

Cone Beamed Computerized Dental Tomography in Dentistry

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Abstract

Cone beamed imaging has been gaining increased popularity in dentistry in recent years. Cone Beam Computed Tomography (CBCT) data are used frequently for diagnosis and treatment since it may provide three dimensional volumetric images. CBCT image data are used in dentistry for; evaluation of the mandibula for making implants, evaluation of the degenerative changes of TME joints on the bone, orthodontic treatment analysis and planning, examination of the teeth and its surrounding structures, evaluation of the proximity of the impacted third molars to the mandibular nerve and evaluation of the damages and changes caused by cysts and tumors on the teeth or bone tissue. The purpose of the present study was to explain the operating principles of CBCT and to evaluate information on its advantages, disadvantages as well as areas of use.

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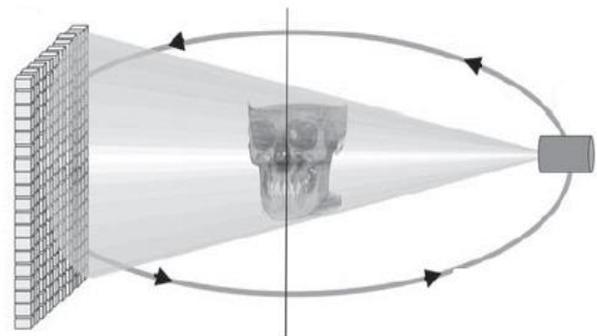
Introduction

Cone Beamed Computed Tomography (CBCT) has been developed around late 1990's for use in dentistry to reduce the radiation dose in comparison with medical computed tomography (1, 2). CBCT, also known as digital volume tomography (DVT) has become a popular radiographic method in recent years preferred in dentistry for diagnosis, treatment planning and patient follow up (3). CBCT is a system used to provide three dimensional images in three planes to the dentist by way of subjecting cone beamed X-rays at the maxilla-facial region to certain operations in the computer environment (4).

Operating Principle of CBCT Devices

CBCT consists of a single 360-degree scan where the X-ray source and a reciprocating array of detectors move simultaneously around the patient's head which is stabilized with a head holder (Picture 1). Single projection images, known as "basis" images, are acquired at certain degree intervals. These images resemble lateral

cephalometric radiographic images and each of these images is equidistant from each other. The series of such basis projection images is referred to as the projection data, on which software programs incorporating sophisticated algorithms are applied to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in all three orthogonal planes (5, 6). The scanning time varies around 5-70 seconds. It is important that the X photons used by CBCT are generated at n times (n is the number of the slices and is used to measure the related volume) (7). Voxel dimension may vary between 0,125 mm to 4.000 mm (8).



Picture 1. CBCT Imaging Diagram (9). (Detector, Axis of Rotation, X-Ray Source).

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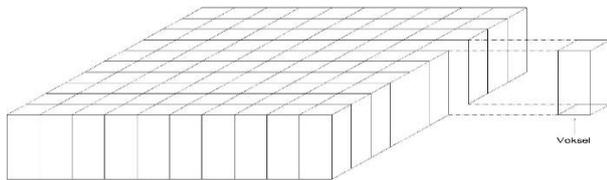
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CBCT Terminology

VOXEL: The small cubical structures each of which represents x-ray absorption at certain areas is known as voxel, from the combination of volume and pixel (Picture 2).

The number of cubes per unit area increases with decreasing voxel size and accordingly while the clarity and resolution of the image increases, the amount of radiation administered to the patient and the imaging time increases with decreasing voxel (10). Voxel dimension determines image resolution and clarity. Voxel dimensions in CBCT may be at submillimetric sizes as low as 0,4 to 0,125 mm (11).



Picture 2. Voxel

FOV: It is the imaging area to be examined (*FOV*- field of view). Dentistry studies have put forth that a voxel interval of 0,3 mm is sufficient for images with a satisfactory quality. High resolution images can be acquired by using large voxels on small areas. The area where the patient is subject to radiation increases with increasing FOV area. CBCT devices have wide range of FOV intervals at different magnitudes (12). FOV can be selected based on the area to be examined. While small areas can be viewed with small FOV, only imaged area of the patient is subject to radiation. The magnitude of FOV can vary from the imaging of the whole head reconstruction to imaging an area of only several centimeter cubes. The tissues subject to radiation increase with increasing FOV interval.

There may be different FOV intervals for different CBCT devices such as;

- <8 cm for the dentoalveolar region
- Between 8cm-15cm for the maxillary and the mandibular regions,
- Between 15 cm-21 cm for the skeletal region
- >21 cm for the head-neck region (12).

RECONSTRUCTION: *Reconstruction* is the process of acquiring volumetric image data in computer environment (Dicom) from raw image data. Reconstruction process can vary between 3-5 minutes according to CBCT device and voxel interval (13).

CONTRAST RESOLUTION: Contrast resolution is the ability of the imaging device to distinguish the weakness in texture or the ability for an imaging system to distinguish the objects in the background (14, 15). An imaging system with high contrast resolution increases the sufficiency to decode the objects in the background and hence high sensitivity is accepted (16). Intensity difference which is an important factor of image quality varies between -1000 and +3000 Hounsfield Units (HU) (-1000: Air, 0: Water, +3000: Enamel). It is difficult to distinguish differences in texture in low contrast regions such as soft tissue (16). Tube flow, slice thickness, thickness of the imaged area, detector sensitivity, reconstruction algorithm and image screen are important factors that have an impact on intensity difference. Densitometric measurements meaning the differences in density can be made thanks to HU scale and hard tissue destructions can be detected (15).

Advantages of CBCT

CBCT provides quite good and detailed images to the doctor for the imaging of the craniofacial region (11). Contrast structures can be seen clearly and it is very useful for the evaluation of the teeth and bone tissues (17, 18). Moreover, even though CBCT has a limited use for the imaging of soft tissues, studies are ongoing for the development of various techniques and software algorithms in order to improve the noise to signal ratio and to increase the contrast (11).

The use of CBCT in clinical applications for the imaging of the maxillofacial region provides various advantages in comparison with other imaging methods such as traditional CT:

- *Imaging:* CBCT enables the three dimensional imaging of the maxillofacial region (7). The images obtained via intraoral radiographies are two dimensional images and superposition, magnification and distortion may develop. The three dimensional images acquired via CBCT do not have this problem, the images can be examined in three axes and measurements

can be made at actual dimensions (19).

- *Applicability:* Undesired image faults such as superposition and magnification are inevitable in traditional radiographic imaging methods, however there are no such undesired faults in CBCT and the doctor may examine the desired tissue or the area in the desired image slice (10).

- *Fast Scan Time:* All basis images are acquired via CBCT in single rotation and the scan time varies between 5 to 70 seconds on average and the images acquired at 0,3 voxel interval with a scan time of 9 seconds are generally accepted as satisfactory (10, 11).

- *Dose Reduction:* The studies carried out have put forth that the effective radiation dose for CBCT (average interval 36,9-50,3 μ Sv) is lower by 98% in comparison with "conventional" fan beam CT systems (average interval for the mandibula 1.320–3.324 μ Sv and for the maxilla 1.031–1.420). It has been indicated that this effective radiation dose corresponds to the radiation dose for the full mouth periapical film radiation dose (13-100uSv) or about 4-15 times that of the radiation dose for a single panoramic radiography (2,9-11uSv) (11).

- *Image Accuracy:* Measurements at actual size and lengths can be obtained from the images since they are reshaped at an isotropic structure between 0,125-0,4mm with CBCT (20).

- *Imaging Modes Specific to Maxillofacial Imaging:* CBCT data can be used by personal computers. The software can be applied not by a radiology expert but by the doctor following a short training of about 3-5 hours. This enables the clinician to carry out real time analysis at actual size in a task oriented manner. However, centers are required for access to medical CT data and their evaluation (11). Volume, angle, length and bone density can be measured quantitatively via CBCT based on the suitability of the software (10).

- *Image Quality:* CBCT is quite suitable for the imaging of the craniofacial region. It provides clear images in high contrast structures and is convenient for the evaluation of bone tissues (17, 18).

Three dimensional evaluations of anatomic structures, ability to subject only the desired region to X-ray beam by adjusting the FOV area, obtaining images that are close to the actual appearance, no deviation from the actual size and growth in the images, the ability to

record and archive the images in the digital environment are advantages of CBCT (20).

Disadvantages of CBCT

- *Radiation adjustment:* International Commission on Radiological Protection (ICRP) has put forth that radiation received during CBCT is not harmful to human health if it remains under certain limits and that the risks involved are not higher than the health risks involved with modern life (21). Dental radiology is one of the fields among all medical applications where X ray is used most frequently (22). Risk and benefit analysis should first be carried out in CBCT indication (12). ALARA (As low as reasonably achievable) principles, that is the principle based on examination using the lowest possible dose should be adopted in order to determine whether the CBCT imaging protocol is suited for a certain dentistry application or not (23).

The basic principle in radiography is to evaluate the benefits and harms involved with the radiation beam to be used in the required imaging method for diagnosis and treatment related with the region to be imaged and to acquire the images with the lowest radiation dose possible (24). While CBCT generates less radiation dose in comparison with computerized tomography, it generates greater radiation doses on the patient in comparison with the other dental imaging methods of panoramic and periapical radiographies (25). Cancer risk ratio for adults in CBCT is 1 in 100000 to 3500000. This ratio is double for children (26).

- *Cost:* High costs involved has limited its routine use in dental examinations. Even though it is less costly in comparison with CT, it is still more expensive than traditional x-ray devices (27).

- *Contrast resolution:* Since the contrast resolution of CBCT is low, it does not have good soft tissue resolution. Soft tissue images are clearer with CT since it has higher soft tissue contrast image (27).

- *Device information:* It is required to know how to use the device software, to use the right dose adjustment, to have knowledge of computers, anatomy and radiology in order to be able to use the CBCT device. Soft tissue contrast is 1-3 HU for modern medical CTs and 8-10 HU on average for CBCT systems (27).

Artefact: Artefacts are among important imaging faults that have an adverse impact on

image quality. The artefacts that develop in CBCT are those that develop due to the presence of metal in the scanned region related with the patient subject to their etiologies or the scanner (28). CBCT image quality is affected by metal artefacts. When an X-ray beam passes through an object, low energy photons are absorbed more in comparison with high energy photons. The flash effect that takes place in metallic objects due to a physical event called beam hardening results in the formation of lines and dark bands amidst the tissues as well as bright areas in the image (29).

Clinical Areas of Use for CBCT

CBCT has many different areas of use. The areas of use for CBCT can be listed as below:

- Evaluation of toothless areas and crests, examination of alveolar bone irregularities, evaluation of whether the patient is suited for implant and prosthesis (30)
- Determination of the skeletal and dental irregularities in patients that require orthodontic treatment, follow up of treatment by way of orthodontic analyses (31)
- Dental Traumas (31)
- Determination of mineralization densities of the bones and teeth (32)
- Determination of respiratory tract obstructions (33)
- Endodontic treatment of the teeth in anomalies such as root anomalies, dens in dente, dilacerations (34, 35)
- Implant planning and surgery and the formation of guiding systems (36)
- Tumor, cyst and lesion dimensions, their relations with neighboring tissues and the damages caused in the bone (9)
- Evaluation of the relationship of the impacted third molars with the mandibular channel, in cases when the teeth roots are superposed with the channel in radiographies obtained via traditional methods and in cases when the channel cannot be monitored properly (37, 38)
- In TME morphologies and pathologies (28) and the diagnosis of erosion, anchyloses, fracture, osteoarthritis and developmental anomalies (39),
- In chronic orofacial pains due to paranasal sinus pathologies and the presence of mucosal thickenings in the maxillary sinus

that are of odontogenic origin (40)

- Determination of the limits of the cleft for patients with cleft lip-palate (28)
- In cases when there are suspicions of root resorptions and fracture (10)
- In the diagnosis of occlusal and aproximal caries (10)
- Evaluation of the radiolucency of the periapical regions (41).

Conclusions

CBCT has been gaining importance in dentistry. It continues to simplify the lives of dentists thanks to the continuous advancements in computer software. However, it should not be used routinely due to the fact that the patients are subject to higher doses of radiation in comparison with traditional imaging methods and it should be kept in mind to be the first option in cases when traditional radiography methods are not sufficient for diagnosis and treatment. The development of CBCT devices that can operate at low radiation doses is required for the use of CBCT in routine dental applications in the future.

Declaration of Interest

The authors report no conflict of interest.

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