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Guidelines for reporting on CBCT scans

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Abstract

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The aim of a radiographic report is to provide an accurate interpretation of images to facilitate the diagnostic process, and when indicated prompt the appropriate management for the patient. It is part of the patient's clinical records. This paper describes the imaging chain involved in the cone beam computed tomography (CBCT) workflow from referring to reporting on a CBCT scan. It provides guidelines on the essential information required before and immediately after a CBCT scan is taken, and optimizing the viewing conditions. Finally, it describes a framework for a systematic, comprehensive and tailored CBCT radiographic report. It is aimed at endodontists, clinicians and radiologists reporting on CBCT scans of the dentoalveolar region.

Keywords: cone beam computed tomography, endodontic diagnosis, radiography.

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Introduction

Over the last three decades, there has been a gradual increase in the use of CBCT in Endodontics (Setzer *et al.* 2017) with a continuing rise in the number of clinical studies demonstrating the benefit of CBCT on diagnosis, treatment planning, decision-making and reducing practitioner stress levels (Abella *et al.* 2014, Davies *et al.* 2016, Rodriguez *et al.* 2017a,b, Patel *et al.* 2019a). A measure of the impact of CBCT in Endodontics is the position statements published by several specialist societies (European Society of Endodontology 2014, 2019, American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology 2015). Comprehensive reports have been published on CBCT in Endodontics (Ball *et al.* 2013, Patel *et al.* 2019b).

Only small FOV (i.e. <5 cm) is applicable in Endodontics, thus minimizing the effective dose and improving the spatial resolution (European Society of Endodontology 2019). It is essential that CBCT data sets be reported upon appropriately, these reports are an important component of the imaging framework and a fundamental part of the patient's clinical records (European Society of Radiology 2011). To date, there are no guidelines on formulating reports for CBCT scans prescribed in Endodontics.

Two levels of continuous education are recommended by the European Academy of DentoMaxilloFacial Radiology (EADMFR). Level 1 training (core) is to be undertaken by those *prescribing/referring* for CBCT examinations, and a level 2 training (advanced), by those *reporting* on CBCT data sets (Brown *et al.* 2014).

The imaging chain

The imaging chain is the term used to describe the stages involved in imaging, it starts with the decision to take an image and ends with the image being reported on. The imaging chain may be quite simple, for example, with intraoral radiography the dentist usually acts as the referrer, practitioner, operator (radiographer) and operator (reporting). However, with CBCT the roles are not usually carried out by the same individual; rather, it is common for a team

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to be involved in the imaging chain. The roles and processes may vary and are determined by each country's specific radiation protection regulatory framework and legislation. It is good practice to have the imaging chain clearly laid out, recorded and agreed by all parties involved, especially in instances when all the roles are not carried out at the same site (Table 1).

The aims of this paper were as follows: first, to provide appropriate viewing conditions; and secondly, to determine how to formulate an actionable radiographic report for small field-of-view cone beam computed tomography (CBCT) scans taken for the diagnosis and management of endodontic disease.

Preliminary information

Patient details

This is essential information to ensure that the correct scan is assigned to the correct patient (Table 1). The patient's forename and surname, date of birth and, in addition, at least one other unique identifier (e.g. address) should be used, this is useful in case there are typographic errors when entered onto a computer system or differences in spelling of names (e.g. Shanon, Shannon).

The patient's age, sex and ethnicity may also be relevant for the differential diagnoses (e.g. fibro–cemento–osseous dysplasia is commonly associated with 40+-year-old women of African/Afro-Caribbean ethnicity) or root (canal) morphology (Martins *et al.* 2018).

Clinical details

This section has two main purposes: first, to act as a record of the treatment rationale at the time of the scan; and secondly, to provide information to a third party if the report is outsourced/second opinion is sought. This gives the reporter who sought the second opinion an 'insight' into the rationale for the CBCT scan and gives the report context.

Relevant medical systemic conditions (e.g. breast cancer). A dental history should also be included – for example, a (previous) history of bisphosphonate medication, atypical facial pain, previous dental trauma or a symptomatic endodontically treated tooth. Finally, justification for the CBCT scan should also be included with the scan.

Table 1 The principle stages of the imaging chain

Refer	Supply the relevant clinical info (provisional diagnosis and treatment plan), medical and dental history to enable justification
Justify	Weigh up the risks and benefit of the scan
Protocol	Select the appropriate field of view, area to image and exposure settings
Take the scan	Identify the correct patient, position them, take the scan and 'post-process'
Report	Produce actionable report

Previous imaging

Either the relevant report or preferably the images should be included – this is particularly relevant for CBCT as it is rarely the 'first-line' imaging technique; the 2D image can give further insight into the clinical situation.

Radiography log

The following details should be recorded:

- operator's name,
- exposure parameters (e.g. 180/360° rotation, mAs, kV, resolution, scanner details)
- the anatomical region (e.g. left posterior mandible, anterior maxilla)
- Quality of scan and, where appropriate, relevant comments (e.g. 'First scan grade 2 – patient moved during scan, scan aborted and retaken. Second scan grade 1')

It should be noted that CBCT scans are graded differently to other dental radiographic imaging; CBCT grade 1 means 'acceptable', and grade 2 means 'unacceptable'. The pan-European SEDENTEXCT project advised that 'As a minimum target, no greater than 5% of CBCT examinations should be classified as "unacceptable"'. The aim should be to reduce the proportion of unacceptable examinations by 50% in each successive audit cycle (SEDENTEXCT project 2012a, 2012b).

Details of exposure parameters are essential to improve problem-solving when a diagnostically poor-quality scan has been taken. Furthermore, if future (follow-up) scans are required these exposure parameters may be modified to potentially improve image quality, or replicated for comparison.

Viewing conditions

As with any medical image, reconstructed CBCT scans should be assessed and reported using a medical

grade monitor or specifically selected high-resolution monitor (Gutierrez *et al.* 2005). The majority of 'off-the-shelf' monitors have a lower diagnostic performance compared with medical monitors, which have higher quality hardware architecture and electronics (American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology 2015). Recommended objective, technical standards for monitor quality have been produced by the Royal College of Radiologists, UK, and the monitor should be calibrated regularly with a test pattern (e.g. https://www.eizo.be/monitor-test/). Dental surgeries are also too bright for optimal assessment of X-ray images, regardless of whether they are 2-dimensional intraoral radiographs or reconstructed 3-dimensional CBCT images. Viewing monitors should not be positioned in front of windows. It is well established that the ambient light may have a negative impact on the assessment of radiographic images due to the combined effects of inducing pupillary contraction and interfering with the viewing monitor's primary emission of light (Flynn & Badano 1999, Uffmann *et al.* 2005). Inappropriate viewing conditions can have a deleterious impact on the assessment and reporting of radiographic images (Butt & Savage 2015).

CBCT scans should therefore be assessed in a dedicated reporting room [or in surgery before or after clinic thus allowing for the most appropriate viewing (dimly lit) conditions] on a medical grade monitor. The low-resolution monitors commonly used in dental surgeries may however be useful as a secondary monitor, for demonstration to a patient or to refer to during the course of treatment.

If the CBCT scan is being viewed in the surgery in the presence of the patient, they must be made aware that this is only a brief assessment and that only after a thorough assessment can a diagnosis be made and, where appropriate, a treatment plan may be devised. This allows the clinician the necessary time to systematically assess the entire volume of data without being distracted by an understandably inquisitive patient, and ultimately devise a (provisional) radiographic diagnosis (Harvey & Patel 2020).

Artefacts (e.g. beam hardening, extinction, partial volume effects, noise and motion artefacts) may compromise the quality of the reconstructed CBCT images. A good knowledge of different artefacts, how they are caused and what they look like is essential for CBCT interpretation (Schulze *et al.* 2011).

Report on the CBCT data

The scout views and entire volume of CBCT data set *must* be systematically assessed and reported upon. It is good practice to assess the entire data set systematically in all three orthogonal planes (axial, sagittal and coronal). It is poor practice to only concentrate on a specific area of interest (e.g. the tooth that has a suspected endodontic problem) (European Society of Endodontology 2019). Incidental findings are relatively common, missing a significant incidental finding is considered to be negligent and therefore indefensible (Royal College of Radiologists 2018, Mahmood *et al.* 2019).

The following information must be included in a CBCT report (Table 2):

- *Which teeth are present?*

Where only part of a tooth is included on the scan, for example, the mesial or distal aspects, it is justifiable to acknowledge this on the report, for example 'unable to confidently report on tooth 38 as only mesial half of tooth is visible on scan'. However, any relevant findings of the partially visible tooth must be noted, and where indicated, a relevant intraoral radiograph and/or CBCT should be taken.

- *Which teeth are unerupted?*

The presence and orientation/impaction to neighbouring teeth and adjacent anatomical structures should be noted.

- *Systematic assessment of each tooth*

Using the native CBCT or third-party software, each tooth should be 'uprighted' to give the clearest view of the anatomy prior to assessment. Each root of a multi-rooted tooth should be uprighted and individually assessed.

Dentoalveolar assessment

Coronal status

- Radiographic signs of attempted access cavity preparation should be noted. Furthermore, beam hardening artefact from adjacent teeth may also have a deleterious impact on the interpretation, in these situations, a caveat should be included to the radiographic report 'crown evaluation is not possible due to beam hardening artefact'. CBCT should not be used as a primary method for diagnosis of caries due to poor resolution and beam

Table 2 Aide memoire of key features for a CBCT radiographic report

Referrer: Name, Job title, Address for report to be sent
Patient details: Name, Date of birth, Additional identifier (e.g. address)
Clinical details: Signs and symptoms, Relevant medical history, Relevant dental history, Relevant previous imaging, Justification for scan, Specific questions to be answered (if any)
Radiography log: kV, mA, Exposure time, Scan protocol, Operator, Grade, Comments
Report introduction
Anatomical region of the scan
Teeth Present
Erupted/Unerupted
Coronal status
Caries, External cervical resorption, Invagination (dens-in-dente)
Root (canal status)
Number of root canals, Curvatures & configuration, Quality & extent of root filling/posts, Presence of fractured instruments, Presence of (near) perforation, invagination (dens-in-dente)
Root resorption
Nature and location
(internal [inflammatory/replacement)] or (external [cervical/inflammatory/replacement)]
Perforation of root (internal resorption) or root canal (external resorption)
Periapical/radicular radiolucency
Radiological description including surrounding trabecular bone pattern
Relationship and effects on anatomical structures
Movement/displacement or destruction of adjacent anatomy, proximity of vital structures (e.g. inferior alveolar bundle, maxillary sinus)
Peripheral findings
Significant findings particularly if relevant to treatment or matters which need further management
Conclusion
Concise summary and answer to any questions asked
Sign off: Name, Job title, Professional registration number

hardening from adjacent teeth and restorations (Li *et al.* 2011, Patel *et al.* 2019b).

Root (canal) status

- Developmental anomalies (e.g. invaginations or evagination, and, if possible, type/size)
- Number of roots, their curvature and canal configuration.
- Presence and quality of root filling. A note should be made of the apical level and quality of root fillings, and of any unfilled canal. Be descriptive of the imaging rather than opinionated – for example, 'the MB2 canal root filling is short of the apex by 5mm with unfilled apical canal' is factual, and 'poor-quality MB2 root canal filling' is an opinion. Significant signs of iatrogenic tooth damage, for example the presence of (near) perforations, should also be noted, even if repaired.

Periapical/periradicular bone loss

- The nature and position of periapical and/or periradicular bone loss should be described, as this can have an influence on the final diagnosis; for example, 'J-shaped' PDL widening is commonly associated with a vertical root fracture.

Root resorption

- The presence, location, type (external cervical, external inflammatory, external replacement, internal inflammatory and metaplastic/replacement root resorption) and size of any resorptive defects; communication of the defect to the PDL space; and root canal system and classification (if applicable) should be noted.

Relationship to relevant adjacent anatomy

- Proximity and/or relationship of roots to adjacent anatomy should be noted, for example the maxillary sinus floor, nasopalatine canal, mental foramen or inferior dental canal. Associated signs of pathosis should also be noted, for example maxillary sinus membrane thickening.

A radiological description of any pathosis followed by diagnosis

- The site, size, shape, relationships, radiodensity, outline, internal structure, expansion and effects on other structures should be included in a radiographic report.

Radiographic diagnosis

When devising a radiographic diagnosis, a measure of the reporter's confidence is desirable: for example, 'This is typical of' demonstrates a high level of confidence in a single diagnosis; conversely, 'this may be A, B or C' indicates that several diagnoses may be considered and that perhaps more investigations are indicated. Typically, the differential diagnoses are in

order of likelihood, starting from most to least common. In some cases, it may not be possible to come to a definitive diagnosis for a lesion; however, it may be helpful if the lesion/anomaly can be placed in a 'category', for example 'The diagnosis is equivocal, however, this is likely to be a dental cyst'. One may also consider the opinion from a second reporter to ascertain whether a definitive diagnosis is possible.

Treatment planning options are typically left to the treating clinician, and as such, these decisions are not usually included in the report. The obvious exception to this rule is if the reporter thinks there is a serious matter that needs to be addressed, for example 'the ragged radiolucency is suspicious for malignancy and urgent biopsy is advised'.

It is good practice to carry out another review of the CBCT scan in all three planes again for anything outside the focus of your examination. 'Incidentalomas' are not uncommon – for example mucous retention cysts in the base on the maxillary antrum (Dief *et al*. 2019). Whilst these are unlikely to be clinically relevant to the dental problem in hand, it demonstrates a thorough approach to examining the volume of the scan. In the future, artificial intelligence may aid the reporting of CBCT data sets.

The report is completed with the reporter's name, job title, registration number and (electronic) signature for verification; in addition, a contact method (e.g. secure email) is helpful for any follow-up questions or clarifications. Radiological reports form part of the patient's clinical record, which is accessible to the patient on request.

Conclusion

The aim of a CBCT report is to provide an accurate interpretation of the images assessed, as with any radiographic report, it should conclude with a clinical impression and, where appropriate, an answer to the clinical question. A radiographic report should be actionable and, where indicated, prompt appropriate management, which may include referral to another specialty. An opinion from a specialist dental and maxillofacial radiologist should be sought if there is anything unusual and suspicion and/or the clinician feels they are out of their competence.

The importance of undertaking appropriate postgraduate training in CBCT cannot be over-emphasized, as this will give the necessary foundation required for clinicians to interpret and write accurate and appropriate CBCT.

Conflict of interest

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

Disclaimer

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