Question to be investigated
What are the specific clinical criteria/conditions under which cone beam technology (CBT) provides more positive outcomes versus traditional radiographic imaging? (Be sure to include radiation exposure as part of your review.)

Executive Summary
Cone Beam Computed Tomography (CBCT) was introduced in dental practice more than a decade ago (1998). There are more than 20 manufacturers on the market that sell either machines or specialized software to manipulate the CBCT scan data for advanced treatment planning in several dental disciplines. CBCT has the ability to depict hard tissue structures in the head and neck area in three planes of space, with minimal distortion or magnification. Tissues that are difficult to see with conventional radiographs due to superimposition can often be accurately visualized using CBCT. CBCT does not allow accurate visualization of soft tissue structures.

No studies have been conducted to evaluate whether CBTs lead to more successful treatment outcomes. There are a few studies documenting the impact of CBCT on either treatment planning or diagnostic thinking. Most of the current evidence on CBCT is on diagnostic accuracy which ranks low as a source for clinical decision making. As a result, uncertain benefits in terms of improved procedure outcomes have to be weighed against the known harms of diagnostic ionizing radiation. The harms of CBCT include:

- Increased cancer risk and mortality caused by the additional radiation dose. This harm is relevant when it comes to dentistry due to the high prevalence of dental care. For instance, close to 50% of children born in the U.S. (or approximately two million children) undergo orthodontic treatment each year.
- Lack of legislation on CBCT standards may lead to unbridled usage: There is a common lack of understanding on the part of both medical and dental practitioners regarding the harms of radiation. For instance, despite the efforts on the part of the ADA to inform dentists on the harms of ionizing radiation, many dentists do not follow the ALARA principle. For instance, D-film use continues to be highly prevalent in dental practices despite the fact that guidelines have advised against their use for over two decades now. The same has occurred in medicine where some have come to the conclusion that legislation is the only approach to ensure that guidelines regarding ionizing radiation exposures are followed.
- More likely occurrence of incidentalomas (definition: incidental findings during routine dental examinations). These incidentalomas may include false positive findings, cases of overdiagnosis, and true disease that will progress to clinical symptoms.
  o Overdiagnosis is the diagnosis of histologically verifiable disease that does not progress to clinical symptoms.
  o A false positive is the diagnosis of a disease that is determined not to be present upon further diagnostic testing.
  o True disease is a clinical condition that is verified as truly present upon further clinical examination and that will eventually lead to morbidity or mortality.
- Incidentalomas may have the following negative consequences:
  o Further diagnostic follow-up testing which may include biopsies and additional diagnostic radiation.
  o Psychological harms, temporary or permanent, associated with discovering the presence of occult disease
  o Legal dilemmas for the practitioner.

We conclude that CBCT may have applications in clinical dentistry for a few specific clinical conditions only after it has been demonstrated that conventional radiography does not obtain information that is deemed necessary for therapeutic decision making.

**Research sources and thoroughness estimate**

In the absence of reliable evidence on benefits and known harms, recommendations for the use of CBCT in dentistry have been developed or are being developed by organized dentistry. Most of the current guidelines suffer from the absence of a formal scientific review process. For instance, the *American Academy of Oral and Maxillofacial Radiology* does not report the utilization of accepted systematic review guidelines for the construction of clinical guidelines and instead appears to rely on expert opinion. Currently, the SEDENTEXCT are the only evidence-based guidelines that incorporated some aspects of the systematic review process in the formulation of guidelines.

The absence of a more formal process for the construction of CBCT practice guidelines by professional guidelines is of concern. The presence of professional biases in the construction of guidelines has become of increasing concern. The *Institute of Medicine (IOM)* has provided suggestions for the development of clinical guidelines. Few of these suggestions were adhered to in the current CBCT guidelines. For instance, the IOM has suggested that the development of guidelines for clinical practice should be executed by individuals who are free from conflicts of interest, and when such individuals are necessary, they should make up a minority of the panel. The IOM has noted that this is particularly important when guidelines are created in the absence of evidence which is the case for CBCT guidelines.

Review panels for the American Academy of Oral and Maxillofacial Radiology (AAOMR), the American Academy of Endodontics (2007), and the SEDENTEXCT (Safety and Efficacy of a New and Emerging Dental X-ray Modality) project in Europe agree that CBCT scans should not be used routinely in dentistry. The decision to order a CBCT scan must be based on the patient’s history and clinical examination, and justified on an individual basis. These organizations often suggest that clinicians should make a scientific decision on an issue where no scientific evidence exists; namely that the benefits to the patient outweigh the potential risks of exposure to ionizing radiation. Making such a decision is especially challenging for infants, children or young adults in whom the cancer risk subsequent to ionizing radiation can increase several-fold when compared to adults. The recommendations typically state that CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities. Insufficient research has been conducted to provide probabilistic estimates when such situations arise.

At this time, all CBCT equipment produces dose levels and beam energies (radiation dose and risk) that are typically higher than conventional dental radiography (intraoral and panoramic) but lower than conventional CT scans of the dental area. The dose received with CBCT will depend on the diagnostic need, protocol and scanner used. There is no standard radiation exposure published for each possible dental application described in this report;
however, some generalizations can be made. In general, except for endodontic applications which require a very small field of view\(^1\) (FOV) and high resolution, most other applications (e.g., implant treatment planning, orthodontics and orthognatic surgery planning) can be accomplished with voxel\(^2\) sizes of 0.4 mm\(^{12}\), which means lower radiation doses. In addition, the information obtained from CBCT imaging requires a substantial level of expertise for interpretation. This implies that the untrained clinician is likely to have a substantial error rate in the interpretation of CBCT images resulting in a high percentage of missed or false positive diagnoses\(^{13}\).

While there may be numerous articles in the literature describing the use of CBCT for specific dental applications, there are currently no clinical studies demonstrating improved patient outcomes or systematic reviews of such studies. To the contrary, existing systematic reviews appear to often point to the absence of good evidence on the benefits of CBCT\(^{14,15}\). The scientific evidence that the use of CBCT alters diagnosis and improves treatment plans is starting to be studied\(^{16-20}\). The results of such studies suggest that diagnostic radiography does not necessarily impact diagnostic thinking, treatment planning, or diagnostic accuracy. For certain clinical applications, the use of CBCT is justified by the parachute argument (e.g., the benefits for the 3-D localization of a cuspid are reported to be so obvious no scientific studies are needed)\(^{14}\). Often, specific indications for acquiring CBCT images and protocols (e.g., doses) are based on anecdotal evidence.

Some of the following recommendations and guidelines were extracted from sources such as the American Academy of Oral and Maxillofacial Radiology (AAOMR), American Academy of Endodontics, and the European SEDENTEXCT project. It is expected that in the near future additional recommendations (e.g., from the American Dental Association) will be available. Many of the findings and conclusions reported reflect expert opinion of the involved panels and do not necessarily reflect the opinions of the authors of this document.

**Findings and Conclusions**

**Safety and radiation dose:**
CBCT allows for multiplanar reconstruction, non-orthogonal reconstruction and 3-dimensional rendering of hard tissue structures. The beam is conical, usually requires one rotation, and voxel sizes range from 0.4 mm to 0.076 mm. CBCT has an advantage over medical grade CT as radiation doses from commonly used CBCT acquisition protocols are lower by an order of magnitude, plus it allows for greater spatial resolution and non-orthogonal reconstruction. The doses of CBCT, however, are significantly higher than the traditional dental radiography tools.

To provide some estimates of the cancer burden due to diagnostic radiation, the following two examples are provided. The first example provides a range of radiation doses which are commonly associated with orthodontic therapy\(^{21,22}\). The below dose estimates show a range of possible thyroid cancer burdens associated with orthodontic diagnostic radiation. CBCT can be expected to lead to increases in doses to the thyroid ranging from 1.2 mGray for the I-CAT\(^{23}\) to 6.3 mGray for the CB Mercuray\(^{24}\). The number of individuals developing thyroid cancer is calculated for the year 1996 where the number of children and adolescents undergoing orthodontic therapy was approximately 1.5 million.

---

\(^{1}\) The Field of View (FOV) is that part of the skull that is visible through the imaging

\(^{2}\) A voxel is a volume element in a 3-dimensional space. A voxel is the 3-D equivalent of a pixel in a 2-D space.
Lifetime Attributable Thyroid Cancer Risk  
(Age at Exposure 10-19)

<table>
<thead>
<tr>
<th>Dose</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mgray</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>2.5 mgray</td>
<td>68</td>
<td>10</td>
</tr>
<tr>
<td>5 mgray</td>
<td>96</td>
<td>13</td>
</tr>
<tr>
<td>10 mgray</td>
<td>193</td>
<td>27</td>
</tr>
</tbody>
</table>

1996 cohort – 1.5 million treated, 65% females

As a second example, the number of orthodontic patients developing leukemia as a consequence of 2 CBCT and CT is provided. The number of expected cases was calculated under the same assumptions as the calculations for thyroid cancers.

Lifetime Attributable Leukemia Risk (Age at Exposure: 10)

<table>
<thead>
<tr>
<th>Dose</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>CT</td>
<td>19</td>
<td>14</td>
</tr>
</tbody>
</table>

1996 cohort – 1.5 million treated, 65% females

As CBCT use has increased in dentistry (especially amongst orthodontists, oral and maxillofacial surgeons, dentists who perform implants or treat patients with facial pain or temporomandibular disorders), there is concern about the possible overuse or misuse of this technology. As endorsed by the American Dental Association, the fundamental objective of diagnostic radiology is summarized in the ALARA principle: radiation doses must be kept “As Low As Reasonably Achievable”, consistent with the diagnostic needs and goals. All ionizing radiation is potentially damaging, and thus every prescription for exposure to ionizing radiation has to be justified. Within this framework, the ADA has engaged into discussions regarding the most appropriate use of CBCT in dental practice. The ADA Council on Scientific Affairs is currently developing its own set of guidelines on the use of CBCT.

Such voluntary guidelines rarely have an impact on clinical practice. Case in point, the Scientific Council of the American Dental Association recommended in 1984 to abandon the
use of D-film speed\textsuperscript{27}. These suggestions have not been adhered to according to national surveys that have subsequently been conducted. Current industry estimates suggest that 70% of the film is still D-speed film\textsuperscript{6}. Similarly, while the ADA has recommended the use of thyroid shields for decades\textsuperscript{25,27-29}, the prevalence of its utilization has been reported to low\textsuperscript{30}. The lack of impact of guidelines when it comes to minimizing radiation is driving the call for legislation in medicine.

At this time, all CBCT equipment produce dose levels and beam energies (radiation dose and risk) that are higher than conventional dental radiography (intraoral and panoramic), that expose organs such as brain and thyroid that do not get exposed with other radiographic projections\textsuperscript{11}. Dose is dependent on equipment type and exposure settings, especially the “field of view” (FOV) selected. The size of the FOV describes the scan volume of the CBCT machine and is dependent on the detector size and shape, beam projection geometry and the ability to collimate the beam. Beam collimation limits the x-radiation exposure to the region of interest and ensures that an optimal FOV can be selected based on disease presentation (Geist, 2011). The FOV can range from 10 cm or less scan height for small FOV scanners (e.g., for individual teeth or quadrant), greater than 10 cm but less than 15 cm of height for medium FOV scanners (e.g., for both arches including TMJ), and 15 cm or greater scan height for large FOV scanners (e.g., for full head scan). Selection of the most appropriate imaging protocol and scanner depends on the diagnostic task at hand. For example, in endodontics, if it is important to be able to detect disruptions in the periodontal ligament space, which measures approximately 200\textmu m, and optimal resolution is necessary, a small FOV scanner would be the one recommended.

Also, doses vary significantly between CBCT machines, as exemplified in the tables below from the SEDENTEXCT project (2009). Please note that CBCT technology is rapidly developing as manufacturers are regularly bringing out new models or up-grading existing software to models that are on the market. Consequently, the doses quoted in the table might not apply to newer versions of CBCT equipment with the same name. Also, reported radiation doses measured in idealized phantom situations with optimal collimation rarely approximate real-life doses.

The conclusion is that careful attention must be paid to the scanner to be used, and voxel size and FOV needed for a specific dental need in order to help minimize the dose received by the patient. In addition, the use of the technology requires practical training and protection measures for office personnel. Clinicians must be trained in use and interpretation of CBCT scans. Appropriate qualified experts should be consulted prior to and after installation to meet state and federal requirements, and manufacturer’s recommended calibration routines should be conducted at the recommended intervals.

<table>
<thead>
<tr>
<th>Dental CBCT unit</th>
<th>Effective dose (\textmu Sv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Craniofacial</td>
</tr>
<tr>
<td>NewTom</td>
<td>41-75</td>
</tr>
<tr>
<td>Accuitomo/ Veraviewepocs</td>
<td>11-102</td>
</tr>
<tr>
<td>Galileos</td>
<td>70-128</td>
</tr>
<tr>
<td>Promax</td>
<td>488-652</td>
</tr>
</tbody>
</table>

September 2011
Delta Dental Plans Association
<table>
<thead>
<tr>
<th>Machine</th>
<th>Effective dose (μSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prexion</td>
<td>189-388</td>
</tr>
<tr>
<td>i-CAT</td>
<td>34-89</td>
</tr>
<tr>
<td>CB MercuRay</td>
<td>407</td>
</tr>
<tr>
<td>Illuma</td>
<td>98-498</td>
</tr>
<tr>
<td>i-CAT</td>
<td>48-206</td>
</tr>
<tr>
<td>CB MercuRay</td>
<td>283-1073</td>
</tr>
<tr>
<td>Illuma</td>
<td>98-498</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effective dose (μSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-oral radiograph</td>
</tr>
<tr>
<td>Panoramic radiograph</td>
</tr>
<tr>
<td>CT maxillo-mandibular</td>
</tr>
<tr>
<td>CT maxilla</td>
</tr>
</tbody>
</table>

Guidelines for CBCT use as reported by different organizations:
The SEDENTEXCT (Safety and Efficacy of a New and Emerging Dental X-ray Modality) project in Europe has established guidelines (Consensus Guidelines of the European Academy of Dental and Maxillofacial Radiology) for the use of CBCT in dental diagnosis (2009). The “Basic Principles on the use of Cone Beam CT” according to a consensus reached by faculty of several European universities are based on the following premises: 32
<table>
<thead>
<tr>
<th></th>
<th>CBCT examinations must not be carried out unless a history and clinical examination have been performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks</td>
</tr>
<tr>
<td>3</td>
<td>CBCT examinations should potentially add new information to aid the patient’s management</td>
</tr>
<tr>
<td>4</td>
<td>CBCT should not be repeated ‘routinely’ on a patient without a new risk/benefit assessment having been performed</td>
</tr>
<tr>
<td>5</td>
<td>When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process</td>
</tr>
<tr>
<td>6</td>
<td>CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography</td>
</tr>
<tr>
<td>7</td>
<td>CBCT images must undergo a thorough clinical evaluation (‘radiological report’) of the entire image dataset</td>
</tr>
<tr>
<td>8</td>
<td>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</td>
</tr>
<tr>
<td>9</td>
<td>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 less radiation dose to the patient</td>
</tr>
<tr>
<td>10</td>
<td>Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used</td>
</tr>
<tr>
<td>11</td>
<td>A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures</td>
</tr>
<tr>
<td>12</td>
<td>Aids to accurate positioning (light beam markers) must always be used</td>
</tr>
<tr>
<td>13</td>
<td>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</td>
</tr>
<tr>
<td>14</td>
<td>CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated</td>
</tr>
<tr>
<td>15</td>
<td>For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document ‘Radiation Protection 136. European Guidelines on Radiation Protection in Dental Radiology’ should be followed</td>
</tr>
<tr>
<td>16</td>
<td>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</td>
</tr>
<tr>
<td>17</td>
<td>Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted</td>
</tr>
<tr>
<td>18</td>
<td>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 DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist</td>
</tr>
<tr>
<td>19</td>
<td>For dento-alveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (e.g. 8cm x 8cm or smaller fields of view), clinical evaluation (‘radiological report’) should be made by a specially trained DMF Radiologist or,</td>
</tr>
</tbody>
</table>
where this is impracticable, an adequately trained general dental practitioner

20  For non-dento-alveolar small fields of view (e.g. temporal bone) and all craniofacial CBCT images (fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose), clinical evaluation ('radiological report') should be made by a specially trained DMF Radiologist or by a Clinical Radiologist (Medical Radiologist)

Indications for CBCT referrals:
Despite limited high levels of evidence, specific indications for CBCT referral as suggested by several organizations are summarized below.

Implant site assessment*
Radiographic assessment of the jaw can be a considered useful for implant placement in certain anatomical areas such as the mandibular region between the mental foramen and the foramen mandibulare. While it is often stated that panoramic and periapical radiography has distortion, this is an insufficient justification for switching to CBCT. With the use of standardization devices such as a fissure bur during radiographic exposure, panoramic radiographs can provide accurate estimation for the placement of mandibular implants in the area of the inferior alveolar nerve in the majority of cases\textsuperscript{33}.

The fact that the AAOMR has recommended that all potential implant sites be evaluated with “cross sectional imaging orthogonal to the site of interest”, referring to planar or computed tomography\textsuperscript{34}, may be a reflection of their conflicts of interest, rather than science as other organizations or expert clinicians have not made such recommendations. Given the increasing evidence that implant length is not related to implant success\textsuperscript{35}, CBCT may not be required to determine the inferior alveolar nerve (IAN) position in clinical settings with more than 12 mm of bone between the alveolar crest and the inferior alveolar nerve (IAN) can be identified on a panoramic radiograph. If cross-sectional radiographs are indicated, then CBCT may be preferred over other tomographic modalities\textsuperscript{36}. Radiation dose increases with increased resolution, and so resolution needs to match the task at hand. Implant treatment planning can be accomplished generally with voxel sizes of 0.4 mm\textsuperscript{12,37}.

Often anecdotal evidence is provided to justify CBCT for implant therapy. For instance, one author in a non-refereed dental journal has suggested that CBCT can be valuable in the following tasks in implant assessment\textsuperscript{12}:

a) Measuring distances between the alveolar crest and various anatomic landmarks
b) Evaluating the quality of cortical and medullar bone in the potential implant site
c) Visualizing the inclination of the alveolar process to predict a successful path of insertion
d) Providing the basis for treatment planning with the use of special algorithms

Clinical research will be required to determine whether such anecdotal justifications stand up to an evidence-based assessment.
According to the SEDENTEXCT project (2009), recommendations for use of CBCT for implant placement include:

- *The use of CBCT is not recommended as a routine imaging technique for all implant cases*

- *CBCT is justified for cross-sectional imaging prior to implant placement as an alternative to existing cross-sectional techniques where the radiation dose is shown to be lower*

- *The advantage of CBCT with adjustable fields of view, compared with conventional CT, becomes greater where the region of interest is a localized part of the jaw, as a similar sized field of view can be used*

**TMJ evaluations**

Decisions on radiograph exposures of the TMJ are often based on the need to establish a diagnosis. A systematic review of TMJ imaging concluded that CBCT provides the same diagnostic accuracy regarding degenerative condylar changes as CT, at lower cost and radiation dosage. To what extent a diagnosis of a degenerative condylar changes contributes to better patient outcomes is unclear.

Regarding other TMJ diseases (e.g., neoplasia of the condyle) CBCT has been reported to have similar sensitivity and specificity to CT.

According to the SEDENTEXCT project (2009);

- *Where the existing imaging modality for examination of the TMJ is conventional CT, CBCT should be considered as an alternative where radiation dose is shown to be lower*

**Orthodontics**

Despite the increasing popularity of CBCT in orthodontics, the effects of information derived from these images in altering diagnosis and treatment decisions has not been demonstrated. It has, therefore, been recommended that CBCT not be used routinely during orthodontic treatment (American Association of Orthodontists Resolution 26–10H, 2010), but be used only in select cases in which conventional radiography cannot supply satisfactory diagnostic information. According to Kapila et al, these cases include cleft palate patients, assessment of unerupted tooth position, supernumerary teeth, identification of root resorption, and for planning orthognatic surgery. Once again, it should be realized that justification for using CBCT for these special cases is anecdotal.

The need to image other types of cases – according to Kapila - should be made on a case-by-case basis following an assessment of benefits vs. risks of scanning in these situations. Orthodontic or orthognatic surgical planning can be accomplished generally with voxel sizes of 0.4 mm.

Orthodontics is of particular concern when it comes to CBCT usage because of the high prevalence of orthodontic care in the U.S. population and the typical age of care. Several organs in children and adolescents are more sensitive to radiation than are adults. For
instance, the radiosensitivity of the thyroid varies significantly as a function of age and gender (red for females, and green for males).

The Academy of Oral and Maxillofacial Radiology (AAOMR) and the American Association of Orthodontists are working together to develop guidelines and selection criteria for the use of CBCT in orthodontics with special consideration for minimizing radiation dose in children (as orthodontics involves a course of treatment over a period of time with multiple radiographic exposures).

According to the SEDENTEXCT project (2009):

- **Large volume CBCT should not be used routinely for orthodontic diagnosis**
- **Where the current imaging method of choice for the assessment of cleft palate is MSCT, CBCT may be preferred where radiation dose is lower. The smallest volume size compatible with the situation should be selected because of reduced radiation dose**
- **For complex cases of skeletal abnormality, particularly those requiring combined orthodontic/surgical management, large volume CBCT may be justified in planning the definitive procedure, particularly where MSCT is the current imaging method of choice**
- **Research is needed to define robust guidance on clinical selection for large volume CBCT in orthodontics, based upon quantification of benefit to patient outcome**
Oral Surgery
The ability to depict the dento-alveolar complex in three dimensions can help localize structures. It has been suggested that CBCT can help better visualize impacted third molars (which should minimize the risk of complications; 41), help reposition the condyle during fracture surgeries (reducing postoperative complications; 42), etc. However, due to the poor ability of CBCT to depict soft tissues, it is not indicated for fractures with extension into the cranium or tumors with soft tissue involvement 43.

According to the SEDENTEXCT project (2009):
- For the localized assessment of an impacted tooth (including consideration of resorption of an adjacent tooth) where the current imaging method of choice is MSCT, CBCT may be preferred because of reduced radiation dose
- For the localized assessment of an impacted tooth (including consideration of resorption of an adjacent tooth) where the current imaging method of choice is conventional dental radiography, CBCT may be used when the information cannot be obtained adequately by lower dose conventional (traditional) radiography
- For the localized assessment of an impacted tooth (including consideration of resorption of an adjacent tooth), the smallest volume size compatible with the situation should be selected because of reduced radiation dose. The use of CBCT units offering only large volumes (craniofacial CBCT) requires very careful justification and is generally discouraged
- CBCT may be justifiable in the assessment of dento-alveolar trauma in selected cases, where conventional radiographs provide inadequate information for treatment planning
- Where conventional radiographs suggest a close relationship between a mandibular third molar and the inferior dental canal, and when a decision to perform surgical removal has been made, CBCT is justified.

It should be noted that this latter guideline may be outdated. A recent systematic review suggested that there are only two studies that compared CBCT and panoramic radiographs with a valid reference method and presented the results in terms of percentage of correct diagnoses14. While there was a trend for better sensitivity results with CBCT, the difference was not significant.
- CBCT may be justified for pre-surgical assessment of an unerupted tooth in selected cases where conventional radiographs fail to provide the information required
- For maxillofacial fracture assessment, where cross-sectional imaging is judged to be necessary, CBCT may be used as an alternative imaging modality to conventional CT where radiation dose is shown to be lower and soft tissue detail is not required
- CBCT should not be used routinely for imaging the craniofacial skeleton
CBCT may be used, in selected cases, where only bone information is required, for obtaining three-dimensional datasets of the craniofacial skeleton

Endodontics
Radiography has historically been considered important for the successful diagnosis of odontogenic and non-odontogenic pathoses, treatment of the pulp chamber and canals of a compromised tooth, biomechanical instrumentation, evaluation of final canal obturation, and assessment of healing. With the development of new diagnostic instruments (apex locators) the use of ionizing radiation in endodontics may also come under re-evaluation.

In a joint position statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology, it was concluded that CBCT must NOT be used routinely for endodontic diagnosis or for screening purposes in the absence of clinical signs and symptoms. The patient’s history and clinical examination must justify the use of CBCT by demonstrating that the benefits to the patient outweigh the potential risks. It is unclear if such a situation exists since dental implant can eliminate the need for CBCTs.

Clinicians have been advised to use the CBCT when the need for imaging cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities. Endodontics usually requires high resolution and voxel size less than 0.4 mm are generally needed (Farman et al., 2010). However, every effort should be made to reduce the effective radiation dose to the patient for endodontic-specific tasks. Using the smallest possible FOV, the smallest voxel size, the lowest mA setting and the shortest exposure time in conjunction with a pulsed exposure mode of acquisition is recommended (in fact small or limited FOV units are probably the most adequate for this as they can provide a resolution as low as 0.076 voxel size). If extension of pathology beyond the area surrounding the tooth apices or a multifocal lesion with possible systemic etiology is suspected, and/or a non-endodontic cause for devitalization of the tooth is established clinically, appropriate larger field of view protocols may be employed on a case-by-case basis. Limited field of view CBCT systems can provide images of several teeth from approximately the same radiation dose as two periapical radiographs, and they may provide a dose savings over multiple traditional images in complex cases. In fact, for most endodontic applications, limited volume CBCT is preferred over large volume CBCT for the following reasons:

a) Increased spatial resolution to improve the accuracy of endodontic-specific tasks such as the visualization of small features including accessory canals, root fractures, apical deltas, calcifications, etc.

b) Highest possible spatial resolution that provides a diagnostically acceptable signal-to-noise ratio for the task at hand.

c) Decreased radiation exposure to the patient.

d) Time savings due to smaller volume to be interpreted.

According to the joint report of the AAOMR and AAE (2010), the use of CBCT in endodontics should be limited to the assessment and treatment of complex endodontic conditions such as:
a) Identification of potential accessory canals in teeth with suspected complex morphology based on conventional imaging.

b) Identification of root canal system anomalies and determination of root curvature.

c) Diagnosis of dental periapical pathosis in patients who present with contradictory or nonspecific clinical signs and symptoms, who have poorly localized symptoms associated with an untreated or previously endodontically treated tooth with no evidence of pathosis identified by conventional imaging, and in cases where anatomic superimposition of roots or areas of the maxillofacial skeleton is required to perform task-specific procedures.

d) Diagnosis of non-endodontic origin pathosis in order to determine the extent of the lesion and its effect on surrounding structures.

e) Intra- or post-operative assessment of endodontic treatment complications, such as overextended root canal obturation material, separated endodontic instruments, calcified canal identification, and localization of perforations.

f) Diagnosis and management of dento-alveolar trauma, especially root fractures, luxation and/or displacement of teeth, and alveolar fractures.

g) Localization and differentiation of external from internal root resorption or invasive cervical resorption from other conditions, and the determination of appropriate treatment and prognosis.

h) Pre-surgical case planning to determine the exact location of root apex/apices and to evaluate the proximity of adjacent anatomical structures.

According to the SEDENTEXCT project (2009):

- **CBCT should not be used routinely for identification of periapical pathosis**

- **CBCT may be considered for periapical assessment, in selected cases, when conventional radiographs give a negative finding when there are contradictory positive clinical signs and symptoms**

- **Where CBCT images include the teeth, care should be taken to check for periapical disease when performing a clinical evaluation (report)**

- **CBCT should not be used routinely for endodontic diagnosis**

- **CBCT may be justifiable for selected cases, where intraoral radiographs provide information on root canal anatomy that is equivocal or inadequate for planning treatment, most probably in multi-rooted teeth**

- **CBCT may be justifiable for selected cases, where endodontic treatment is complicated by concurrent factors, such as resorption lesions, combined periodontal/endodontic lesions, perforations and atypical pulp anatomy**

- **CBCT may be justifiable for selected cases when planning surgical endodontic procedures. The decision should be based upon potential complicating factors, such as the proximity of important anatomical structures**
Other Applications:
According to the SEDENTEXCT project (2009):
- **CBCT should not be used as a routine method of caries detection and diagnosis. But, where CBCT images include the teeth, care should be taken to check for caries when performing a clinical evaluation (report)**

- **CBCT should not be used as a routine method of imaging periodontal bone support**

- **CBCT may be useful in selected cases of infra-bony defects and furcation lesions, where clinical and conventional radiographic examinations do not provide the information needed for management.**

- **Where CBCT images include the teeth, care should be taken to check for periodontal bone levels when performing a clinical evaluation (report)**

Conclusions
CBCT must not be used routinely for dental care. Systematic reviews indicate that there is currently no evidence to suggest better patient outcomes when CBCT is used. Clinicians should use CBCT only if appropriately trained and when the need for imaging cannot be answered adequately by lower dose conventional dental radiography or alternate imaging modalities.

Strength of the Evidence
There is a great need for future research regarding the contribution of CBCT to dental applications. In areas where the use of CBCT may appear logical (as described above, CBCT may be useful), the specific indications for acquiring CBCT images and protocols (e.g., doses) to be used for imaging and extracting appropriate information have not been resolved. In absence of other sources, the recommendations provided in this report were extracted from sources such as the American Academy of Oral and Maxillofacial Radiology (AAOMR), American Academy of Endodontics, and the European SEDENTEXCT project. It is expected that in the near future additional recommendations (e.g., from the American Dental Association) will be available.

These professional guidelines were formulated in the absence of high-level evidence on the usefulness of diagnostic tests, without adhering to principles of guideline formulation as stipulated by the institute of medicine. Until clinical trials demonstrate that CBCTs do improve the oral health related quality of life, it may be prudent to obtain informed consent. This informed consent should inform the patient regarding the organ-specific radiation doses, expected cancer risks, risk for discovering incidentalomas, and expected benefits in terms of providing a successful procedure outcome.
References


