Review Article

A Role of Cone-beam Computed Tomography in Periodontics: A Review

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Abstract

Diagnosis of periodontal disease is based on clinical signs and symptoms. However, when there is bone destruction, radiographs are convenient diagnostic method for clinical examination. Two-dimensional periapical and panoramic radiographs are frequently used for diagnosis. In 2D imaging, bone craters, lamina dura, and periodontal bone level evaluation are limited by projection geometry and superimpositions of adjacent anatomical structures. These limitations can be eliminated by the use of three-dimensional imaging techniques such as computed tomography (CT). Cone-beam CT (CBCT) generates 3D volumetric images. CBCT displays 3D images that are necessary for the diagnosis of intrabony defects, furcation involvements, and buccal/lingual bone destructions. Its applications provide benefits in periodontics, however; it should be used only considering the necessity and the potential hazards of the examination.

Keywords: Cone-beam computed tomography, Implant imaging, Periodontal application.

Introduction

In the present era, the area of radiology and medical imaging is constantly evolving, which has a high impact on general practitioners and dentists, who may evaluate the presence, absence and progression of lesions, permitting to establish a correct diagnosis and useful treatment, along with other laboratory investigations.[1]

Periodontal disease is an inflammatory disease; its diagnosis mainly depends on clinical signs and symptoms. However, in case of bone destruction; radiography is a valuable tool as an adjunct to the clinical examination.

Radiographs provide information about the quality localization of the bone defect and the pattern of the bone resorption, changes in the bony trabeculae, condition of the lamina dura, length and shape of the root, and the crown root ratio. The orthopantogram (OPG) is the widely and most commonly used radiographically method for evaluation of alveolar bone levels in periodontal disease, for visualizing the maxilla and mandible in one film, for patient education, for the evaluation of impacted teeth, in the evaluation of multiple unerupted supernumerary teeth, to evaluate traumatic injuries, and for radiographic examination of patients with limited mouth opening. The most important disadvantage of the intraoral periapical radiography and OPG is that they are 2D in nature. These disadvantages of the 2D radiography can be eliminated using a 3D imaging technique such as the computed tomography (CT).[2]

The aim of this article is to outline the role of cone-beam computerized topography (CBCT), which gives complete aid and provide new details in diagnosing periodontal lesions.

CBCT

Cone-beam technology appeared for the 1st time on the European market in 1996 by QR SRL (NewTom 9000) and on the American one – in 2001. The original members of the research group awarded a prize for the invention of CBCT, on October 2003. The image produced by CBCT, achieved at a relatively low radiation dose, is not used only for diagnosis but also for helping specialists to reach a higher level of performance.[2] CBCT is a relatively new imaging modality and with the introduction of dedicated dentomaxillofacial CBCT scanners in the late 1990s, there has been an explosion of interest in these devices in the

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field dentistry. It has the obvious advantage of relatively low cost and low dose.

The traditional principle of **ALARA**, " As Low As Reasonably Achievable" now modified to the acronym **ALARP** "As Low As Reasonably Practicable" helps to minimize radiation exposure. Based on this principle, there are four major ways to reduce radiation exposure:

- Shielding: With the use of proper barriers that block or minimize ionizing radiation
- Time: Minimize the time spent in radiation fields
- Distance: Maintaining adequate distance between radioactive sources and subjects
- Amount: Minimizing the usage of radioactive material.[3]

Historical Backgrounds

CBCT was invented by Sir Godfrey N. Hounsefield in 1967. It was initially developed for angiography in 1982, subsequently applied to maxillofacial imaging. Only since late 1990s that it has been possible to produce clinical systems that is both inexpensive and small enough to be used in dental office.

A brief history of CBCT

1885 Wilhelm Conroed Roentgen – Discovery of X-ray radiation.

1896 F.H. Williams – First Chest X-ray in Boston.

1903 E.A.O Posche – Collimator for suppressing scattered radiation was built.

1913 William D Collidge – High vacuum hot – cathode was built.

1930–1931 – Planigraphy and stratigraphy were developed.

1972 Godfrey N. Housefield – Development of CT.

1974 – First CT from a medical equipment manufacturer.

1976 – Whole body CT.

1978 – ECG synchronized CT images.

1989 – First spiral CT.

1992 – Integrated CT angiography.

1998 – Cardio CT in routine operation.

2002 – 16 slices per rotation.

- **Recent advances:** 64 slice CT, 4-Dimensional CBCT, and Micro-CT (Figure 1).

Principles of CBCT

- CT scanner consists of X-ray source detector mounted on a rotating gantry (Scrafe and Farman, 2006)
- During rotation of gantry, the receptor detects X-ray attenuated by patient
- These raw data are reconstructed by computer algorithm to generate cross-sectional images.
- CBCT is combination of
- 3-Dimensional X-ray beam
- Circular collimation[4]

CBCT image production

CBCT machines scan patients in the following three possible positions: Sitting, standing, or supine. Despite patient orientation within the equipment, the principles of image production remain the same. The four components of CBCT image production are as follows:

Acquisition configuration

Continuous or pulsed X-ray beam and charged couple device detectors moving synchronously around the fixed fulcrum within the patient's head.

Image detection

It is determined by individual volume elements or *voxels* produced from the volumetric data set. CBCT units provide voxel resolutions that are isotropic (equal in all three dimensions).

Image reconstruction

The processing of acquired projection frames to the volumetric data set is done on the personal computer which is called as reconstruction.

Image display

The compilation of all available voxels is presented to the clinician on the computer screen as secondary reconstructed images in three orthogonal planes.[5]

Imaging techniques for implant placement

Proper diagnosis and treatment planning are critical steps in implant therapy. The objective is to place implants in alveolar sites that are favorable for achieving osseointegration. The choice of implant imaging should be based on clinical demands such as the need for portrayal of anatomic or topographic conditions, ease of image production information expected from the image, biologic risk for the patient, and financial considerations. An anatomic variation in jaw morphology makes imaging an integral component of implant planning. With conventional tomography, it is possible to obtain cross-sectional images that can be used to determine bone width. With both conventional and CT, it is possible to obtain information about the width, height, and inclination of the alveolar process anatomic and topographic structures and to some extent, the trabecular architecture.

In general, the radiographic evaluation of implant patients should be carried out according to the following three axioms:

- General considerations: Before implant placement, it seems appropriate to consider panoramic radiography as a standard radiographic examination for referred patients, it provides an accurate means of determining implant length in both the maxilla and mandible with low biologic risk. Periapical radiographs may be indicated in regions not sharply depicted in the panoramic radiograph

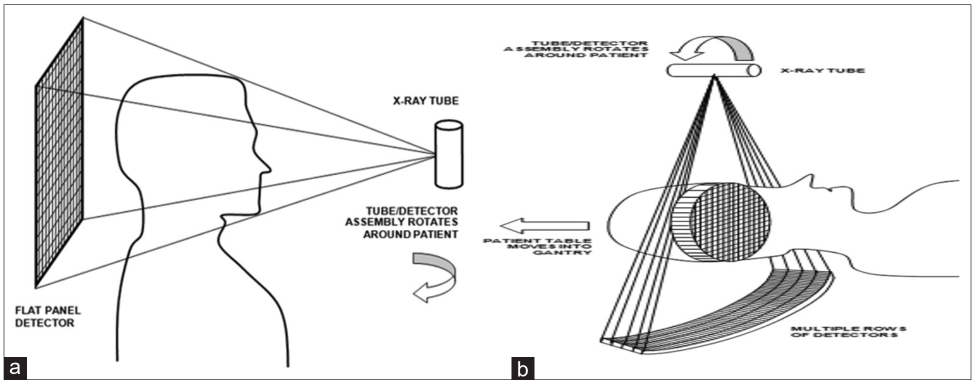

Figure 1: (a) Fan beam. (b) Cone beam

- Applications for cross-sectional imaging: In the maxilla, cross-sectional imaging should be advised:

1. In patients with severe bone loss in the alveolar process, together with signs of enlargement of the incisive canal in the periapical radiograph, for single implants in the incisor region or multiple implants in the incisor and canine region
2. In sites with severe bone loss and close proximity of the maxillary sinus and
3. In patients planning for fixed prosthesis in the completely edentulous maxilla is planned. In the mandible, cross-sectional imaging should be used when a fixed prosthesis is planned.[3]

Advantages of CBCT

1. It has a rapid scan time as compared with panoramic radiography
2. It gives complete 3D reconstruction and display from any angle
3. Its beam collimation enables limitation of X-radiation to the area of interest
4. Image accuracy produces images with submillimeter isotropic voxel resolution ranging from 0.4 mm to as low as 0.076 mm
5. Reduced patient radiation dose (29–477 µSv) as compared with conventional CT (approx. 2000 µSv). Patient radiation dose is 5 times lower than normal CT, as the exposure time is approximately 18 s, that is, one-seventh the amount compared with the conventional medical CT
6. CBCT units reconstruct the projection data to provide inter-relational images in three orthogonal planes (axial, sagittal, and coronal)
7. Multiplanar reformation is possible by sectioning volumetric datasets non-orthogonally
8. Multiplanar image can be "thickened" by increasing the number of adjacent voxels included in the display, referred to as *ray sum*
9. 3D volume rendering is possible by direct or indirect technique
10. The three positioning beams make patient positioning easy. Scout images enable even more accurate positioning
11. Reduced image artifacts: CBCT projection geometry, together with fast acquisition time, results in a low level of metal artifact in primary and secondary reconstructions.[5]

Disadvantages of CBCT

1. The high cost compared to that of standard 2D radiographies
2. It cannot offer a resolution with increased contrast and also it is not indicated in the exploration of soft tissues, but only in the exploration of bone tissue in the maxilla facial sphere
3. A significant disadvantage of CBCT is represented by the artifacts that may be present on the image – not due to the scan, but to the presence of implants, restorations from the amalgam, metallic prosthetic restorations, or endodontic treatments. These artifacts are characterized by hyperdense lines and dark images, which affect the quality of the desired image.[1]

Indications of CBCT

1. 3D view of teeth position and structure
2. Determination of anatomic bone sizes
3. Study of the air ways
4. Positioning of temporary anchoring devices
5. Cephalometric analyses
6. ATM evaluation
7. Evaluation before the implant
8. Endodontic evaluation
9. Periodontal evaluation
10. Evaluation of bone resorption
11. 3D reconstructions.[1]

Strengths and limitations

- Strengths
- Size and Cost

CBCT equipment has a greatly reduced size which can be easily accommodated in dental office. Cost is almost one-fourth to one-fifth to the cost of CT.

- High-speed scanning

CBCT requires only single scan to capture necessary data compared with conventional CT scanners, hence scanning time is much reduced.

- Image accuracy – submillimeter resolution

The volumetric data set comprises a 3D block of cuboidal structures, known as voxels. The size of the voxels determines the resolution of the image. CBCT provides voxel resolution that is isotropic – equal in all three dimensions. This produces submillimeter resolution.

- Low patient radiation dose

As per International Committee on radiation protection, the effective dose for CBCT range from 52 to 1025 microsieverts (μSv) which 96–51% less than of conventional head CT (range 1400–21,000 [μSv]). Moreover, in CBCT, X-ray beam can be collimated to reduce the irradiated area, thereby reducing the dosage and exposure. Patient radiation dose can be lowered by providing thyroid and cervical spine shielding.

- Interactive analysis

Acquired scan data are reconstructed through certain software which also provide extended applications for implant site assessment, cephalometric analysis. Cursor driven measurements are also possible (White and Pharoah, 2011).

- Limitations
- Image noise

Image noise, a random variation of brightness or color information in the images, contributes to CBCT image degradation. Along with basic image protection, certain other volume of radiation are irradiated, these are recorded as pixels on the cone beam area detector. It does not actually reflect the object or anatomical site of interest (White and Pharoah, 2011).

In homogeneity of X-ray photon and increased X-ray beam, divergence also causes image noise.

- Poor soft-tissue contrast

X-ray photon intensities vary according to the tissue through which it is transmitted.

It differs with the density of the tissue, anatomic number, and thickness. There is scattering of X-ray beam and that contributes to the poor soft-tissue contrast.[4]

Periodontal application

The first reported applications of CBCT in periodontology were for diagnostic and treatment outcome evaluations of periodontitis. Usefulness of CBCT for periodontal applications is still in progress. Field of interest for the use in periodontology would be the diagnostic and quantitative measurements of soft tissue and alveolar bone levels in three dimensions, imaging of periodontal intrabony defects, dehiscence and fenestration defects, diagnosis of furcation-involved molars, and implant site imaging.

- CBCT as a soft-tissue assessment tool
    - Used to determine the dimension and the relationship of the structure of dentogingival unit
    - Provides only quantitative assessment not qualitative assessment
    - The differences between the epithelial, fat, and connective tissues cannot be distinguished on the soft-tissue CBCT.[2]
    - Periodontal ligament (PDL) space

- The earliest signs of periodontal disease in radiographs are fuzziness, break in the continuity of lamina dura, and a wedge-shaped radiolucent area at the mesial and distal aspect of the PDL space
- The proper observation of PDL space may offer some potential regarding detection of occlusal trauma and the effects of systemic diseases on the periodontium.[6]

- **Alveolar Bone Defect**
    - Provide better diagnostic and quantitative information on periodontal bone levels in three dimensions than conventional radiography
    - Accurate as direct measurements using a periodontal probe and as reliable as radiographs for interproximal areas
    - CBCT is a superior technique when buccal and lingual defects cannot be diagnosed with radiography.[7]

- CBCT in regenerative therapy
    - Furcation involvement

- Provides detailed information about areas of multirooted teeth
- CBCT images of maxillary molars provided detailed information of furcation involvement
- It provides high accuracy in assessing the loss of periodontal tissue and classify the degree of furcation involvement in maxillary molars.[6]
- Regenerative periodontal therapy and bone graft
    - CBCT is significantly more accurate than digital intraoral radiographs and served as the gold standard for the evaluation of intrabony defects' regenerative treatment outcomes
    - Pre-operative scans could aid in quantitatively determining the bone amount needed to adequately fill the bone defect, and the post-operative scans give accurate follow-up evaluation after surgery.[6]

- CBCT in implant planning
    - Used for determining the width, height, and distance to the anatomical structures of alveolar process in pre-surgical implant planning
    - Commonly utilized in post-surgical evaluations to assess bone grafts and the implant's position in the alveolus.[6]

Conclusions

For early diagnosis and better periodontal interventions, CBCT is the choice of appropriate radiographic aid. In periodontology, CBCT has the potential to gather accurate diagnostic and quantitative information about bone conditions like bony defects,craters and furcation involvements whereas bone quality and PDL space scored better on conventional intraoral radiography. Furthermore, in the field of implantology, CBCT has been seen to be effective in providing essential information and the bone morphology and for implant site measurements. CBCT with its high spatial resolution, affordability, smaller size, lower acquisition, and maintenance has made it as a natural fit in periodontal imaging.

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