CBCT evaluation of maxillary sinus prior to dental implant placement: A review.

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Abstract
Dental implants are widely used now a days for the rehabilitation of edentulous spaces in patients. Diagnostic images of the surgical site are a must essential for preoperative planning, intra-operative assessment, and postoperative evaluation. Considering the pros and cons, Cone-Beam Computed Tomography (CBCT) seems to be the better choice for qualitative and quantitative analysis of the surgical site prior to implant placement and post operative evaluation. CBCT software helps to visualize the ideal dimension, position and orientation of an implant. This article briefly describes the importance of CBCT for implants placement and explains how to evaluate the maxillary sinus as a parameter before placement of a dental implant.

Keyword: CBCT, implant, maxillary sinus, ideal dimension, bone quality.

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Email- debarati1993@gmail.com **DOI:** 10.5281/zenodo.5205329
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Introduction

Dental implant is an artificial device made of alloplastic material placed into alveolar bone beneath the mucosal layer to support a permanent dental prosthesis. They are gaining popularity and wide acceptance in recent times because they not only replace lost teeth in the arch but also provide permanent restorations which do not interfere with oral functions like speech or compromise the self-esteem of a patient.[1] The placement of dental implants requires proper planning and careful surgical procedures. A preoperative radiographic evaluation helps in identifying the pathological lesions, determines the quantity and quality of the alveolar bone, identify critical important anatomical structures at the potential implant sites, and assess the orientation of the implants to be placed. The desired quantity and quality of the jaw bone can influence the choice of implants with respect to their number, diameter, length and type. That's why preoperative radiographic assessment has an important role in treatment planning for implant-supported prostheses.

Many imaging modalities have been reported to be useful for dental implant placement such as intra-oral periapical, cephalometric, panoramic and tomographic radiography, computed tomography (CT), interactive CT, and magnetic resonance imaging (MRI) etc. Among them the use of Cone-Beam Computed Tomography (CBCT) with interactive planning software appears to meet the standard of care required for planning dental implant therapy.[2]

Discussion:

The maxillary sinus is an anatomic structure of primary concern during dental practice in the maxillary posterior region, especially in endodontic procedures, dental implantations, and extractions.[3] Sometimes the maxillary sinus floor (MSF) extends between the roots, or the root apices of maxillary molars may penetrate into the sinus cavity. Infection and sinusitis may occur from foreign bodies, such as endodontic instruments and root canal filling materials, into the sinus during root canal treatment.[4]

Conventional diagnostic radiographs are used for pre-planning and assessment of the close relationship between the root apex and the MSF. However, they may give insufficient diagnostic informations because of their 2-dimensional representations of a 3-dimensional (3D) structure.[5]

Demerits of two‑dimensional (2D) images:

Two‑dimensional (2D) radiographs used in implantology are; intraoral periapical radiography (IOPAR), orthopantomography (OPG), and occlusal radiography, while the three‑dimensional (3D) imaging modalities include computed tomography (CT), and CBCT and MRI.

Although easily available, IOPARs have anatomical limitations and may caused either foreshortening or elongation of image. OPGs exhibit asymmetrical distortion, leading to imperfect interpretation and measurements. Occlusal radiographs, used to determine bucco‑lingual dimensions of the alveolar ridge may give a false impression of excess availability of bone in mandible and in case of maxilla it fails to provide precise measurements because of its anatomic limitations.[6]

Advantages of CBCT for implant placement:

CBCT gained prominence as a radiographic diagnostic tool immediately after its introduction in 1967 by Sir Godfrey Hounsefield and since it improved the visibility of anatomical structures that were unclearly observed by intraoral and panoramic radiographs. CBCT provides more precise 2D diagnostic information (from reformatted images like axial, coronal, sagittal, cross‑sectional, panoramic images) in all three dimensions compared to CT.[7]

In 2-dimensional imaging, each 2-dimensional pixel represents a 3-dimensional cube or voxel. Each pixel measures the total X-ray absorption throughout each voxel. This 2-dimensional limitation has been overcome by low dosage cone-beam computed tomography (CBCT), which employs a cone-shaped X-ray beam rather than the flat fan shaped beam used in conventional CT. The overall effective dosage is 0.035 to 0.10 mSv, which is equivalent to 2-8 panoramic radiographs. Individual voxels are much smaller than conventional CT voxels, resulting in greater resolution of images. Examples: NewTom DVT 9000 (Quantitative Radiology, Verona, Italy), i-CAT (Imaging Sciences International, Hatfield, USA), and 3D Accuitomo (J. Morita, Kyoto, Japan).[2]

Moreover, it has lesser radiation dose (15 times lower) and scanning time, compared to a multi-slice CT. CBCT software can evaluate multiple variations of individual implant position (different depth and mesiodistal ororofacial angulations) and encourages interdisciplinary communication between the radiologist and referring dentist, to attain the optimal treatment plan. Also, pre and postoperative CBCT images help to compare the alveolar ridge resorption/preservation following grafting procedures. Thus, CBCT seems to be the most proficient imaging modality for dental implants now a days.[8]

Shortcomings of CBCT for implant placement:

There are some drawbacks of CBCT such as; Lack of availability, higher cost compared to two‑dimensional images and beam‑hardening artefacts around titanium implants. Because of these artefacts, <6 mm of bone, adjoining an implant can be either underestimated or be imperceptible sometimes.[9] Table 1 shows a comparison between Conventional Radiograph (IOPA,OPG), CT Scan and CBCT:

Optimal dimension and safe zone of implants:

Diagnostic and planning software of CBCT help in virtual mock surgery of implant placement of different diameters and lengths, so that the optimal dimension can be selected precisely and providing 360° rotating visualisation [Figure 1] of the anatomical structures around implants enable detailed pictures of the region.[10]

Evaluation of bone quality:

There are many classifications for presurgical assessment of the bone given by various authors such as; Seibert, Allen et al., Misch and Judy, Studer et al., Chen et al., etc.. Among them the most commonly used classification is the Lekholm and Zarb index [Table 2], which roughly predicts the time required for osseointegration, based on the radiographic proportion and structure of compact and trabecular bone.[11]

Post-surgical assessment:

Villarinho et. al. stated that, "an implant can be considered successful if there is no clinically observable movement, no peri‑implant radiolucency, vertical bone loss <2 mm in the first year and <0.2 mm in subsequent years, and no persistent signs or symptoms, such as pain, infection, neuropathy, paresthesia, and injury to the mandibular canal".[12]

Essential anatomical landmarks for implant placement:

Appropriate knowledge of anatomical structures and meticulous preoperative radiological evaluation limits operative and post‑surgical complications. Since variations exist in every patient, CBCT helps in determining the limits of safe area for surgery. The noteworthy anatomical structures and their significance are discussed below:

Incisive (Nasopalatine) canal, Nasal floor, Maxillary sinus, Mandibular canal, Anterior loop, Mandibular incisive canal, Midline lingual canal, Lingual undercut, Soft tissue etc.

Clinicians must be aware of the close proximity between the roots and the maxillary sinus floor (MSF) before both conventional and surgical procedures to minimize the risk of creating communication between the oral cavity and the maxillary sinus.

Maxillary sinus as a parameter in implant placement:

The use of oral implants in the posterior region of the maxilla has become a routine practice in dentistry. The frequent placement of oral implants has raised the number of neurosensory disturbances and hemorrhages; therefore, it is important for surgeons to detect neurovascular structures in the upper jaw bone. Because of its location in the anterolateral maxillary sinus wall, the intraosseous artery has the potential to cause bleeding complications in one-fifth of the lateral window osteotomies. An accurate pre-operative radiographic examination such as CBCT is therefore recommended before maxillary sinus augmentation procedure during implant placement.[13]

The maxillary sinus shows variation as the anterior border has been observed as far as the midline. Posterior migration of the sinus towards maxillary process is more common. The posterior border of maxillary sinus is seen as a thin, vertical, radiopaque line. Often the maxillary sinus is transverse by radiopaque lines called septa which represents folds of cortical bone oriented vertically.[14]

The roots of maxillary posterior teeth are in close proximity with the maxillary sinus. Ruling out sinusitis and other potential pathological conditions is necessary before sinus floor elevation. With a prevalence of 9.5%‑55.2%, sinus septa is a major contributing factor for sinus membrane perforation. During sinus augmentation, the posterior superior alveolar artery (which most commonly runs within the bone) may cause bleeding, especially in the lateral wall of the maxillary sinus, where it joins the infra‑orbital artery.[15]

The vertical and horizontal relationship between the root apex of maxillary molars and the MSF are described below in Figure 2 and Figure 3.[5]

Conclusion:

CBCT has revolutionised planning and evaluation of implants by providing unmatched quality and precision of measurements. Its unique interactive software helps in accurate diagnosis and treatment planning, so that implant surgeries can proceed uneventfully, fulfilling functional and aesthetic demands. It is also the best non‑invasive tool for the successive re‑evaluation of those dental implants.

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Conflicts of interest:

There are no conflicts of interest.

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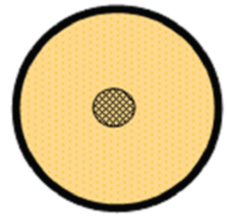
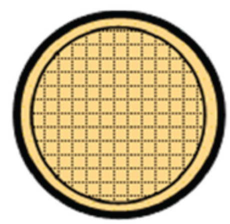
TABLES:

Table 1

Features	Conventional radiograph	CT Scan	CBCT
Customization	no	yes	yes
Radiation Dose	<1 mSv	4-10 mSv	0.027-1.073 mSv
Pixel	Non pixeled	3 D Voxel	3 D Voxel
Exact extension	poor	better	better
Dianostic aquaracy	poor	better	better
Data preservation	no	yes	ideal
Time required	more	Less than conventional but more than CBCT	less
Bone density	Cant asses properly	Better assessment	Ideal assessment
Detailed description	poor	better	best
Object localization	poor	Proper coronal, sagittal and axial plane	Detailed planar angulation
Cost	less	high	Less than Multiplanar CT
Patient compliance	less	more	more
Technical sensitivity	less	more	more
Hounsefield unit		Proportional to the degree of x-ray attenuation by the tissue	The degree of x ry attenuation is shown by gray scale(voxel)

Table 2

Lekholm and Zarb classification: according to the structure of alveolar bone	Diagrammatic ratio of the outer compact bone and the inner trabecular bone
Type I :- Almost the entire bone is composed of homogenous compact bone and its resistance felt during drilling is comparable to oak wood. Has restricted blood supply and takes about 5 months to integrate with an implant.	
Type II :- Thick layer of compact bone surrounds a core of dense trabecular bone and the resistance is comparable to pine wood. Considered to be the best bone for osseointegration, which requires approximately 4 months.	
Type III :- Thin layer of cortical bone surrounds a core of dense trabecular bone and the resistance is comparable to balsa wood. May necessitate a delay of about 6 months before loading an implant.	
Type IV :- A thin layer of cortical bone surrounds a core of low density trabecular bone and the resistance is comparable to styrofoam. Usually takes 8 months to integrate with the implant and often entails bone manipulation.	

FIGURES

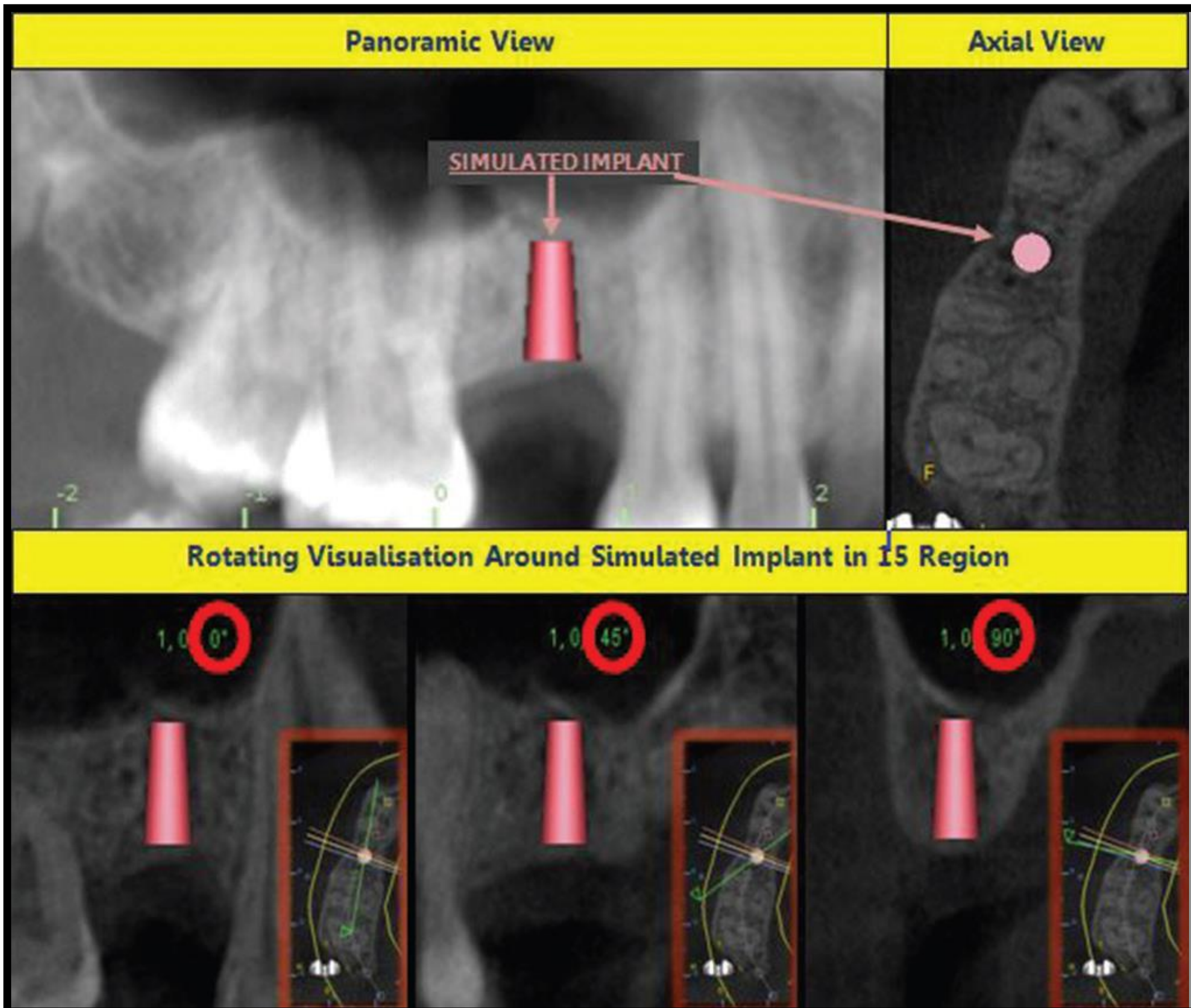


Figure 1: Visualisation around a simulated implant. Degrees of rotation are encircled in red

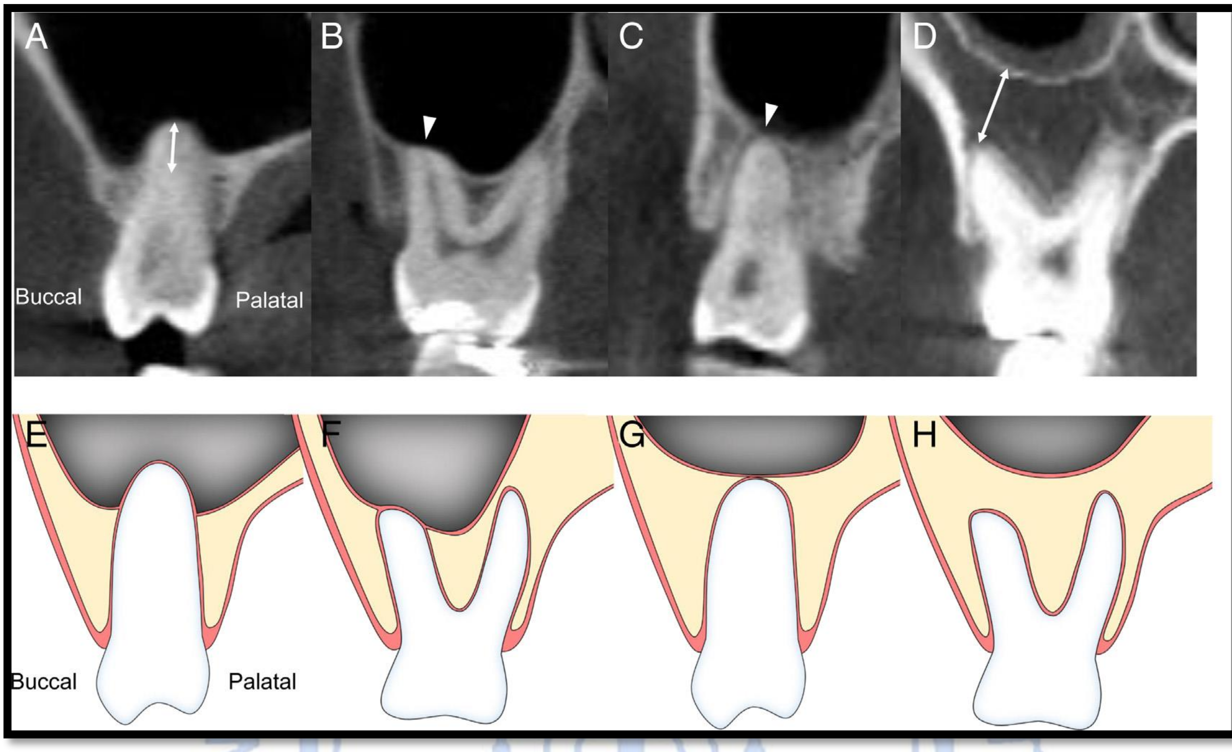


Figure 2: Maxillary CBCT images for the classification of the vertical relationship between the root apex of the maxillary posterior teeth and the MSF.

(A) The root apex protruded into the maxillary sinus

(B) The root apex was in contact with the MSF, producing a small elevation on the floor

(C) The root apex was in close contact with the MSF

(D) The root apex was below the MSF

E,F,G,H are the schematic diagrams of A,B,C,D respectively.

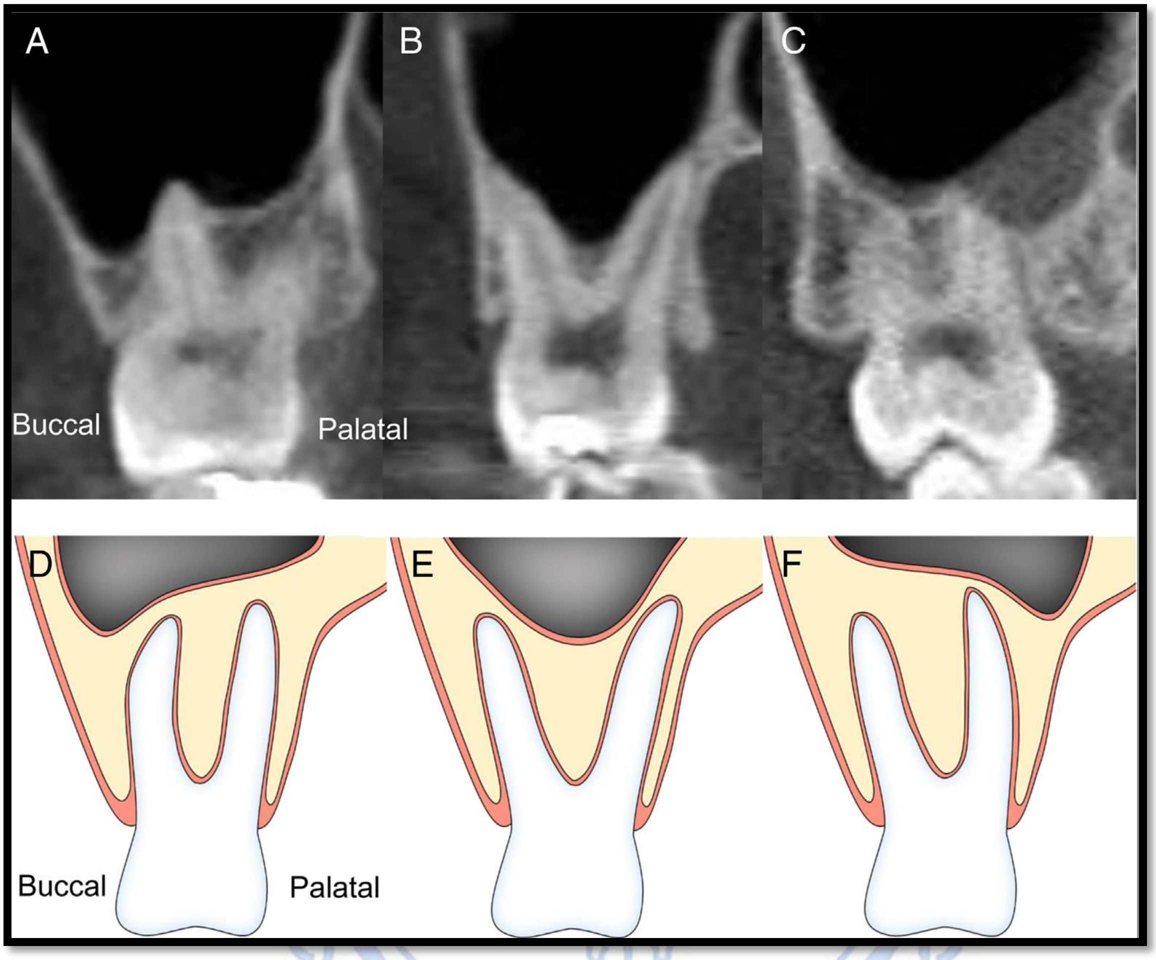


Figure 3: Maxillary CBCT images of the 3 groups for the classification of the horizontal relationship between the root apex of maxillary molars and the MSF.

(A) The lowest point of the MSF was located more toward the buccal side than the buccal root.

(B) The lowest point of the MSF was centrally located, relative to the roots.

(C) The lowest point of the MSF was located more toward the palatal side than the palatal root.

D,E,F, are the schematic diagrams of A,B,C, respectively.