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CBCT: A Boon in Periodontics – A Review

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Abstract

Periodontal disease is an inflammatory disease that can be diagnosed mainly based on clinical signs and symptoms. Two-dimensional radiographs are valuable diagnostic tools as an adjunct to the clinical examination in assessing periodontal bone level. Two-dimensional images do not provide accurate bone levels due to its limitations like projection geometry, superimposition of adjacent anatomic structures, leading to the need for three-dimensional imaging that overcomes these limitations. The diagnosis and treatment planning in dentistry has been revolutionized by the invention of computed tomography (CT) having advantages like reduced artifacts, significant reduction in scan time, high-contrast resolution, and no superimposition. But its use is limited in dentistry due to its large size, high radiation dose, and cost factor. Cone beam computed tomography (CBCT), which has evolved from CT scan, has overcome the shortcomings of both two-dimensional radiographs and CT scan. CBCT displays three-dimensional images that are essential for the diagnosis of buccal/lingual bone destructions, intrabony defects, and furcation involvements. The use of CBCT has proven to be a useful tool in the field periodontology, but it should be used only after considering the pros and cons. Therefore, the aim of this review article is to get an insight into the advantages of using CBCT in periodontics and critically analyze the evidence that support its usage.

Keywords: Cone beam computed tomography (CBCT), periodontics, radiology, 2D radiographs, bone levels, furcation involvement

INTRODUCTION

One of the most important factors on which the success of periodontal therapy depends is an accurate image of the periodontal bone destruction for accurate treatment planning [1]. Dentistry evolved rapidly with the discovery of X-ray on 8th November 1895 by a German physicist, Professor Wilhelm Conrad Roentgen. William Herbert Rollins in 1900s enclosed the X-ray in lead housing to collimate the X-ray exposure to expose the area of interest only. He also recommended safe X-radiation dosages for the patient [2]. Radiographs are important in determining the extent and severity of the periodontal lesions [3,4]. Two-dimensional (2D) radiographic techniques like periapical and panoramic radiography (PAN) have the drawbacks of lacking the transversal information and the precise anatomical locations [5]. Consequently, additional cross-sectional images can be important to determine the amount of bone structure available, dental implant size, need for surgeries for bone grafting, and/or other important procedures to enable the proper placement of dental implants and rehabilitation of oral health [6]. Three-dimensional (3D) imaging is an advanced technology that has evolved to reduce the treatment time and increase the efficiency. CBCT is a specialized extra-oral imaging technology designed for 3D imaging of the oral

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and maxillofacial regions. It offers a more affordable and lower radiation dose alternative compared to traditional CT scans [7]. Although the concept of 3D imaging was first introduced by British engineer Godfrey Hounsfield in 1967 [8], the initial prototype of the CBCT scanner was created for use in radiotherapy and later adapted for angiography in 1982 [9]. The commercial release of CBCT technology faced delays, becoming available in Europe in 1998 and in the United States in 2001. In dentistry, 3D dental software was first introduced by Columbia Scientific Inc. in 1988, and CBCT began appearing in dental research publications two years later [10]. Therefore, the aim of this review article is to get an insight into the advantages of using CBCT in periodontics and critically analyze the evidence that support its usage.

CBCT

CBCT is a modern imaging method that produces 3D images similar to those from spiral CT scans, but with reduced radiation exposure. It offers a high-quality imaging of hard tissues [11]. Since it overcomes the inherent drawbacks of plain radiograph, it has been widely used in dentistry, including periodontics [12]. CBCT has been used to overcome the problem with conventional 2D radiographic techniques [12]. The images produced by a conventional periapical radiograph are a 2D representation of a 3D area of interest and possess inherent limitations of magnification, distortion, and superimposition [13].

CBCT scanners utilize a 2D detector, which enables a single rotation of the gantry to capture an entire region of interest in one scan. In contrast, traditional CT scanners require multiple “slices” that need to be combined to form a complete image. Compared to conventional fan-beam or spiral CT methods, CBCT’s cone-beam geometry is more X-ray efficient, allows for rapid volumetric data acquisition, and lowers CT costs. The CBCT technique captures the entire object, known as the field of view (the anatomical area covered by the cone of X-rays), with just one scan. Therefore, the time needed to acquire a single cone-beam projection is like that required for a single fan-beam projection [14].

APPLICATION OF CBCT IN PERIODONTOLOGY

- *CBCT in assessing periodontal ligament space:* The periodontal ligament (PDL) contains crucial cells involved in the interaction between teeth and bone [15]. The earliest radiographic signs of periodontal disease include a loss of lamina dura continuity, fuzziness, and a wedge-shaped radiolucent area at the mesial or distal aspects of the PDL space. Accurate observation of the PDL space can also help detect occlusal trauma and assess the impact of systemic diseases on the periodontium [14]. This highlights the need for a more sensitive imaging technique to detect early changes in the PDL space. While traditional film-based radiographs have been useful in periodontal diagnosis, they have limitations, such as anatomical structure overlap [15,16]. Ozmeric et al. [17] found that periapical radiographs were superior to CBCT for measuring the PDL space. However, another study by Jervoe-Storm et al. [18] concluded that CBCT images provided greater accuracy than intraoral radiographs in assessing the periodontal space.
- *CBCT in assessing alveolar bone defects:* Periodontal tissue destruction can be assessed by alveolar bone level [19]. This important variable guides the diagnosis and treatment process. To determine the periodontal destruction, the extent of periodontal marginal bone loss is necessary [19]. The most used radiographs to support periodontal diagnosis are periapical, bitewing, and panoramic radiographs. However, conventional radiographs demonstrate alveolar bone loss when 30%–50% demineralization of bone in a specific area has occurred. Surgical exposure remains the most precise method for assessing bone levels, considered the gold standard because it accurately identifies the extent and type of bone loss and evaluates bone gain after treatment. Pour et al. [20] found that CBCT accurately measures bone loss and is comparable to surgical exploration, making it a valuable tool for diagnosing bone defects in periodontal diseases within clinical settings. Mol and Balasundaram [21] compared CBCT with conventional radiography for assessing alveolar bone levels and concluded that CBCT offers slightly superior diagnostic and

quantitative information in three dimensions. However, they noted limited accuracy in the anterior jaw regions with both imaging techniques.

On the other hand, several studies have shown that CBCT provides measurements of periodontal bone levels and defects like those obtained from intraoral radiography [22, 23]. Vandenberghe et al. [24] reported that while CBCT images offer a better morphological description of periodontal bone defects, digital radiography provides more detailed bone information.

- *CBCT in assessing fenestration and dehiscence:* A dehiscence refers to the loss of alveolar bone on the facial (or rarely lingual) side of a tooth, extending through the marginal bone. In contrast, a fenestration is a "window-like" bone loss on the facial or lingual side of a tooth with the marginal bone remaining intact.

  Peterson et al. [25] and Peterson et al. [26] found that CBCT overestimates the presence of both dehiscence and fenestration defects. Conversely, Leung et al. [27] found that CBCT was more accurate in detecting root fenestrations than dehiscence.
- *CBCT in assessing soft tissue:* A limitation of CBCT is its inability to distinguish soft tissues effectively, making it more suitable for evaluating mineralized or hard tissues [28]. To address this, a technique called soft tissue CBCT (ST CBCT) was developed to assess the dimensions and relationships within the dent gingival unit. Januario et al. [29] used ST CBCT to measure the average thickness of the palatal mucosa based on age and specific locations and reported high-quality images of the palatal masticatory mucosa with ST CBCT. They further concluded that this technique offers a quantitative rather than a qualitative assessment of the tissue.

CBCT IN REGENERATIVE THERAPY

- *In furcation involvement:* Assessing radicular bone is crucial for planning treatment for furcation involvement. Conventional radiographs are not always accurate in evaluating bone support in the intraradicular area of maxillary molars [30]. Studies have shown that CBCT data accurately confirmed intrasurgical findings 82.4% of the time in maxillary molars, although CBCT tended to underestimate both horizontal and vertical bone loss [18]. Mengel et al. [31] concluded that CBCT is a reliable method for identifying early furcation involvement with an accuracy between 78% and 88% in artificially created furcation involvement in pig mandibles. Additionally, Vandenberghe et al. found that intraoral radiographs missed crater and furcation involvement in 29% and 44% of the cases, while CBCT was 100% accurate in detecting both types of defects.
- *In regenerative periodontal therapy and bone graft:* Bone grafting is frequently employed for maxillary sinus lifts and in treating intrabony defects, but conventional radiography may fall short in evaluating the regeneration of osseous defects due to image superimpositions [31]. Grimard et al. [32] found that CBCT provided significantly more accurate results than digital intraoral radiographs. However, direct surgical measurements remain the gold standard for evaluating the outcomes of regenerative treatments for intrabony defects. They concluded that CBCT can effectively replace the need for surgical re-entry by offering 3D images and measurements that are nearly equivalent to those obtained directly through surgery. In another study, Ito et al. [33] utilized CBCT to assess the results of regenerative therapy and found CBCT to be effective in creating a template for the guided tissue regeneration (GTR) membrane, which significantly reduced the time needed for membrane trimming.
- *CBCT for implant placement:* Accurate evaluation of the implant site is crucial for successful implant placement and to avoid damaging nearby vital structures. Addressing alveolar bone defects is essential for the success of dental implants [34]. CBCT aids in treatment planning by predicting the implant length to be used during surgery. Hu et al. [35] compared the reliability of PAN and CBCT, noting that while digital PAN radiography is adequate for planning mandibular implants, CBCT is preferable for the maxilla. Correa et al. [36] found that implant sizes measured with cross-sectional CBCT images were narrower and shorter compared to those obtained from

digital PAN radiographs and CBCT-PAN views. Al-Ekrish et al. [37] studied the impact of exposure time on the accuracy and reliability of CBCT for assessing implant site dimensions in dry skulls, concluding that reduced exposure time does not compromise the accuracy of implant site measurements. CBCT provides detailed information about bone density, alveolar shape, and the dimensions of the proposed implant site, contributing to reduced implant failures. It is also commonly used for postsurgical evaluation of bone grafts and implant positioning [35].

ADVANTAGES OF CBCT

1. *Faster scan time:* CBCT scans are quicker compared to PAN.
2. *Complete 3D reconstruction:* It offers full 3D reconstruction and can display images from any angle.
3. *Precise beam collimation:* The collimation of the X-ray beam focuses radiation on the specific area of interest.
4. *High image accuracy:* CBCT provides highly accurate imaging.
5. *Lower radiation dose:* It delivers a radiation dose that is five times lower than conventional CT, with an exposure time of about 18 seconds – one-seventh of what is needed for conventional medical CT.
6. *Three orthogonal planes:* CBCT reconstructs projection data to provide images in axial, sagittal, and coronal planes.
7. *Multiplanar reformation:* It allows for non-orthogonal sectioning of volumetric datasets for detailed analysis.
8. *3D volume rendering:* It supports 3D volume rendering.
9. *Easy patient positioning:* The use of three positioning beams simplifies patient alignment.
10. *Reduced image artifacts:* CBCT minimizes image distortions and artifacts [14].

DISADVANTAGES OF CBCT

1. *High cost:* The expense of CBCT limits its routine use.
2. *Scattering and beam hardening artifacts:* High-density structures, such as enamel and radiopaque materials, can cause artifacts that affect image quality and diagnostic accuracy [38].
3. *Reduced contrast:* Scatter radiation lowers contrast and limits the ability to image soft tissues.
4. *Primary use for hard tissues:* CBCT is mainly suited for imaging hard tissues due to its limitations with soft tissue imaging [39].
5. *Bone density estimation limitations:* CBCT cannot be used to estimate bone density due to distortions in Hounsfield units.
6. *Long scan times:* CBCT scans take 15–20 seconds and require the patient to remain completely still [40].

SUMMARY

Table 1 provides an overview of research evaluating the use of cone-beam computed tomography (CBCT) in different dental diagnostic procedures. It compares CBCT with other imaging methods in the assessment of PDL space, alveolar bone defects, fenestration and dehiscence, soft tissue, furcation involvement, bone regeneration therapies, and implant planning. The table also highlights the strengths and limitations of CBCT, as reported by various studies, while noting differing opinions where applicable.

Table 1. Diagnostic utility of CBCT in periodontal and implant assessments.

Parameters	Authors in Favor	Authors Contradicting	Inference
Assessment of PDL space	[18]	–	Higher accuracy than intraoral radiograph in determination of PDL space.
	–	[17]	Periapical radiographs superior to CBCT for the measurement of PDL space.

Assessment of alveolar bone defects	[20]		CBCT enables accurate measurement of bone loss comparable to surgical exploration.
	[21]		CBCT provided better diagnostic and quantitative information on periodontal bone levels.
	[24]		CBCT provides better morphological details while digital radiography provides more bone details.
Assessment of fenestration and dehiscence		[25]	CBCT overestimated the presence of dehiscence and fenestration defects.
		[26]	CBCT overestimated the presence of dehiscence and fenestration defects.
	[27]		Higher rate of diagnostic accuracy for the detection of root fenestration than for dehiscence.
Assessment of soft tissue	[29]		CBCT obtain high-quality images of the palatal masticatory mucosa.
Assessment of furcation involvement	[32]		Reliable and accurate method for detecting incipient furcation involvement.
	[24]		Not accurate for detection of furcation involvement.
Regenerative periodontal therapy and bone graft	[33]		CBCT was found to be helpful in observing the morphology of periodontal bone defects in three dimensions.
	[32]		CBCT was found to be more accurate than digital intraoral radiographs.
Diagnostic imaging for the implant patient	[35]		CBCT was found to be useful for implant planning for maxilla.
		[36]	Implant sizes measured using CS CBCT images were both narrower and shorter than the sizes obtained from digital PAN radiographs.
	[37]		Lowering the CBCT exposure time does not affect the reliability or accuracy of implant site measurements.

CONCLUSION

Recent advancements in imaging technologies have transformed dental diagnostics and treatment planning. By correctly applying and interpreting these imaging techniques, while adhering to ALARA (As Low as Reasonably Achievable) principles and considering cost-effectiveness, newer radiographic methods can identify pathologies at very early stages. This early detection ultimately reduces morbidity and mortality and enhances patients' quality of life. Although the use of CBCT has significantly increased, it is important to be aware of its disadvantages and limitations before prescribing it. This awareness should not discourage dental professionals from using CBCT, as its benefits often outweigh its risks. Proper training and education in CBCT for oral and maxillofacial radiologists and dentists are essential to ensure its effective and responsible use.

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