Medico Research Chronicles

ISSN No. 2394-3971

Review Article

EVALUATING THE POTENTIAL CLINICAL APPLICATIONS OF CONE BEAM COMPUTERISED TOMOGRAPHY IN ORAL AND MAXILLOFACIAL SURGERY: A REVIEW

Rakshit Vijay Sinai Khandeparker[1*], Patel Sanikumar Kamleshbhai[2], Saurabh Kamat[3], Purva Vijay Sinai Khandeparker[3]

1. Oral and Maxillofacial Surgery, Consultant, Victor Apollo Hospital, Margao, Goa India.

2. Oral and Maxillofacial Surgery, Private Practitioner, Gujarat, India.

3. Oral and Maxillofacial Surgery, Private Practitioner, Goa, India.

Submitted on: July 2015
Accepted on: July 2015
For Correspondence
Email ID:
rockdotcom1386@gmail.com

Abstract

While oral and maxillofacial surgeons have successfully practiced using panoramic radiography, the limitations of this imaging technique include variable magnification, distortion, superimposition of structures, and suboptimal imaging of structures not located in the focal trough. The introduction of Cone Beam Technology has dramatically changed how an oral and maxillofacial surgeon conducts his/her practice. This article is intended to discuss the potential clinical applications of Cone beam computerized tomography as compared to conventional radiography and conventional computed tomography, in the field of Oral and Maxillofacial Surgery, as reported in the literature.

Keywords: Cone beam computerized tomography, conventional computed tomography, panoramic radiography, 3D imaging, oral and maxillofacial surgery.

Introduction

Although a thorough history and clinical examination are instrumental in establishing the diagnosis, yet, the role of radiographic imaging cannot be understated. While Oral and Maxillofacial Surgeons have practiced successfully using panoramic radiography (2D Imaging), the inherent limitations unique to this imaging modality include variable distortion, magnification, superimposition of structures and suboptimal imaging of structures not located in the focal trough.[1]

Over the last few decades, the introduction of 3D imaging characterized by computed tomography (CT) and magnetic resonance imaging (MRI) technologies has had a tremendous impact on the practice and teaching of maxillofacial surgery. The tomographic nature of CT and MRI provides thin slices at much higher inherent contrast than achievable with 2D projection radiography, which in turn allows for a better delineation of the bone and soft-tissue boundaries and a deeper appreciation of the intricate interrelations of the complex anatomy of the maxillofacial region.

In the last decade, a CT system specifically dedicated to the maxillofacial region has been developed and has become increasingly popular. These so called Cone Beam CT (CBCT) scanners are capable of producing 3D images that can guide diagnosis, treatment and follow up. The use of CBCT was independently reported for maxillofacial imaging by Mozzo et al in 1998[2] and Arai et al in 1999[3]. Since then, there has been a rapidly growing interest in CBCT technology and its maxillofacial imaging applications.

CBCT machines have 2 major differences compared with so-called "medical" CT scanners. First, CBCT uses a low-energy fixed anode tube, similar to that used in dental panoramic x-ray machines. Second, CBCT machines rotate around the patient only once, capturing the data using a cone-shaped x-ray beam. These changes allow for a less expensive, smaller machine that exposes the patient to approximately 20% of the radiation of a helical CT, equivalent to the exposure from a full-mouth periapical series[4, 5]. It is important to note that by utilizing a relatively low ionizing radiation, CBCT offers 3D representation of the hard tissues with minimal soft tissue information. Currently neither Multidetector CT (MDCT) nor CBCT can replace MRI where soft tissue diagnosis is the primary aim.

This imaging modality offers numerous advantages over traditional 2D imaging, including a lack of superimposition, 1:1 measurements, absence of geometric distortions and 3D display.

This article intends to discuss the potential clinical applications of Cone Beam technology in the field of Oral and Maxillofacial Surgery and compare it with conventional radiography and MDCT as reported in the literature.

Clinical Applications in Oral and Maxillofacial Surgery

1. Impacted Teeth

Surgical removal of impacted teeth is one of the most common surgical procedures performed by oral surgeons and requires precise knowledge of the tooth location in the jaw and its relation to other teeth and surrounding anatomical structures.

The following information can be accurately and precisely obtained using CBCT:

1. Relationship of the mandibular impacted tooth roots to the inferior mandibular canal.
2. Assessment of a tortuous inferior mandibular canal, whether bifurcated or trifurcated allows the surgeon to develop a safer surgical plan related to access to the tooth and root elevation.
3. Orientation of the maxillary impacted canines, whether buccal or palatal and its relationship to the roots of the lateral incisor.
4. Ankylosis of impacted teeth.
5. Relationship of maxillary impacted teeth to the maxillary sinus.

Although conventional panoramic radiographs are routinely employed to evaluate impacted teeth per-operatively, however, the 2D nature of the image and superimposition of adjacent anatomical structures impede precise assessment of the tooth relative to adjacent anatomical structures[6]. CBCT in comparison allows for better risk assessment of impacted teeth removal by adding the third dimension. CBCT orthographic tomographic slices and panoramic reconstructions are superior to conventional panoramic radiographs in determining the location and orientation of an impacted tooth and its relationship to adjacent vital structures in the maxilla and the mandible[7-9].

2. Maxillofacial Trauma.

Although simple dental and jaw fractures and initial assessment of complex jaw fractures can be performed using either periapical or panoramic radiographs, however, vertical root fractures or multiple jaw fractures with bone displacement are better evaluated with CBCT. Multiplanar views of CBCT allow better assessment of undisplaced interarticular fractures of the condylar head that are difficult to diagnose with conventional radiography. CBCT offers a valid alternative tool to MDCT for complex jaw fractures, considering the radiation dose and image quality[10].

In addition to overcoming the structural superimpositions that can be seen in panoramic images, CBCT allows accurate measurement of surface distances[11, 12]. This particular advantage has made CBCT the technique of choice for investigating and managing midfacial and orbital fractures, post-fracture assessment, inter-operative visualization of the maxillofacial bones, and intraoperative navigation during procedures involving gunshot wounds.[13-16]

A few limitations to use of CBCT in maxillofacial trauma include: involvement of cranium and cerebrospinal leakage cannot be studied and CBCT machines in current configuration requires the patient to be in upright sitting or standing position thereby precluding its use in patients with trauma to the cervical vertebrae or in those in whom the neck has been stabilized.

The role of CBCT in fracture diagnosis, therefore, appears to be limited to fracture of teeth and jaw fractures from fall, sports-related injury or minor assault. MDCT with or without MRI is a better imaging choice in automobile or industrial accidents involving jaws and other parts of the body.

3. Implantology

The role of imaging in the pre-operative assessment of oral implant placement cannot be neglected. Most oral surgeons use panoramic and intra-oral radiographs for this purpose; however the inherent 2D nature of such modalities hampers detailed pre-operative planning. Also, an average panoramic machine produces approximately 25% magnification that must be accounted for when planning implant placement.

In some countries, cone beam 3D images are becoming a standard of care in planning for implant cases by providing important information such as the amount of available bone, quality of the bone, proximity to vital structures, and disease at the region of the proposed implant site[17].CBCT imaging has become a valuable tool by providing information about the angle of the proposed implant and virtual abutments and helping to plan the restorations. CBCT scan data is also utilized in the generation of treatment plans and surgical guided templates to achieve precision implant placement and to avoid implant failure due to incorrect positioning[18-20]. CBCT scans also allow for post-surgical evaluations of bone grafts and implants position in the alveolus[21]. From the above statements, it is obvious that CBCT is striving to become the method of choice for pre-operative implant planning procedures.

4. Maxillofacial Pathology

4A: Benign Lesions and Cysts

Multiplanar views of CBCT provide precise information on the presence and extent of bone resorption, sclerosis of neighboring bone, cortical expansion and internal or external calcifications and proximity to other vital anatomy as compared to intra-oral or panoramic radiographs[22].

Although the above information can be obtained using a conventional CT, however, given the higher resolution, lower radiation dose and lower cost of CBCT, it stands to reason that CBCT can easily replace conventional CT in this regard.

Newer CBCT units allow slice thickness to be as low as 0.1 mm, allowing for better visualization of the bony margins of a lesion. CBCT data can also be useful in creating a stereolithic model of the area of interest.

Apart from presurgical evaluation of aggressive benign cysts or tumours, CBCT is also helpful in post-surgical follow-up of the margins of lesions that may have a high recurrence rate. For surgical planning, a lesion may need to be measured from different angles. For osseous components, when compared to the gold standard dry skull, the measurements on CBCT images are acceptably accurate with less than 1% error[23, 24]. In comparison, panoramic radiographs are not reliable for size measurement due to variable magnification error[25].

4B: Malignant Lesions.

Panoramic radiographs offer gross limitation in depicting the margins of a lesion and a lesion appearing benign on such radiographs could reveal ominous features in thin slices of CBCT scans. Although conventional CT scan precisely depict the irregular margins of the malignant lesions, however CBCT offers the similar advantage at a lower radiation dose and lower cost.

CBCT images are as reliable as MDCT images in predicting bone invasion by malignant lesions[26]. CBCT images are not useful in analyzing soft tissue tumours, rather MRI or soft tissue window MDCT is a better diagnostic tool.

4C: Soft Tissue Calcifications

Soft tissue calcifications like sialioliths, tonsilloliths, carotid atherosclerosis are adequately viewed on the CBCT despite its low contrast[27, 28]. Ossification of the stylohyoid ligament, although can be easily diagnosed on the panoramic radiograph, the relationship of the ligament to other structures is better evaluated by 3D reconstruction of CBCT.

4D: Others

Since most currently available CBCT systems acquire volumes that extend beyond the dentition and the surrounding alveolus, unsuspected lesions in the paranasal sinuses, parotic region, masticatory space, floor of the mouth and the hyoid region are frequently detected and reported[29, 30].

5. Temporomandibular (TMJ) disorders.

The diagnosis and treatment planning of TMJ disorders are often quite challenging. MRI remains the gold standard for imaging the intra-articular components of the TMJ. Nonetheless, most TMJ examinations begin with a panoramic radiograph to assess for gross changes in the condylar head and the temporal components. However, a low diagnostic accuracy is provided in evaluating the temporal joint components coupled with low sensitivity in evaluating the changes in the condyle and poor reliability.

CBCT makes it possible to examine the joint space and the true position of the condyle within the fossa, which is instrumental in revealing possible dislocation of the joint disk[31, 32]. CBCT's accuracy and lack of superimposition makes it possible to measure the roof of the glenoid fossa and visualize the location of the soft tissue around the TMJ, which can offer a workable diagnosis and reduce the need for MRI[33-35].

These advantages outlined above have made CBCT the best imaging device for cases involving trauma, fibro-osseous ankylosis, pain, dysfunction, and condylar cortical erosion and cysts[36-38].

Given the significantly reduced radiation dose and cost compared to conventional CT, CBCT may soon become the investigational tool of choice for evaluating bony changes of the TMJ.

6. Cranifacial Disorders

The role of panoramic radiographs is limited to identifying the alveolar cleft only. Also, the young age of the patients limits the use of conventional CT due to delivery of high radiation dose to the patients.

CBCT is rapidly replacing MDCT for this task since it provides excellent 3D visualization of the palate at the premaxilla region at a lower patient dose. Cross-sectional imaging, such as with CBCT, assists in the assessment of the width of the cleft, tooth proximity to the cleft, deviation of the nasal septum and its degree of fusion to the palate, as well as the location of supernumerary teeth and the visualization of the entire osseous defect.

7. Orthognathic Surgery

For orthognathic surgery, DICOM data from CBCT can be used to fabricate physical stereolithographic models or to generate virtual 3-D models[12, 39, 40]. Such 3-D reconstructions are most useful for morphological analysis and spatial relationship of the neighboring structures as well as for growth and developmental anomalies, gross tumor development or fracture displacement. These 3-D surface models generated from CBCT data may be slightly inferior to that from MDCT, but are usually of acceptable quality[41]. The 3-D reconstructions are extremely useful in the diagnosing and treatment planning of facial asymmetry cases.

Airway measurement techniques are improving with newer software options[42, 43]. These data are being used for surgical orthodontic cases as well as for sleep apnoea patients[44]. Follow-up CBCT imaging is useful in evaluating the success of orthognathic surgery as well as to measure the displacement of the surgical segments in all three orientations[12].

8. Inflammatory Bone Changes

If the infection is acute, neither plain film radiography nor CBCT scan is useful, as early infection does not cause enough bony change to be radiographically detectable. The margin of a chronic infection is often sclerotic and can be adequately viewed on plain film radiographs. To identify periosteal bony reactions, oral and maxillofacial surgeons traditionally used occlusal radiographs. However, wrong exposure factors or angulation can limit the utility of an occlusal radiograph to demonstrate a thin periosteal bony layer. With CBCT images, where multiplanar slices are easy to adjust, thin layers of periosteal bones are better viewed compared to occlusal radiographs. In addition, small bony sequestra associated with osteomyelitis are better identified with cross-sectional imaging.

Features of osteomyelitis are also seen in bisphosphonate related osteonecrosis of the jaws (BRONJ). In evaluating BRONJ, CBCT images are better than panoramic radiography[45]. Currently, all these imaging modalities have limited values in detecting early stages of the disease. BRONJ may also be associated with failing dental implants. In implant cases, MDCT is likely to produce image artefacts arising from metal implants. CBCT can be used to evaluate the status of alveolar bone adjacent to the implants and also as a follow-up examination.

Conclusion

The introduction of CBCT has dramatically changed how an oral and maxillofacial surgeon conducts his/her practice. CBCT examinations must not be performed unless they are necessary and benefits clearly outweigh the risks. Currently, CBCT is mostly a tool for diagnosing diseases of osseous structures and is not useful for lesions limited to soft tissues. A combination of clinical findings and radiographic interpretations should be considered to determine the need for surgery or follow-up examinations.

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