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 1886. 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 so-called method of the original cone-beam algorithm developed by Feldkamp et al. in 1984. Images of the craniotelenar 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 applications—diagnosis, treatment and follow-up—of CBCT in the various dental disciplines. The goal of the following systematic 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 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 systematic 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 para-sanal sinuses and obstructions of the sleep apnoea (Fig. 1). As the images are collected from many different 2-D slices, the system has proven its superiority in obtaining 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 intra-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 orthosphoric 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 control of post-treatment aesthetics, for example in clef palate cases to evaluate lip and palate bony 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 enable a definitive rental 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 to establishing the working length and angulations of roots and canals. As a key phrase it also allows 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 presurgical 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.
Additionally, in cases in which teeth are assessed after trauma and in emergency cases, its appi - cation can be a useful aid in reaching a proper diagnosis and treatment approach.95,97,99–101

Recently, owing to its reliability and accuracy, CBCT has also been used to evaluate the canal preparation in different instrumenta-
tion techniques.79–81

Implantology
With increased demand for replacing missing teeth with dental implants, accurate measurements are needed to avoid damage to vital structures. This was achievable with conventional CT. However, with CBCT giving more accurate measurements at lower dosages, it is the preferred option in implant dentistry today (Figs. 4a & b).18,26,70,80–81

With new software that constructs surgical guides, damage is also reduced further.77,80–81 Heiland et al.14 describe a technique in which CBCT was used inter-operatively in two cases to navigate the implant insertion following microsurgical bone transfer.

CBCT enables the assessment of bone quality and bone quantity.18,26,70,84,95–97 This leads to reduced implant failure, as case selection can be based on much more reliable information.

This advantage is also used for post-treatment evaluation and to assess the success of bone grafts (Figs. 5a–d).10,13

Orthodontics
Orthodontists can use CBCT images in orthodontic assessment and cephalometric analysis.77,80–81 Today, CBCT is already the tool of choice in the assessment of facial growth, age, airway function and disturbances in tooth eruption.105–107

CBCT is a reliable tool in the assessment of the proximity to vital structures that may interfere with orthodontic treatment.20,21 In cases in which mini-screw implants are placed to serve as a temporary anchorage, CBCT is useful for ensuring a safe insertion107–109 and to assess the bone density before, during and after treatment (Fig. 6).108–109

Having different views in one scan, such as frontal, right and left lateral, 45-degree views and sub-montal, also adds to the advantages of CBCT.110–112 As the images are self-corrected from the magnification to produce orthogonal images with 1:1 ratio, higher accuracy is ensured. CBCT is thus considered a better option for the clinician.113

Temporomandibular joint disorder
One of the major advantages of CBCT is its ability to define the true position of the condyloid in the fossa, which often reveals possible dislocation of the condyloid in the joint, and the extent of transla-
tion of the condyle in the fossa.114–116 With its accuracy, measurements of the roof of the glenoid fossa can be done easily.117,118 Another advantage of some of the available devices is their ability to visualise soft tissue around the TMJ, which may reduce the need for magnetic resonance imaging in these cases.119

Owing to these advantages, CBCT is the imaging device of choice in cases of trauma, pain, dysfunction, fibro-osseous ankylosis and in detecting condylar cortical erosion and cysts.70,71,119–120 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.120

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.121–123 The measurements proved to be as accurate as direct measurements with a periodontal probe.124–125 Furthermore, it also aids in assessing fucrination in-
volveements.126,127

CBCT can be used to detect buccal and lingual defects, which was previously not possible with conventional 2-D radiographs.128 Additionally, owing to the high accuracy of CBCT measurements, intra-bony de-
fects can accurately be measured and dehisence, fenestration de-
fects and periodontal cysts as-
sessed.129,130–132 CBCT has also proved its superiority in evaluating the outcome of regenerative periodontal therapy.133

General dentistry
Based on the available literature, 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.28 Table 2 shows the patient’s exposure to typical doses of various dental radiological procedures in dental practice.

Forensic dentistry

Many dental and bone 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.36

Discussion

CBCT scanners represent a great advance in dento-maxillofacial (DMF) diagnostic technology, introduced into dental use in the late 1990s,129 has advanced dentistry significantly. The number of CBCT-related papers published each year has increased exponentially 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 indications of this new image technique in different dental specialities.

Bone-cell computed tomography in dentistry—try was used as a control in the present systematic 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.11

The clinical applications for CBCT imaging in dentistry are increasing. The results of this review demonstrate that CBCT 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 the operative dentistry owing to the high radiation dose required in relation to its diagnostic value.128

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 prosthodontics was found. However, several overlapping indications were found in other dental specialties attributing to the final standards of comprehensive treatment. These indications include but are not limited to bone grafting, soft-tissue grafting, prosthetically driven implant planning, orthodontics, 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.25-28

The latest CBCT units have a higher resolution, lower exposure, are less expensive and designed for use in addition. Additionally, the flat-panel detector appears to be less prone to beam-hardening artefacts. There are, however, several important disadvantages as well, such as susceptibility to movement artefacts, low contrast resolution, limited capability to visualise internal soft tissues and, owing to the distortion of Hounsfield Units, CBCT cannot be used for the estimation of bone density.128

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 in order to interpret the scanned data thoroughly. Dentists should assess 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 a greater risk. Continuous training, education and thorough research 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.140,145 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 examination for new-user groups. As a result, the European Academy of Den-to-Maxillofacial Radiology has developed the following basic principles on the use of CBCT in dentistry:128

1. CBCT examinations must not be carried out unless a history and clinical examination have been performed.28

2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks.28

3. CBCT examinations should potentially add new information to aid the patient’s management.28

4. CBCT should not be repeated on a patient ‘routinely’ with an out new risk/benefit assessment having been performed.28

5. When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of previous investigations) to allow the CBCT practitioner to perform the justifi-

6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (radiation) imaging.129

7. CBCT images must undergo a thorough clinical examination (radiological report) of the entire image dataset.129

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.129

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.129

10. Where CBCT equipment offers a choice of resolution, the resolution compatible with an adequate diagnosis and the lowest achievable dose should be used.129

11. A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality-control procedures.129

12. Aids to image positioning (light-beam markers) must always be used.129

13. All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal.129

14. CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice facility users and patients, has not significantly deteriorated.129

15. For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the EU Commission documentation Radiation protection 156: European guidelines on radiation protection in dental radiology should be followed.129

16. All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection.129

17. Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted.129

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.129

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, that is, 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 oral and maxillofacial 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 prosthodontics are also desirable.

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