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 commonly 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 algorithm developed by Feldkamp et al, in 1984. Images of the cranium-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. 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 application 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 546 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 I).

**Analysis**

**Oral and maxillofacial surgery**

CBCT enables the analysis of jaw pathology, the assessment of impacted teeth (Fig. 1), supernumerary 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 sinuses and obstructive sleep apnea.

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 orthognathic surgery planning when facial orthomorphic surgery is indicated that requires detailed visualisation of the inter-occusal 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 cleft 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 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 (Figs. 3a & b). Coton et al. used CBCT as a tool to assess whether the lesion was of 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. CBCT can also be used to determine root morphology, the number of roots, canals and accessory canals, as well as to establish the working length and angulations of roots and canals. It is also 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.

CBCT is also a reliable tool for presurgical as - sessment 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 measurement.

**Table I**

<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>32</td>
<td>23.88</td>
</tr>
<tr>
<td>Implantology</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 teeth in close proximity to vital structures should be evaluated with CBCT.

**Figs. 2a & b:** Periapical lesion shown on peri-apical radiograph (a) and CBCT (b) images courtesy of Dr Fred Barnett.
Additionally, in cases in which teeth are assessed after trauma and in emergency cases, its application can be a useful aid in reaching a proper diagnosis and treatment approach.4,35,75–76

Recently, owing to its reliability and accuracy, CBCT has also been used to evaluate the canal preparation in different instrumentation techniques.37–38

**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).4,15,18,27–28

With new software that constructs surgical guides, damage is also reduced further.39,43–45 Helid et al.46 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.18,26,30–33,43–44 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 assessment and cephalometric analysis.5,70,80–81 Today, CBCT is already the tool of choice in the assessment of facial growth, age, airway function and disturbances in tooth eruption.100–105

CBCT is a reliable tool in the assessment of the proximity to vital structures that may interfere with orthodontic treatment.106–108

This advantage is also used for post-treatment evaluation and to assess the success of bone grafts (Figs. 5a–d).10–12

**Table II. Typical doses of various dental radiological procedures.**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital CT scan (both jaws)</td>
<td>0.6 mSv</td>
</tr>
<tr>
<td>Dental panoramic technique (F speed, rare-earth screen)</td>
<td>0.015 mSv</td>
</tr>
<tr>
<td>Lateral cephalogram (F speed, round collimator)</td>
<td>0.002 mSv</td>
</tr>
<tr>
<td>Full-mouth set (E speed, round collimator)</td>
<td>0.080 mSv</td>
</tr>
<tr>
<td>Intra-oral (E speed, rectangular collimator)</td>
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</tr>
<tr>
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<td>0.068 mSv</td>
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**Fig. 5c.** Clinical picture of multiple implants placed in 2005.

**Fig. 5b.** Panoramic radiograph for the implants replacing teeth #8 and #9. Little data can be collected from such an image.

**Fig. 5a.** The CBCT image clearly demonstrates the amount of bone loss.

**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 dislocation of the disk in the joint, and the extent of translation of the condyle in the fossa.107,108 With its accuracy, measurements of the roof of the glenoid fossa can be done easily.109 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.110

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.107,110–112 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.110

**Periodontics**

CBCT can be used in assessing a detailed morphological description of the bone because it has proved to be accurate with only minimal error margins.113,114 The measurements proved to be as accurate as direct measurements with a periodontal probe.114,115 Furthermore, it also aids in assessing furcation involvements.116,117

CBCT can be used to detect buccal and lingual defects, which was previously not possible with conventional 2-D radiographs.118,119 Additionally, owing to the high accuracy of CBCT measurements, intra-bony defects can accurately be measured and dehiscence, fenestration defects and periodontal cysts assessed.120–127 CBCT has also proved its superiority in evaluating the outcome of regenerative periodontal therapies.128,129

**General dentistry**

Based on the available literature, CBCT is not justified for use in children and adolescents below 18 years of age.130

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Fig. 7a

Fig. 7b

Fig. 7c

Fig. 7d

Fig. 7e

Fig. 7f

Fig. 7g

Fig. 7h

Fig. 7i

Fig. 7j

Fig. 7k

Fig. 7l

Fig. 7m

Fig. 7n

Fig. 7o

Fig. 7p

Fig. 7q

Fig. 7r

Fig. 7s

Fig. 7t

Fig. 7u

Fig. 7v

Fig. 7w

Fig. 7x

Fig. 7y

Fig. 7z

Fig. 7AA

Fig. 7BB

Fig. 7CC

Fig. 7DD

Fig. 7EE

Fig. 7FF

Fig. 7GG

Fig. 7HH

Fig. 7II

Fig. 7JJ

Fig. 7KK

Fig. 7LL

Fig. 7MM

Fig. 7NN

Fig. 7OO

Fig. 7PP

Fig. 7QQ

Fig. 7RR

Fig. 7SS

Fig. 7TT

Fig. 7UU

Fig. 7VV

Fig. 7WW

Fig. 7XX

Fig. 7YY

Fig. 7ZZ


developed the following basic prin ciples 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. 128

2. CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks. 128

3. CBCT examinations should potentially add new information to aid the patient’s management. 128

4. CBCT should not be repeated on a patient “routinely” without a new risk/benefit assessment having been performed. 128

5. When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of the clinical examination) to allow the CBCT practitioner to perform the justification process. 128

6. CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography. 128

7. CBCT images must undergo a thorough clinical validation (radiological) report of the entire image dataset. 128

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. 128

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. 128

10. Where CBCT equipment offers a choice of resolution, the resolution compatible with an adequate diagnosis and the lowest achievable dose should be used. 128

11. A quality-assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality-control procedures. 128

12. Aids to patient positioning (light-beam markers) must always be used. 128

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. 128

14. CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice facility users and patients, has not significantly deteriorated. 128

15. For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document Radiation protection 156: European guidelines for protection in dental radiology should be followed. 128

16. All those involved with CBCT must have received adequate theoretical and practical training for their specific purpose of radiological practices and relevant competence in radiation protection. 128

17. Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted. 128

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 dental-maxillofacial radiology exist, the design and delivery of CBCT training programmes should involve a DFM radiologist. 128

19. For dental-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 is required. 128

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

Conclusion

CBCT is most frequently applied in dental 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. Additionally, publications on CBCT indications in forensic dentistry and prosthetics are also desirable.

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