A Health Technology Assessment Report on Cone Beam Computed Tomography vs. Conventional Two Dimensional Imaging Techniques in Implantology

by

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The views expressed in this report are those of the author(s) and do not necessarily reflect the views of the Faculty of Dentistry, McGill University. This report was developed for the course ‘DENT 655- Health Technology Assessment’ and assumes a call from general dentists to assist decision-making in dental offices, clinical and hospitals. All are welcome to make use of it. However, to help us estimate the impact, it would be deeply appreciated if users could inform us whether it has influenced policy decisions in any way.

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Acronyms

- 2D: Two-dimensional space
- 3D: Three-dimensional space, the physical universe
- AETMIS: L'Agence d'évaluation des technologies et des modes d'intervention en santé
- CADTH: Canadian Agency for Drugs and Technologies in Health
- CBCT: Cone Beam Computed Tomography
- CT: Computed Tomography
- FDA: Food and Drug Administration, agency of the United States Department of Health and Human Services, responsible for protecting and promoting public health through the regulation and supervision of food safety, tobacco products, etc.
- INAHTA: International Network of Agencies for Health Technology Assessment
- mSv: milliSievert. International System of Units (SI) derived unit of dose equivalent radiation
- NICE: National Institute for Health and Clinical Excellence
- QR: Quantitative Radiology
- TMJ: Temporomandibular Joint
- US: United States of America
- X-rays: a form of electromagnetic radiation. X-rays have a wavelength in the range of 0.01 to 10 nm.
- μSv: microSievert. Unit of dose equivalent radiation.
1. **Background**

Dental radiography is an area of study that has changed a lot throughout the years. Initially called X-rays, dentists use this tool in their offices every day in order to give better and more accurate diagnosis. In the dental office, these images are used to diagnose cavities, cancerous or benign masses, hidden dental structures, bone loss hidden under the gums. Furthermore, this technique is used to check the status of a procedure and even as a follow-up of some treatments (1-3).

The images taken with these technologies are usually able to show calcified structures such as teeth, bones, and sometimes one can visualize the surrounding soft tissues. The picture shown on an X-ray is formed by the radiation emitted by a machine. This radiation will enter the oral structures at different levels, depending on varying anatomical densities. For example, teeth appear lighter because less radiation penetrates them to reach the film. In the case of cavities or bone loss, they look usually darker because X-rays penetrate these less dense structures, so more radiation can reach the film (1-3).

In the case of dental radiography the dosage of radiation received by a patient is typically around 0.005–0.03 mSv (miliSievert). This is considered really low, equivalent to a few days of background environmental radiation exposure. This exposure can be reduced using different protective lead barriers (1, 3).

In dentistry there are two types of radiographs intraoral and extraoral. Intraoral X-rays are the most common, since they give a high level of detail, also they help the dentist in a very fast way to diagnose anomalies like caries, check shapes and pathologies near the tooth roots, also to check possible bone loss, stages of tooth development or even just to monitor good oral health (1-3).
In the case of extraoral techniques, as the name indicates, they are radiographs which are taken with the film outside the mouth. Generally these are considered the "big picture" X-rays. In these we can observe teeth, bone, eventual tumors and anatomic structures. However, often the analysis of these radiographs focuses more on the facial bones. These types of radiographs are frequently used in areas of dentistry like orthodontics, in order to monitor growth and development. In maxillofacial and oral surgery, these are very commonly used for the assessment of impacted teeth or possible impacted pathologies within bone, also to examine relationships between teeth and jaws and examining the temporomandibular joint or other bones of the face. Within these techniques we can find panorex or panoramic X-ray, cephalometric projections, cone beam computerized tomography, tomograms and sialographies (1, 3-5).

The panoramic x-ray is known by different names: orthopantomogram or dental panoramic radiograph or "panorex". Basically, it consists of a dental X-ray scanning of the upper and lower jaws, in two-dimensions which show a view of a half-circle from ear to ear. It depends on the tomography principles, since the images of specific radiographic planes are taken to make up the larger panoramic image. The equipment used in this technique consist of a horizontal rotating arm which holds an X-ray source on one side and in the other side a moving film mechanism (carrying a film). The patient is located between the x-ray source and the film. The arm rotates around an instant center (patients head) which shifts on a dedicated trajectory. The X-ray source is collimated toward the film, to give the least distortion possible, after crossing the patient's skull (4, 6).

In the case of lateral or cephalometric, these are extraoral radiographs taken from the side of the head, showing a two dimensional picture of the side of the head of the patient. This technique is often used to gauge the size and spacial relationships of the teeth, jaws, and cranium. This
analysis informs treatment planning, quantifies changes during treatment, and provides data for clinical research in the areas of orthodontics and maxillofacial and oral surgery (3).

In general all this two dimensional techniques are nowadays available as digital radiography. This change has become the standard of care, since with these type of techniques we can reduce the radiation, improve the quality of the image and make different analysis using different type of dental software (5).

The general disadvantage that these techniques encounter is that all are mainly dependent on patient positioning. Furthermore, due to the certain limitations such as lack of a third dimension in the picture and patient discomfort, three dimensional imaging techniques like computed tomography (CT) and similar techniques has become a necessity in the dental practice. CT scan is the fundamental technique in modern medical radiology (7).

After the introduction of the CT scan in mid-1970, this technique has shown a major advancement in the area of dentistry. In hospitals the spiral/helical CT scan became the standard instrument for medical imaging since 1990’s. The introduction of multi-slice CT scan in 1998 revolutionized the field; this technique produces clearer pictures with more detail and in a lot less time than it takes for a conventional spiral CT. The use of 3D techniques in dentistry has increased the diagnostic information and treatment planning benefits in oral anomalies. Medical CT scans have been used in craniofacial imaging since its introduction but it did not become very popular until 1980s when high resolution scanners with slice thickness of 2mm were developed. They allow the acquisition of several cross-sectional slices at the time thus reducing the scanning time. Conventional CT scans are mainly designed for the full body scanning at high speed to reduce the artifacts caused by lungs, heart and bowels. They are not well suited for imaging the dentomaxillo-facial areas, where cost consideration is also important (8, 9).
The major disadvantage of conventional or multi-slice CT scan is the high amount of radiation exposure required. More recently a decade ago, the cone beam computed tomography (CBCT) has been introduced (10). In the conventional CT scanner a collimated fan shaped X-ray beam is projected through a limited thickness slice through the human body. In this technique the X-ray tube and detector are continuously moving around the patient. The projections are detected through a linear array of detectors while the patient is advanced through the gantry. In the case of CBCT, it uses a cone shaped beam and an area detector, which acquires a full volume of images in a single rotation with no need for patient movement. The x-ray source rotates 360 degree, around the head to obtain multiple images. The CBCT scan generates voxels which are reassembled into a digital image (8). The voxels are the smallest subunit of a digital volume. Unique property about voxel is its isotropic nature which means they have equal dimensions in all the three planes (7). Therefore, the digital image produced by isotropic voxels has high spatial resolution due to lack of any spacing between them, which contributes to the accuracy and precision in visualizing the anatomical structures (5,10,11).

**Figure 1** (12): Example of how a CBCT works. A cone-shaped x-ray beam irradiates a patient’s jaw. The transmitted x-rays are detected by a sensor; the data is sent to a computer and reconstructed into 3-D images by software. Hamamatsu Corp.
The first use of the CBCT was focus in the maxillofacial area, and it was first introduced in 1996. The FDA approved the first dental CBCT unit in March 8, 2001. The first company which marketed this technology in the US market was QR (Verona, Italy), in May 2001. The advantages of this technology have become one of the strongest points of marketing over other technologies such as panorex, cephalometry, digital intraoral radiograph and even conventional CT. Within these advantages we could find high quality 3D images, high spatial resolution, takes less time and most importantly the radiation exposure is almost 15 times lower than the conventional CT scan. CBCT is ideal for high quality and affordable in-house CT scanning of the head and neck in dentomaxillofacial applications. Although CBCT has been used in all the fields of dentistry, it has a very useful role in the implant placement because of its 3D nature and high resolution (2, 6, 9, 13).

Radiographic analyzes of the jaws in potential implant sites depends on combinations of periapical, panoramic, planar tomographic and CT imaging. CBCT has been recognized to improve measuring of distances between alveolar crest and anatomic landmarks, evaluating quality of cortical and medullary bone in the potential implant sites, visualizing inclination of the alveolar process to increase the chances of a successful implant placement, and finally giving the basis for treatment planning with the use of special algorithms (10).

2. Methodology

We did a systematic literature review using major databases in the area of health technology assessment (INAHTA, NICE, AETMIS and CADTH) and also we included searches in medical literature databases such as MEDLINE, EMBASE (searches were performed through Ovid Online) and Cochrane library.
The keywords used for search are: “cone beam computed tomography” or “CBCT” AND “implant*” AND/OR (“panoramic radiography” OR “orthopantomography” OR “cephalometry”)

Our inclusion criteria includes the dental implants, randomized controlled trials, clinical studies (case series), the article included have to be published only in peer review journals. The language of articles used is English only, limited to articles published from 1st of January 1996 to 31st of January 2012. In the area of cost analysis data is focused related to North America.

Exclusion criteria includes other implants located outside of the oral area, in vitro studies, animal studies, studies related to cancer diagnosis and treatment, studies in which the CBCT was done only as post implant placement evaluation, editorial letters, overdentures implants, abstracts and commentaries.
3. **Results**

3.1. **Measurements**

In this literature review, we found 16 studies which are discussing about the potential measurements that can be taken with CBCT in assessing the implant planning. This explains high benefit of CBCT in the ability to visualize different anatomical variables in three dimension view.

Assessment of magnification ratio is very important while visualizing different anatomical areas; most significantly in the evaluation of residual ridge. Studies have shown differences in the magnification ratios when panoramic radiography is used at different tooth locations (1). Results differ with different panoramic equipment used. With the use of panoramic radiograph, magnification ratio is found to be 1.2 times. CBCT is found to reduce this difference. CBCT showed no significant difference in the magnification ratio according to the location of tooth. Therefore, while using CBCT one does not have to consider more than one magnification ratio according to the location of the implant, which is not the case with panoramic radiography (3). However, authors have accepted the possibility of differences in results due to objective evaluation and patient positioning (1).

CBCT can be used to fabricate surgical guides in the placement of mini-implants. The software associated helps the clinician to simulate mini-implant placement and simultaneously view the anatomical structures such as bone, tooth, sinuses, and vessels (22). The simulated implant can be moved in any direction until the ideal location is achieved preventing impingement to any surrounding structures. Once the implant position is attained by computer simulation, the data can be saved and emailed to the processing center. This is not feasible with the use of panoramic radiography which does not allow bucco-lingual assessment of the alveolar ridge (16).
Also, alveolar ridge can be assessed qualitatively and quantitatively better than orthopantograph. The measurements done in the anterior mandibular area from the root apices of anterior teeth to mandibular base showed significant difference between two techniques (16). The differences were not significant except in the canine region when the distance was measured from root apices to incisive canal (16); however the incisive canal is not well visualized in orthopantograph as compared with CBCT (15).

Ridge mapping is a common technique used to evaluate the residual ridge for implant placement. Even though, this technique is simple and easy to apply, the information that can be obtained from a conventional ridge mapping is only about ridge width not its shape since it is measured by a caliper (26). Although, improved ridge mapping techniques which uses a template can be applied to measure the topography of the alveolar ridge, its accuracy still remained to be defined (27). In this scenario, CBCT plays an essential role to evaluate the ridge for the accurate placement of implant. Measurements can be done after making a template and then taking CBCT scan on which different reference points are marked for ridge measurements with CBCT software (22). There has been found a significant difference between ridge mapping and CBCT techniques at all the implant sites with mean difference of about 0.4mm (25). Nonetheless, improved ridge mapping can still be used in cases with mild to moderate resorbed ridges and when implant is placed coronal to the alveolar sulcus (25). CBCT images can also be used to visualize alveolar crest during ridge expansion procedure, which provided better view than a panoramic radiograph (34).

Authors have reported accuracy and reliability in the identification of condylar cortical erosion and in general measurements can be more precise and consistent than using traditional linear cephalometric, posteroanterior, and submentovertex radiographs (11).
3.2. **Evaluation time**

CBCT has been considered better in pre-operative evaluation of the implant site according to the tooth location using premeasured guttapercha or metal ball as compared to the panoramic radiograph (16). CBCT can also be used for the post-operative evaluation of the implant placed CBCT can be very useful tool in the evaluation of placement of implant in the aesthetic area to achieve better results (2). After the extraction of a tooth, there is a significant amount of bone loss over a period of time. This can be more critical in the aesthetic area for the consideration of implant placement. To avoid the bone loss, clinicians have started placing an implant immediately in the tooth socket (8). This technique has many advantages but if the immediate implant is not positioned accurately in the 3-D spacing, it can lead to further complications. One of the studies used CBCT to accurately replace missing lateral incisor by evaluating the angulation and position of the adjacent incisor so that the implant can be placed as closely to the natural tooth position (12).

3.3. **Ortho-implant**

We found 4 articles which studied the placement of ortho implants with the use of CBCT imaging. Mini implants have become a very popular skeletal anchorage system in the area of orthodontics. However, the success of this implants is still under study, since the factors influencing this success are still unknown (14). Failure rate of micro implants is about 11 to 30%. The failure mainly occurs due to the impingement of micro implant on the roots of the adjacent teeth or due to the premature loosening of the implant. 2-D imaging techniques such as panoramic radiograph are widely used for the assessment of the accurate positioning of an ortho implant (18). But due to many disadvantages such as superimposition of the anatomical
structures, it is very difficult to clearly assess the implant site. Hence, CBCT can act as an adjunct in this scenario to reconstruct 3-D images with the help of computer software provided with the equipment, which can be further used to produce surgical guides for the accurate placement of the micro implant. The recommended length of a micro implant is 6mm and diameter is 1.2 to 1.6mm (11). One of the studies measured the amount of interradicular space, cortical bone thickness and alveolar process width in maxilla and mandible to evaluate the suitable areas for micro implant placement. They found that the appropriate site for micro implant in maxilla is between second premolar and first molar, whereas in mandible is the interradicular space between first premolar to second molar in the buccal alveolar process. They also suggested that midpalatal and retromolar area are also optimal sites for micro implant placement in maxilla. One of studies evaluated the positions of micro implants in the anterior region and they found the area between central incisor and lateral in maxilla and the area between lateral incisor and canine is best for micro implant positioning (29).

In the orthodontics residency programs in US and Canada, the CBCT has become essential part of the treatment planning. In programs where the CBCT is exclusively used for diagnose 100% of the times was for the localization of a supernumerary or an impacted teeth, the use of this technique in the diagnostic period, has increase significantly the diagnose confidence of the residents. Also 100% of the schools promote the use of CBCT as an evaluation tool for craniofacial anormalies/abnotmalities (11).

3.4. **Implant site**

One of the studies showed the importance of evaluation of images of teeth in the anterior maxillary area by CBCT measurements (2). One of the studies evaluated the thickness of buccal
and palatal bone in the mid-root and apical level in the maxillary central incisors using CBCT. CBCT images of the fully formed, intact maxillary incisor were evaluated using software. After the CBCT measurements, they classified the positions and angulations of the tooth roots in reference to the alveolar process. The mean thickness of buccal bone at mid root (0.9 mm) and apical level (2.04 ± 1.01 mm) is much lesser than the palatal counterparts (3.76 ± 1.37 mm mid root and 8.51 ± 2.54 mm apical). Most of the central incisors were placed buccally (78.85 %). These can be further used for the aesthetic placement of implant in the 3-dimension position immediately after extraction. Also by examining the angulation of the root, they showed that CBCT imaging can be used to place implant with long term best aesthetic results (2).

CBCT imaging is very informative when implant placement is planned in the posterior mandibular area. Not only it provides accurate information about adjacent root proximities but also about the maxillary sinus distance which is very important to prevent perforation by an implant (19). CBCT image helps in the preparation of surgical guides to place implant in the posterior maxillary region. This is very efficient in the placement of orthodontic miniscrews and mini-implants too (22). The 2-D techniques such as periapical X-rays are inefficient in the placement of orthodontic implants because of lack of 3-D vision and one has to take several periapical radiographs for the site evaluation (27). 3-D placement of a simulated implant with the help of CBCT imaging provides rapid and accurate fixing of the implant.

3.5. **Bone assessment**

Within our literature review we have found 5 articles taking about different techniques to assess bone in the implant sites.
The objective in implant dentistry is not the implant by itself but the tooth that will be placed as replacement, true restorative driven implant dentistry must start with the theory that the implant positioning should be consistent with the tooth that it will replace and the final implant supported restoration that will be located at the end (15).

In general, it is known that the computerized tomography technique have revolutionized the bone analysis and the treatment planning in implantology. This technique has become very popular due to reasons that we will explain later on, like low radiation and possibility of analyzing bone and soft tissues (16).

Using different interactive treatment planning software applications has become a very useful tool for implant planning. The author Scott Ganz, has developed under that type of technology the concept of the triangle of bone (TOB). This concept analyzes bone quality, quantity and disposition at prospective dental implant site using CBCT scans, the objective of this technique is to aid in the process of determining where is the best place to place the implant (15).

CBCT is a technique recommended to be used to assess bone support for dental implants, TMJ analyzes, examination of bones and teeth for orthodontics treatment, wisdom tooth oral surgeries, diagnose of pathologies such as cyst, tumors or infections (16).

In implants the dynamic loading communicates forces to the surrounding bone. Therefore, there is the idea that bone density is directly proportional to the load-bearing capacity of the bone, and an implant could fail if this density is diminished. The use of CBCT can make this assessment of the bone quality easier, since it can determine bone quality with more accuracy than a two dimension imaging system (17).

One of the articles included in this review evaluated the possibility of using the CBCT as an assessment tool for a pre-implant bone graft procedure. They used the technique to evaluate
integration and survivability of the graft pre and post-surgery. The bone grafting is a critical procedure that has to be done sometime previous to the implant placement, and the assessment of the integration of the graft is vital for the success of the graft (18).

4. **Guidelines for CBCT use**

Several guidelines have become available throughout the internet. However initially, the European Academy of Dentomaxillary Radiology set the ground rules for the use of the CBCT by different professions (16). The key points of the guidelines include that CBCT imaging should be applied in those cases where more information is needed after the appropriate clinical examination and standard radiographic techniques have been performed (19). Also, the clinician should decide on the basis of clinical examination that the patient requires a cross-sectional imaging or not. The technique chosen should provide the required diagnostic information with least radiation exposure to the patient (31). The guidelines emphasize that cross-sectional imaging is of principle value in pre-treatment assessment and treatment planning but it should not be used inadvertently (2). Therefore, CBCT should be used according to the diagnostic detail required in a specific case.

In the US, the regulations are different depending on the state of practice, therefore we would advise the practitioner to inform him/herself with the radiation safety section of their state in order to check possible variations that have to be done. As an example, Michigan State is one place where it is asked that the any dentist willing to buy a CBCT machine obtains a certificate of radiation safety, also him/her will have to demonstrate that in the last 12 months at least 200 patients were candidates for dental CBCT, and finally the machine has to be registered in the respective health department (10).
There are three manufacturers licensed in Canada to sell dental CBCT scanners, at the point of March 2006. They reported for that date the installation of 5 units, one is installed in a private dental office, another one in a dental radiology practice in Toronto, two scanners in private radiology practices also located in Toronto, and one is in Ottawa in a dental office. For that moment they had more request for installation however, were not approved until further notice (19).

Interestingly, all the units were operated by “HARP certified” dental assistants, except for one imaging center in Toronto that hires a medical radiation technologist. The need for special qualifications or continuing education to operate a CBCT scanner are undefined (19).

Following the same instructions of traditional radiographs, the prescription of a CBCT and the interpretation of dental CBCT images are usually completed by dentists (19).

As mentioned before, provincial, federal, and international regulations and guidelines occur to encourage radiation safety of dental radiology. Although none of them specifically mention dental CBCT scanners, most of those are related to intra and extraoral radiographic techniques (19).

As an example, in Ontario, the HARP Act covers installation, use and testing of dental x-ray machines. It does not explicitly address the use of dental CBCT scanners. It stipulates that operators of an x-ray machine in a dental diagnostic x-ray facility must complete one of the following(19):

1. Course in dental radiation safety approved by the Commission.
2. Program or course in dental assisting that is approved by the Commission at a College of Applied Arts and Technology.
3. On and after the 1st day of January, 1981, a dental assisting program that is approved by the Commission.

4. A program or course in dental assisting offered by the Canadian Armed Forces. However again, these are regulations that are specific for Ontario as a province. Other provinces have similar regulations, but none specifically for CBCT. Different universities are offering now 2 day courses or continuing educational programs in the CBCT technique in order to communicate and instruct the operators of these machines and the professionals of dentistry. Within this literature review only 3 articles mentioned the guidelines topic; however it should be studied more since we couldn’t find the regulations at least for all the provinces in Canada.

5. **Ethical and legal considerations**

Since dental implantology is under evolution, and nowadays it is more frequent to access internet by all the patients. It has become ethical duty of a practitioner to explain the patients the treatment plan and the possible alternatives, prior of its implementation (16). In this review we have found not many articles talking about legal and ethical considerations. We could hypothesize that it could be due to the differences in regulations that are valid in each province in the case of Canada or states in the case of US. However, this topic should be addressed since the final diagnose and possible prognosis of a dental treatment could be improved just if the right procedure is taken into place.

During the process of diagnosis and planning of a treatment for a patient conception and study of the tridimensional structure of the patient oral cavity could benefit a dental practice, since it will enrich diagnosis, risk assessment, treatment outcome, and treatment efficiency, and therefore all this would result in reducing the possible treatment complications (17).
One important term in the health-legal area is “standard of care”, which generally is defined as what a rational and judicious health professionals would do or should have done. In the area of dentistry, it is supposed that the dentist meets or exceeds the standard of care. Presenting all the possible alternative treatments as well as all the techniques available to the patient makes this successful protocol that follows the standard of care principle. The failure to practice the “standard of care” could be considered in a court of all as professional negligence, also called malpractice. In regards of CBCT, it has been qualified as a standard of care technology (17).

In some cases an informed consent may not be a good defense in cases where a dental implant affects a nerve or penetrates the sinus cavity, or even where orthodontic treatment is delayed due to a non-visible mesiodens, or when we found roots of an impacted asymptomatic tooth. However, performing a CBCT previous to the dental treatment could give the opportunity to visualize, plan and explain more clearly the situation to the patient. Hence, the standard of care by definition involves that, in all the cases where it is required and possible, the CBCT or some three dimensional technique should be offered to the patients. In the case that the patient declines after being informed of the risks, benefits, and alternatives, then informed refusal should be obtained and documented (17).

The ethical considerations also should include the problem of who is allowed to make the diagnosis. Since this is a specific dental technique most of the people agree on giving the dentist or the faculty of making the final diagnose, however, on the other side many medical professionals question this opinion and mention that dentist are not trained to read this type of CT, therefore their opinion is that a radiologist should read a CBCT scan. We found several articles which didn’t met the criteria talking about this; however none of the peer review journals has published anything about it, so more information should be published about this situation, in
order to make a final decision of who has the ability of reading and making a diagnosis with CBCT.

6. Radiation

The fundamental objective of diagnostic radiology should be based on the concept advocated by ADA known as ALARA principle which implies that the diagnostic radiation dose should be kept as low as reasonably achievable, consistent with the diagnostic goals (10, 11). The effective irradiation dose for CBCT is between 6 to 477 μSv (16). However, there are differences between different equipment therefore this has to be analyzed before making the investment. In the specific case of orthodontics, several studies publish that CBCT has a radiation dosage considerably higher than conventional radiographs, nevertheless, this radiation dose is still lower than conventional CT scan (11).

The most relevant measurement of radiation is called the effective dose, which provides a good way to compare the risks of biological damage induced by radiation exposure of varying types. These doses take into account the total amount of radiation absorbed, by the tissues, the damage caused by the types of radiation and the sensitivity of the tissues (10).

Table 1: Average radiation doses reported for different imaging techniques (10)

<table>
<thead>
<tr>
<th>Field of View</th>
<th>Technique</th>
<th>Min Effective dose (µSv)</th>
<th>Max Effective Dose (µSv)</th>
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<tbody>
<tr>
<td>Small</td>
<td>CBCT</td>
<td>5</td>
<td>658</td>
</tr>
<tr>
<td>Medium</td>
<td>CBCT</td>
<td>48</td>
<td>560</td>
</tr>
<tr>
<td>Large</td>
<td>CBCT</td>
<td>30</td>
<td>1073</td>
</tr>
<tr>
<td>Conventional Multi slice CT</td>
<td>474</td>
<td>1,410</td>
<td></td>
</tr>
<tr>
<td>Panoramic radiography</td>
<td>14,2</td>
<td>24,3</td>
<td></td>
</tr>
<tr>
<td>Bitewing</td>
<td></td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Full mouth series</td>
<td></td>
<td>34,9</td>
<td>388</td>
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<tr>
<td>Cephalometric radiography</td>
<td>5,1</td>
<td>5,6</td>
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7. **Cost Analysis**

In the cost analysis we have analyzed different aspects or variables that could affect the final result. Also, several popular brands have been averaged for the different variables, however most of the figures are guess estimates, therefore we could find differences in real life. All the prices are evaluated in Canadian dollars and for the last fiscal trimester of year 2011.

**COST ANALYSIS**

<table>
<thead>
<tr>
<th></th>
<th>Average Amount</th>
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<tr>
<td><strong>Initial purchase</strong></td>
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<tr>
<td>Machine</td>
<td>250.000</td>
</tr>
<tr>
<td>Installation</td>
<td>0</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>15.000</td>
</tr>
<tr>
<td><strong>Recurrent expenses per year</strong></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>10.000</td>
</tr>
<tr>
<td>Disposable items</td>
<td>1.250</td>
</tr>
<tr>
<td><strong>Operative cost</strong></td>
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</table>

Depends on the machine

Included in machine price

Estimated

Average per year

Estimated

Excluded, due to variations of (setting) in different jurisdictions

The CBCT equipment price includes the installation fee; however, in Canada we have found that the room where the machine is placed is designed in a way to protect from radiation the rest of the practice. This is not required in many places around US. This special design is calculated to cost 15.000 CAN, however this estimation could change depending on the initial clinical set up.
The operative cost, depends on the salary of the professional which is managing the machine, this could be the dental hygienist, dental assistant, a technician, or the dentist. All their salaries vary significantly, and depending on the province, those professionals might need extra knowledge of specialty to operate the machine.

In general, we have found that life of these machines is around 10 years, therefore, we have calculated using the approach that the machine will last for 10 years, and during this period we will have expenses beyond the initial investment of maintenance and disposables. This would mean that the year cost for this technology would be $37,750 CAN per year. If we assume that the cost for a patient of a CBCT is approximately $430 CAN.

Note: we are assuming here 2 facts, a) equipment depreciation is allowed for the same lifespan of 10 years, so we will have an equal yearly cost, and b) there is no financing, which implies no interest charges are considered as part of the cost. Last but not least, no taxes (like income or sales tax) are considered in these figures.

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<table>
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<tbody>
<tr>
<td>Total of the investment/year</td>
<td>37750.00</td>
</tr>
<tr>
<td>Cost of CBCT</td>
<td>430.00</td>
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<tr>
<td># of CBCT per year</td>
<td>87.7907</td>
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</tbody>
</table>

We would need to use the equipment at least 88 CBCT scans per year to cover the expenses that the machine is producing. It is worth to remember at this point that this estimation does not include the salary of the operator of the machine.

The main reason, as was mentioned before, to use this type of technique is to avoid failures due to bad positioning of the implant. We have estimated that a misplacement of an implant could cost $2.500 CAN. Within this price we would include, the removal of the misplaced implant and
all the surgical procedures and materials necessary, follow up visits, also new surgical placement of the new implant and the other materials used within the procedures and the follow up visits related to the second implant.

Nevertheless, we know that the bad positioning of an implant is not the only reason for implant failures, however, if we adjust for:

- Age of the patient: Approx. 30 years old
- Gender: Male
- Health: Without any major affection
- Nutrition: Normal
- Care after the first implant placement: patient has good care and hygiene in the area
- Non smoking
- Good oral health (adjusted restorations, no periodontal disease)
- No bone graft needed previous to implant surgery

<table>
<thead>
<tr>
<th>Total of the investment/year</th>
<th>37.750</th>
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</thead>
<tbody>
<tr>
<td>Cost of an implant failure</td>
<td>2.500</td>
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<tr>
<td>Avoid Implant failures</td>
<td>15.1</td>
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</table>

Then we could say that, by avoiding 15.1 implant failures per year could cover the year fee that this technology has included to the dental practice.

8. Discussion

Panoramic radiographs are very well known and have several advantages, however on the other hand, disadvantages like not illustrating width of buccolingual alveolar ridge or the angle for
future implants and an eventual distortion of the image, become very crucial drawbacks of the technique and a good reason to explore new possible techniques. Some authors have classified the orthopantomography as a technique which overestimates the space and that could influence the possibility of a success in implantology (16).

CBCT has the advantage of having a superior spatial resolution compatible with dental implants simulation programs, which becomes a highly important advantage in the area of implantology in comparison with all the other techniques (16). Along with having high image quality, CBCT has lot more benefits such as compact size, fast scan time, low radiation dose and ease of accessibility. Another clinically valuable aspect of CBCT is the sophisticated software which can be used to create different image portfolios for each patient. All these variables make CBCT a valued technique in the emerging field of implantology. However, all the guidelines and specific considerations should be followed prior to the use of CBCT in a dental clinic setting.

9. **Conclusion**

The development of the CBCT technology opens the door for the clinicians to obtain the highest quality diagnostic images with an absorbed dose that is comparable to other dental surveys and less than a conventional CT. All these advantages presented during this review can confirm that in the case of implant placement, the use of a technique such as CBCT can improve the success rate of the implantology in the dental practice (17).

Furthermore, this technique is still growing, and several studies have to be made in order to assess possible disadvantages, since at this moment seems to be a technique almost without any problem, or major problem reported.
The fact on the internet, we cannot find a health technology assessment report of the CBCT demonstrates the early stage of the technique. Therefore, the authors of this review recommend more studies in the area of possible radiation problems, as well as in the area ethical and legal guidelines.

Specifically, in the legal area, a consensus is needed for the professional responsibility for the final diagnose, and for the images and use of those in the clinical practice or for educational purposes. These are recommendations since none of the articles included talked about it. In the area of guidelines, we have found a “big black hole”, it is not clear exactly what should be the procedure to buy a CBCT machine? Or which are the requirements for the infrastructure. This situation is happening in all North America, and until now, there are not clear rules about it.

Despite all these recommendations, we still think that this technology has a very promising future and eventually will revolutionize the area of dentistry, transforming the actual 2D diagnostic image field into a 3D diagnostic area where the professionals can be more confident of their treatment plan and the end result.
### Appendix #1

<table>
<thead>
<tr>
<th>Authors</th>
<th>Study design / Sample size</th>
<th>Age range/ pop. charact.</th>
<th>Techniq. used</th>
<th>Implant site</th>
<th>Measurem.</th>
<th>Objectives</th>
<th>CBCT Eval. period</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yim, Jin hyok, et al. (2011)/ JCS /Seul, Korea (20)</td>
<td>CS/ 110 pxt</td>
<td>Pxt from 04/2005 to 09/2007 visited the hospital were eval., no age specific.</td>
<td>OPG and CBCT</td>
<td>intra-oral implant sites (191 sites)</td>
<td>Vert. length of gutta-percha or metal ball was measured on the images</td>
<td>Eval. tooth image measur. according to the tooth loc. and to calc. the magnif. rate for comp. and analysis in digit. OPG and CBCT images</td>
<td>Pre-tx</td>
<td>1. Single magnif. ratio for evaluating a OPG is not appropriate in implant placement planning 2. No significance difference using CBCT</td>
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<tr>
<td>Lau SL, et al. (2011)/ JOMS/ Hong Kong. China(21)</td>
<td>DS/ 170 images</td>
<td>Mean pat age was 47 years (range 13 to 85 years)</td>
<td>CBCT</td>
<td>A Mx</td>
<td>Mean thickness of the B bone at the mid-root level 0.9 ± 0.4 mm and at apical level 2.04 ± 1.01 mm. thickness at Pa bone was 3.76 ± 1.37 mm and 8.51 ± 2.54 mm at mid-root and apical level respectively. apical bone height was 9.53 ± 2.76mm</td>
<td>Analyze the positions and angulations of central maxillary incisors with ref. to alveolus for the immediate implant placement in the aesthetic zone</td>
<td>Pre-tx</td>
<td>B bone thickness at the apical level less than 5mm in 98.8% of the pxt, half of the pxt thickness of less than 2mm. In contrast, 96.3 % of pxt had a P bone thickness of 8mm or +; 97.6% of pxt had apical bone height 4mm or +; Eval. of socket in 3D for good outcome</td>
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<tr>
<td>Kim SH, et al. (2011)/ WJO/South Korea (22)</td>
<td>Case study/ 1</td>
<td>24 years</td>
<td>CBCT and cephalometry</td>
<td>P Mx</td>
<td>Positioning of the implant using CBCT image; Patient was examined over a period of 14 months after the mini-implant placement</td>
<td>Describ a clinical application of a new surgical guide system that uses CBCT images, an implant positioning program, stereolithography to make a surgical guide for the accurate placement of orthodontic mini-implants</td>
<td>Pre/post tx</td>
<td>Post CBCT demonst. accurate placement of the mini-implant on the left and a minor discrepancy (was slightly apically) between the simulated mini-implant position and clinical position on the right</td>
</tr>
<tr>
<td>Angelopoulos C, et al. (2008)/JO M S/ New York, USA(23)</td>
<td>CS/ 68 mand. canals</td>
<td>No age consideration</td>
<td>CBCT and OPG</td>
<td>Mn</td>
<td>Mand. canal visualization rating scale; 0 - less than 25%; 1 - more than 25% but &lt;50%; 2 - more than 50% but &lt;75%; 3 - more than 75%</td>
<td>Comp. CBCT reformatted OPG images and digital OPG images for the identification of Mn canal as part of preimplant assessment</td>
<td>Pre-tx</td>
<td>CBCT reformatted OPG images outperformed the digital OPG images in the identification of the Mn canal</td>
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<tr>
<td>Dreiseidler T, et al. (2009)/OMR/ Cologne, Germany(24)</td>
<td>Case control study/ 28 pxt</td>
<td>Mean-age was 56.04 ± 10.11 years (range 35 to 71years); Cases: 27; Control - 29</td>
<td>OPG, CT and CBCT</td>
<td>Mn</td>
<td>Ranking of the image quality; Sign test value frequencies</td>
<td>Establish a basis of weighing of diagnostic and therapeutic benefits of CBCT compared with CT and OPG imaging in implant dentistry</td>
<td>Pre-tx</td>
<td>Superior information about the anatomical structures by CBCT as compared to OPG and CT</td>
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<td>Luk LC, et al. (2011)/ TIDOM/ Hong Kong, China (25)</td>
<td>CS/ 14 pxt</td>
<td>Age range 24 to 56 years (mean 41 years)</td>
<td>CBCT</td>
<td>A Mx, A Mn, P Mn</td>
<td>Ridge dimension measurements</td>
<td>Compare the relative accuracy of the ridge-mapping method against that of CBCT</td>
<td>Pre-tx</td>
<td>Alveolar bone dimensions differ significantly in both the techniques. Mean difference is around 0.4mm. Ridge mapping is indicated only for mild or moderately resorbed ridges CBCT is better</td>
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<tr>
<td>Georgescu CE, et al. (2010)/ RIME/ Romania(16)</td>
<td>CS; case control/ 132 pxt</td>
<td>Pxt 20-77 years for quantitative analysis and 20-79 for qualitative analysis</td>
<td>OPG and CBCT</td>
<td>A Mn</td>
<td>Measurements were made between dental apices, and incisive canal and Mn. base</td>
<td>Quantitatively and qualitatively evaluate am. Mand. area on CBCT comparing to OPG</td>
<td>Pre-tx</td>
<td>Measurements on CBCT are more accurate when compared with OPG. BD of central incisor region is higher. More visibility if incisive canal in CBCT images as compared with OPG. CBCT permits the clinician to have all necessary information when planning dental implants.</td>
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<tr>
<td>Gane, et al. (2008)/ CCED/ New Jersey, USA (15)</td>
<td>Case study/ 1</td>
<td>17 years</td>
<td>CT and CBCT</td>
<td>A Mx</td>
<td>Bone quality, Bone volume, bone defects, Implant length and width</td>
<td>CBCT combined with virtual treatment planning software enhance the diagnostic capabilities of implant-receptor site</td>
<td>Pre/post tx</td>
<td>Combination of CBCT and virtual implant placement allows the accurate positioning of the implant</td>
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<tr>
<td>Study</td>
<td>Year</td>
<td>Methodology</td>
<td>Subjects</td>
<td>CBCT Technique</td>
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<td>Assessment</td>
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<td>Butura CC, et al. (2011)/ JOMS/ USA (27)</td>
<td>2011</td>
<td>Radiographic/ 10 cases</td>
<td>Age range was 34 to 72 years</td>
<td>CBCT Mn</td>
<td>Bone height and bone width measurements</td>
<td>Determine the incidence and tx of hour glass variant mand. for All On Four immediate function. Alveodoplasty might be helpful in such cases</td>
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<tr>
<td>Bornstein MM, et al. (2011)/ COIR/ Berne, Switzerland (28)</td>
<td>2011</td>
<td>DS and RS/ 100 patients</td>
<td>Mean age 43.09 years</td>
<td>CBCT A Mx</td>
<td>B bone wall measurements</td>
<td>Analyze the dimensions and anatomic characteristics of the NP canal and the corresponding Bu bone plate of the alveolar process, using limited CBCT imaging</td>
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<tr>
<td>Fayed MM, et al. (2010)/ AO/ Cairo, Egypt (14)</td>
<td>2010</td>
<td>DS/ 100 patients</td>
<td>Two age groups - 13 to 18 years and 19 to 27 years</td>
<td>CBCT MX and Mn</td>
<td>For each interradicular space in the maxilla and the mandible : MD distance BL thickness. Cortical bone thickness</td>
<td>The optimal site for mini-implant placement in the A region is between the central and lat.1 incisors in the Mx and between the lateral incisor and the canine in the Mn at the 6-mm level from the CEJ. The males and the age group older than 18 years had a significantly higher BL, PA, and B cortical thickness at specific levels and sites in the Mx and Mn.</td>
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<tr>
<td>Nickeng HJ, et al. (2007)/ICS / Cologne, Germany (29)</td>
<td>2007</td>
<td>PS/ 102 px</td>
<td>Mean px age was 42.4 years</td>
<td>CBCT Preopera tive OPG - post operativen</td>
<td>P Mn</td>
<td>Implant placement measurements</td>
<td>Implant placement after virtual planning of implant placement using CBCT</td>
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<tr>
<td>Madrigal C, et al. (2008)/ MOPOCB/ Spain (30)</td>
<td>2008</td>
<td>Cohort study/ 50 subjects</td>
<td>14 male and 36 female, or partially or completely edentulous in the ant. Mand. area</td>
<td>OPG and CBCT A Mn</td>
<td>1. Mental foramen to midline dist 2. Dist between mental foramina 3. Total bone height 4. Max bone height 5. Red osteotomy to 5/6 mm 6. Implant height I/II</td>
<td>Analyze the availability of bone in the interforaminal region and to demonstrate the variation in dx between OPG x-ray and CBCT</td>
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<td>Avila G, et al. (2010)/ JP/ Michigan, USA (31)</td>
<td>2010</td>
<td>Follow up study/20 subjects</td>
<td>Adult px in need of sinus augmentation - 9 males and 12 females with a mean age of 57.6 years (range, 23 to 69)</td>
<td>CBCT, Radiograph P Mx</td>
<td>BPD ranged from 5.4 to 22.7 mm, with a mean value of 12.5 – 3.7 mm</td>
<td>Assess the influence of the distance from the lateral to the medial wall of the Mx sinus on the outcomes of sinus augmentation procedures</td>
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<tr>
<td>Braut V, et al. (2011)/ TIPIRD/ Bern, Switzerland (32)</td>
<td>2011</td>
<td>RS radiographic/ 125 CBCT, Sample of 498 teeth</td>
<td>PAX referred to the department of oral surgery for implant therapy in the ant. Max. 60 males and 65 females, with mean age of 47.3 ± 19.5 years (range from 17 to 84 years)</td>
<td>CBCT A Mx</td>
<td>B bone thickness: at the crest 0.5 (0-2.1 mm) and at the middle of the root 0.6 (0-2.8 mm)</td>
<td>Analyse thickness of facial bone wall at various tooth positions in the A Mx., and this results are not affected by age or gender.</td>
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<tr>
<td>Park J, et al. (2009)/AJ</td>
<td>2009</td>
<td>DS and RS/ 60</td>
<td>30 men, 30 women;</td>
<td>CBCT Ortho Mx. and Mn. B cortical bone</td>
<td>Measure interradicular space, thickness of</td>
<td>In the alveolar process, 1mm or more cortical bone thickness can be expected</td>
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<tr>
<td>Authors</td>
<td>Study Design</td>
<td>Follow up</td>
<td>Mean Age</td>
<td>Bone thickness</td>
<td>Bone Graft</td>
<td>Findings</td>
<td>Methodology</td>
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<td>Maloney K, et al. (2011)/JOMS/Seoul, Korea</td>
<td>Online survey/25 pxt</td>
<td>Average 26 years/7 males and 18 females seeking ortho tx at Uijeongbu St Mary’s Hospital</td>
<td>CBCT Ortho</td>
<td>Eval. the use of CBCT in postgraduate ortho. residency programs.</td>
<td>Pre-tx</td>
<td>Overall postgraduate ortho. residency program CBCT accessibility, usage, training, and interpretation are consistent in the Eastern and Western Regions. CBCT imaging is accessible in 83 percent of the programs and used on a regular basis in 75%. Most CBCT use is for specific diagnostic purposes only. The majority of resident training is didactic and practical. A qualified radiologist is directly responsible for CBCT interpretation.</td>
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<td>Geist JR. (2011)/JOMD/Michigan, USA</td>
<td>RA</td>
<td>___</td>
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<td>Examine the physical principles of CBCT, illustrate with examples the currently included also accepted indications and contraindications of the tech., and review research into potential future directions for its use. The concern raised about possible abuse of CBCT in the context of the guiding principles of X-ray imaging and dentists’ professional judgment.</td>
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<tr>
<td>Hurley A, et al. (2010)/JOMS/Daejeon, Korea</td>
<td>Follow up study/9 subjects</td>
<td>Mean age, 48.2 years, with twelve grafts (8 in the control group and 4 in the experimental group)</td>
<td>CBCT Mx and Mn</td>
<td>N/A</td>
<td>Efficacy of resorbable fixation screws to secure autologous cortical onlay grafts to the Mx or Mn. to augment alveolar bone height and/or width before implant placement.</td>
<td>Pre/Post tx</td>
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<tr>
<td>Sohn DS, et al. (2010)/JOMS/Daejeon, Republic of Korea</td>
<td>Follow up study/32 subjects, 84 implants</td>
<td>5 men and 27 women, mean age of 48 years</td>
<td>CBCT and OPG</td>
<td>P Mn</td>
<td>BL ridge dimension ranging from 2 to 4 mm. but it does not say how was it measure</td>
<td>Report the clinical results of a surgical technique that expands a narrow Mn ridge using an immediate and a delayed lateral expansion technique.</td>
<td>Pre/Post tx</td>
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<tr>
<td>Quereshy FA, et al. (2010)/Journal of Oral and Maxillofacial Surgery/Ohio, USA</td>
<td>Follow up study/9 subjects</td>
<td>Mean age, 48.2 years, with twelve grafts (8 in the control group and 4 in the experimental group)</td>
<td>CBCT</td>
<td>Mx and Mn</td>
<td>N/A</td>
<td>Efficacy of resorbable fixation screws to secure autologous cortical onlay grafts to the Mx or Mn. to augment alveolar bone height and/or width before implant placement.</td>
<td>Pre/Post tx</td>
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<tr>
<td>ODO/California, USA (33)</td>
<td>Pxt</td>
<td>Mean age, 27.1 years</td>
<td>Thicknesses were 1.12 to 1.33 mm and 1.25 to 2.98 mm, respectively</td>
<td>Cortical bone, and alveolar process width at prospec. micro implant placement sites in order to understand both safety and stability aspects of micro implant placement by using CBCT</td>
<td>in the post, dentition area. Safe locations for micro implant placements would be between the second premolar and the 1st molar in the Mx B alveolar bone, between the molars in the maxillary palatal alveolar bone, and interradicular spaces from the 1st premolar to the 2nd molar in the Mn. B alveolar bone. The midpalatal area and the retro molar pad area are also excellent locations for micro implant placement. Because of limited interradicular spaces, the recommended diameter of a micro implant is 1.2 to 1.6 mm for placement in the alveolar bone, and the recommended length is 6-7 mm.</td>
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References


