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內文：

Introduction

Cone beam computed tomography (CBCT) is a relatively new method to visualize an individual tooth or dentition in relation to surrounding skeletal tissues and to create three-dimensional images of the area to be examined (Cotton et al. 2007, Patel 2009). The use of CBCT in Endodontics is rapidly increasing worldwide.

Compared with traditional radiographic methods, which reproduce the three-dimensional anatomy as a two-dimensional image, CBCT is a three-dimensional imaging method that offers the possibility to view an individual tooth or teeth in any view, rather than predetermined 'default' views. Therefore, CBCT can be a powerful tool in endodontic diagnosis, treatment planning and follow-up. At the same time CBCT has limitations, and radiation dose to the patients must always be taken into consideration when selecting the modes of diagnostics.

There is a need for evidenced-based guidelines on when to use CBCT in Endodontics, thus aiding the decision on when it is appropriate to take a CBCT scan. Therefore, the aim of this review is to present the pertinent literature high-lighting the relative advantages and also disadvantages of CBCT in the various aspects of Endodontics.

Radiological aspects of CBCT

Principles in use of ionizing radiation in diagnostic imaging

A clinical examination must be carried out before considering any radiographic examination. A clinician should also be aware of the patient's imaging history, and whenever possible obtain previous radiographs/scans. As with any radiographic examination, a CBCT must be justified, and the potential benefits should outweigh the exposure to ionizing radiation (ICRP 2007). This is especially relevant when assessing children who are more susceptible to the potential effects of ionizing radiation (Theodorakou et al. 2012). If a radiographic procedure is prescribed it should be carried out with a dose as low as reason-ably achievable (ALARA). Patient exposure to ioniz-ing radiation such as X-rays must never be considered as routine. A CBCT examination should only be prescribed by a clinician who has:

- appropriate training in CBCT radiology (Brown et al. 2014);
- adequate knowledge of the endodontic applications of CBCT;
- experience in the interpretation of CBCT images;
- an appreciation of the limitations of CBCT.

CBCT radiation dose and digital image quality

The effective dose of CBCT scans is higher than periapical and panoramic radiography (Table 1), but lower than multislice computed tomography (MSCT) (Ludlow & Ivanovic 2008, Pauwels et al. 2012). The effective dose varies between scanners. It is also dependent on the region of the jaw being scanned, exposure settings of the CBCT scanner, the size of the field of view (FOV), exposure time (s), tube current (mA) and the energy/potential (kV) (Suomalainen et al. 2009, Pauwels et al. 2012).

Table 1 Effective dosages from different sources of dental radiation

Imaging source (digital)|	Effective dose (μSv) ICRP 2007,
CBCT small FOV	19–44
CBCT medium FOV	28–265
CBCT large FOV	68–368
Panoramic radiography (digital)[a]	14–24
Periapical radiography[b]	2[c]–9[d]

[a]Pauwels *et al.* (2012), [b]Ludlow & Ivanovic (2008), [c]Rectangular collimation, [d]Round cone.
CBCT, cone beam computed tomography; FOV, field of view.

Limitations

Metal restorations, metal posts and root fillings and to some extent adjacent dental implants typically cause artefacts to the reconstructed images (Scarfe & Far-man 2008). The potentially deleterious impact this may have on reconstructed images should be considered before considering a CBCT scan (So_gur et al. 2007, Bueno et al. 2011).

The scan time of CBCT devices can be as long as 20 s and is therefore significantly longer compared with that of an intra-oral radiograph (<0.3 s). Therefore, even the slightest movement of a patient during the scan may render the resulting reconstructed images of minimal diagnostic use. Therefore, this may be a problem with children, elderly patients and those with neuro-logical disturbances, for example Parkinson's disease.

- The decision to expose a patient to a CBCT investigation must be carried out on a case-by-case selection;
- The potential benefits of the CBCT scan should outweigh the potential risks;
- Radiology is constantly evolving; clinicians must regularly update their core knowledge in CBCT;
- Postgraduate endodontic programmes should incorporate the use of CBCT into their curriculum to ensure graduates are competent;
- The impact of CBCT on decision-making in endodontic treatment planning requires further investigation.

Assessment of periapical periodontitis

- Due to the limitations of conventional radiography, the size of periapical lesions is underestimated when compared to CBCT (Christiansen et al. 2009, Paula-Silva et al. 2009b);
- The current evidence suggests that CBCT does have a higher sensitivity compared with periapical radiography for the detection of periapical lesions. The specificity of both types of imaging systems is similar;
- CBCT should not be used for routine assessment of periapical disease prior to Endodontic treatment. However, it may be indicated to aid the diagnosis of (non)odontogenic pain when clinical examination and conventional radiographic assessment is not clear;
- CBCT should not be used for the routine assessment of the outcome of root canal treatment. However, with ethical approval, it would be justifiable to use small FOV CBCT scans in clinical research trials, for example to assess new treatment protocols, disinfection techniques, thus providing a more objective impression of the outcome of treatment;
- Future CBCT research should be aimed at assessing the prognostic factors

influencing the outcome of root canal treatment.

Vertical root fractures

Numerous ex vivo studies have concluded that CBCT is able to diagnose VRF in root filled teeth. However, these results should be interpreted with caution as the simulated VRFs in some of these investigations were potentially wide enough to be detected clinically and/or radiographically in a clinical setting. In addition, ex vivo studies do not take into account very subtle patient movement during the 10–20 s CBCT scan, these subtle movements will have a negative impact on the reconstruction algorithms and thus the images generated (Horner et al. 2013).

Cone beam computed tomography cannot be recommended for the diagnosis of VRF; more clinical studies are required to quantify and assess the value of CBCT in diagnosing root fractures, especially in root filled teeth and with a proper control group. However, CBCT may reveal subtle signs of periradicular bone loss associated with an undetected VRF.

Assessment of root canal anatomy

Cone beam computed tomography is a useful addition to the endodontist's armamentarium for identifying root canals (Matherne et al. 2008, Filho et al. 2009); however, it should only be reserved for cases where root canal anatomy cannot be fully appreciated with existing aids, such as parallax radiographs and the dental operating microscope.

Pre-surgical assessment

In addition to revealing radiographic signs of periapical pathosis and root canal anatomy, CBCT scans accurately determine the relationship of adjacent anatomical structures to teeth with endodontic problems. This clinically relevant information may be useful for treatment planning and the subsequent management of the tooth in question.

Diagnosis and management of root resorption

The available literature supports the use of CBCT as a diagnostic tool to assess the true nature of teeth (provisionally) diagnosed with root resorption to improve diagnosis and aid management. This should ultimately improve the prognosis of teeth with root resorption that require endodontic management.

CBCT applications for dental trauma assessment

It is clear that CBCT reveals a considerable amount of information about the nature of dentoalveolar injuries. This information may not only aid formulating a diagnosis but also improvement management. Ultimately, this may improve treatment outcomes.

When the diagnosis from clinical and conventional radiographic assessment is inconclusive, CBCT should be considered as a potentially useful imaging device.

Conclusion

Cone beam computed tomography overcomes many of the limitations of periapical radiography. The increased diagnostic data should result in more accurate diagnosis and therefore improved decision-making for the management of complex endodontic problems. It is a desirable addition to the endodontist's armamentarium, and its use should be incorporated into endodontic postgraduate programmes. All endodontists should be familiar with CBCT and should always liaise with a maxillo-facial radiologist or equivalent specialist when appropriate.

Cone beam computed tomography uses ionizing radiation and therefore is not without risk. 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 (Farman 2005, Vandenberghe et al. 2007). More research is required in several areas, these include:

- how the additional diagnostic information from CBCT influences clinical decision-making and also outcome of specific types of endodontic treatment (e.g. management of dental trauma and root resorption);
- Comparative analysis of different small FOV CBCT scanners for diagnosis of various endodontic problems.

Endodontic cases should be judged individually, and until further evidence is available, CBCT should only be considered in situations where information from alternative imaging systems do not yield an adequate amount of information to allow appropriate management of the endodontic problem.

題號	題目
1	下列何項關於CBCT的敘述是錯誤的？ (A) CBCT是診斷出root resorption的良好診斷工具 (B) CBCT可以精確地診斷出病患牙齒是否有vertical root fracture (C) CBCT可以用在與牙科有關的外傷病人身上 (D) CBCT在診斷periapical periodontitis時有著比傳統方式較好的sensitivity
答案(B)	Cone beam computed tomography in Endodontics
題號	題目
2	下列何項關於CBCT的敘述是錯誤的？ (A) CBCT適用於絕大多數的病患,包括小孩子和成年之患者 (B) CBCT帶來的診斷價值比它的輻射危險因子來的重要許多 (C) 金屬補綴物較多的患者在使用CBCT上可能會有較多限制 (D) CBCT的輻射量大於根尖片及環口片但小於MSCT (multislice computed tomography)
答案(A)	Cone beam computed tomography in Endodontics