CBCT applications in dental practice: A literature review

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Two-dimensional imaging modalities have been used in dentistry since the first intra-oral radiograph was taken in 1896. Significant progress in dental imaging techniques has since been made, including panoramic imaging and tomography, which enable reduced radiation and faster processing times. However, the imaging geometry has not changed with these common used intraoral and panoramic technologies.

 Cone-beam computed tomography (CBCT) is a new medical imaging technique that generates 3-D images at a lower cost and absorbed dose compared with conventional computed tomography (CT). This imaging technique is based on a cone-shaped X-ray beam centred on a 2-D detector that performs one rotation around the object, producing a series of 2-D images. These images are re-constructed in 3-D using a modification of the original cone-beam algorithm developed by Feldkamp et al., in 1984. Images of the craniofacial region are often collected with a higher resolution than those collected with a conventional CT. In addition, the new systems are more practical, as they come in smaller sizes.

Today, much attention is focused on the clinical application — diagnosis, treatment and follow-up — of CBCT in the various dental disciplines. The goal of the following systemic review is to review the available clinical and scientific literature pertaining to different clinical applications of CBCT in the dental practice.

Materials and methods

Clinical and scientific literature discussing CBCT imaging in dental clinical applications was reviewed. A MEDLINE (PubMed) search from 1 January 1998 to 15 July 2010 was conducted. Cone-beam computed tomography in dentistry was used as a key phrase to extend the search to all the various dental disciplines. The search revealed 540 papers that were screened in detail. Owing to a lack of relevance to the subject, 406 papers were excluded. Thus, the systemic review consisted of 134 clinically relevant papers, which were analysed and categorised (Table 1).

Analysis

Oral and maxillofacial surgery

CBCT enables the analysis of jaw pathology, the assessment of impacted teeth (Fig. 1), super-numerary teeth and their relation to vital structures, changes in the cortical and trabecular bone related to bisphosphonate-associated osteonecrosis of the jaw, and the assessment of bone grafts. It is also helpful in analysing and assessing paranasal sinus and obstructive sleep apnoea.

As the images are collected from many different 2-D slices, the system has proven its superiority in overcoming superimpositions and calculating surface distances. This advantage made it the technique of choice in mid-face fracture cases, orbital fracture assessment and management and for inter-operative visualisation of the facial bones after fracture. Since it is not a magnetic resonance technique, it is the best option for intra-operative navigation during procedures, including gun-shot wounds.

CBCT is largely used in orthodontic surgery planning when facial orthosurgical surgery is indicated that requires detailed visualisation of the inter-occlusal relationship in order to augment the 3-D virtual skull model with a detailed dental surface. With the aid of advanced software, CBCT facilitates the visualisation of soft tissue to allow for control of post-treatment aesthetics, for example in clef palate cases to evaluate lip and palate bone depressions.

Research is underway to assess its ability to detect salivary gland defects. Honda et al. describe a clinical case in which the time needed to complete a tooth auto-transplant case was significantly shortened owing to the application of CBCT.

Endodontics

CBCT is a very useful tool in diagnosing apical lesions (Figs. 2a & b). A number of studies have demonstrated its ability to provide a differential diagnosis of apical lesions by measuring the density from the contrasted images of these lesions, in whether the lesion is an apical granuloma or an apical cyst. Cotton et al. used CBCT as a tool to assess whether the lesion was endodontic or non-endodontic origin.

CBCT also demonstrated superiority to 2-D radiographs in detecting fractured roots. Vertical and horizontal root fracture detection is described in several clinical cases. It is also agreed that CBCT is superior to peri-apical radiographs in detecting these fractures, whether they be bucco-lingual or mesiodistal.

In cases with inflammatory root resorption, lesions are detected much easier in early stages with CBCT compared to conventional 2-D X-ray. In other cases, such as external root resorption, external cervical and internal resorption, not only the presence of resorption was detected, but also the extent of it.

CBCT can also be used to determine root morphology, the number of roots, canals and accessory canals, as well as establishing the working length and angulations of roots and canals. It also is key pharynx. It also is accurate in assessing root-canal fillings. Owing to its accuracy, it is very helpful in detecting the pulpal extensions in talon cusps and the position of fractured instruments.

It is also a reliable tool for pre-surgical assessment of the proximity of the tooth to adjacent vital structures, size and extent of lesions, as well as the anatomy and morphology of roots with very accurate measurements.

Only limited data can be obtained from this image.

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Additionally, in cases in which teeth are assessed after trauma and in emergency cases, its appli - cation can be a useful aid in reaching a proper diagnos - is and treatment approach.63–74

Recently, owing to its reliabil- ity and accuracy, CBCT has also been used to evaluate the canal preparation in different instru- ments, as CBCT is used to evaluate the canal preparation in different instru- ments.75–76

Implantology
With increased demand for replacing missing teeth with dental implants, accurate measure- ments are needed to avoid damage to vital structures. This was achievable with conven- tional CT. However, with CBCT giving more acurate measure- ments at lower doses, it is the preferred option in implant den- 

This advantage is also used for post-treatment evaluation and to assess the success of bone grafts (Figs. 5a–d).7,86

Orthodontics
Orthodontists can use CBCT images in orthodontic assess- ment and cephalometric analy- sis.17,73,78–80 Today, CBCT is al- ready the tool of choice in the as- sessment of facial growth, age, airway function and distur- bances in tooth eruption.7,38–40 This leads to reduced implant failure, as case selection can be based on much more reliable information.

Intra-oral (F speed, rectangular collimator) 0.001 mSv
Intra-oral (F speed, round collimator) 0.004 mSv
Full-mouth set (F speed, round collimator) 0.080 mSv
Lateral cephalogram (F speed, soft screen) 0.002 mSv
Dental panoramic technique (F speed, soft screen) 0.015 mSv
CBCT (both jaws) 0.068 mSv
Hospital CT scan (both jaws) 0.6 mSv

Table II: Typical doses of various dental radiological procedures.

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CBCT is a reliable tool in the assessment of the proximity to vi- tal structures that may interfere with orthodontic treatment.79–80 In cases in which mini-screw im- plants are placed to serve as a temporary anchorage, CBCT is useful for ensuring a safe inser- tion79,80 and to assess the bone density before, during and after treatment (Fig. 6).100–101

Having different views in one scan, such as frontal, right and left lateral, 45-degree views and sub-mental, also adds to the ad- vantages of CBCT.102–103 As the im- ages are self-corrected from the magnification to produce or- thogonal images with 1:1 ratio, higher accuracy is ensured.

Temporomandibular joint disorder
One of the major advantages of CBCT is its ability to define the true position of the condyle in the fossa, which often reveals possible dis -location of the condyle in the joint, and the extent of transla- tion of the condyle in the fossa.70–78 With its accuracy, measurements of the roof of the glenoid fossa can be done easi- ly.101–104 Another advantage of some of the available devices is their ability to visualise soft tis- sue around the TMJ, which may reduce the need for magnetic resonance imaging in these cases.105

Owing to these advantages, CBCT is the imaging device of choice in cases of trauma, pain, dysfunction, fibro-osseous anky- losis and in detecting condylar cortical erosion and cysts.70,71,105–108 With the use of the 3-D features, the image-guided puncture technique, which is a treatment modality for TMJ disk adhesion, can safely be performed.109

Periodontics
CBCT can be used in assessing a detailed morphologic de- scription of the bone because it has proved to be accurate with only minimal error margins.110,111 The measurements proved to be as accurate as direct measure- ments with a periodontal probe.112,113 Furthermore, it also aids in assessing furcation in- volvements.109,110,111

CBCT can be used to detect buccal and lingual defects, which was previously not possi- ble with conventional 2-D radiographs.114 Additionally, owing to the high accuracy of CBCT measurements, intra-bony de- fects can accurately be measured and dehiscence, fenestration de- fects and periodontal cysts as- sessed.110,112–114 CBCT has also proved its superiority in evaluat- ing the outcome of regenerative periodontal therapy.112

General dentistry
Based on the available litera- ture, CBCT is not justified for use
in detecting occlusal caries, since the dose is much higher than conventional radiographs with no additional information gained. However, it proved to be useful in assessing proximal caries and its depth. Table II shows the radiation doses of various dental radiological procedures in dental practice.

Forensic dentistry
Several dental use estimation methods, which are a key element in forensic science, are described in the literature. CBCT was established as a non-invasive method to estimate the age of a person based on the pulp-tooth ratio.20

Discussion
CBCT scanners represent a great advance in dento-maxillofacial (DMF) imaging technology, introduced into dental use in the late 1990s,21 has advanced dentistry significantly. The number of CBCT-related papers published each year has increased, with a considerable increase in the last years. The above systematic review of the literature - related to CBCT applications in dental practice was undertaken in order to summarise concisely the current state of this new image technique in different dental specialties.

Con-beam computed tomography in dentistry - try was used as a control in the systemic review. Other terminology encountered in the literature, such as cone-beam volumetric computed tomography, dental CT, dental 3-D CT and cone-beam volumetric imaging, did not result in additional relevant papers.22

The clinical applications for CBCT imaging in dentistry are increasing. The results of this review demonstrate that 154 papers were clinically relevant and that the most common clinical applications are in the field of oral and maxillofacial surgery, implant dentistry, and endodontics. CBCT has limited use in intraopera
tive dentistry owing to the high radiation dose required in relation to the result.

The literature on CBCT is promising and needs further research, especially with regard to its use in forensic dentistry, in order to explore more potentially beneficial indications in that area. No literature concerning direct CBCT indications in prosthetics was found. However, several overlapping indications were found in other dental specialties attributing to the final standardisation of prosthetic treatment. These indications include but are not limited to bone grafting, soft-tissue grafting, prosthetically driven implant planning and temporomandibular joint disorder. CBCT images can also be of great value in special cases in which multiple teeth have to be assessed for restorability.23,24

The latest CBCT units have a higher resolution, lower exposure, are less expensive and designed for use in dentistry. Additionally, the flat-panel detectors appear to be less prone to beam-hardening artefacts. There are, however, several important disadvantages as well, such as susceptibility to movement artefacts, contrast resolution, limited capability to visualise internal soft tissues and, owing to distortion of Hounsfield units, CBCT cannot be used for the estimation of bone density.

It is crucial that the ALARA principle (As Low As Reasonably Achievable) is respected during treatment, as far as the radiation dose of CBCT imaging is concerned. CBCT imaging will improve patient care, but users have to be trained to be able to interpret the scanned data thoroughly. Dentists should ask themselves whether these imaging modalities actually add to their diagnostic knowledge and raise the standard of dental care or whether they only place the patient at an increased risk. Continuous training and education are thus absolutely essential.

One of the most clinically useful aspects of CBCT imaging is the highly sophisticated software that allows the huge volume of data collected to be broken down, processed or reconstructed.25 This makes data interpretation much more user friendly, if the appropriate technical and educational knowledge is available.

The increasing popularity of CBCT resulted in numerous CBCT-unit manufacturers, frequent presentations at conferences and an increase in published papers. This resulted in an uncontrolled and non-evidence based exchange of radiation dose values and attributed to the limited technical knowledge about medical history and examinations for new-user groups. As a result, the European Academy of Den
to-Maxillo-Facial Radiology has developed the following basic principles on the use of CBCT in dentistry.17

1. CBCT examinations must not be carried out unless a history and clinical examination have been performed.

2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.

3. CBCT examinations should potentially add new information to aid the patient’s management.

4. CBCT should not be repeated on a patient “routinely” with a low risk/benefit assessment having been performed.

5. When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of history and examination) to allow the CBCT practitioner to perform the justification.

6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (radiographic) examination.

7. CBCT images must undergo a thorough clinical evaluation (radiological report) of the entire image dataset.

8. Where it is likely that evaluation of soft tissues will be required as part of the patient’s radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT.

9. CBCT equipment should offer a choice of volume sizes, and examinations must use the smallest that is compatible with the clinical situation, if this provides a lower radiation dose to the patient.

10. Where CBCT equipment offers a choice of resolution, the resolution compatible with an adequate diagnosis and the lowest achievable dose should be used.

11. A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality-nature controls.

12. Aids to image positioning (light-beam markers) must be used.

13. All new installations of CBCT equipment should undergo a critical examination and detection test before use to ensure that radiation protection for staff, members of the public and patient are optimal.

14. CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice facility users and patients, has not significantly deteriorated.

15. For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission Document Radiation protection 156: European guidelines on radiation protection in dentistry should be followed.

16. All those involved with CBCT must have received adequate theoretical and practical training for the specific purpose of radiological practices and relevant competence in radiation protection.

17. Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted.

18. Dentists responsible for CBCT facilities, who have not previously received “adequate theoretical and practical training”, should undergo a period of additional theoretical and practical training that has been validated by an academic institution (university or equivalent). Where national specialist qualifications in dento-maxillofacial radiology exist, the design and delivery of CBCT training programmes should involve a DMF radiologist.

19. For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (for example, 8 cm x 8 cm or smaller fields of view), clinical evaluation (radiological report) should be done by a specially trained DMF radiologist or, where this is impracticable, an adequately trained general dental practitioner.

20. For non-dento-alveolar small fields of view (for example, temporal bone) and craniofacial CBCT images (fields of view extending beyond the teeth, and including supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose), clinical evaluation (radiological report) should be done by a specially trained DMF radiologist or by a clinical radiologist (medical radiologist).

Conclusion
CBCT is most frequently applied in forensic dentistry, oral surgical surgery, endodontics, implant dentistry and orthodontics. CBCT examination must not be carried out unless its medical necessity is proven and the benefits outweigh the risks.

Furthermore, CBCT images must undergo thorough clinical evaluation (radiological report) of the entire image dataset in order to maximise the benefits. Future research should focus on accurate data with regard to the radiation dose of these units. CBCT units have small detector sizes and the field of view and scanned volumes are limited, which is the reason that CBCT units specific to orthodontic and orthognathic surgery are not yet available. Additional publications on CBCT indications in forensic dentistry and prosthetics are also desirable.

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