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Title – Cone Beam Computed Tomography – A trump card in restorative dentistry

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ABSTRACT

Treatment of dental problems relies on diagnostic imaging techniques that provide important information about the teeth examined. CBCT is useful in the diagnosis of conditions and diseases related to the pulp and periapical tissues by detecting additional canals, different root morphologies, bone morphology, temporomandibular joint diseases, bone defects, and periapical changes. Currently restorative dentistry is a trilogy which deals with prosthodontics, periodontology and conservative dentistry and endodontics. This review article focuses on the basics, mechanisms, and applications of CBCT in restorative dentistry.

Key words – Cone Beam Computed Tomography, conventional radiography, Endodontics, prosthodontics, periodontics, diagnosis, 3 D radiography.

I. INTRODUCTION

The most important part of treating dental problems relies on diagnostic imaging technology, which provides important information about the tooth being examined and its surrounding structures. The diagnostic yield of 2D images is often compromised by noise and geometric representation caused by the surrounding anatomical structures of the region of interest.[1] To overcome the limitations of conventional radiography, Arai et al in Japan and Mozzo et al in Italy working independently introduced Cone Beam Computed Tomography in 1996. This is a type of medical imaging technique that uses a conical X-ray beam and advanced computer programs to create three-dimensional images of structures. The purpose of this article is to review the basics of CBCT and discuss its application and limitations in daily clinical practice.

Image acquisition and reconstruction

A CBCT image capturing device consists of an X-ray source and a detector or sensor mounted on a rotating gantry. During imaging, the X-ray source emits a conical X-ray beam that is directed at the region of interest of the patient's maxilla of facial skeleton.

After the beam passes through the region of interest, it is projected on to the X-ray detector, and the source and detector simultaneously rotate 180° to 360°around the patient's head in one span. Scan times vary depending on the equipment and exposure parameters used, but are typically 10 to 40 seconds.[2]

During the acquisition period, hundreds of basic images (projection images) of the region of interest are acquired. Projected images are then reconstructed using advanced software for example.: Planmeca Romexis, Sidexis 4, Acteon, RAY, etc. are used to generate a cylindrical or spherical data volume called the field of view (FOV). The reconstructed 3D dataset consists of 512^3 3D pixels or voxels. The region of interest images are displayed simultaneously in three orthogonal planes (axial, sagittal and coronal), allowing the clinician to see the region of interest in three dimensions.

Based on field of view (FOV) dimensions, CBCT scans are classified as:[3]

The maximum height of the scan volume for small-volume (focused, small-field, limited-field, or limited-volume) systems is 5 cm.

In a single-arch CBCT scan, the height of the field of view (FOV) is 5-7 cm. The height of the FOV for inter-arch CBCT scans is 7-10 cm. The height of FOV for maxillofacial CBCT scans is 10-15 cm and for craniofacial scans it is greater than 15 cm.

Advantages of CBCT -

Three-dimensional image information provides clinicians with a comprehensive understanding of anatomical structures and their spatial relationships.[4] Clinicians can select slices of volumetric data and view them in all planes. Anatomical noise can be easily reduced.[4] The voxels of cone beam CT are isotropic, so the images produced are accurate and undistorted in any plane.[5] The X-ray source can be collimated to illuminate only the area of interest.[3] The software which aids in CBCT data reconstruction can be run on personal computers, thus serving as a chairside diagnostic and treatment planning tool.[3]

Applications of CBCT in endodontic practice

Apical periodontitis (AP)

CBCT is sensitive and more effective than periapical radiography in detecting apical periodontitis in humans.[7] Periapical bone loss associated with endodontic infection can be identified using CBCT. The presence of these lesions can be detected, even before they can be seen on 2D radiographs.[8] Patel et al. (2012a) found that periapical lesions in 20% and 48% of 123 teeth which were scheduled for primary root canal treatment when Periapical Radiograph (PR) and CBCT were used, respectively.[10] The results demonstrated that the sensitivity of CBCT in the detection of simulated lesions of apical periodontitis was 1.0 (100% accuracy). In contrast, Intraoral periapical radiographs detected the simulated lesions in only 24.8% of the cases with a statistically significant difference.[9] Prevalence of apical periodontitis in root canal-treated teeth, when comparing the panoramic and IOPAR and CBCT images was 17.6%, 35.3%, and 63.3% respectively (P >.001).[7]

In non-surgical Re-Treatment

Using CBCT, nonsurgical re-treatment of cases with possible unidentified canals and/or previous treatment complications (e.g. perforations) and the location of extensively calcified canals is possible.[1]

Evaluation of the outcome of root canal treatment

The early detection of AP using CBCT leads to early diagnosis and treatment of endodontic disease.[29] Paula-Silva et al. published the first root canal outcomes study using CBCT. Where he compared the outcome of root canal treatment in dogs using PR and CBCT. Six months after the treatment, a favorable result was detected in 79% of teeth assessed with PR, but in only 35% when CBCT was used.[30] Root filling voids were detected in 16% and 46% of cases with PR and CBCT, respectively the majority (77%) of voids evident on CBCT scans were in the buccolingual plane.[31] Patel et al. assessed the results of primary root canal treatment using PR and CBCT, 1 year after treatment. The rate of AP was 87% and 62.5% (completely healed), and 95.1% and 84.7 (healing), when assessed with PR and CBCT, respectively.[10]

CBCT for pre surgical assessment

CBCT provides clinicians with the opportunity to preoperatively assess the entire surgical field without restrictions, facilitating the surgical procedure.[1] In multi-rooted teeth, the ability to identify specific roots with AP allows the clinician to be root-specific and eliminate the removal of alveolar bone and dentine associated with unaffected roots, all of which serve to improve patient comfort, simplify the procedure and reduce treatment time and cost.[34] Permits the accurate assessment of the dimensions and extent of the lesion as well as its relationship to adjacent anatomical structures and the presence of any expansion or perforation of cortical bone.[2] Digital Imaging and Communications in Medicine (DICOM) data sets may be used to fabricate custom surgical guides.[35] Bornstein et al. (2011) compared the ability of PR and CBCT to evaluate the distance between the apices of mandibular molars and the inferior dental nerve canal in teeth undergoing apical surgery. This distance could only be measured accurately in 35.3% and 100% of cases using PR and CBCT, respectively.[36] The orientation of the long axis of the root to the cortical plate can be determined with CBCT. [11]

Dental trauma

CBCT can be used to accurately assess the thickness of the dentin covering the pulp.[28] It allows for a more precise visualization of the progression of the often oblique nature of these fractures and their relationship to the pulp, periodontium and crestal bone, thus facilitating their management.[28] PR detects horizontal root fractures when the X-ray beam is within 15–20° of the direction of the fracture line.[27] CBCT is significantly more sensitive than PR in detecting PDL space widening and early lesions of apical periodontitis.[26] CBCT allows unobstructed visualization in all planes and allows accurate assessment of the type of displacement in cases of luxation injuries.[26]

Root resorption

The buccopalatal location of internal and external resorptive lesions of the root can only be accurately assessed using CBCT. This information may be relevant in determining the treatment prognosis.[22] Estrela et al. (2009) found that CBCT and PR detected inflammatory root resorption in 100% and 68.8% of cases, respectively.[23] Patel et al. (2009) found that CBCT was superior to PR in accurately diagnosing clinical root resorption leading to a more appropriate treatment planning.[24] Additionally, the nature of External cervical resorption (ECR) (fibrovascular and bone-like tissue) will also better elucidated with CBCT information, which is relevant for treatment planning.[24] Vaz de Souza et al. (2017) created simulated ECR lesions according to the four Heithersay classes and found that CBCT was significantly more accurate than PR at classifying ECR.[25]

Vertical root fracture (VRF)

PR detects VRF if they are displaced and in the plane of the X-ray beam and in situations where there is minimal anatomical noise.[18] Wang et al. (2011) concluded that the sensitivity of CBCT was higher than that of PR in evaluating 95 root fractures. However, the accuracy was compromised by the presence of root filling due to scattering from the radiopaque root filling material.[19] In a meta-analysis, Long et al. (2014) suggested that CBCT provided a high diagnostic yield for the detection of tooth fractures, with a reported sensitivity and specificity of 0.92 and 0.85, respectively.[20] Chavda et al. (2014) evaluated PR and CBCT images and compared them to atraumatically extracted teeth to confirm the presence or absence of fracture. They reported a sensitivity of 0.16 and 0.27 for PR and CBCT, respectively, and a relatively high specificity of 0.92 and 0.83 for PR and CBCT, respectively.[21]

Assessment of root canal anatomy

Cone beam computed tomography scans improve the identification, localization and evaluation of teeth with anomalous anatomy, for example, dens invaginatus.[14] Due to the 2D nature of PR, they might underestimate the true anatomical complexity of the root canal system.[15] Matherne et al. (2008) reported that endodontists failed to locate at least one canal in up to 41% of cases when evaluated with PR while CBCT was used as the gold standard.[15] Abubara et al. (2013) reported that by using PR only 8% of MB2 canals were located and while using CBCT, 54% of cases were found.[16] Stents with guide sleeves have been 3D printed using optical surface scans and CBCT data sets to allow guided access cavity preparation.[17]

A patient aged 50 years visited Department of Conservative Dentistry and Endodontics, Bapuji Dental College and Hospital, Davangere with a chief complaint of pain and swelling in the upper front tooth region. On clinical examination, full coverage restoration in relation to 11, 12, 21 and 22 were present.

Upon removal of full coverage restorations, secondary caries was detected in relation to 11, 12 and 21.

IOPAR examination in relation to 12 and 11 reveals a diffuse radiolucency periapically.

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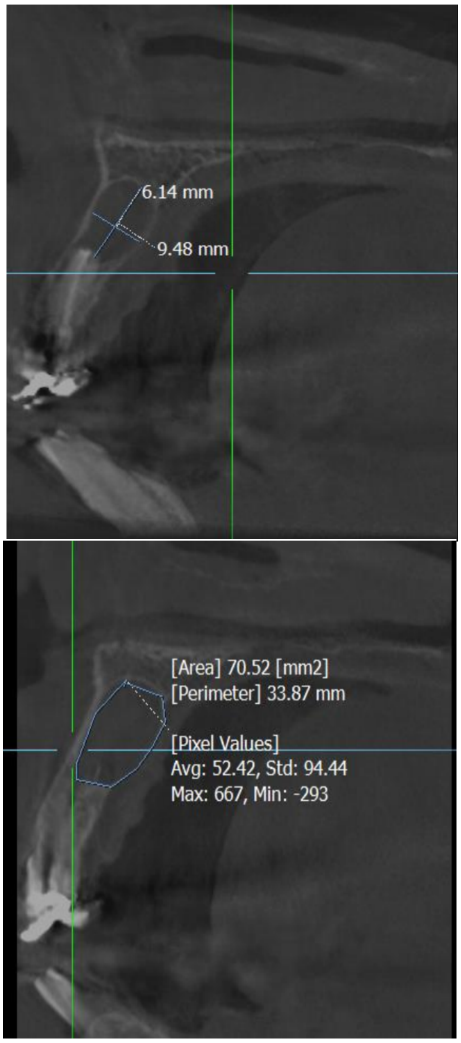
Using CBCT, the height of the cyst in relation to 12 was 6.14mm and width was 9.48mm and area was found to be 70.52mm².



Applications of CBCT in Periodontics

Diagnosing periodontal defects traditionally relies upon the interpretation of two-dimensional (2D) radiographs combined with clinical evaluation consisting of probing depths, bone sounding. 2D imaging modalities are easy to acquire, have high resolution and are cost effective with minimal radiation exposure. However, there are some limitations[7] and studies have shown that intra-oral radiography underestimates bone loss due to projection and or observer errors. we identified that bony defects and furcations can be detected with less invasiveness and are clearly visible as a patient education tool. Braun et al.[12] have reported that CBCT was superior to IOPAR in detecting intrabony defects and furcation involvement. Overall, the accurate identification of intrabony defects occurred 82.7% using IOPAR and 99.7% with CBCT. CBCT was also better at identifying furcation involvement (94.8%) compared to IOPAR (75.6%).

CBCT has shown 84% accuracy in assessing furcation involvement and is useful in the maxillary molar region where the zygomatic bone overlaps the tooth`s root surface.[13] Accordingly, it was found that CBCT is very useful and accurate in diagnosing of infra-bony defects and furcation involvement. It is equally reliable in the evaluation of the outcome of periodontal surgery and regenerative therapy.

Applications of CBCT in Prosthodontics

Diagnosis and treatment planning for prosthodontic patients. Before focusing on the height and width of the remaining alveolar bone to measure the dimensions of the implant placement, the entire volume must be examined to exclude pathological entities. Recommendations for sinus augmentation surgery using residual alveolar bone height classification can serve as a reference for predictable planning of implant treatment. Preoperative radiographs indicate that additional surgical procedures may be required before or at the time of implant placement to ensure adequate clearance with adjacent anatomical structures and sufficient surrounding bone volume for a stable implant. Also determines whether indirect or direct sinus lift is necessary.

Radiographic measurements of the partially edentulous site. Mesial-distal (MD) dimensions: to preserve adequate blood supply and maintain healthy hard and soft tissues between an implant and a tooth at least 1.5 mm and between 2 implants at least 3 mm space is required. Buccalpalatal/lingual (BP/L) dimension: at least 1.5 mm from the buccal bone is recommended to maintain tissue structure after tooth extraction and implant placement. Any postoperative complications, such as implant mobility or sensory nerve defects, should be assessed with CBCT to better examine the possible impact on the surrounding anatomic structures.

For partially edentulous patients, planning is accomplished by merging the Digital Imaging and Communications in Medicine (DICOM) file from the CBCT and the standard tessellation language or standard triangulation language (.stl) file from the digital wax-up. The surgical template can be made, either by milling or printing for pilot or fully guided operations. CBCT is often used in postoperative examinations to evaluate the position of the bone graft and the implant in the alveolus.[5]

Limitations –

When a CBCT X-ray beam hits a very dense object, such as tooth enamel or a metal restoration, the low-energy photons in the beam are absorbed by the structure. This increases the average energy of the x-rays.

This is called "beam hardening," and this phenomenon produces two types of artifacts. Distortion of the metal structure, so-called “cupping artifacts” and the appearance of stripes or dark bands between two dense structures.[4,7] Patient movement during scanning can affect the sharpness of the final image.[11] The spatial resolution of CBCT is approximately 2 line pairs per mm, which is inferior to conventional dental radiography, which has a spatial resolution of approximately 15 to 20 line pairs. The contrast resolution of CBCT is low and inferior to the high contrast resolution of CT.[4] The effective dose of CBCT is generally higher than that of conventional intraoral radiography.[13]

II. CONCLUSION –

This review article focuses on the potential uses of CBCT in the assessment of dental problems in day-to-day practice. This 3D imaging technology helps overcome the limitations of traditional radiography. To be justified, a CBCT scan must outweigh the potential risks of the procedure. Radiation doses should be as low as reasonably achievable (ALARA). CBCT scans to treat endodontic problems, whether clinical or radiological, should be performed on a case-by-case basis and only when other diagnostic tests do not provide sufficient diagnostic information.

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