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 mo- dification of the original cone-beam algo- rithm developed by Feldkamp et al. in 1984. Images of the cranio- facial 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.2

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 systemic review is to review the available clinical and scientific literature pertaining to different clinical applica- tion of CBCT in the dental practice.

Materials and methods

Clinical and scientific litera- ture discussing CBCT imaging in dental clinical applications was reviewed. A MEDLINE (PubMed) search from 1 January 1998 to 15 July 2010 was con- ducted. Cone-beam computed tomography in dentistry was used as key phrase to extend the search to all the various dental disciplines. The search revealed 546 papers that were screened in detail. Owing to a lack of rele- vance to the subject, 406 papers were excluded. Thus, the sys- temic 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,3 the assessment of impacted teeth (Fig. 1), super- numerary teeth and their relation- tion to vital structures,4 changes in the cortical and tra- nscapillary bone related to bisphos- phonate-associated osteonecro- sis of the jaw,5,22–23 and the assess- ment of bone grafts.6 It is also helpful in analysing and assess- ing paranasal sinuses6,7 and ob- structive sleep apnoea.8–10

As the images are collected from many dif- ferent 2-D slices, the system has proven its superior- ity in overcoming superimposi- tions and calculating surface distances.11–14 This advantage made it the technique of choice in mid-face fracture cases,6,7,22–23 orbital fracture assessment and management24 and for inter-op- erative visualisation of the facial bones after fracture.12,15 Since it is not a magnetic resonance technique, it is the best option for intra-operative navigation dur- ing procedures, including gun- shot wounds.16–18

CBCT is largely used in or- thodontic surgery planning when facial orthomor sur- gery is indicated that requires de- tailed visualisation of the inter- ocellular relationship in order to augment the 3-D virtual skull model with a detailed dental sur- face. With the aid of advanced software, CBCT facilitates the vi- sualisation of soft tissue to allow for control of post-treatment aethetics, for example in clef palate cases to evaluate lip and palate bony depressions.19–21

Research is underway to as- sess its ability to detect salivary gland defects.22 Honda et al.23 de- scribe a clinical case in which the time needed to complete a tooth auto-transplant case was signifi- cantly shortened owing to the ap- plication of CBCT.

Endodontics

CBCT is a very useful tool in diagnosing apical lesions (Figs. 2a & b).24–26 A number of studies have demonstrated its ability to enable a difff - 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 (Figs. 3a & b).27–29 Cotton et al.30 used CBCT as a tool to assess whether the lesion was en- dodontic or non-endodontic ori- gin. CBCT also demonstrated supe-riority to 2-D radiographs in detecting fractured roots. Vertical and horizontal root fracture detection is described in several clinical cases.27–30 It is also agreed that CBCT is superior to periapical radiography in de- tecting these fractures, whether they be bucco-lingual or mesiodistal.31–33

CBCT can also be used to de- termine root morphology, the number of roots, canals and ac- cessory canals, as well as to es- tablishing the working length and angulations of roots and canals.23,34,35 As key phrase. It also is also accurate in assessing root-canal fillings.35–38 Owing to its accu- racy, it is very helpful in detecting the pulpal extensions in talon cusps29 and the position of frac- tured instruments.39

It is also a reliable tool for pre- surgICAL as a measure of the proximity of the tooth to adja-cent vital structures, size and extent of lesions, as well as the anatomy and morphology of roots with very accurate measurements.40–42,43,44,45,46

Table 1

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Number of articles</th>
<th>in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral and maxillofacial surgery</td>
<td>36</td>
<td>26.86</td>
</tr>
<tr>
<td>Endodontics</td>
<td>22</td>
<td>16.42</td>
</tr>
<tr>
<td>Orthodontics</td>
<td>16</td>
<td>11.94</td>
</tr>
<tr>
<td>General dentistry</td>
<td>14</td>
<td>10.45</td>
</tr>
<tr>
<td>Temporomandibular joint disorder</td>
<td>8</td>
<td>5.97</td>
</tr>
<tr>
<td>Periodontics</td>
<td>5</td>
<td>3.73</td>
</tr>
<tr>
<td>Forensic dentistry</td>
<td>1</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Fig. 1 Impacted tooth in close proximity to vital structures should be evaluated with CBCT.

Figs. 2a & b Periapical lesion shown as peri-apical radiograph (a) and CBCT (b, images courtesy of Dr Fred Barnett).

Fig. 3a & b Apical cyst shown as orthopantomogram (a) and CBCT (b).

Fig. 4a Orthopantomogram for a full-mouth rehabilitation case.

Fig. 4b CBCT images for the same patient. Data obtained from these images regarding bone quality, implant length and diameter, implant location and proximity to vital structures is magnificent.
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 diagnos- is and treatment approach. 26,29,76

Recently, owing to its reliabil- ity and accuracy, CBCT has also been used to analyze the canal preparation in different instru- mentation techniques. 77,96

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 dosages, it is the preferred option in implant den- 

Table II. Typical doses of various dental radiographic procedures.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Typical Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral cephalogram (F speed, rare-earth screen)</td>
<td>0.002 mSv</td>
</tr>
<tr>
<td>Dental panoramic technique (F speed, rare-earth screen)</td>
<td>0.015 mSv</td>
</tr>
<tr>
<td>CBCT (both jaws)</td>
<td>0.068 mSv</td>
</tr>
<tr>
<td>Hospital CT scan (both jaws)</td>
<td>0.6 mSv</td>
</tr>
</tbody>
</table>

Fig. 5d

Implantology today (Figs. 4a & b). 77,93,102–103

With new software that con- structs surgical guides, damage is also reduced further. 77,103,104 Heiland et al. 11 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 assess- ment of bone quality and bone quantity. 112,116,117 This leads to reduced implant failure, as case selection can be based on much more reliable information.

Orthodontics
Orthodontists can use CBCT images in orthodontic assess- ment and cephalometric analy- sis. 118,119,120,121 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. 109–110

CBCT is a reliable tool in the assessment of the proximity to vi- 

thogonal 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 condyle in the fossa, which often reveals possi- ble dis - location or affection of the joint, and the extent of transla- tion of the condyle in the fossa. 115,116,117 With its accuracy, measurements of the roof of the glenoid fossa can be done easi- er. 118 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. 119

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. 79,120–122 With the use of the 3-D features, the imageguided puncture technique, which is a treatment modality for TMJ disk adhesion, can safely be per- formed. 123

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. 124 The measurements proved to be as accurate as direct measure- ments with a periodontal probe. 125 Furthermore, it also aids in assessing furcation in- volvements. 126,127

CBCT can be used to detect bucal and lingual defects, which was previously not possi- ble with conventional 2-D radi- ographs. 128 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. 129,130–132 CBCT has also proved its superiority in evaluat- ing the outcome of regenerative periodontal therapy. 133

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. Moreover, it proved to be useful in assessing proximal caries and its depth.8 Table II shows the dose of typical images of various dental radiological procedures in dental practice.

Forensic dentistry

Many dental age 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.180

Discussion

CBCT scanners represent a great advance in dento-maxillofacial (DMF) imaging technology, introduced into dental use in the late 1990s.180,181 It 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 forensic applications in dental practice was undertaken in order to summarise concisely the current state of the field of CBCT imaging in different dental specialties.

Con-beam computed tomography in dentistry - try was used as control in the volumetric scan- ning, volumetric computed tomography, dental CT, dental 5-D CT and cone-beam volumetric imaging, did not result in additional relevant papers.18

The clinical applications for CBCT imaging in dentistry are increasing. The results of this review demonstrate that 114 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 routine settings in this area.

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 contributing to the final standard of root canal treatment. These indications include but are not limited to bone grafting, soft-tissue grafting, prosthetically driven implant placement, 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.7,8-10

The latest CBCT units have a higher resolution, lower exposure, are less expensive and designed for use in dentistry. Additionally, the flat-panel detector appear 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 voxel size of CBCT data, images cannot be used for the estimation of bone density.20

It is crucial that the ALARA (As Low As Reasonably Achievable) principle 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 whether they only place the patient at a higher risk. Continuing 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.182 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-toMaxillofacial Radiology has developed the following basic principles on the use of CBCT in dentistry.182

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” without a new 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 previous examination) to allow the CBCT practitioner to perform the justifi-
cation (radiological report) of the entire image dataset.18
6. CBCT examination must not be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (tra-di - tional) radiography.
7. CBCT images must undergo a thorough clinical evaluation (radiological report) before they are required, particularly when new CBCT equipment or techniques are adopted.
8. Dentists referring to 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 DFM radiologist.
9. 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 DFM radiologist or by a clinical radiologist (medical radiologist).

Conclusion

CBCT is most frequently applied in the field of 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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