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Imaging Techniques for Dental Implants: Review Article

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

In modern era, dental implant supported prosthesis is first choice of the many patients and clinicians. Before going to opt the dental implant for patient, assessment of bone is prime requisite of clinician. It requires extensive radiographic examinations. In these days, many imaging techniques are popular like periapical, panoramic, lateral cephalometric, tomographic radiography, interactive computed tomography, magnetic resonance imaging. In this review paper, various imaging techniques used for preoperative, operative and postoperative assessment of dental implant are discussed.

Keywords: Implants; dental; imaging; diagnostic.

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1. INTRODUCTION

In modern dental practice, dental implant is boon for edentulous patient. It not only restores form and function but also results good aesthetics. Patient accepts dental implant easily as they don't want to get their teeth prepared for crown or bridge or they don't have sufficient abutment teeth for fix dental prosthesis (FDP). According to glossary of prosthodontic terms implant can be defined as "any object or material, such as an alloplastic substance or other tissue, which is partially or completely inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes" [1]. Implant technology has enabled the dentist to help affected patients regain the ability to chew normally and function without embarrassment.

Various diagnostic imaging techniques can access the patient's oral health, bone type, available bone, and any asymptomatic pathology of bone or soft tissue. There are three stages for doing implant diagnostic imaging; 1) presurgical diagnosis and treatment planning, 2) surgical during implant placement, 3) postoperatively after implant placement to access the osseointegration and prosthetic restoration phase for longevity of the prosthesis (fixed or removable dental prosthesis). These imaging modalities are two dimensional or three dimensional [2,3]. In the past, success has been attributed to increasingly sophisticated imaging technology that has been applied to all phases of implant therapy [3].

This review paper is focused on various diagnostic imaging modalities used for presurgical, surgical and postsurgical treatment planning of dental implants.

2. IDEAL IMAGING MODALITY CHARACTERISTICS FOR IMPLANT

According to Pharoah MJ the ideal imaging modality should have: 1. Cross-sectional views for the visualization of the spatial relationship of internal structures, such as the inferior alveolar canal, and as a means of obtaining accurate dimensions in both the vertical and the horizontal planes. 2. Minimal image distortion to permit accurate measurements. 3. Depiction of the density of the cancellous bone and thickness of the cortical plates of bone. This is of value if initial stabilization of the implant is required. 4. Spatial relationship of the cross-sectional views of the mandible and maxillae to one another. 5. A simple means of identifying the exact location of each cross-sectional image to the implant site that can be provided at the time of surgical placement. 6. Ready availability and reasonable cost. 7. Patient radiation dose should be small as possible [3-7].

3. IMPORTANCE/ OBJECTIVES OF IMAGING FOR DENTAL IMPLANTS

3.1 Preprosthetic Phase (Phase I)

In this phase, diagnosis and treatment planning for the dental implant is done. Evaluation of patient's edentulous site, soft tissue condition, bone mineralization and bone type, available bone in edentulous area, number of dental implant required. For example, at maxillary posterior region if bone is less, sinus lift is advised to patient. Any running soft tissue or hard tissue pathology can be rule out. Dentist can give the better prognosis in terms of function and esthetics before starting the surgical phase to save him from legal issues [2,8].

3.2 Surgical Phase (Phase II)

Following things are evaluated in surgical phase; 1) implant surgical site at the time of surgery and after the surgery, 2) assessment of position and angulation of the implant. 3) Osseointegration and healing around implant 4) relation of implant abutment with the natural teeth and occlusion 5) temporary and definitive prosthesis design, 6) loading of temporary prosthesis [2,9].

3.3 Post surgical prosthetic Phase (Phase III)

This phase is started after implant loading with definitive prosthesis. Maintenance of dental implant and prosthesis comes under this phase. Patient is recalled in periodic visits. With the help of various post surgical imaging tools, implantologist evaluates, 1) crestal bone loss around implant, 2) peri-implant tissue and bone health, 3) any running pathology [2,9].

4. IMAGING TECHNIQUES IN IMPLANTOLOGY

The commonly used radiographic procedures with time intervals for treatment planning and assessment of dental implants are:- 1. Periapical radiography 2. Bitewing radiography 3. Cephalometeric radiography 4. Panaromic radiography 5. Conventional Tomography 6. Computed tomography 7. Interactive computed

tomography 8. Cone beam computed tomography 9. Magnetic resonance imaging.

4.1 Periapical Radiography

Periapical radiographs provide detailed information regarding the dimensions in length and height of available bone in small sections. They are indicated during treatment planning for single teeth implant, but are of limited value for more extensive edentulous sites. Paralleling technique should be used when obtaining periapical radiograph. Periapical radiography is useful in ruling out local bone or dental disease and identifying critical structures, but of limited value in depicting the spatial relationship between structure and proposed implant site and determining quantity and bone density because the image may be magnified or distorted and does not depict the third dimension of bone width. Periapical radiography is mostly used for single implant in regions of abundant bone width [4,5,10,11,12] (Figs. 1a and 1b).

4.2 Cephalometric Radiography:- (Lateral Cephalometric Projection)

Cephalometric radiography is accessory tool of implant imaging. This imaging modality is used to evaluate the dental implant site at anterior maxilla and mandible. Implantologist can check the ratio of compact to cancellous bone to get the quality of bone at anterior region of jaw. Bucco-lingual inclination of bone can be assessed for deciding the implant position and orientation in anterior region. With lateral cephalogram, soft tissue profile and skeletal jaw relationship between maxilla and mandible is also evaluated [13,14] (Figs. 2a, 2b).

Fig. 1a. Intra oral periapical radiograph of anterior teeth with root stump Irt 21, Fig. 1b: after immediate implant placement irt 21

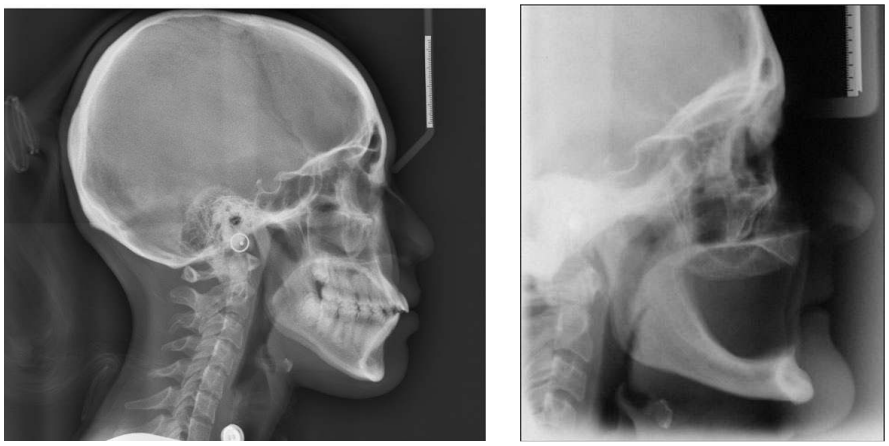

Fig. 2a and 2b. Lateral cepahlogram of dentulous and edentulous patients

With periapical radiograph, it gives the quantitative spatial information and shows the geometry of implant placement site and spatial relationship between implant placement region and critical structures like floor of nasal cavity, naso-palatine canal and the anterior recess of maxillary sinus [5].

4.3 Panoramic Radiography

Panoramic imaging is probably the most used diagnostic modality for implant dentistry (Fig. 3). However, for quantitative preprosthetic implant imaging, panoramic radiography is not the most diagnostic. Panoramic radiography initially can assess opposing landmarks and the vertical height of the bone [2,15].

Fig. 3. Panoramic image with implant in left maxillary central incisor region

Panoramic radiograph covers broad area of jaws and other important anatomic structures [16]. Some features make it different from other diagnostic modalities like magnification in the vertical plane is relatively stable but the magnification in the horizontal plane is much variable [3,13]. In Vertical plane, the efficient source of projection is focal spot on x-ray tube and in horizontal plane, it is rotational center of x-ray beam [17,18]. Panoramic imaging gives accurate angular measurements in compare to linear measurements [7,3,18].

Panoramic radiographs are generally useful to rule out gross pathoses within the jaws [7,18,19].

Various advantages of panoramic imaging includes; initial assessment of vertical bone height, economical in compare of computed tomography, less technique sensitive, less time taking, broad area of jaw is covered [15].

Limitations of panoramic imaging include; bone mineralization cannot be evaluated, quantitative bone analysis is not correct due to magnification (10%). Some Critical structures can be seen but little use in dimensional quantification of implant site [15].

4.4 Conventional Tomography (Body Section Radiography)

Conventional tomography is used as an adjunct to screening films, cross sectional tomograms enhances visualization of the available bone by providing reliable dimensional measurement at proposed implant sites, including the cross sectional (facio-lingual) dimension. Conventional tomography is a high quality complex motion tomography.

For conventional tomography, x-ray tube and film has to move in different types of motion; linear, circular, trispiral, elliptical and hypocycloidal. In compare to linear tomography, complex tomographic images are sharper [19,2]. Thickness of image layer in linear tomography is changes according to the angle of rotation of the x-ray tube. Smaller the angle of x-ray tube, thicker the image layer. As the path of movement increases, the image layer decreases [19,20]. In linear tomographic images, blurring of objects outside the focal plane occurs, which is called “streak artifacts.” Streak artifacts are not present in complex motion tomography [19,21,22]. Conventional tomography is useful for planning single implant sites or for those within a single quadrant [3,13,16].

4.5 Computed Tomography (CT)

Computed tomography is most commonly used imaging modality for implant planning. CT provides a unique means of post imaging analysis of proposed surgery or implant sites by reformatting the image data into any plane, such as axial, sagittal or coronal [23,24]. X-ray beam used in CT imaging is narrower and at the right angle to the long axis of Patient’s body [3,25,26] (Fig. 4).

CT images are useful in determining the buccolingual width of maxilla and mandible which is not possible with panoramic, intraoral and cephalometric views [13,27,28]. CT images are thin in section (1-2 mm). individual element of ct image is called voxel. Each voxel has value referred to in housefield units which describes the density of CT imge at this point. Housefield

unit is 0 for water. CT scanners are used to assess maxillomandibular region like bone quality, bone quantity, bone lesion, maxillofacial deformaties [15]. During dental implant planning, CT play mazor role as it gives the actual dimension of bone at the osteotomy site and also give correct picture of critical structures like nerves, maxillary sinus etc. CT provides reformatted image data to create tangential and crosssectional tomographic images at implant site [15] (Fig. 4).

Patient is scanned with a narrow x-ray beam which is right angle to the long axis of patient's body [3,25,26]. The contrasts of CT images are highly variable and depend on Quality of x-ray beam, the tissue density and characteristics of the detectors used to measure the transmitted energy [3].

It provides greater geometric precision CT allows reconstruction of cross sectional images of the entire maxilla or mandible or both from a single imaging procedure. Very high density material like metal bullets and dental restorations produce severe artifact on CT scan, which makes the interpretation difficult. Very thin contiguous or overlapping slices may result in a high dose of radiation [15,29,30].

4.6 Interactive Computed Tomography (ICT) and Implantology

In ICT, tomographic image taken by the radiologist is transferred to practitioner in form of computer file [15]. Various software are available for reformatted ICT, like SIM-Plant (Materialise Medical, Glen Burnie, Md.), dental scan plus, tooth pix (Cemax Inc., Fremont, Calif.). Implantologist can evaluate the bone quality, quantity, and density with ICT. Implant can be placed virtually at proposed site to check and confirm the accuracy and outcome of the treatment on computer screen. Practitioner can take inform consent and tell the prognosis of treatment to the patient with the ICT Software by showing on computer screen. This save time of both radiologist and practitioner [9,21,26,31,32].

4.7 Cone Beam Computed Tomography (CBCT)

CBCT is start of new era in the field of radiology. It saves the cost, reduces the radiation to the patient, increases the clarity (improves resolution) of image in comparison of dental CT. This technology yields images with isotropic submillimeter spatial resolution; as a result, its use is suited perfectly for dental and maxillofacial cases [32,33] (Fig. 5).

4.7.1 CBCT versus CT

CBCT equipment takes less area in clinic due to its smaller size and lighter weight, which is not possible with medical CT, so CBCT can be easily installed in dental clinics. CBCT equipment is less technique sensitive to operate and much economical than medical CT. No specific temperature is required to maintain the CBCT machine. In CBCT, image is made in sitting position rather than conventional lying position of medical CT. It is seen that patient is more comfortable with CBCT than medical CT as it eliminates the claustrophobic feel. CBCT imaging is more conservative in terms of radiation and the picture quality (high resolution) is much higher than medical CT [32,33,34,35].

4.7.2 Advantages of CBCT in implantlogy

Cost and effective radiation dose can be reduced. Anatomic structures such as the inferior alveolar nerve, maxillary sinus, mental foramen, and adjacent roots are easily visible using CBCT [25]. The CBCT image also allows for precise measurement of distance, area, and volume. Using these features, clinicians can feel confident in the treatment planning for sinus lifts, ridge augmentations, extractions, and implant placements. Before implant placement and during treatment planning, the implant clinician must be able to measure the height and width of the alveolar process to ensure adequate bone and to select appropriately sized implants [36,37,38,39].

4.7.3 Limitations of CBCT

In spite of several advantages, CBCT has some limitation like less soft tissue contrast, image noise and some artifacts (streaking, shading, rings and distortion) which reduces the diagnostic value of reformatted image in some extent for implant planning [40].

4.8 Magnetic Resonance Imaging (MRI)

MRI is accessory diagnostic imaging for implant planning as it does not estimate image quality mineralization and bone diseases. It is discovered by Lauterbur [14]. MRI is mandatory in certain cases where other diagnostic

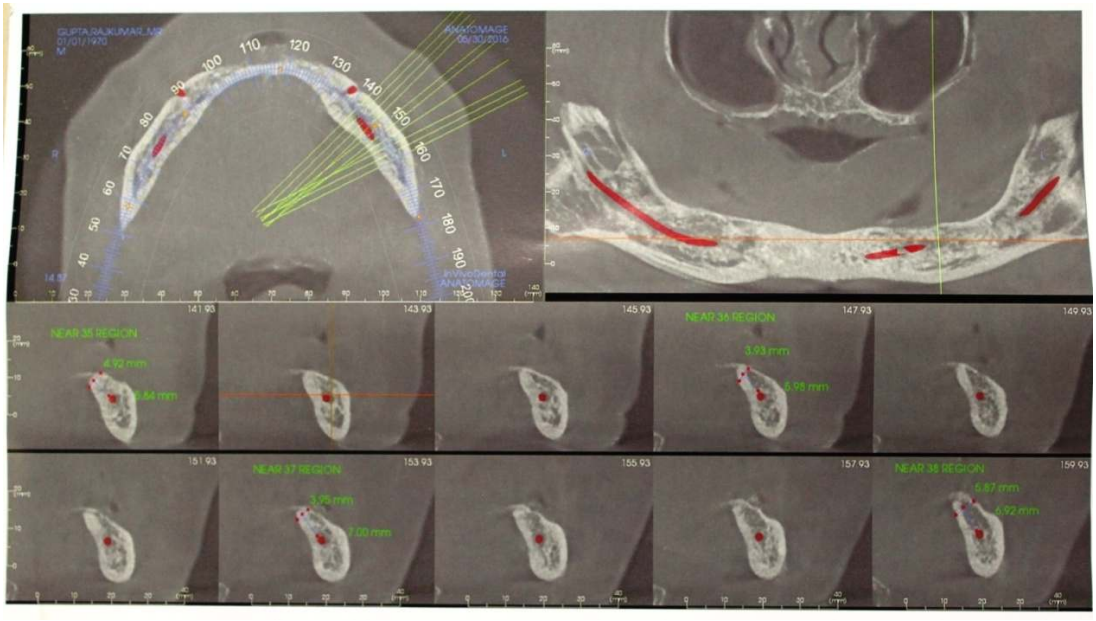

Fig. 4. CT SCAN Showing Reformatted Images, complete maxillary and mandibular region, slices and measurements of bone. Red dots and dark red line showing mandibular canal, nerve and foramina with measurement line

modalities like CT, CBCT fails to differentiate mandibular canal and neurovascular bundle to avoid injury during implant surgery. It is proved that feeromagnetic alloy and non precious feeromagnetic alloys (cobalt-chromium) produces image distortion due high magnetic susceptibility, while precious alloy like gold, silver, titanium are non ferromagnetic has no effect on MRI image. So MRI is not indicated for patients having feeromagnetic implants in their body. Advantage of MRI; it gives less radiation exposure to patient in compare to CT. It is proved that MRI images are not affected by implants of the Branemark system [41-45].

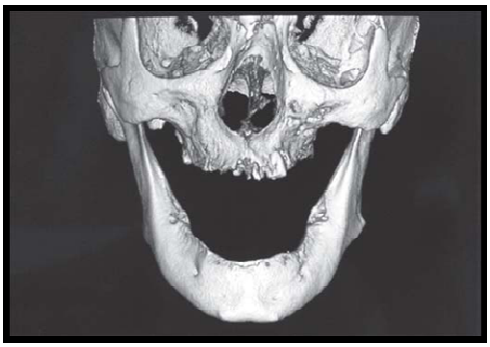

Fig. 5. A Cone Beam computerized image of entire maxillofacial region (Picture courtesy: Lingeshwar D et al. [2])

5. CONCLUSION

It is paramount important for a clinician to know the accurate anatomy of soft tissue and hard tissue of patient's maxillofacial structures before planning for the dental implant. There are so many diagnostic imaging modalities are available. Clinician should know the indication, application and limitation of each type of diagnostic imaging as to obtain greater information at the cost of low radiation to the patient. The evaluation of CT and CBCT changes the era of implant practice as these provide precise information of bone quality, bone quantity, maxillary sinus, inferior alveolar canal, mental foramen and adjacent root with low radiation.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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