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Review Article

Advancement in Dentistry: The Application of Cone Beam Computed Tomography (CBCT)

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ABSTRACT:
The several clinical uses of cone-beam computed tomography (CBCT) are reviewed in this article. Oral and maxillofacial surgery, endodontics, implantology, orthodontics, temporomandibular joint dysfunction, periodontics, restorative and forensic dentistry, and more have all made use of CBCT, according to a study of the literature. This analysis of the literature demonstrated how the requirements of the particular dental specialty and the kind of procedure carried out determine the various CBCT indications.

Keywords: Cone-beam Computed tomography, Dental Application

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INTRODUCTION

Radiology plays a crucial role in diagnosing dental patients, and guidelines for selecting appropriate radiographic procedures for those suspected of having dental or maxillofacial conditions are available.[1] The American Academy of Oral and Maxillofacial Radiology (AAOMR) has developed "parameters of care," offering guidelines for image selection used in diagnosing, treatment planning, and monitoring patients with conditions affecting the oral and maxillofacial region, such as temporomandibular joint (TMJ) dysfunction, jaw diseases and dental implant planning.[2] While traditional x-ray projections and panoramic radiography may suffice in many cases, radiographic evaluations may sometimes benefit from multiplanar imaging, including computed tomography (CT). Advanced imaging techniques have been limited for many dental practitioners due to cost, availability, and radiation exposure concerns. However, the advent of cone-beam computed tomography (CBCT) for the maxillofacial area offers dental professionals the ability to request multiplanar imaging. Many are familiar with the thin-slice axial plane images produced by traditional helical fan-beam CT. CBCT enables real-time creation of images not only in the axial plane but also in 2D coronal, sagittal, and even oblique or curved planes through a process called multiplanar reformation (MPR). Additionally, CBCT data can be reformed into volumes rather than slices, offering 3D imaging. This article aims to highlight the distinct imaging features of maxillofacial CBCT systems and demonstrate their clinical applications.[3]

PRINCIPLE OF ACTION

A stationary x-ray source and detector positioned atop a rotating gantry are the foundation of CBCT. The cone-shaped ionizing radiation beam from the x-ray source travels through the patient's head's center of the scan region of interest (ROI) and is picked up by the x-ray detector on the other side.[4] The x-ray source constantly or sporadically emits radiation as the gantry revolves in 360-degree arcs around the patient's head, producing projection radiographs, also known as "basis images."These images are somewhat offset from each other and resemble lateral cephalometric radiographs. The projection data is the collection of these basis projection images.[5]Advanced software programs, utilizing complex algorithms such as back-filtered projection, process these image data to create a 3D volumetric dataset. This dataset is then used to generate primary reconstructed images in three orthogonal planes: axial, sagittal, and coronal.[6]
The available Field of View (FOV) or chosen scan volume height can be used to classify CBCT systems

as follows: Localized area: dentoalveolar, temporomandibular joint, etc.; about 5 cm or less 5 to 7 cm for a single arch (maxilla or mandible, for example) Interarch: 7–10 cm (mandible, superiorly, including inferior concha, for example). 10 to 15 cm maxillofacial (mandible and extending to Nasion, for example) Craniofacial: more than 15 cm, such as the distance between the head's vertex and the mandible's bottom border

APPLICATION IN DENTISTRY

IMPLANTOLOGY

The use of CBCT has had a significant impact on the field of dental implantology, more so than in other areas of dentistry. It provides detailed cross-sectional images in various planes, allowing for accurate assessment of the alveolar bone's height, width, and angulation. Additionally, CBCT helps in precisely locating vital structures, such as the inferior alveolar canal in the mandible and the sinus in the maxilla.[7]The application of CBCT in implantology has improved both the safety and precision of implant procedures, reducing or even eliminating the need for supplementary procedures like bone and tissue grafts in many cases.

Radiographic markers can be added during the scan to serve as precise reference points for implant placement. Stents act as fiducial radiographic landmarks, enabling the correlation of the proposed implant location and angulation with the available alveolar bone.[8] Using DICOM data, computer-generated surgical guides (such as stereolithographic models) can be created from CBCT scans, eliminating the need for traditional impressions and guide stents, which may introduce inaccuracies. This technology allows surgeons to place implants with higher accuracy, predictability, and safety, as the procedure is planned in virtual software.[8]Additionally, minimally invasive techniques can be used, avoiding the need to raise a flap, which helps reduce surgery time, postoperative pain, swelling, and recovery time.[9]

The dental laboratory can use the surgical template information to create a master cast and provisional restoration before surgery, enabling the immediate placement of the restoration after the procedure (e.g., Teeth-in-an-Hour). The advent of computer-guided implant surgery has greatly improved the dental implant team’s ability to plan, place, and restore implants with a level of precision that was previously unattainable. This approach offers patients a higher standard of care, with reduced treatment times and more predictable outcomes.[10]

LOCATION OF INFERIOR ALVEOLAR CANAL

Accurate evaluation of the relationship between the inferior alveolar canal and the roots of the mandibular third molar is crucial in preventing nerve injury during procedures like the extraction of impacted third molars and implant placement. By understanding this relationship, the risk of causing permanent sensory loss to the lower lip can be significantly reduced.[1] While traditional panoramic radiographs may suffice when the third molar is not in close proximity to the canal, in cases where there is radiographic superimposition or uncertainty about the canal's position, a 3D imaging approach is recommended for a more precise assessment.

Cone Beam Computed Tomography (CBCT) provides an effective solution, offering three-dimensional images at a relatively low radiation dose compared to other advanced imaging techniques. This is particularly beneficial for dental professionals when assessing complex anatomical relationships, such as those between the third molar and the inferior alveolar canal. The integration of CBCT with either the proprietary software that comes with the imaging device or third-party diagnostic software enhances its utility, allowing for more accurate and detailed views of the area of interest. This advanced imaging capability aids in planning surgical procedures with greater precision, ultimately improving patient safety and minimizing the risk of complications. The ability to visualize the anatomical structures in 3D allows for more informed decision-making, reducing the likelihood of nerve damage during extraction or implant placement.[7]

TEMPOROMANDIBULAR JOINT

The assessment of hard tissue or bony changes in the joint has been the most important use of conventional CBCT in TMJ imaging. In order to aid in the investigation and diagnosis of bone morphologic features, joint space, and dynamic function—all of which are crucial for determining the course of treatment for patients exhibiting TMJ indications and symptoms—it offers 3D pictures of the condyle and adjacent structures. CBCT provides the best picture of pathologic alterations such osteophytes, condylar erosion, fractures, ankylosis, dislocation, and growth anomalies like condylar hyperplasia, rheumatic arthritis, and degenerative joint disorders.[11]

ORTHODONTICS

Orthodontists traditionally used 2D radiographs like cephalometric, panoramic, and periapical images for diagnosis and treatment planning. While useful, these images only offer limited views of the complex 3D anatomy.[12] CBCT (Cone Beam Computed Tomography), however, provides detailed 3D images, significantly improving orthodontic care by allowing precise analysis of tooth movement in all three planes.CBCT is especially valuable for identifying the position of impacted and supernumerary teeth, and their relationships to adjacent teeth, roots, and vital structures. It enables accurate planning of tooth movements, considering factors like root resorption, bone width for buccolingual movement, and tooth inclination. It also improves the visualization of soft tissue relationships, essential for comprehensive treatment planning.[13]

Additionally, CBCT allows for 3D cephalometric analysis, offering precise linear measurements, better representation of dentoskeletal relationships, and the ability to assess facial aesthetics. It also helps monitor patient growth over time, which is vital in pediatric orthodontics. By capturing detailed 3D data throughout treatment, orthodontists can make informed adjustments and anticipate future growth, leading to more effective, personalized care.Incorporating CBCT into orthodontics enhances diagnostic accuracy, treatment planning, The pharyngeal airway had been evaluated using several diagnostic methods, i.e., nasal resistance and airflow tests, nasoendoscopy, lateral cephalometric, Magnetic Resonance Imaging (MRI) and 3-dimensional (3D) imaging techniques like CT and CBCT outcomes, making it an invaluable tool for modern practice.[14]

ENDODONTICS

CBCT is not yet fully optimized for caries detection, and its use should be limited to non-restored teeth. The impact of beam hardening on potential artifacts and false positives is still unclear, and while it may increase sensitivity, it should not sacrifice specificity.[16]

In contrast, CBCT is highly valuable in endodontics, offering 3D imaging to detect perforations and abnormal canals during treatment. This technology improves diagnostic accuracy, potentially saving many teeth each year. CBCT is particularly effective for assessing apical lesions, root fractures, canal identification, and internal and external root resorption, often providing more reliable results than 2D imaging.

PERIODONTICS

Bitewing radiographs, combined with a periodontal probe, have traditionally been the standard method for monitoring periodontal bone loss. While this approach is low-cost, it is technique-sensitive and provides an incomplete view of the area. Most software now offers tools for assessing and tracking bone density, along with enhanced visualization through CBCT images. These features can help predict treatment outcomes, evaluate treatment effectiveness, and identify potential areas of concern for future monitoring.[7]

In terms of periodontal disease, CBCT is no more accurate than 2D imaging for measuring bone height, but it is superior for visualizing bone topography and lesion structure. However, it's important to consider that views of the alveolar crest may be obscured by dental restorations.

ORAL AND MAXILLOFACIAL SURGERY

In oral surgery and pathology, CBCT data can significantly influence decision-making. It provides exceptional clarity in visualizing the location, root configuration of impacted or erupted teeth, and their proximity to adjacent structures with digital accuracy. CBCT clearly defines periapical lesions, bone destruction, and maxillary sinus involvement, helping eliminate doubts about artifacts seen in traditional radiographs.[15-16]

Visualizing pathologies in 3D aids both diagnosis and treatment planning. Unlike plain film tomograms, CBCT captures images more quickly, which is beneficial for patients who may struggle to stay still. Additionally, CBCT images are less distorted, offering a clearer understanding of bone density.[17]

While panoramic radiographs are commonly used in dental practices, they have limitations, such as providing only 2D images and suffering from superimposition of structures. CBCT overcomes these issues by enabling 3D visualization and allowing for precise digital manipulation of the images. Additionally, panoramic X-rays can be distorted and magnified, making distance measurements unreliable, even when the magnification factor is known.[17]

DISCUSSION

Cone Beam Computed Tomography (CBCT) is an advanced imaging technology that offers high-quality images, enhancing diagnostic accuracy in the maxillofacial region. First used for angiography in 1982, CBCT has rapidly evolved, providing 3D visualization of the complex maxillofacial anatomy. Currently, CBCT is already recognized as an indispensable tool in dental imaging.CBCT systems deliver diagnostic images across various sections (coronal, axial, sagittal), requiring a solid understanding of anatomical structures for accurate interpretation. It provides unique advantages, such as high-resolution, three-dimensional imaging that allows dental professionals to view and analyze complex anatomical structures with remarkable clarity. This capability is particularly valuable in fields such as implantology, orthodontics, and oral surgery, where precise imaging is essential for successful outcomes. Despite its current high cost and limited accessibility, CBCT remains an invaluable asset in the dental imaging repertoire, offering unparalleled diagnostic insights that improve treatment accuracy and patient care. As technology continues to progress, CBCT's role in modern dentistry is likely to expand, becoming even more central to clinical practice.

Future advancements in CBCT technology, combined with the continued development of Computer-Aided Advanced Technology, are anticipated to result in systems that offer even more precise diagnostic capabilities and reduced radiation doses. These innovations could lead to more efficient imaging with enhanced accuracy, allowing for better detection and treatment planning while minimizing risks to patients. As these technologies evolve, the overall cost of CBCT systems may decrease, making them more accessible to dental practices of all sizes. This reduction in price could potentially usher in a new era where CBCT becomes the primary method of dental imaging, overtaking traditional 2D radiographs as the standard practice in dental diagnostics.

CONCLUSION

The rapid advancement and widespread availability of CBCT technology, specifically tailored for imaging the maxillofacial region, are expected to greatly improve dental professionals' ability to access 3D radiographic assessments in clinical practice. This innovation provides dental practitioners with high-resolution images, offering sub-millimeter accuracy that is essential for precise diagnostics and treatment planning. One of the major advantages of CBCT is its relatively short scanning time, typically ranging from just 10 to 70 seconds, making it a more efficient option for both patients and clinicians. Furthermore, the radiation dose associated with CBCT is relatively low, being equivalent to that of 4 to 15 panoramic radiographs. This combination of high-quality imaging, speed, and reduced radiation exposure makes CBCT an appealing and valuable tool for a wide range of dental and maxillofacial procedures, from routine assessments to more complex surgical planning. As its availability continues to grow, it is anticipated that CBCT will become an integral part of everyday clinical practice, providing dental professionals with a powerful tool for enhancing patient care and treatment outcomes.

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