Importance of CBCT as a diagnostic tool for evaluating the position of inferior alveolar canal during dental implant placement: A systemic review.

Mainak Datta[1], Rupam Sinha[2], Soumyabrata Sarkar[3], Suman Sen[3], Subhadeep Maity[4], Harshvardhan Jha[4]
[1]Post graduate trainee, Department of oral medicine and radiology, Haldia institute of dental sciences and research, India.
[2]Professor & Head, Department of oral medicine and radiology, Haldia institute of dental sciences and research, India.
[3]Associate Professor, Department of oral medicine and radiology, Haldia institute of dental sciences and research, India.
[4]Assistant Professor, Department of oral medicine and radiology, Haldia institute of dental sciences and research, India.

Abstract
Dental implants are most acceptable tool used for the prosthetic rehabilitation of edentulous areas. Diagnostic images of surgical site is necessary for pre-operative treatment planning, intra-operative work assessment, and postoperative treatment evaluation. At present, cone-beam computed tomography (CBCT) is the best imaging modality for qualitative and quantitative analysis of the surgical site for implant placement. It allows proper planning and subsequent post-operative evaluation with sub-millimetric accuracy in implant placement of lower jaw considering the position of inferior alveolar nerve canal. CBCT software enables simulation of implant placement to choose the ideal dimension, position and orientation by evaluating bone quality and position of inferior alveolar nerve canal with different anatomical type and variety. This article describes why CBCT is crucial for pre-surgical assessment dental implants following position of inferior alveolar nerve canal in mandibular area.

Keyword: Inferior alveolar nerve canal, CBCT, implant safe zone, post-surgical assessment.

Address of correspondence: Mainak Datta, Jiaganj, Murshidabad, West Bengal India, Pin: 742123.
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Introduction

Tooth loss is such a physiologic phenomenon which cause partial or complete edentulism. There are various causes, associated with tooth loss including compromised periodontal health secondary to local factors including plaque and calculus, hormonal imbalance, collagenopathy, pulpitis and progressively periapical or periodontal abscess. Also, traumatic injury, musculo-skeletal degenerative disorder passively causes early exfoliation. Systemic issues also causes early exfoliation including diabetes, hypertension, smoking, poor nutritional supply etc.[1] Partial or complete edentulism can be manage by various kinds of prosthetic rehabilitation tools including removable partial denture, complete denture, crown and bridge etc. But the newest and convenient one is 'dental implant' which gradually becoming more convenient and patient friendly day to day with an emerging importance.[2] Dental implants are widely being implemented for the rehabilitation of edentulous spaces. Success of dental implant predominantly depends on treatment planning. Assessment of the site of implant placement in all dimensions, relative to the hard and soft tissues and addressing the inadequacies can significantly reduce the chances of complication.[1] Diagnostic imaging is so important for the preoperative assessment of dental implant placement. Assessment during intraoperative stage and evaluation at postoperative stage is important. There are many diagnostic tools available for pre and post surgical assessment of implant retained prosthesis, including cone-beam computed tomography (CBCT) which has become a very popular radiographic diagnostic tool for the assessment of dental implant therapy to ensure predictable results (Figure 1).[3] Dental implant placement in partially edentulous jaw is challenge to practitioners due to the course of the inferior alveolar nerve and its exit from the mental foramen (MF). The pathway of the inferior alveolar nerve (IAN) and its association to the teeth has been investigated by various investigators. There are a lot of study done on variation of location of mental foramen and course of inferior alveolar nerve.

Ideal Requirement of Diagnostic Radiographic tool for assessment of Implant placement

An ideal radiograph guide as about the bony quality and amount of compact bone, relative relationship of the important anatomical structures, dimension of placed implants, occlusal discrepancy, and prosthetic design, apart from ruling out the presence of pathologies in the area of interest. It must also be readily accessible with minimal radiation risk.[2] Implants with is accurate dimension, position, and orientation will increase the post-placement success rate.[3] International Team for Implantology (ITI), in 2013, suggested cross-sectional imaging to detect the topography and spatial relationship of surrounding anatomical structures with the implant.[4]

Limitations of Conventional Radiographic images

Two-dimensional (2D) radiographs utilized in implantology include intraoral periapical radiography (IOPAR), occlusal radiography and orthopantomogram (OPG), while the three-dimensional (3D) imaging modalities include computed tomography (CT), and Cone Beam CT.[1] Though easily accessible , periapical radiograph have anatomical limitations and any misguided technique of acquisition can leads to either foreshortening or elongation of image. OPGs are also most important to exhibit proper measurements but in two-dimensional scenario. The conventional radiographs, used to determine bucco-lingual dimensions are not provided by OPGs or IOPARs. They show the widest portion (normally positioned inferior to the alveolar ridge) of the mandible, giving a misguided impression of excess availability of bone. Occlusal radiographs is not sufficient for such measurements for maxilla because of its anatomic limitations.[2] This limitations of conventional images projects the necessity of a superior diagnostic assessment tools for implants (Table no. 1).

Advantages of CBCT

CBCT has proved itself as potent radiographic diagnostic tool after its discovery in 1982[5] for providing undistorted accurate images, chances of superimposition of neighbouring structures is less (Figure 2).[6]

- It is possible to view all aspects of the insertion site on the computer screen, virtually, noninvasively, as though you are dissecting your actual patient.
- Modern software packages generally provide various perspectives that usually are customizable and adjustable based on the clinician's preference.
- It is possible to view a 3D model (volumetric view) of the entire scanned object or only parts of it or to create tomographic slices in all three planes of space and navigate through volume of interest with desired thickness.
- CBCT technology allows an exact visual identification of the location, shape, and divergence of the mesial and distal dental roots, the floor of the maxillary sinus, and the buccal and lingual wall of the alveolar process.

- Qualitative assessments, therefore, can be made with much greater accuracy than on a regular 2D radiograph.
- CBCT data can be quantified using the appropriate software packages.
- Thus, distances between two points such as interradicular distance or buccal bone thickness can be measured with considerable accuracy angulation between three points can be calculated (e.g., to determine root divergence);
- The density of objects including bone can be assessed
- More detailed approach to planning and placing of the mini-screw implants.

Optimal dimension and safe zone of implants

Implant selection with the most accurate size ensures good prognostic outcome. There are various softwares available for diagnostic and planning purpose, and also allow show mock surgery proper implant placement procedure. So that an optimum dimension can be determined. Moreover, provision by most software for 360° rotating visualization of the anatomical structures around such simulated implants enable detailed scrutiny of the region.

With Increasing diameter implant stability and strength also increased due to increase of bone to implant contact area.[9] If initial stability is less , it causes micro-movement of the implant, also results the formation of fibrous tissue into the implant-bone junction, and prevent osseointegration.[10] Thus, the ideal diameter is the greatest implant diameter, within morphologic limits.[9] Since lesser amount of surrounding bone thickness can hamper success of implant placement, at least 1 mm of bone should present around the orofacial (bucco-lingual) sides of the whole implant.[11] Even a gap of 2 mm can hamper the association of the implant with the bone.[12] Although 1.5 mm of orofacial bone thickness around the point of emergence of the implant shoulder is considered adequate[13] and 2 mm of bone thickness on the labial side is highly recommended in the aesthetic zone to prevent crestal bone loss and recession of gingival coverage. The implant is to be placed 2-3 mm below the cemento-enamel junction (CEJ) of the adjacent natural teeth, to create an ideal emergence profile and its diameter should not exceed radicular surface area at this level. Difference of 1-1.5mm should be maintained between an implant and tooth root.[3] Minimum 3mm of bone must be present between two adjacent implants at the implant-abutment level.[14]

A shorter implant generally have inadequate bony contact, resulting lower initial implant stability.[10] During immediate placement, the apical portion of the implant should be placed at least 3-5 mm within the host bone to encourage initial stability.[3] The available bone height from the crestal area of an implant site is bounded apically by anatomical structures like mandibular canal, floor of the maxillary sinus, and nasal floor.[15] A safety margin of 1.5 mm is generally recommended while calculating the available bone height.[16] Ideally, the long axis of the implant should coincide with those of the prosthetic teeth and occlusal plane of the final prosthesis.[17]

These important pre-assessment shows the importance of accurate measurements should be taken provided by CBCT assessment. Concept of safety margin and implant dimension is really variable, the customized measurements should be produced before selecting the ideal implant for mock surgery. CBCT software usually have inbuilt database of implants with different size and shape (in accordance with the manufacturing companies) to choose from to increase prognostic accuracy.

Inferior alveolar canal as anatomical landmarks for mandibular implant placement

Appropriate knowledge of anatomical structures and preoperative radiological evaluation limits the chances of post-implant placement complications. Though, variations exist in every patient, CBCT helps in to determine the safe area of placement. The Inferior alveolar canal as anatomical structures and their significance are discussed below (Figure 3):

Mandibular canal

It runs near the roots of mandibular molars and second premolars,[10] with it's different morphometric variation with bi-fid and tri-fid configuration.[11] Mandibular canals, containing the inferior alveolar nerves, arteries, and veins, extend bilaterally from the mandibular foramen to the mental foramen,[12] changing its course from lingual position posteriorly (near second molars) to a buccal position anteriorly (second premolar region).[6] Thus, evaluation of its bucco-lingual position, ideally with cross-sectional images, is of considerable importance.

Anterior loop

Sometimes, though inferior alveolar nerve divides into two branches (mental and incisive) near the mental foramen, the undivided terminal portion passes below and beyond the mental foramen and gives off the incisive branch. The main branch curves back and emerges out of the mental foramen as the mental nerve.[13] This mental neurovascular bundle that crosses anterior to the mental foramen, then doubles back to exit through the mental foramen, is called anterior loop.[14] Anterior loops, larger than 2 mm are more likely to cause sensory disturbances or hemorrhagic complications when dental implants are installed in the most distal area of the inter-foraminal region.[13]

Rules/ Guidelines for successful Planning and Treatment of Mandibular Edentulism Using Dental Implants:

Rule no. 1: Superior or Inferior dimension of the mandible should be greater than equals to 10mm.

Rule no. 2: Inter-occlusal dimension or alveolar crest to occlusal plane distance should be greater than equals to10 mm.

Rule no. 3: Anterior/posterior distribution of implants must be at least 10 mm for the supported fixed prosthesis.

Evaluation of bone quality by CBCT

Selection of an implant site was evaluated by determining the bone density using Hounsfield Units (HU). These grey values are not trustable in CBCT due to its variable value with machine model, patients, and different sites of the same patient.[14] However, the bone structure parameters assessed in CBCT can provide better assessment of the implant success[13] because the bone quality is not only a matter of mineral content but also of the structure.[2] The most commonly used classification for pre-surgical assessment of the bone is the Lekholm and Zarb index, which approximately predicts the time required for osseointegration,[17] based on the radiographic proportion and ratio compact and trabecular bone.[11]

Mandible usually has more compact bony density compared to maxilla, and their thickness generally increases anteriorly.[14] Prediction of initial implant stability is more accurate by evaluating the bone structure, not by the bone density. Ridge with cortical thickness greater than 0.75 mm and an usual appearance of the inferior mandibular cortex causes high value implant torque.[16] Thus, CBCT assessment can evaluate the time needed for osseointegration of implants and can predict the required time interval between implant placement and prosthetic loading.

Post-surgical Implant assessment by CBCT

- The mis-interpretation of the images can be attributed to scatter radiation and alteration of the screw dimensions on the scan.
- This is a useful example of how findings from diagnostic imaging should be placed in the perspective of clinical observations.
- Clinician self-assessment.
- The orthodontist placing mini implants should evaluate if the implemented clinical protocol led to the desired outcome or at least be aware of how close the final result came to the planned ideal insertion.
- This self-assessment is the primary and important approach to improve future Temporary Anchorage Device (TAD) insertions.
- While a review of the final mini screw position can be interesting, it is more meaningful if compared with the virtually placed implant

Post-surgical assessment

The post placement osseointegration process, characterised by an intimate interfacial contact between the bone and implant surface, determines success or prognostic value. Osteoclastic changes are evident radiographically by the presence of apical migration of alveolar bone or by a prominent radiolucent osseous margin. As per a proposed criterion, "an implant can be considered successful if there is no observable clinical movement, no peri-implant radiolucency, vertical bone loss is less than 2 mm in the first year and less than 0.2 mm in subsequent years, and no persistent signs or symptoms, such as pain, infection, neuropathy, paresthesia, and injury to the mandibular canal".

Early failure, due to lack of osseointigration is linked to impaired healing ability of the bone, disruption of a weak bone-to-implant interface and infection. Late failure after the successful osseointegration is associated with occlusal overload or peri-implantitis (irreversible and progressive marginal bone loss after initial bone remodeling). An implant with a radiolucent border palatally and no osseous covering buccally. The apical end of the placed implant lies within the soft tissue lining of the nasal floor.

CBCT image assessment can detect peri-implant bone defects in three planes, without distortion– as revealed by histological evaluation. While neuropathic pain triggered by implant placement, CBCT images can be assessed to explore the relative position of the implant and the adjacent nerve, so that, decompression of the nerve can be planned if required. In case of mis-placement of implants and migration into the craniofacial structures like maxillary sinus, the ethmoid sinus, sphenoid sinus, orbit, cranial fossae, and submandibular fossa, CBCT can locate the exact position of such implants and assist in subsequent treatment.

Limitations of CBCT for implants

Shortcomings of CBCT for implants includes Lack of availability, higher cost compared to two-dimensional images and beam-hardening artefacts around titanium implants are the major drawbacks of CBCT. Due to this artefact, less than 6 mm of bone surrounding an implant, can be discouraged.

Conclusion

CBCT has revolutionized planning and Pre- and Post-surgical evaluation of implants by providing unbiased quality and precision of measurements. Its unique interactive software help in accurate diagnosis and treatment planning, so that implant surgeries can proceed uneventfully, fulfilling functional and aesthetic demands without any known complications. It has been proved itself as the most potent 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:

Features	Conventional Radiograph (IOPA, PG, Extra-oral)	Computed Tomographic Scan/ CT Scan	Cone Beam Computed Tomography (CBCT)
Customization	Not	Can be customized	Can be customized
Tube Voltage	64kV	120kV	84kV
Tube Current	16mA	80mA	145mA
Exposure Time	14.1s	0.75	12
Radiation Dose	Summation will be more in Conventional radiation exposure for each area Estimated dose 10µSv	Summation exposure will be more for multiplanar sliced CT images Estimated Dose 400 µSv	Image reconstruction by specialized CBCT software, Single time radiation exposure Estimated dose 100 µSv
Volume Of Interest (VOI)	Cannot show only the pathological area or area of interest	Can show area of interest, but not in reconstructed form	Clinician can see area of interest 3D Voxel
Voxel and Pixel	No Pixel	3D Voxel	3D Voxel
Exact Extension	Can't demarcate exact pathological area extension	Can localize exact pathological area but not in wholesome	Can localize exact pathological area but not in wholesome
Diagnostic Accuracy	Less	More	More
Data preservation for future	Can't preserve data for future reference	Preserve data, but volume of preserve data acquisition is larger	Accurate date preservation and ideal for data transfer in referral cases

Time Required	Summation of required time is more for total anatomic area	Summation of required time is less that conventional, but more than CBCT	Required time is less
Bone quality (Density, Thickness)	Can't asses Properly	An Overview or idea can be taken	An precise idea is found
Anatomical Angulation calculation	Angulation cant be measured properly	Can be measured, but due to multiplanar appearance, it becomes time taking	Can be measured and less time taking comparison to CT due to proper image acquisition
Detailed description	Shows 2D area of 3D object, so no detailed description in 3D plane extension	More detailed anatomic approach but time lengthening	More detailed anatomic approach can be assessed
Object localization with Position	Can't be localized properly	Can be localized in proper 3 plane angular orientation (Coronal, Sagittal and Axial plane)	More detailed Planar angulation for localization
Cost	Less	More for Multiplanar CT	More, but slightly less than Multiplanar CT
Patient compliance	Less	More	More
Technical Sensitivity	Less technique sensitive	More technique sensitive	More technique sensitive

TABLE no.1: Comparison between Conventional, CT scan and CBCT

FIGURES

Figure 1: assessment of Position of ID canal before implant placement

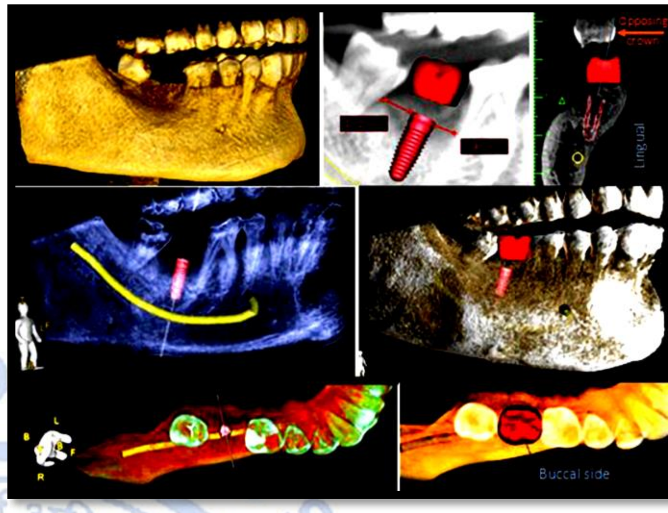

Figure 2: Pre-assessment of Implant Position by Cone Beam Computed Tomography (CBCT)

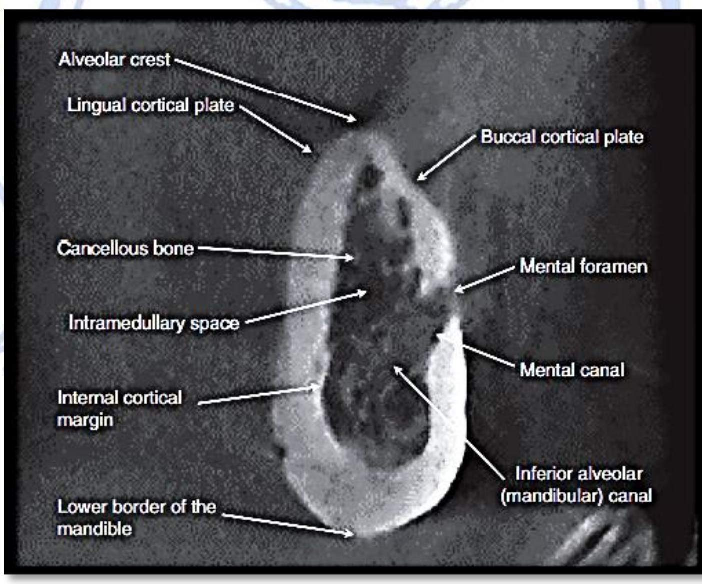

Figure 3: Anatomical Structure in Sliced CBCT section of mandibular body