (e.g. amalgam restorations, metal posts and/or crowns, and implants) or even gutta-percha can cause significant radiographic artefact, sufficient to compromise details of root canal anatomy and relevant pathosis such as root resorption and root fractures. Metal artefact reduction algorithms (MAR) are becoming more common in operating and viewing software in order to overcome this disadvantage (Queiroz *et al.* 2018a). These are mathematical post-processing programmes which analyse an area of image where streak, beam hardening and photon starvation artefact are found, and analyse the adjacent 'normal' image to deduce what grey shades should be found in the boundary zones immediately adjacent to the artefact. These grey shades are then applied in the affected areas of the image where information is deficient, essentially smoothing the image and approximating the true detail. This is, however, open to error, and resultant images may reduce accurate fine detail (Bechara *et al.* 2013a) and so images generated with artefact reduction programmes are to be used with caution. These programmes are only truly effective in full rotation scans (Queiroz *et al.* 2018b). They are particularly effective when compensating for artefacts around metal objects and are less effective when employed to compensate for artefacts adjacent to gutta-percha (Bechara *et al.* 2012, Queiroz *et al.* 2018a). The efficacy of the programmes is further improved when the offending metal object is in the centre of the field of view (Queiroz *et al.* 2017).

Concluding remarks:

- A CBCT scan should be tailored to the individual patient and their diagnostic needs;
- The potential benefits of the CBCT scan should outweigh the potential risks;
- Clinicians must regularly update their core knowledge in CBCT;
- Undergraduate curricula should include an introduction to CBCT radiology;
- Post-graduate endodontic programmes should incorporate the use of CBCT.

Assessment of periapical periodontitis

Periapical radiography (PR) is the accepted reference standard for the radiological detection of AP (ESE 2006). However, anatomical noise may hide early stages of AP-related periapical bone destruction (Bender & Seltzer 1961, Tsai *et al.* 2013, Kanagasingam *et al.* 2017a). This can lead to difficulty in the diagnosis of early signs of endodontic disease, especially in cases where clinical signs and symptoms indicate pulp necrosis or irreversible pulpitis (Abella *et al.* 2012a, 2014, Kruse *et al.* 2015).

Detection of apical periodontitis

It is well established from the results of *ex vivo* studies with reference standards, that is where the periapical status is known beforehand, that CBCT is more accurate than PR to detect periapical periodontitis (Patel *et al.* 2009a,b, Sogur *et al.* 2009, Ahlowalia *et al.* 2013, Liang *et al.* 2013).

Patel *et al.* (2012a) detected periapical lesions in 20% and 48% of 123 teeth planned for primary root canal treatment when PR and CBCT were used, respectively. Similar findings have been reported in other studies (Davies *et al.* 2015, Uraba *et al.* 2016, Torabinejad *et al.* 2018) (Table 2).

Results of *in vivo* dog studies, using histological block dissections as the reference standard, have corroborated the findings of the aforementioned *ex vivo* and clinical studies, concluding that CBCT is more accurate than PR for diagnosing AP in root filled teeth in dogs (Paula-Silva *et al.* 2009a). These results have been also confirmed by Kanagasingam *et al.* (2017b) in a comparative study using histological block dissections of fresh human cadavers as a reference standard. Using human cadavers as a reference standard, Kruse *et al.* (2018) concluded that the diagnosis of AP was dependent on the 'treatment status' of the tooth. The diagnostic accuracy of CBCT was high with almost all cases of AP being diagnosed correctly in non-root filled teeth; however, the diagnostic accuracy was lower for root filled roots.

Cone beam computed tomography may reveal the presence of previously undiagnosed pathoses (Nakata *et al.* 2006). Cone beam computed tomography may also be indicated to assist in confirming the absence of an odontogenic aetiology of pain when PR

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Table 2 Clinical studies comparing the detection of periapical lesions between CBCT and periapical radiographs (PR) in untreated and endodontically treated teeth

Primary endodontic treatment		
	CBCT > PR	Teeth
Estrela *et al.* 2009	39%	83 (untreated)
Patel *et al.* 2012a,b	28%	151 (untreated)
Abella *et al.* 2012a,b	11%	128 (irreversible)
Abella *et al.* 2014	19%	161 (non-vital)
Secondary endodontic treatment		
	CBCT > PR	Teeth
Lofthag-Hansen *et al.* 2007	20%	46 (re-rct)
Estrela *et al.* 2009	28%	1425 (re-rct)
Low *et al.* 2008	34%	74 (re-rct)
Bornstein *et al.* 2011	26%	38 (re-rct)
Cheung *et al.* 2013	30%	60 (re-rct)
Venskutonis *et al.* 2014	25%	35 (re-rct)
Davies *et al.* 2015	30%	100 (re-rct)
Uraba *et al.* 2016	21%	178 (re-rct)
Primary + secondary endodontic treatment		
	CBCT > radiographs	Teeth
Weissman *et al.* 2015	22%	67 (untreated + re-rct)

Cone beam computed tomography was associated with a greater prevalence of periapical lesions when compared to PR (11%–39%).

examination is unremarkable (Patel 2009, Pigg *et al.* 2011, ESE 2014).

Small periapical lesions which may not be readily detected with PR may be detected with CBCT. This may have an impact on treatment planning in cases of gross caries and/or pulpitis where a decision between endodontic treatment and conservative treatment must be made (Hashem *et al.* 2015, 2018, Patel & Vincer 2017).

The radiographic appearance of a healthy periodontal ligament is more variable when assessed with CBCT compared to PR (Pigg *et al.* 2014), and therefore, a healthy periodontium may be misdiagnosed as diseased. The importance of suitable training is essential. It has been shown that the clinician's experience also appears to be correlated to their ability to correctly diagnose periapical disease on CBCT scans (Parker *et al.* 2017).

Assessment of the outcome of root canal treatment

It is well established that the root canal treatment of teeth with radiographic signs of chronic apical periodontitis has poorer (radiographic) outcomes than teeth with no preoperative signs of AP (Ng *et al.* 2011). Thus, earlier identification of AP with CBCT may result in earlier diagnosis and treatment of endodontic disease.

The increased accuracy of CBCT images in identifying periapical radiolucencies should result in a more objective and accurate assessment of the outcome of pulp preservation, primary root canal and secondary root canal treatment as well as periapical microsurgery (Liang *et al.* 2011, Davies *et al.* 2016).

Paula-Silva *et al.* (2009b) published the first root canal outcome study using CBCT. They compared the outcome of root canal treatment in dogs using PR and CBCT. Six months after treatment, a favourable outcome was detected in 79% of teeth assessed with PR, but in only 35% when CBCT was used. Unfavourable outcomes occurred more frequently in single-visit root canal treatment than two-visit treatments.

Liang *et al.* (2011) assessed the radiographic quality of root canal treatment carried out in teeth with vital pulps at 2 years with PR and CBCT. In 41% of cases, there was a difference in the quality of root fillings, with CBCT revealing more poor-quality root fillings than periapical radiographs. Root filling voids were detected in 16% and 46% of cases with PR and CBCT, respectively; the majority (77%) of voids evident on CBCT scans were in the bucco-lingual plane. When assessed with CBCT, root filling quality, that is the absence of voids, and quality of coronal restorations were determined to be prognostic factors in the outcome of the treatment. In a follow-up study, Liang *et al.* (2013) compared the outcome of root canal treatment with and without ultrasonic activation of irrigants and found no difference in outcome.

Patel *et al.* (2012b) assessed the outcome of primary root canal treatment using PR and CBCT, 1 year after treatment. The healed and healing rate of AP was 87% and 62.5% (healed), and 95.1% and 84.7 (healing), when assessed with PR and CBCT, respectively. CBCT detected a 14 times higher failure rate in teeth with no preoperative periapical radiolucency at 1-year review. Using the same methodology to assess the outcome of retreatment cases, similar results were observed by Davies *et al.* (2016). Both these studies revealed that treatment of molar teeth had a lower success rates than that of anterior and premolar teeth.

Al-Nuaimi *et al.* (2017) concluded that a favourable outcome was more likely when at least 30% residual tooth structure was present at the commencement of root canal retreatment. In a pooled

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analysis of 354 root filled teeth (123 primary treatments and 231 retreatments), the success rate for root canal treatment was lower when assessed using CBCT compared to PR. Furthermore, molar teeth had a significantly poorer success rate than premolar and anterior teeth (Al-Nuaimi *et al.* 2018).

Fernández *et al.* (2013), using PR and CBCT, retrospectively assessed the outcome of root canal treatment carried out on teeth with vital pulps 5 years previously. Of 17 prognostic factors assessed, four factors appeared to have a negative impact on the outcome of treatment when assessed with CBCT. These were root canal curvature, disinfection of guttapercha, unidentified root canals and the quality of the coronal restoration. However, these results should be interpreted with caution as no pre-treatment CBCT scans were taken.

Concluding remarks

- Due to the limitations of conventional radiography, the size of periapical lesions is underestimated when compared to CBCT;
- Current evidence suggests that CBCT has a higher sensitivity than PR for the detection of periapical lesions;
- Cone beam computed tomography may be indicated to aid the diagnosis of (non-)odontogenic pain when clinical examination and conventional radiographic assessment are not clear;
- Cone beam computed tomography may be considered when (in)direct pulp capping or pulpotomy is being planned in extensively carious teeth where PR does not reveal anything untoward.

CBCT for pre-surgical assessment

Cone beam computed tomography has been advocated as a useful diagnostic aid and treatment planning tool in cases of endodontic surgery (Tsurumachi & Honda 2007, Low *et al.* 2008, Durack & Patel 2012). The inter-individual and regional, intra-individual variations in the dimensions and location of anatomical structures including, and contained within, the alveolar bone surrounding teeth, complicate the endodontic surgical procedure. Cone beam computed tomography provides a more reliable and effective method for identification of missed anatomy and accessory canals as well as the true nature and extension of a periapical lesion (Bornstein *et al.* 2015, Patel *et al.* 2015). Cone beam computed tomography affords the clinician the ability to preoperatively assess the entire surgical field without restriction, facilitating the surgical procedure.

Detection of apical periodontitis and identification of affected roots

In multi-rooted teeth, the ability to identify specific roots with AP allows the clinician to be root-specific (Kraus *et al.* 2015) and eliminate the removal of alveolar bone and dentine associated with unaffected roots, all of which serve to improve patient comfort, simplify the procedure and reduce treatment time and cost.

Cone beam computed tomography permits the accurate assessment of the dimensions and extent of the lesion as well as its relationship to adjacent anatomical structures and the presence of any expansion or perforation of cortical bone (Bornstein *et al.* 2012). This aids planning, for example flap design, and limits unnecessary excavation of lesions which are in close proximity to vital neighbouring structures.

Digital Imaging and Communications in Medicine (DICOM) data sets may be used to fabricate custom surgical guides for tissue retraction and root-end location in teeth undergoing apical surgery (Patel *et al.* 2017, Ye *et al.* 2018).

Assessment of the root, root canal and the surrounding anatomical structures and landmarks relevant to apical surgery

Cone beam computed tomography is a diagnostically accurate and reliable tool for the measurement of root length (Liang *et al.* 2013, Metska *et al.* 2014); the identification of the apical foramen (Jeger *et al.* 2012, Liang *et al.* 2013); the assessment of root, and root canal, anatomy and curvature (Park *et al.* 2013); and the presence and position of bone defects (Low *et al.* 2008). Accurate identification of anatomical structures and landmarks reduces operative morbidity. Pre-treatment evaluation will enhance patient comfort and minimize treatment time and complexity. These precise assessments cannot be accurately undertaken with PR.

Bornstein *et al.* (2011) compared the ability of PR and CBCT to measure the distance between the apices of mandibular molars and the inferior dental nerve canal in teeth undergoing apical surgery. This distance could only be measured accurately in 35.3%

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and 100% of cases using PR and CBCT, respectively. The thickness of the cortical plate and the combined thickness of cortical plate and cancellous bone could also be measured accurately using CBCT, measurements that simply cannot be made with periapical radiography. von Arx *et al.* (2013) used CBCT to evaluate the location and dimensions of the mental foramen as well as the course and angulation of the mental canal exiting the mental foramen. They related this information, using CBCT, to the position of adjacent teeth and to that of the upper and lower borders of the mandible.

The orientation of the long axis of the root to the cortical plate can be determined with CBCT so that correct bur orientation and depth of cut for root resection can be planned prior to treatment. Identification of root canals missed clinically, or indeed, verification of the absence of supplemental canals is enhanced by CBCT (Lofthag-Hansen *et al.* 2007, Davies *et al.* 2015). So too are the identification of isthmi (Soares de Toubes *et al.* 2012) and anomalous tooth forms (Song *et al.* 2010, Durack & Patel 2011, Radwan & Kim 2014) in teeth which may require endodontic surgery.

Concluding remarks

CBCT is recommended for:

- Complex surgical cases (i.e. multi-rooted teeth and complex anatomy);
- When the root apices are in close proximity to important anatomical structures or where these structures cannot be accurately assessed with PR.

Dental trauma

Contemporary guidelines for the management of traumatic dental injuries (TDI) advocate that an anterior occlusal radiograph should supplement the findings of two periapical radiographs when an injured tooth is assessed (Di Angelis *et al.* 2012). Additional radiographs to assess any lip and cheek lacerations are further advised to identify potential embedded debris. Even with these additional radiographs, the true nature of TDIs is often extremely difficult to visualize.

Use of CBCT to assess TDI

Cone beam computed tomography provides enhanced visualization of TDIs over PR (Di Angelis *et al.* 2012, Tsukiboshi & Durack 2016) and has been indicated in situations where PR provides limited diagnostic information (Patel *et al.* 2015); in reality, it is likely that CBCT offers much more than an adjunctive role in the assessment of TDI.

Injuries to the hard tissues and dental pulp

Crown fractures. Cone beam computed tomography may provide a more objective assessment of the thickness of the dentine overlying the pulp (Tsukiboshi & Durack 2016).

Crown root fractures. Cone beam computed tomography permits a more accurate visualization of the course of the often oblique nature of these fractures and the relationship of the fracture to the pulp, periodontium and crestal bone, thus facilitating management (Martos *et al.* 2017, Doğan *et al.* 2018).

Horizontal root fractures. Horizontal root fractures (HRF) generally have an oblique orientation when they occur in the apical and middle thirds of the root and can only be identified with PR when the X-ray beam passes within 15–20° of the orientation of the fracture line (Bender & Friedland 1983, Andreasen & Andreasen 1988). As such, these injuries may be missed with PR, but they are reliably identified with CBCT (Jones *et al.* 2015, Tsukiboshi & Durack 2016).

By altering CBCT exposure parameters, the radiation dose may be reduced by up to 80% with little impact on the diagnostic yield in the detection of HRF (Jones *et al.* 2015).

Injuries to the periodontal tissues

Concussion and Subluxation. Cone beam computed tomography is significantly more sensitive than PR in the detection of PDL space widening and in the detection of incipient lesions of apical periodontitis (Cheung *et al.* 2013, Tsai *et al.* 2013). Therefore, in severe subluxation injuries with significant tooth mobility, widening of the PDL space may only be evident on CBCT; this may influence the management (Tsukiboshi & Durack 2016, Patel & Saberi 2018).

Luxation injuries (lateral luxation, intrusive luxation and extrusive luxation). The nature of luxation injuries may not always be readily appreciated from a clinical examination, especially in mixed dentition, and/or where there are concomitant dental injuries, for example lateral luxation in conjunction with intrusion or extrusion (Tsukiboshi & Durack 2016). With PR, it may be very

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difficult to visualize the bucco-palatal orientation of these injuries (Cohenca *et al.* 2007, Tsukiboshi & Durack 2016). IADT guidelines advise that lateral luxation injuries are best viewed using eccentric or occlusal conventional radiographic exposures (Di Angelis *et al.* 2012) to some degree, leaving radiographic visualization to chance. Cone beam computed tomography permits unobstructed visualization in all planes facilitating accurate assessment of the nature of the displacement (Cohenca *et al.* 2007, Tsukiboshi & Durack 2016).

Injuries to the supporting bone

Fractures of the alveolar plates(s) occur as a matter of course with lateral luxation and intrusive luxation injuries (Di Angelis *et al.* 2012). Regardless of the nature of the fracture, they are rarely if ever identified with PR. This is in contrast to CBCT which is sufficiently sensitive to identify the nature of alveolar bone damage in the absence of any evidence on PR (Dölekoglu *et al.* 2010, Tsukiboshi & Durack 2016).

This information may have an impact on treatment planning, for example, when extraction and immediate implant placement are being considered.

Injuries to the soft tissues

The 'scout views' taken to confirm the size and positioning of the field of view prior to scanning, as well as the CBCT images, capture and display the exact location of any radiodense matter embedded in the soft tissues within a given examination (Tsukiboshi & Durack 2016).

Concluding remarks

The effective radiation doses with CBCT are higher than PR, and this must be balanced against the larger number of PRs that must be prescribed in an attempt to yield the same information that can be obtained from a single CBCT scan. Cone beam computed tomography should be considered:

- When the diagnosis from clinical and PR assessment is inconclusive;
- When there are severe injuries to multiple teeth;
- When DTI results in it being impossible to acquire PR due to patient discomfort and/or limited mouth opening;
- Thought should be given to using CBCT as the tool of choice in reviewing traumatically injured teeth to allow earlier detection of complications (e.g. resorption).

Root resorption

The limitations of PR can result in misdiagnosis, inadequate assessment and/or poor management of root resorption (Schwartz *et al.* 2010, Gunst *et al.* 2013, Patel & Saberi 2018). Several *ex vivo* studies have confirmed a greater level of accuracy with CBCT for diagnosing internal (Kamburoğlu *et al.* 2011) and external resorption defects (Durack *et al.* 2011, Bernardes *et al.* 2012, Vaz de Souza *et al.* 2017).

The bucco-palatal extent of internal and external root resorptive lesions can only be accurately assessed with CBCT. This information may be relevant when determining the prognosis of treatment (Patel *et al.* 2010, Bhuva *et al.* 2011).

Estrela *et al.* (2009) found that CBCT and PR detected inflammatory root resorption in 100% and 68.8% of cases, respectively. Patel *et al.* (2009b) found that CBCT was significantly better than PR in correctly diagnosing clinical root resorption, and this resulted in more appropriate treatment planning. Similar conclusions have been found in more recent clinical studies (Ee *et al.* 2014, Patel *et al.* 2016, Rodríguez *et al.* 2017a,b, b).

The 'portal of entry', as well as the true nature of the resorptive lesion, may not be readily detectable on PR (Mavridou *et al.* 2016, Patel *et al.* 2018a). In addition, the true nature of ECR (fibrovascular and bone-like tissue) will also be more clearly discernible with CBCT (Gunst *et al.* 2013), information, which is relevant for treatment planning (Patel & Dawood 2007, Patel *et al.* 2018a).

The Heithersay (1999) classification does not take in account the circumferential spread or depth of ECR. Vaz de Souza *et al.* (2017) created simulated ECR lesions representing the four Heithersay classes and found that CBCT was significantly more accurate than PR at classifying ECR. In a clinical study, Patel *et al.* (2016) concluded that PR had a limited accuracy in the detection of the size, circumferential spread and location of ECR lesions compared to CBCT.

The additional information gained from CBCT has resulted in the introduction of a 3-dimensional classification to describe ECR (Patel *et al.* 2018b). The aim of this descriptive classification is to ensure an accurate diagnosis and aid communication of ECR between clinicians. It should allow objective outcome assessment as well as aid in decision-making. Ultimately, treatment outcome and prognostic factors may also be assessed in relation to the three-dimensional nature of ECR.

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Concluding remarks

In cases where (parallax) radiographs provide limited information, CBCT should be considered as an additional method to assess the nature of a resorptive lesion; this information improves diagnosis and management of root resorption.

Vertical root fractures (VRF)

PR only detect VRF if it they are displaced and in the plane of the X-ray beam (Rud & Ommell 1970, Meister *et al.* 1980) and in situations where there is minimal anatomical noise (Patel *et al.* 2013, Brady *et al.* 2014).

Ex vivo investigations

Several *ex vivo* studies have highlighted that CBCT examinations have a greater accuracy at detecting simulated VRF (Tsesis *et al.* 2008, Hassan *et al.* 2009).

The heterogeneity between studies (Talwar *et al.* 2016), not least the method of fracture induction, which in some studies has produced widely displaced fractured segments, which would be clinical detectable (0.2 mm–0.4 mm), means that the studies have questionable clinical relevance (Hassan *et al.* 2009, Kamburoğlu *et al.* 2010). To overcome this, fractures have been induced by applying a compressive load to a pin inserted into the root (Patel *et al.* 2013, Brady *et al.* 2014). In these studies, a universal testing machine was used to detect the development of the fracture. The overall accuracy for detecting both types of fractures with CBCT was 0.87 and 0.45 for non-root filled teeth and root filled teeth, respectively. The diagnostic accuracy of PR was 0.63 and 0.53 for non-root filled teeth and root filled teeth, respectively.

Detectability also appears to be CBCT scanner-specific (Elsaltani *et al.* 2016, Tiepo *et al.* 2017). The detector sensitivity, voxel parameters, exposure parameters, speed and degree of scan rotation, and variations in image reconstruction have an impact on the accuracy of CBCT (Bechara *et al.* 2013b, Bezerra *et al.* 2015, Talwar *et al.* 2016).

Beam hardening resulting from the root filling reduces the specificity of incomplete and complete fracture detection in root filled teeth (Schulze *et al.* 2011, Khedmat *et al.* 2012, Neves *et al.* 2014). As a result, diagnosis becomes more challenging (Bechara *et al.* 2013c), which may result in inappropriate management (Kajan & Taromsari 2012). Scatter from radiopaque materials may be misinterpreted as fracture lines (Hassan *et al.* 2010, Kajan & Taromsari 2012).

The presence of metallic posts decreases the diagnostic yield of CBCT scans in the detection of root fractures due to the presence of beam hardening artefacts (Costa *et al.* 2011). In contrast, fibre posts do not seem to interfere with the sensitivity and specificity CBCT in the detection of VRF (Neves *et al.* 2014, Pinto *et al.* 2017).

Clinical research

Wang *et al.* (2011) concluded that the sensitivity of CBCT was higher than PR in the assessment of 95 root fractures. However, the accuracy was impaired by the presence of a root filling due to scatter from the radiopaque root filling material (Wang *et al.* 2011). In a meta-analysis, Long *et al.* (2014) suggested that CBCT has a high diagnostic yield for the detection of tooth fractures, with a reported sensitivity and specificity of 0.92 and 0.85, respectively.

Chavda *et al.* (2014) evaluated PR and CBCT images and compared them to atraumatically extracted teeth in order to confirm the presence or absence of a fracture. They reported a sensitivity of 0.16 and 0.27 for PR and CBCT, respectively, and a relatively high specificity of 0.92 and 0.83 for PR and CBCT, respectively.

A systematic review highlighted the heterogeneity of the available data and a high risk of bias, which led the authors to conclude that CBCT may be of limited value in detecting VRF in root filled teeth (Chang *et al.* (2016). This is also in agreement with other systematic reviews (Corbella *et al.* 2014, Rosen *et al.* 2015).

Concluding remarks

There is insufficient evidence to advocate the use of CBCT for detection of VRF. However, CBCT may be indicated where symptoms and/or signs are absent or ambiguous and VRF is suspected. In these cases, CBCT may reveal signs of periradicular bone loss indicating a VRF within the adjacent root.

Assessment of root canal anatomy

Due to the two-dimensional nature of PR, they are likely to underestimate the true anatomical

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complexity of the root canal system (Matherne *et al.* 2008, Abella *et al.* 2012b, Davies *et al.* 2015).

Ex vivo research has demonstrated a significant and predictable benefit to using CBCT examinations in identifying additional roots of mandibular molars (Tu *et al.* 2009). Matherne *et al.* (2008) reported that endodontists failed to identify at least one canal in up to 41% of cases when evaluated with PR when CBCT was used as the gold standard. Abubara *et al.* (2013) reported that only 8% of MB2 canals were identified using PR, whilst with CBCT, MB2 canals were identified in 54% of cases.

Cone beam computed tomography examination improves the identification, location and appreciation of teeth with anomalous anatomy, for example dens invaginatus (Patel 2010, Durack & Patel 2011). More recently, CBCT has been used in conjunction with specialized software (3DEndo®, Dentsply Sirona, Ballaigues, Switzerland) to evaluate the complexity of root canals (Gambarini *et al.* 2018) prior to treatment. Patel *et al.* (2019) found 3DEndo®, software, followed by CBCT, was found to be more desirable for the evaluation of root canal anatomy, working lengths and also reducing the clinician's stress levels than PR. A recent three-dimensional classification of various dental anomalies based on CBCT investigations has been devised (Ahmed & Dummer 2018).

Stents with guide sleeves have been 3D printed from optical surface scans and CBCT data sets to allow guided access cavity preparation (Connert *et al.* 2019). The benefits of guided access cavity preparation include conservative access cavity preparation, decreased chair time and reduced risk of iatrogenic damage (Torres *et al.* 2018, Connert *et al.* 2019).

Concluding remarks

Cone beam computed tomography imaging may be indicated to obtain information about the nature of complex root canal anatomy. CBCT gives an increased appreciation of the root canal anatomy, which should result in more conservative access preparation. The poor resolution of CBCT means that sclerosed and/or accessory anatomy may not be readily identified.

Impact on treatment planning

Treatment options for root canal retreatment failure include non-surgical or surgical endodontic retreatment, intentional replantation and extraction with (out) tooth replacement.

There is poor inter-examiner variation associated with treatment of endodontic pathoses (Reit & Gröndahl 1988). Ee *et al.* (2014) compared the relative value of preoperative PR and CBCT in the decision-making process in endodontic treatment planning. Three American board-certified endodontists separately selected a preoperative diagnosis of 30 randomly arranged sets of PR, and then 2 weeks later, they reviewed 30 CBCT scans of the same teeth. The treatment plan changed with CBCT in 62% of the cases. Similar results were reported by Mota de Almeida *et al.* (2015) and Rodríguez *et al.* (2017a). Davies *et al.* (2016) concluded that CBCT had an impact of the future management of retreatment cases attending for a review when compared to PR.

Rodríguez *et al.* (2017a) assessed the impact of CBCT on decision-making amongst different specialists (prosthodontists, endodontists, oral surgeons and periodontists). Thirty cases with endodontic problems of varying degrees of complexity ($n = 10$ minimum, $n = 10$ moderate and $n = 10$ high difficulty) were assessed. Examiners were given relevant clinical information and PR, and selected the most appropriate treatment plan and graded the difficulty in decision-making. One month later, the examiners reviewed the same 30 cases with the additional information from the CBCT. The authors concluded that the additional information obtained from CBCT scans influences the treatment plan of each specialist group, in high difficulty cases the treatment plan changed in up to 53% of cases. With the exception of endodontists, the different groups of specialists reported a relatively high difficulty in decision-making when viewing the CBCT scans. This may have an impact on other specialist groups assessing endodontic problems with CBCT imaging – it may be prudent to seek an endodontist's opinion in these cases.

Rodríguez *et al.* (2017b) determined the impact of CBCT imaging on decision-making amongst general dental practitioners and endodontists after failed root canal treatment. The examiners altered their treatment plan after viewing the CBCT in 49.8% of the cases. After viewing the CBCT scans, examiners' selection of the option to extract teeth rose from 11.67% to 20%.

Concluding remarks

Diagnostic CBCT may provide additional information when compared to PR, which may an impact on the treatment planning of complex endodontic retreatment cases.

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Conclusion

It is clear that the additional information provided by CBCT may increase and/or improve diagnostic accuracy and confidence in decision-making as well as have an impact of treatment planning. More clinical studies are required to assess the long-term impact of CBCT on the outcomes of endodontic treatment.

However, CBCT imaging comes at the expense of increased radiation dose; therefore, CBCT should only be reserved for cases where there is potential benefit from a three-dimensional assessment. It is essential that patient radiation exposure is kept as low as reasonably practicable (ALARP). The benefits of a CBCT investigation must outweigh any potential risks. Therefore, each scan must be optimized to reduce patient exposure by adjusting the CBCT settings, thus allowing *each examination to be personalized to the individual patient and the diagnostic needs*, rather than just using manufacturer's default settings.

Users of CBCT must attend accredited training on the core (level 1) and/or advanced (level 2) training depending on their level of use.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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Cone-beam Computed Tomography for Detecting Vertical Root Fractures in Endodontically Treated Teeth: A Systematic Review

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Abstract

Introduction: A vertical root fracture (VRF), commonly found in teeth with endodontic treatment, is challenging to diagnose and has poor treatment outcomes. Cone-beam computed tomography (CBCT) has become an increasingly popular imaging modality in endodontics, but image artifacts arising from root-filling materials may hinder VRF detection. The aim of this investigation was to conduct a systematic review to assess the diagnostic ability of CBCT for detecting VRFs in endodontically treated teeth. **Methods:** A systematic review of *in vivo* clinical diagnostic literature (initial search December 2014, updated August 2015) was conducted. Assessment of methodological quality was performed by using the modified Quality Assessment of Diagnostic Accuracy Studies tool. **Results:** Four studies with a total of 130 patients were included. The reported ranges of values were 40%–90% for VRF prevalence, 84% (0.64–0.95) to 100% (0.83–1.00) for sensitivity, 64% (0.35–0.87) to 100% (0.03–1.00) for specificity, 71% (0.51–0.87) to 100% (0.63–1.00) for positive predictive value, and 50% (0.01–0.99) to 100% (0.84–1.00) for negative predictive value. All 4 studies revealed multiple items at high risk or unclear risk of bias. **Conclusions:** Because of the significant imprecision in the range of reported estimates and the biases observed in the included studies, there is currently insufficient evidence to suggest that CBCT is a reliable test in detecting VRFs in endodontically treated teeth. *(J Endod 2016;42:177–185)*

Key Words

Cone beam computed tomography, diagnosis, review literature as topic, tooth fractures

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A vertical root fracture (VRF) is defined as a longitudinally oriented fracture plane that is confined to the tooth root. The prevalence of VRFs is not well-established, but it is thought that they are more commonly found in teeth that have undergone endodontic treatment (1). Clinical studies of endodontically treated teeth that were extracted with the presumption of VRF suggest a prevalence of 2%–5% (2–6), whereas studies that observed VRFs in extracted endodontically treated teeth report a prevalence of between 11% and 20% (7, 8). Traditional methods used to diagnose VRFs include transillumination (9), projection radiography (10), bite testing (11), periodontal probing (3), sinus tract detection (3), and direct visual examination (11). Unfortunately, all of these methods have limited diagnostic reliability because most signs and symptoms are nonspecific for VRF. Hence, distinguishing VRF from pulpal necrosis, failed root canal treatment, and/or periodontal disease is often challenging (12). Particularly in relation to projection radiography, it has been shown that to visualize a VRF, the primary beam needs to be within 4° of the fracture plane (13). Moreover, the superimposition of surrounding anatomic structures makes visualization of a VRF even more difficult (14). Therefore, it is not surprising that a fracture plane is visualized in only approximately one third of VRF cases on periapical radiographs (15). Once a diagnosis is established, the prognosis of a tooth with VRF is poor; there are currently no reliable methods of treating VRF, and the affected tooth is usually extracted (1). In this context, a reliable diagnosis of VRF is of utmost importance to prevent unnecessary extraction of an otherwise treatable tooth.

Cone-beam computed tomography (CBCT) is an imaging modality that uses a revolving cone-shaped x-ray source projected onto a reciprocating digital flat-panel receptor. The acquired projectional "basis" images are then used to construct a three-dimensional volumetric data set that can then be used to reconstruct cross-sectional images in any plane (16). Compared with conventional multidetector CT, CBCT units are typically smaller and less expensive and offer higher-resolution images with lower effective doses to the patient (17). Because of the limitations of conventional radiography, the application of high-resolution CBCT imaging in detecting VRFs has generated considerable interest. Although there are a number of *ex vivo* studies that have attempted to assess the ability of CBCT in detecting artificially induced VRFs in endodontically treated teeth (18–30), these findings do not incorporate the associated periradicular changes in the osseous structures adjacent to the fracture plane, which can often aid in the interpretation of a VRF (31). In our experience, ruling out VRF in a previously endodontically treated tooth is a common reason for CBCT imaging, yet it is one of the most difficult to interpret because of the presence of imaging artifacts that may obscure the putative fracture plane (32). Consequently, the ability of CBCT to detect VRFs in endodontically treated teeth is an important clinical question to address. The purpose of this systematic review was to investigate the diagnostic ability of CBCT in detecting VRFs in endodontically treated teeth. The review format and methodology strictly adhere to those recommended by the Cochrane Collaboration for diagnostic tests of accuracy as well as users' guide to studies of diagnosis (33–35).

Distribution Information
AAE members may reprint this position statement for distribution to patients or referring dentists.

AAE and AAOMR Joint Position Statement

Use of Cone Beam Computed Tomography in Endodontics—2015/2016 Update

About This Document
The following statement was prepared by the Special Committee to Revise the Joint American Association of Endodontists/American Academy of Oral and Maxillofacial Radiology Position Statement on the Use of Cone Beam Computed Tomography in Endodontics. It was approved by the AAE Board of Directors and AAOMR Executive Council in May 2015. Recommendations 13 and 14 were added by the Committee and approved in May 2016.

INTRODUCTION

This updated joint position statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology is intended to provide scientifically based guidance to clinicians regarding the use of cone beam computed tomography in endodontic treatment and reflects new developments since the 2010 statement (1). The guidance in this statement is not intended to substitute for a clinician's independent judgment in light of the conditions and needs of a specific patient.

Endodontic disease adversely affects quality of life and can produce significant morbidity in afflicted patients. Radiography is essential for the successful diagnosis of odontogenic and non-odontogenic pathoses, treatment of the root canal systems of a compromised tooth, biomechanical instrumentation, evaluation of final canal obturation, and assessment of healing.

Until recently, radiographic assessments in endodontic treatment were limited to intraoral and panoramic radiography. These radiographic technologies provide two-dimensional representations of three-dimensional anatomic structures. If any element of the geometric configuration is compromised, the image may demonstrate errors (2). In more complex cases, radiographic projections with different beam angulations can allow parallax localization. However, complex anatomy and surrounding structures can render interpretation of planar images difficult.

The advent of CBCT has made it possible to visualize the dentition, the maxillofacial skeleton, and the relationship of anatomic structures in three dimensions (3). CBCT, as with any technology, has known limitations, including a possible higher radiation dose to the patient. Other limitations include potential for artifact generation, high levels of scatter and noise, and variations in dose distribution within a volume of interest (4).

CBCT should be used only when the patient's history and a clinical examination demonstrate that the benefits to the patient outweigh the potential risks. CBCT should not be used routinely for endodontic

diagnosis or for screening purposes in the absence of clinical signs and symptoms. Clinicians should use CBCT only when the need for imaging cannot be met by lower dose two-dimensional radiography.

Volume Size(s)/Field of View

There are numerous CBCT equipment manufacturers, and several models are available. In general, CBCT is categorized into large, medium and limited-volume units based on the size of their "field of view." The size of the FOV describes the scan volume of CBCT machines. That volume determines the extent of anatomy included. It is dependent on the detector size and shape, beam projection geometry and the ability to collimate the beam. To the extent practical, FOV should only slightly exceed the dimensions of the anatomy of interest.

Generally, the smaller the FOV, the lower the dose associated with the study. Beam collimation limits the radiation exposure to the region of interest and helps ensure that an optimal FOV can be selected based on disease presentation. Smaller scan volumes generally produce higher-resolution images. Because endodontics relies on detecting small alterations such as disruptions in the periodontal ligament space, optimal resolution should be sought (5).

The principal limitations of large FOV CBCT imaging are the size of the field irradiated and the reduced resolution compared to intraoral radiographs and limited-volume CBCT units with inherent small voxel sizes (5). The smaller the voxel size, the higher the spatial resolution. Moreover, the overall scatter generated is reduced due to the limited size of the FOV. Optimization of the exposure protocols keeps doses to a minimum without compromising image quality. If a low-dose protocol can be used for a diagnostic task that requires lower resolution, it should be employed, absent strong indications to the contrary.

In endodontics, the area of interest is limited and determined prior to imaging. For most endodontic applications, limited FOV CBCT is preferred to medium or large FOV CBCT because there is less radiation dose to the patient, higher spatial resolution and shorter volumes to be interpreted.

Dose Considerations

Selection of the most appropriate imaging protocol for the diagnostic task must be consistent with the ALARA principles that every effort should be made to reduce the effective radiation dose to the patient "as low as reasonably achievable." Because radiation dose for a CBCT study is higher than that for an intraoral radiograph, clinicians must consider overall radiation dose over time. For example, will acquiring a CBCT study now eliminate the need for additional imaging procedures in the future? It is recommended to use the smallest possible FOV, the smallest voxel size, the lowest mA setting (depending on the patient's size) and the shortest exposure time in conjunction with a pulsed exposure-mode of acquisition.

If extension of pathoses beyond the area surrounding the tooth apices or a multifocal lesion with possible systemic etiology is suspected, and/or a nonendodontic cause for devitalization of the tooth is established clinically, appropriate larger field of view protocols may be employed on a case-by-case basis.

There is a special concern with overexposure of children (up to and including 18 years of age) to radiation, especially with the increased use of CT scans in medicine. The AAE and the AAOMR support the Image Gently Campaign led by the Alliance for Radiation Safety in Pediatric Imaging. The goal of the campaign is "to change practice; to raise awareness of the opportunities to lower radiation dose in the imaging of children." Information on use of CT is available at *www.imagegently.org/Procedures/ComputedTomography.aspx*.

Interpretation

If a clinician has a question regarding image interpretation, it should be referred to an oral and maxillofacial radiologist (6).

RECOMMENDATIONS

The following recommendations are for limited FOV CBCT scans.

Diagnosis

Endodontic diagnosis is dependent upon thorough evaluation of the patient's chief complaint, history and clinical and radiographic examination. Preoperative radiographs are an essential part of the diagnostic phase of endodontic therapy. Accurate diagnostic imaging supports the clinical diagnosis.

Recommendation 1: Intraoral radiographs should be considered the imaging modality of choice in the evaluation of the endodontic patient.

Recommendation 2: Limited FOV CBCT should be considered the imaging modality of choice for diagnosis in patients who present with contradictory or nonspecific clinical signs and symptoms associated with untreated or previously endodontically treated teeth.

Rationale

- In some cases, the clinical and planar radiographic examinations are inconclusive. Inability to confidently determine the etiology of endodontic pathosis may be attributed to limitations in both clinical vitality testing and intraoral radiographs to detect odontogenic pathoses. CBCT imaging has the ability to detect periapical pathosis before it is apparent on 2-D radiographs (7).
- Preoperative factors such as the presence and true size of a periapical lesion play an important role in endodontic treatment outcome. Success, when measured by radiographic criteria, is higher when teeth are endodontically treated before radiographic signs of periapical disease are detected (8).
- Previous findings have been validated in clinical studies in which primary endodontic disease detected with intraoral radiographs and CBCT was 20% and 48%, respectively. Several clinical studies had similar findings, although with slightly different percentages (9,10). Ex vivo experiments in which simulated periapical lesions were created yielded similar results (11,12). Results of in vivo animal studies, using histologic assessments as the gold standard, also showed similar results observed in human clinical and ex vivo studies (13).
- Persistent intraoral pain following root canal therapy often presents a diagnostic challenge. An example is persistent dentoalveolar pain also known as atypical odontalgia (14). The diagnostic yield of conventional intraoral radiographs and CBCT scans was evaluated in the differentiation between patients presenting with suspected atypical odontalgia versus symptomatic apical periodontitis, without radiographic evidence of periapical bone destruction (15). CBCT imaging detected 17% more teeth with periapical bone loss than conventional radiography.

Initial Treatment

Preoperative

Recommendation 3: Limited FOV CBCT should be considered the imaging modality of choice for initial treatment of teeth with the potential for extra canals and suspected complex morphology, such as mandibular anterior teeth, and maxillary and mandibular premolars and molars, and dental anomalies.

Intraoperative

Recommendation 4: If a preoperative CBCT has not been taken, limited FOV CBCT should be considered as the imaging modality of choice for intra-appointment identification and localization of calcified canals.

Postoperative

Recommendation 5: Intraoral radiographs should be considered the imaging modality of choice for immediate postoperative imaging.

Rationale

- Anatomical variations exist among different types of teeth. The success of nonsurgical root canal therapy depends on identification of canals, cleaning, shaping and obturation of root canal systems, as well as quality of the final restoration.
- 2-D imaging does not consistently reveal the actual number of roots and canals. In studies, data acquired by CBCT showed a very strong correlation between sectioning and histologic examination (16,17).
- In a 2013 study, CBCT showed higher mean values of specificity and sensitivity when compared to intraoral radiographic assessments in the detection of the MB2 canal (18).

Nonsurgical Retreatment

Recommendation 6: Limited FOV CBCT should be considered the imaging modality of choice if clinical examination and 2-D intraoral radiography are inconclusive in the detection of vertical root fracture.

Rationale

- In nonsurgical retreatment, the presence of a vertical root fracture significantly decreases prognosis. In the majority of cases, the indication of a vertical root fracture is more often due to the specific pattern of bone loss and periodontal ligament space enlargement than direct visualization of the fracture. CBCT may be recommended for the diagnosis of vertical root fracture in unrestored teeth when clinical signs and symptoms exist.
- Higher sensitivity and specificity were observed in a clinical study where the definitive diagnosis of vertical root fracture was confirmed at the time of surgery to validate CBCT findings, with sensitivity being 88% and specificity 75% (19). Several case series studies have concluded that CBCT is a useful tool for the diagnosis of vertical root fractures. In vivo and laboratory studies (20, 21) evaluating CBCT in the detection of vertical root fractures agreed that sensitivity, specificity, and accuracy of CBCT were generally higher and reproducible. The detection of fractures was significantly higher for all CBCT systems when compared to intraoral radiographs. However, these results should be interpreted with caution because detection of vertical root fracture is dependent on the size of the fracture, presence of artifacts caused by obturation materials and posts and the spatial resolution of the CBCT.

Recommendation 7: Limited FOV CBCT should be the imaging modality of choice when evaluating the nonhealing of previous endodontic treatment to help determine the need for further treatment, such as nonsurgical, surgical or extraction.

Recommendation 8: Limited FOV CBCT should be the imaging modality of choice for nonsurgical retreatment to assess endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, and localization of perforations.

Rationale

- It is important to evaluate the factors that impact the outcome of root canal treatment. The outcome predictors identified with periapical radiographs and CBCT were evaluated by Liang et al. (22) The results showed that periapical radiographs detected periapical lesions in 18 roots (12%) as compared to 37 on CBCT scans (25%). Eighty percent of apparently short root fillings based on intraoral radiographs images appeared flush on CBCT. Treatment outcome, length and density of root fillings and outcome predictors determined by CBCT showed different values when compared with intraoral radiographs.
- Accurate treatment planning is an essential part of endodontic retreatment. Incorrect, delayed or inadequate endodontic diagnosis and treatment planning places the patient at risk and may result in unnecessary treatment. Treatment planning decisions using CBCT versus intraoral radiographs were compared to the gold standard diagnosis (23). An accurate diagnosis was reached in 36%-40% of the cases with intraoral radiographs compared to 76%-83% with CBCT. A high level of misdiagnosis was noted in invasive cervical resorption and vertical root fracture. In this study, the examiners altered their treatment plan after reviewing the CBCT in 56%-62.2% of the cases, thus indicating the significant influence of CBCT.

Surgical Retreatment

Recommendation 9: Limited FOV CBCT should be considered as the imaging modality of choice for presurgical treatment planning to localize root apex/apices and to evaluate the proximity to adjacent anatomical structures.

Rationale

The use of CBCT has been recommended for treatment planning of endodontic surgery (24, 25). CBCT visualization of the true extent of periapical lesions and their proximity to important vital structures and anatomical landmarks is superior to that of periapical radiographs.

Special Conditions

Implant Placement

Recommendation 10: Limited FOV CBCT should be considered as the imaging modality of choice for surgical placement of implants (26).

Traumatic Injuries

Recommendation 11: Limited FOV CBCT should be considered the imaging modality of choice for diagnosis and management of limited dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures, in the absence of other maxillofacial or soft tissue injury that may require other advanced imaging modalities (27).

Resorptive Defects

Recommendation 12: Limited FOV CBCT is the imaging modality of choice in the localization and differentiation of external and internal resorptive defects and the determination of appropriate treatment and prognosis (28, 29).

Outcome Assessment

Recommendation 13: In the absence of clinical signs or symptoms, intraoral radiographs should be considered the imaging modality of choice for the evaluation of healing following nonsurgical and surgical endodontic treatment.

Recommendation 14: In the absence of signs and symptoms, if limited FOV CBCT was the imaging modality of choice at the time of evaluation and treatment, it may be the modality of choice for follow-up evaluation. In the presence of signs and symptoms, refer to Recommendation #7.

Rationale

- Use of limited FOV CBCT for evaluation of healing following nonsurgical and surgical treatment must be considered on a case-by-case basis, with due consideration given the risks and benefits of exposing the patient to ionizing radiation, the patient's history, clinical findings, mode of endodontic intervention, pre-existing radiographic appearance, temporal changes and any other systemic or extraneous factors that could confound the healing process.
- Accurate diagnosis of complete and uneventful healing as determined radiographically, with unequivocal clinical correlation supporting the radiographic diagnosis, is challenging (30, 31, 32, 33). The healing process is dependent on various factors, both extraneous and

host-related. In the future, once the parameters associated with healing are fully confirmed by evidence-based studies, the use of limited FOV CBCT for outcome assessment can be better interpreted.

CONCLUSION

CBCT is an emerging technology that is revolutionizing the approach to endodontic care of dental patients. The guidance in this statement is not intended to substitute for a clinician's independent judgment in patient care. The use of limited FOV CBCT should be considered on a case-by-case basis, with due consideration given to the risks and benefits of exposing the patient to ionizing radiation, the patient's history, clinical findings and pre-existing radiographs so that superior treatment can be provided to the general public in need of endodontic care.

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Thank you to the Special Committee to Revise the AAE/AAOMR Joint Position Statement on Cone Beam Computed Tomography:

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line	Condition	Treatment
53	PREVENTIVE DENTAL SERVICES	CLEANING, FLUORIDE AND SEALANTS
54	DENTAL CONDITIONS (E.G., INFECTION, PAIN, TRAUMA)	EMERGENCY DENTAL SERVICES
218	DENTAL CONDITIONS (E.G., PERIODONTAL DISEASE)	BASIC PERIODONTICS
267	DENTAL CONDITIONS (TIME SENSITIVE EVENTS)	URGENT DENTAL SERVICES
343	DENTAL CONDITIONS (E.G., CARIES, FRACTURED TOOTH)	BASIC RESTORATIVE (E.G., COMPOSITE RESTORATIONS FOR ANTERIOR TEETH, AMALGAM RESTORATIONS FOR POSTERIOR TEETH)
344	DENTAL CONDITIONS (E.G., SEVERE CARIES, INFECTION)	ORAL SURGERY (I.E., EXTRACTIONS AND OTHER INTRAORAL SURGICAL PROCEDURES)
384	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT ANTERIOR TOOTH)	BASIC ENDODONTICS (I.E., ROOT CANAL THERAPY)
411	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT BICUSPID/PREMOLAR TOOTH)	BASIC ENDODONTICS (I.E., ROOT CANAL THERAPY)
443	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT MOLAR TOOTH)	BASIC ENDODONTICS (I.E., ROOT CANAL THERAPY)
453	DENTAL CONDITIONS (E.G., MISSING TEETH, PROSTHESIS FAILURE)	REMOVABLE PROSTHODONTICS (E.G., FULL AND PARTIAL DENTURES, RELINES)
457	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT ANTERIOR TOOTH)	ADVANCED ENDODONTICS (E.G., RETREATMENT OF PREVIOUS ROOT CANAL THERAPY)
468	DENTAL CONDITIONS (E.G., CARIES, FRACTURED TOOTH)	ADVANCED RESTORATIVE (I.E., BASIC CROWNS)
492	DENTAL CONDITIONS (E.G., PERIODONTAL DISEASE)	ADVANCED PERIODONTICS (E.G., SURGICAL PROCEDURES AND SPLINTING)
507	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT BICUSPID/PREMOLAR TOOTH)	ADVANCED ENDODONTICS (E.G., RETREATMENT OF PREVIOUS ROOT CANAL THERAPY)
537	DENTAL CONDITIONS (E.G., PULPAL PATHOLOGY, PERMANENT MOLAR TOOTH)	ADVANCED ENDODONTICS (E.G., RETREATMENT OF PREVIOUS ROOT CANAL THERAPY)
549	TMJ DISORDER	TMJ SPLINTS
591	DENTAL CONDITIONS (E.G., CARIES, FRACTURED TOOTH)	ADVANCED RESTORATIVE-ELECTIVE (INLAYS, ONLAYS, GOLD FOIL AND HIGH NOBLE METAL RESTORATIONS)
601	DENTAL CONDITIONS (E.G., MISSING TEETH)	COMPLEX PROSTHODONTICS (I.E., FIXED BRIDGES, OVERDENTURES)
618	DENTAL CONDITIONS (E.G., MALOCCLUSION)	ORTHODONTIA (I.E., FIXED AND REMOVABLE APPLIANCES AND ASSOCIATED SURGICAL PROCEDURES)
619	DENTAL CONDITIONS (E.G., MISSING TEETH)	IMPLANTS (I.E., IMPLANT PLACEMENT AND ASSOCIATED CROWN OR PROSTHESIS)
645	DENTAL CONDITIONS WHERE TREATMENT IS CHOSEN PRIMARILY FOR AESTHETIC CONSIDERATIONS	COSMETIC DENTAL SERVICES
646	DENTAL CONDITIONS WHERE TREATMENT RESULTS IN MARGINAL IMPROVEMENT	ELECTIVE DENTAL SERVICES