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Original Research Paper Dental Science

EVIDENCE BASED APPROACH FOR IMPLANT IMAGING

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ABSTRACT Dental Implant is a device made of alloplastic (foreign) material implanted into the jaw bone beneath the mucosal layer to support a fixed or removable dental prosthesis, the use of which has increased dramatically over the last decade and is becoming the preferred choice of treatment. Dental radiology has played an exciting and critical diagnostic role in dentistry. In oral Implantology, success is highly dependent on proper diagnosis and pre-operative treatment planning. Radiography offers the singular method of (non-surgical) analysis of bone required for implant therapy. Thus radiology plays a vital role in providing information to the clinician so that a proper diagnosis and treatment modality could be planned out. This review has been done with the objective of evaluating various radiographic aids available for implant planning and implant placement.

KEYWORDS : dental implants, evidence based approach, imaging modalities

INTRODUCTION

Diagnostic imaging helps in developing an appropriate and precise treatment plan for implant patients. The selection of the type of imaging technique plays a significant role in achieving the required information with the best dimensional accuracy.[1] Successful placement of dental implants depends on meticulous treatment planning therefore it is important for a dentist to be able to place an implant in the oral cavity with a high degree of precision and accuracy.[2] Until the late 1980s, conventional radiographic techniques (intraoral radiographs, cephalometric and panoramic views) were accepted standards. Evolving from there, many developments in cross-sectional imaging techniques became increasingly popular in the preoperative assessment and planning of patients needing implants.[3] Thus the associated advantages and disadvantages are important to know. This article reviews different imaging modalities and its applications in the field of dental implants.

IMAGING OBJECTIVES

The type of the imaging modality to be used depends on the integration of the phases mentioned below: [4,5]

PHASE 1: Pre-prosthetic implant imaging

This phase is useful for diagnosis and treatment planning for the dental implant. Evaluation of patient's edentulous site, soft tissue condition, bone mineralization and bone type, available bone in edentulous area, number of dental implants is required. Also any soft tissue or hard tissue pathology can be ruled out.

PHASE 2: Surgical and intra-operative implant imaging

Following things are evaluated in surgical phase: Implant surgical site at the time of surgery and after the surgery, assessment of position and angulation of the implant, osseo-integration and healing around implant, relation of implant abutment with the natural teeth and occlusion, temporary and definitive prosthesis design, loading of temporary prosthesis.

PHASE 3: Post prosthetic implant imaging

This phase is started after implant loading with definitive prosthesis. Maintenance of dental implant and prosthesis comes under this phase. With the help of various post-surgical imaging tools, implantologist evaluates: Crestal bone loss around implant, peri-implant tissue and bone health, any pathology.

IMAGING MODALITIES

INTRAORAL RADIOGRAPHY:

- CONVENTIONAL PERIAPICAL RADIOGRAPHS: provide detailed information regarding regions of single implants during surgery to determine implant alignment and placement, status of adjacent teeth, the dimensions and height of available bone in small sections or dental disease. The advantages are: they are readily available, relatively inexpensive and have low radiation exposure. The disadvantages are: they are of limited value in depicting the spatial relationship between structure and proposed implant site and determining quantity and bone density. They are usually indicated during treatment planning for single teeth implant in regions of abundant bone width.[2,3,5]
- DIGITAL RADIOGRAPHY: Direct digital intraoral imaging allows rapid acquisition of intraoral images, their enhancement, their storage, retrieval, and transmission to remote sites. The disadvantage is that the size and thickness of the sensor and the position of the connecting cord makes positioning the sensor more difficult in sites, such as those adjacent to tori or the tapered arch form in the region of the canines.[6]
- ELECTRONIC OR CCD IMAGING TECHNIQUES: With charged couple devices (CCDs) presurgical implant assessment is precise. CCDs allow accurate measurement of implant sites preoperatively; provide more information about osseointegration postoperatively than with the film, also, the use of wire grids helps in site selection and bone height determination. Multiple images of a site allow 2/3-D reconstruction of the proposed site. It also enables viewing the information on a video monitor prior to placement.[6]
- **DIGITAL SUBTRACTION RADIOGRAPHY:**

Digital Subtraction Radiography is more accurate than periapical in depicting changes, such as bone volume and bone mineralization, as dark or light shades of grey. It also depicts buccal and lingual changes in the alveolar bone. This technique is however of limited use in clinical practice because of the difficulty in obtaining reproducible periapical. [1]

- **OCCLUSAL RADIOGRAPHY:**

Occlusal radiographs are useful in obtaining information regarding bucco-lingual width and contour for the edentulous mandible/maxilla. It is also applied at individual implant sites and mapping for multidirectional tomography. [6] The main disadvantage is that it records only the widest portion of mandible and little information is available regarding the width of the crest which is actually of chief interest to the operator and the degree of mineralization of trabecular bone cannot be determined from this projection.[3,7]

ORTHOPANTOMOGRAM (OPG):

- OPG is widely used in pre-implant evaluation and treatment protocols. OPG conveys adequate information, less radiation exposure and cost. Panoramic radiography is curved plane tomographic radiograph that is used to depict the body of mandible, maxilla, lower half of maxillary sinus, inferior alveolar nerve and nasal fossa. OPG has following advantages: vertical height of the bone initially assessed, useful in making preliminary estimations of crestal alveolar bone and cortical

boundaries, ease, convenience and speed of the procedure, gross anatomy of jaws and related pathologic findings can be evaluated.[8] Limitations of OPG are: bone mineralization cannot be evaluated, lesser resolution than peri-apical or digital peri-apical radiography, quantitative bone analysis is not correct due to magnification and additional set up is required [3,5]

- ZONOGRAPHY (LIMITED ANGLE LINEAR TOMOGRAPHY): Zonography is a modification of the panoramic X-ray machine. It generates a cross-sectional image of the jaws. The tomographic layer is comparatively thick. The advantage of Zonography is that it allows appreciation of spatial relationship between the critical structures and the implant site. The disadvantages are: blurred adjacent structures superimposed on the image, and inability to identify the differences in bone densities or presence of disease pathology at the implant site.[3,9]

CEPHELOMETRIC RADIOGRAPHY:

- Cephalometric Radiographs provide pertinent information that includes angulation, thickness and vertical bone height, the midline; inter jaw skeletal relationships and the soft tissue profile. The advantages are low cost, easy acquisition and ready availability. The disadvantage is that the cross-sectional anatomic information is limited to the midline of the maxilla and mandible. [10]

CONVENTIONAL TOMOGRAPHY (BODY SECTION RADIOGRAPHY):

- Conventional Tomography is a cross-sectional imaging which is designed to obtain clear images of structures lying within a plane of interest.[8] Advantages include: uniform magnification, cross-sectional views available at any location and reproducible imaging geometry when used with cephalostat, moderate expense. The disadvantages are: limited availability, more time needed to produce the images than with the standard panoramic radiography and significant experience and training needed to interpret. It is used with single tooth or several teeth implant within limited area. [10]

COMPUTERIZED TOMOGRAPHY (CT):

- It is a 3 dimensional (3D) radiograph that reproduces the anatomy with sub-millimetric accuracy which helps to reveal multiple views of implant site; which are axial, reconstructed panoramic and cross-sectional views of the jaws.[4] Adequate information about the residual ridge is provided by the coronal sections. The advantages of CT are: Uniform magnification, high contrast image, easier identification of bone grafts or hydroxyapatite materials used to augment maxillary bone in the sinus region than with conventional tomography, simultaneous study of multiple implant sites and availability of software image analysis. The disadvantages are: expensive, limited availability of reconstruction software, higher doses of radiation compared to conventional tomography and Cone Beam Computed Tomography, lack of usefulness for implant-interface follow up because of metallic streak artifacts[10] Recent advances in CT are microtomograph and multi slice helical CT. [8]

- DENTA SCAN IMAGING [3]: Denta-Scan is a unique computer software program which provides computed tomographic imaging of the mandible and maxilla in three planes of reference: axial, panoramic, and cross-sectional. It is applied in both, single as well as multiple implants, ridge augmentation and edentulous ridge. Its advantages are: Bone height and width can be obtained, identification of soft and hard tissue pathology, anatomical structures can be located, measuring vital quantitative dimensions necessary for implant placement. Its disadvantages are: Radiation exposure and expensive.

1) INTERACTIVE COMPUTED TOMOGRAPHY (ICT): ICT allows the transfer of images to the clinician as a computer file. It also helps the clinician measure the length and the width of the alveolus and also bone quality. An important feature of ICT is that the clinician and radiologist can together perform "electronic surgery". [9]

2) TRANSTOMOGRAPHY OR SECTIONAL TOMOGRAPHY: Welander et al (2004) described that direct digital transtomographic images could be obtained by combining the translational movement with the pendular movement of the beam and detector in advanced panoramic machines. Its advantage is: immediate results can be obtained using a computer program intra-operatively (especially during blind surgical procedures) and measurements can be taken on the screen. This is achieved by positioning the patient using an individualized silicon key which enables a limited distortion of the images compared to conventional tomographs and CT.[1, 7]

TURNED APERTURE COMPUTED TOMOGRAPHY (TACT):

- TACT is a new, promising and alternative method to film-based tomography and CT for dento-alveolar imaging based on optical aperture theory. TACT can map the incrementally collected data into a single three-dimensional matrix and also isolates the images of desired structures limited to certain depths. It has the ability to accommodate patient's motion between exposures. It has considerable flexibility to adjust contrast and resolution. [10,6]

CONE BEAM COMPUTED TOMOGRAPHY (CBCT):

- CBCT scanners are specifically designed for diagnosis and treatment planning in implant therapy. [7] CBCT scanners are based on volumetric tomography, using a 2D extended digital array providing an area detector which is combined with a 3D X-ray beam that generates 3D volumetric data set, which can be used to provide primary reconstruction images in three orthogonal planes (axial, sagittal and coronal). CBCT scan is useful in achieving the ideal placement of the prosthetics, occlusion and associated supporting implants. For each implant site, it can: Determine bone height and width, bone quality with comparative density analysis in three long axis of the alveolar bone, jaw boundaries, able to identify and localize internal anatomies, such as nerves and sinus cavities, pathology in 3D scale and scope, transfer of radiographic planning information, communicate radiographic diagnostic and planning information, multiple pictures of the region of interest are generated in a single scan which enables the dentist to perform minimally invasive surgery without raising a flap, thereby reducing surgery time, postoperative pain and swelling, and faster recovery is achieved.[2,10,9] Its advantages are: High resolution, low radiation dose, less disturbance from metal artifacts, reduced cost, easy accessibility and handling. Its disadvantages are: Low contrast range, limited detector size which causes limited field of view and limited scanned volume and limited inner soft tissue formation.

MAGNETIC RESONANCE IMAGING (MRI):

- The phenomenon used in MRI is of nuclear magnetic resonance (NMRI). MRI is used as a secondary imaging technique when primary imaging techniques like CT, CBCT fails. MRI visualizes the fat in trabecular bone and differentiates the inferior alveolar canal and neurovascular bundle from the adjacent trabecular bone. Oriented MRI imaging of the posterior mandible is dimensionally quantitative and enables spatial differentiation between critical structures and the proposed implant site. Advantages are: it gives less radiation exposure to patient compared to CT. MRI is not indicated for patients having ferromagnetic implants in their body. [6,5]

There have been many research studies on implant imaging. They are mentioned in the table below: TABLE 1

TABLE 1: Evidence based research studies on implant imaging

AUTHOR AND YEAR	TYPE OF EVIDENCE	DETAILS OF STUDY
Almog D M et al. 2006 [15]	Case Report	Systematic approach with CT-based Dental imaging for implant planning and surgical guidance was assessed on a case of 51 years old white female for single implant supported crown in maxillary second premolar region. The outcomes were assessed and it states that by incorporating the restorative planning during the pre-operative assessment of the implant site by using a radiographic template with a radio-opaque indicator in conjunction with a CT-based imaging system increased the success of implant.
Kullman L et al. 2007 [12]	Retrospective study	Panoramic and Intraoral radiographic methods for assessment of per-implant marginal bone were compared (in 10 patients), also an additional comparison of Intra-observer (Oral and Maxillofacial Radiologist) and Inter-observer (Oral and Maxillofacial Surgeon) was made for the assessment of bone level. There were no significant difference in the two radiographic methods but Intra-observer was more successful in assessing bone level.
Pedroso L A M et al. 2014 [13]	Cohort study	The impact of CBCT in assessment of implant planning and on prediction of implant size was investigated. Initial assessment was done on clinical examination and Panoramic radiography (PAN), final assessment was done on CBCT on 95 implants of 27 patients. The study concluded that CBCT improves the ability of predicting the actual implant length ($p<0.001$) and reduces inaccuracy in surgical implant treatment planning.
Bahlis A et al. 2010 [14]	In vitro study	The accuracy for bone height estimation at mental foramen area was determined for Periapical, Panoramic and CBCT radiographic methods on 20 dry human hemi-mandibles. The study concluded that Periapical and CBCT showed the best accuracy, Panoramic radiography showed greatest difference in radiographic measurement and actual jaw measurement.
Ramakrishnan P et al. 2014 [17]	Epidemiological study	A survey on radiographic prescriptions practices in dental implant assessments among dentists in Kerala, India was made comparing OPG, IOPA and CT techniques. 300 dentists were interviewed employing a questionnaire. The results stated that OPG was the most prescribed imaging modality for dental implants followed by combination of OPG with IOPA. Many of them were unaware of the recommendations regarding cross-sectional imaging.
Akcicek G et al. 2012 [18]	Cohort study	3 different imaging modalities were compared in pairs for the evaluation of proximity between molars and mandibular canal. They were periapical and intraoral phosphor plate (intraoral PSP), periapical and panoramic phosphor plate (panoramic PSP), and intraoral PSP and panoramic PSP. The results showed agreement levels of 99%, 91% and 91% respectively ($p=0.234$). The study concluded that all the 3 imaging modalities can be used interchangeably to evaluate the proximity of molars and mandibular canal.
Bornstein M M et al. 2014 [19]	Systematic review	The aim of this systematic review is to evaluate the evidence on the guidelines, indications and contraindications, and associated radiation dose risk of CBCT in dental implant. It states that the indications for the use of CBCT vary from preoperative analysis to postoperative evaluation. Moreover it is stated that it will be difficult to prove the clear and statistically significant benefit of CBCT over conventional imaging modalities. It is also mentioned that practitioners who prescribe CBCT should prescribe specific CBCT equipment protocols for more effective use.
Peker I et al.2008 [20]	In vitro study	The study was to investigate the use of 3 imaging modalities namely panoramic, conventional tomography and computerized tomography. 6 dry adult human skulls were used in the study. The outcome suggested that the measurements obtained from computerized tomographic images were more consistent with direct measurement than the measurements obtained from panoramic radiography or conventional tomographic images.
Singh K P et al. 2015 [21]	Epidemiological study	The study compared conventional radiography (IOPA) and digital radiography (RVG) using bitewing technique in detecting the depth of alveolar bone loss. The study was carried out on 40 males and 10 females (aged 20-65). The conclusion was that digital radiographs showed better results when compared to conventional radiographs in terms of alveolar bone loss as RVG has superior image recording capabilities.

CONCLUSION:

This article reviews various imaging modalities and mentions research studies comparing imaging modalities for implant treatment. The studies included in this review are from January 2007 to July 2017 comprising of systematic review, randomized control trial, cohort study, case control, epidemiological study and an animal study. The results of the studies showed that CBCT and CT were proved to be a better imaging modality for implant and they improve the ability of predicting the actual implant length and reduces inaccuracy in surgical implant treatment planning. The selection should be made considering type and number of implants, location and surrounding anatomy. The selection criteria for the type of imaging modality must be applied individually for each patient.

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