In response to an enquiry from the Scottish Dental Public Health Quality Improvement Group

Is cone beam computed tomography clinically effective, cost effective and safe compared with standard extraoral and intraoral radiography in the diagnosis of hard tissue pathology in routine dental practice?

What is a scoping report
Scoping reports ascertain the quantity and quality of the published clinical and cost-effectiveness evidence on health technologies under consideration by decision makers within NHSScotland. They also serve to clarify definitions related to the research question(s) on that topic. They are intended to provide an overview of the evidence base, including gaps and uncertainties, and inform decisions on the feasibility of producing an evidence review product on the topic. Scoping reports are undertaken in an approximately 1-month period. They are based upon a high-level literature search and selection of the best evidence that Healthcare Improvement Scotland could identify within the time available. The reports are subject to peer review. Scoping reports do not make recommendations for NHSScotland, however the Scottish Health Technologies Group (SHTG) produce an Advice Statement to accompany all evidence reviews. Further information on scoping reports is available at www.healthcareimprovementscotland.org

Key definitions

Alveolar: the part of the jaw that teeth arise from.

Effective dose: this measure takes into account both the type of radiation, and the radiosensitivity of the tissues being irradiated.

Exodontia: tooth extraction.

Field of view (FOV): the volume of the image dataset.

Furcation lesions: a lesion, in a multirooted tooth, where the root divides.

High resolution CBCT: the use of voxel (volumetric pixel) sizes of 0.2mm or smaller.

Infra-bony defect: a periodontal pocket (space between the tooth and gum) with a base that is apical to the level of the adjacent alveolar bone.

Maxilla: upper jaw.

Mandible: lower jaw.

Occlusal: biting surface of a tooth.

Periodontal disease: infection or inflammation of the tissues that surround the teeth.

Proximal caries: caries on the mesial or distal surface of a tooth.

Background
In dentistry, radiology has a role in treatment planning, monitoring disease progression and in assessing treatment efficacy1. Both intraoral and panoramic radiographs are commonly used. In intraoral radiographs, the X-ray sensitive film is inside the mouth. Panoramic radiographs are extraoral, and the entire mouth can be shown in a single image.

More recently, cone beam computed tomography (CBCT) has become available which can be used to generate a three dimensional image of the oral hard tissues to assist diagnosis of conditions and treatment (C Jones, Consultant in Dental Public Health. Personal Communication, 5 February 2013). A typical scan takes approximately 20 seconds, in which the machine orbits the patient and images a cylindrical volume or field of view (FOV)2. There may be instances where the improved imaging benefits patient treatment, but conversely it exposes people to increased doses of ionising radiation.

When people have radiographs, there can be damage to deoxyribonucleic acid (DNA) from the X-rays used in this form of examination. Most of the time, the body repairs...
this damage. Rarely, the chromosome becomes permanently altered, which can ultimately lead to the formation of a tumour. The period between exposure to an X-ray and formation of a tumour can be many years. The risk, while still small, is slightly elevated in younger people. The risks can be considered as chance effects, where the magnitude of the risk, though not the severity of the effect, is proportional to the radiation dose.

The annual radiation dose to the United Kingdom (UK) population is approximately 2,700 µSv (micro-sieverts) per person. The radiation dose (and hence risks) from dental CBCT scans are generally higher than conventional dental radiography (intraoral and panoramic) but lower than multi-slice CT (MSCT) of the dental area. For a panoramic radiograph, the effective dose is reported as 24µSv. This is equivalent to a few days exposure to natural background radiation, and carries an additional lifetime cancer risk of one in a few million. The effective dose for a small FOV CBCT scan is 48–652µSv, and for a large FOV CBCT scan is 68–1073µSv.

In Scotland, there are CBCT machines in the oral-maxillofacial radiology departments in Glasgow, Aberdeen and Dundee. Most general dental practices do not have a CBCT machine onsite. If dentists feel the need for access to CBCT, they generally refer to specialist practices. A retrospective observational study from the Glasgow Dental Hospital reported on referrals from the orthodontic department for CBCT from 2006 to 2011. During this time, 290 patients were referred for CBCT and approximately one third of scans were carried out within 4 weeks of referral. The smallest FOV height of 4cm was used for approximately one third of the scans investigated. Sixty-two percent of the scans examined the maxilla only, 32% both jaws and 6% the mandible only. The two most common reasons for referral were to accurately determine the position of impacted teeth and to identify the presence of root resorption in relation to impacted teeth.

The capital costs for CBCT systems are higher than standard intraoral and extraoral radiographic equipment used in dentistry. CBCT equipment costs range between £95,000 to £130,000 (dependent on software package). Private sector cost per CBCT scan is estimated at between £290–350. The NHS cost is likely to be greater, as it requires that a radiologist is present.

There is a need to establish conditions for which the use of CBCT is appropriate. The focus of this scoping report is on the use of CBCT in routine dentistry. The routine dental conditions of particular interest are dental caries; periodontal disease; assessment of periapical disease; and exodontias.

The following question was scoped:

Is CBCT clinically effective, cost effective and safe compared with standard extraoral and intraoral radiography in the diagnosis of hard tissue pathology in routine dental practice?

Literature search

A systematic search of the secondary literature was carried out between 17–18 April 2013 to identify systematic reviews, health technology assessments and other evidence-based reports. Medline, Medline in process, Embase, Cinahl and Web of Science databases were searched for systematic reviews and meta-analyses. The primary literature was systematically searched between 28–31 May 2013 using the following databases: Medline, Medline in process, Embase, and Cinahl. Results were limited to English language from 2010 onwards, in order to update a guideline identified from the secondary literature search.

Key websites were searched for guidelines, policy documents, clinical summaries and economic studies.

Concepts used in all searches included: cone beam computed tomography (CBCT), volumetric radiography, volume computed tomography, extraoral, intraoral and dentistry. A full list of resources searched and terms used is available on request.
Evidence base

Table 1 Included evidence sources

<table>
<thead>
<tr>
<th>Publication type</th>
<th>Number of publications</th>
<th>References</th>
</tr>
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<tr>
<td>Laboratory study</td>
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<td>15-24</td>
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Findings

A recent guideline (2012) produced by the European Commission was identified (prepared by the SEDENTEXCT consortium). This provides guidance on CBCT for dental and maxillofacial radiology. It is based on a systematic review of the literature up to October 2010, and is of good quality (although the included evidence is mostly lower level studies). Most of the information included in this scoping report comes from the guideline.

For this scoping report, a search was carried out to identify literature published since this guideline, identifying a further systematic review and 19 primary studies.

Clinical effectiveness

The authors of the SEDENTEXCT guideline used Fryback and Thornbury's hierarchy of diagnostic efficacy in reviewing the evidence:

- technical efficacy
- diagnostic accuracy efficacy
- diagnostic thinking efficacy
- therapeutic efficacy
- patient outcome efficacy
- societal efficacy.

The studies included in the guideline are mostly case series or case studies, and the authors recognise that understanding of the diagnostic efficacy of CBCT is largely limited to the first two of these levels. Only a few publications were identified which addressed higher levels of diagnostic efficacy (for example patient outcome efficacy).

The guideline covers a number of indications. For the four of interest to this scope (dental caries detection; periodontal disease; assessment of periapical disease; and exodontia), the evidence mainly comes from laboratory-based studies, case studies and case series. The results are as follows:

- **Dental caries detection**: Seven laboratory-based studies on proximal caries detection were included. Overall, these suggested that limited CBCT (small volumes with specific equipment) has a similar diagnostic accuracy to conventional radiography for the detection of proximal caries in posterior teeth in the laboratory setting. Three laboratory-based studies of occlusal caries detection were also included, all of which present data indicating increased sensitivity for occlusal caries diagnosis compared with conventional radiography, although highlight that more research is required.

The guideline concluded that the evidence does not support the clinical use of CBCT for caries detection and diagnosis.

- **Periodontal assessment**: The diagnosis of periodontal diseases depends on a clinical examination. Radiographs do not have a role in the diagnosis of periodontal disease, but are used as a means of demonstrating the hard tissue effects of periodontal disease, particularly bony attachment loss. The authors concluded that the literature in this area is small, mainly laboratory based and involves a limited number of CBCT systems. Furthermore, the impact of CBCT on management decisions and treatment impact in clinical practice has not been considered. For these reasons, the authors recommend that CBCT is not indicated as a routine method of imaging periodontal bone support.

However, the authors also report on some case series which suggest that CBCT may have a role to play in the management of complex periodontal defects for which surgery is the treatment option. They go on to recommend: ‘Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management.’
Assessment of periapical disease: Case reports, laboratory-based studies and non-systematic reviews were included which suggest that high-resolution CBCT may have a higher sensitivity for the detection of periapical lesions than conventional radiography without the loss of specificity. The diagnostic evidence, however, is limited by the difficulty in obtaining a true reference standard in human clinical studies. Also, in practice, clinical signs and symptoms play a more important role in diagnosis than radiological evidence. These factors, along with the higher cost of CBCT compared with conventional radiography, led the authors to conclude that they could not recommend the use of CBCT as a standard method for the diagnosis of periapical disease.

Based on the expert opinion of the group, the authors make a further two recommendations:

1. ‘Limited volume, high resolution CBCT may be indicated for periapical assessment in selected cases, when conventional radiographs give a negative finding when there are contradictory positive clinical signs and symptoms.’

2. ‘Where CBCT images include the teeth, care should be taken to check for periapical disease when performing a clinical evaluation.’

Exodontia: There is no identified evidence on the use of CBCT as part of the pre-extraction assessment of erupted teeth. The evidence on unerupted teeth is predominantly in relation to the mandibular third molar and its inter-relation to the mandibular canal, although there is a small amount of related evidence on the removal of impacted maxillary canines. There is contradictory evidence (from two diagnostic accuracy studies) that CBCT is significantly superior to conventional radiography in predicting neurovascular bundle exposure during extraction. However the weight of wider evidence (from clinical studies, case series and non-systematic reviews) led the authors to recommend: ‘Where conventional radiographs suggest a direct inter-relation between a mandibular third molar and the mandibular canal, and when a decision to perform surgical removal has been made, CBCT may be indicated.’

Dental caries: Six laboratory-based studies were identified which evaluated the use of CBCT in the detection of dental caries. One study suggested that for proximal caries, CBCT did not improve detection accuracy compared with periapical radiography; similarly another study concluded that CBCT was no better than digital images for the detection of proximal enamel caries. Two studies were on occlusal caries detection. One concluded that CBCT may outperform intraoral imaging for deep enamel and dentine caries, the other that there was no difference in accuracy between the two modalities. A further study suggested that CBCT may be more accurate for the detection of proximal cavities compared with digital intraoral images. Two studies were on occlusal caries detection. One concluded that CBCT may outperform intraoral imaging for deep enamel and dentine caries, the other that there was no difference in accuracy between the two modalities. A further study concluded that CBCT outperformed intraoral radiography in the detection of artificial buccal caries under restorations.

Taken together, these studies are inconsistent and are not strong enough to alter the conclusions of the SEDENTEXCT guideline; the
current evidence does not support the clinical use of CBCT for caries detection and diagnosis.

- Periodontal assessment: Two laboratory-based studies\(^{23,24}\), a small case series (n=6)\(^{14}\), and a larger retrospective case series (51 sites)\(^{13}\) were identified. The larger series compared periapical radiographs with CBCT in detecting and localising alveolar bone loss. The authors concluded that CBCT allowed for improved visualisation of the morphology of the defect\(^{13}\). However, these additional studies are not sufficient to alter the conclusions of the SEDENTEXCT guideline.

- Assessment of periapical disease: The systematic review concluded that there was insufficient scientific support, based on either clinical observation or laboratory-based studies, to determine whether the diagnostic accuracy of CBCT is greater than that of intraoral radiographic techniques in detecting periapical bone lesions\(^{5}\).

One laboratory-based study\(^{22}\), one retrospective case series\(^{10}\), and three prospective case series\(^{9,11,12}\) were also identified. All compared CBCT with periapical radiography, and all but one favoured CBCT. These additional studies do not alter the conclusions of the SEDENTEXCT guideline.

- Exodontia: A laboratory-based study\(^{21}\), a retrospective series\(^{7}\), a prospective case series\(^{8}\) and a pilot RCT\(^{6}\) were identified. The prospective series and RCT demonstrated superiority of CBCT for assessing impacted wisdom teeth at increased risk of inferior alveolar nerve injury, compared with panoramic radiography. Both studies are in agreement with the recommendations of the SEDENTEXCT guideline.

Safety

The SEDENTEXCT guideline states that the doses and risks for dental radiology are small\(^{1}\). However, they refer to epidemiological studies that provide some evidence of an increased risk of brain, salivary gland and thyroid tumours for dental radiography.

The authors describe three fundamental principles for the system of protection:

- justification - appropriate referral criteria should be in place to enable justification of the procedure.
- optimisation - the optimised medical exposure is not always the one with the lowest dose but the one which carefully balances the detriment from the exposure and the resources available for the protection of individuals.
- dose limits - this involves setting upper dose limits that may be received by any member of staff or member of the public from any man-made exposures other than medical exposures. For medical exposures, the limitation of the dose to the patient is not recommended. For patients, the emphasis is placed on justification and optimisation.

The guideline also provides recommendations (mostly based on good practice and expert opinion) relating to:

- CBCT equipment factors in the reduction of radiation risk to patients
- quality standards and quality assurance
- staff protection.

The Health Protection Agency has also produced guidance on the safe use of dental CBCT equipment\(^{3}\).

Cost effectiveness

No economic evaluations of CBCT in dentistry were identified.

One study (from Sweden) applied a framework for costing the radiographic examination of maxillary canines with eruption disturbances using two different imaging methods: (i) a new method with CBCT and panoramic radiography and (ii) a conventional method using intraoral and panoramic radiography\(^{26}\). The mean total cost per examination for the new method was €128.38 (£107.87) and €81.80 (£68.73) for the conventional method. The study also reported that the purchase cost for the CBCT equipment was double that of the panoramic equipment and over five times higher than that for intraoral radiography. (Note: all reported costs converted to pounds sterling using the exchange rate as at 24 September 2013).
Summary

A good quality guideline, published by the European Commission in 2012, made the recommendations shown below. An adaptation of the grading system used by the Scottish Intercollegiate Guidelines Network (SIGN) was used (for more information, refer to the SEDENTEXCT guideline1):

- CBCT is not indicated as a method of caries detection and diagnosis (B grade)1.
- CBCT is not indicated as a routine method of imaging periodontal bone support (C grade)1.
- Limited volume, high resolution CBCT may be indicated in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management (C grade).
- Where CBCT images include the teeth, care should be taken to check for periodontal bone levels when performing a clinical evaluation (good practice point).
- CBCT is not indicated as a standard method for identification of periapical pathosis (good practice point)1.
- Limited volume, high resolution CBCT may be indicated for periapical assessment, in selected cases, when conventional radiographs give a negative finding when there are contradictory positive clinical signs and symptoms (good practice point)1.
- Where CBCT images include the teeth, care should be taken to check for periapical disease when performing clinical evaluation (good practice point)1.
- Where conventional radiographs suggest a direct inter-relationship between a mandibular third molar and the mandibular canal, and when a decision to perform surgical removal has been made, CBCT may be indicated (C grade)1.
- CBCT may be indicated for pre-surgical assessment of an unerupted tooth in selected cases where conventional radiographs fail to provide the information required (good practice point)1.

A search of the primary literature highlighted a further systematic review and 19 primary studies. These were not critically appraised. They do not alter the conclusions of the SEDENTEXCT guideline.

No economic evaluations were identified.

Further work for Healthcare Improvement Scotland

No further work is anticipated for Healthcare Improvement Scotland.

Equality and diversity

Healthcare Improvement Scotland is committed to equality and diversity in respect of the nine equality groups defined by age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion, sex, and sexual orientation. As a scoping report summarises information and does not provide recommendations a full equality impact assessment is not deemed necessary.

The scoping report process has been assessed and no adverse impact across any of these groups is expected. The completed equality and diversity checklist is available on www.healthcareimprovementscotland.org
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Healthcare Improvement Scotland invited the following individuals and organisations to peer review the draft technologies scoping report:

Derek Richards, Consultant in Dental Public Health, NHS Tayside, Independent clinical expert
Laetitia Brocklebank, Clinical Senior Lecturer and Honorary Consultant in Oral Radiology, University of Glasgow Dental School, Independent clinical expert
Carestream Dental and Xograph Healthcare Ltd, Manufacturer of technology

Declarations of interest were sought from the clinical advisor and all peer reviewers. All contributions from peer reviewers were considered by the group. However the peer reviewers had no role in authorship or editorial control and the views expressed are those of Healthcare Improvement Scotland.

Joanna Kelly, Lead Author/Health Services Researcher
Paul Cannon, Information Scientist
Susan Downie, Medical Writer
Marina Tudor, Team Support Administrator
Members of the SHTG evidence review committee
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NICE has accredited the process used by Healthcare Improvement Scotland to produce its evidence review products. Accreditation is valid for 5 years from January 2013. More information on accreditation can be viewed at www.nice.org.uk/accreditation
References


References continued


