REVIEW ARTICLE

IMAGING MODALITIES OF MAXILLOFACIAL IMPLANTS: A REVIEW

Prasanna H. R[1], A. Rajesh[2], Sadananda M. P[3], H. J. Jayakrishna[4]

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ABSTRACT: A Dental implant is a device (usually root shaped) precisely placed in the jaws to provide support for or retention of a dental restoration, fixed bridge or removable partial denture. There are several excellent type of imaging modalities that exist today can enhance the success of implant placement. Selection of projections should be made with consideration to the type and number of implants, location and surrounding anatomy individual to each patient.
KEYWORDS: Implants, Osteointegration imaging cancer cells.

INTRODUCTION: HISTORY OF IMPLANTS: Archeological findings showed that the ancient Egyptian and South American civilizations already experimented with re-implanting lost teeth with hand-shaped ivory or wood substitutes. In the 18th century lost teeth were sometimes replaced with extracted teeth of other human donors. In 1809, Maggiolo fabricated a gold implant which was placed into fresh extraction sockets to which he attached a tooth after a certain healing period. In 1887, a physician named Harris attempted the same procedure with a platinum post, instead of a gold post. In 1886 Edmunds was the first in the US to implant a platinum disc into the jawbone, to which a porcelain crown was fixated. Strock placed the first somewhat successful oral implants of Vitallium in 1937 at Harvard University[1].

AIMS AND OBJECTIVES: This study Envisage to make use of recent excellent imaging modalities exists today to enhance the maximum success of implant placement.

TYPES OF DENTAL IMPLANT SYSTEMS:

Subperiosteal implants

Transosseous Implants

Endosseous Implants Osseointegrated root-form implants:

CONCEPT OF OSSEOINTEGRATION: P. I. Branemark defined osseointegration as a direct connection between living bone and a load carrying endosseous implant at the light microscope level.

In 1952, the Laboratory of Vital Microscopy at the University of Lund, Sweden, a Swedish research team headed by Per Ingvar Branemark, an Orthopedic Surgeon who was conducting studies on the microscopic healing events in bone was experimenting Titanium metal cylinder, screwed into a rabbit's thighbone. After the experiment, they realized that the titanium cylinder had fused to the bone. This phenomenon was named Osseointegration[2] depends on,

1. Implant design.
2. Force distribution.
3. Implant surface characteristics.
4. Micromotion.

Factors Affecting Dental Implant Selection: Since an array of local and systemic factors can influence the choice of and prognosis of the implant supported prosthesis, it becomes mandatory to carry out investigations including imaging to qualitatively and quantitatively assess the bone bed.[2]

Local factors	**Systemic Factors**:
• Condition & position of remaining natural teeth. • Occlusion. • Status of periodontal tissues. • Oral hygiene. • Condition - quality and quantity of remaining natural bone. Condition of oral soft tissues.	• Patient Age. • Osteoporosis. • Diabetes Mellitus. • Radiation. • Corticosteroid Therapy. • Habits – Smoking, parafunction. • Addictions. • Oral Burn Syndrome – deleterious effects to soft tissues around implants after consumption of hot foods (Cullen). • Genetics and the Immune System. • Cluster Phenomenon – Individually each factor poses less risk but collectively detrimental.

Imaging Modalities for Implant assessment: No single radiographic procedure provides ideal images for all of the steps in the implant planning process. Today more than ever a plethora of imaging modalities is available for the dentist who is contemplating implants for his patient.[3]

Radiography	Imaging
• Periapical Radiographs - Conventional & digital. • Occlusal. • Panoramic Radiographs. • Lateral Cephalogram. • Digital subtraction radiography. • Cross sectional Linear Tomography.	• CT. • Multiplanar CT. • TACT. • MRI. • Imaging for implant placement - CT guided.

Need for Imaging Evaluation for Implants?

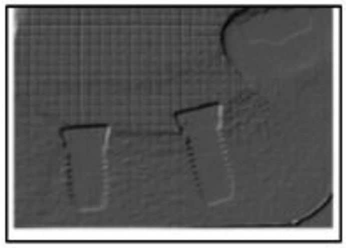
Pre-Operative	Post-operative
To determine • Position & size of relevant normal anatomical structures. • Shape & size of Antra. • Presence of underlying bone disease. • Presence of retained roots or buried teeth. • Quantity of alveolar crest/ basal bone allowing direct measurements of the Ht, width, shape. • Quality/ density of the bone. • Amount of cortical bone left. • Density of cancellous bone. • Size of trabecular spaces.	**To determine** • Position of the fixture in the bone & its relation to the nearby anatomic structures. • Healing & integration of the fixture in the bone. • Peri implant bone level & any subsequent vertical bone loss. • Development of any assoc disease – Peri implantitis. • Fit of abutment to fixture. • Fit of abutment to crown/prosthesis. • Possible fracture of implant prosthesis. • Monitoring of implants.

PLAIN FILM RADIOGRAPHY:
Intra Oral Periapical radiography

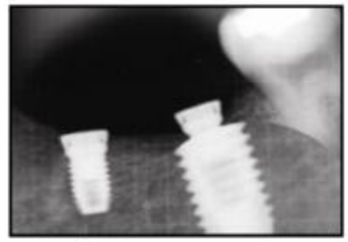
Benefits	Pitfalls
• Bone Architecture • Bone Quality • Mesio distal bone width and Vertical bone height • Amount of trabecular and cortical bone present	• Two dimensional picture only • Bucco lingual Bone width not assessed • Bone height • Anatomic limitations • Geometric limitations

Digital Radiography: Uses digital sensors like CCD, phosphor plates for image capture allowing manipulation with computer software for enhanced visualization of details.

Video Inversion



Emboss tool

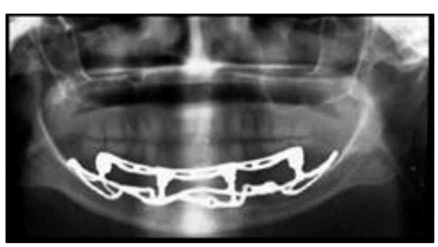


Zoom tool

Benefits	Pitfalls
• Faster image capture. • Minimal Radiation dose. • Image Manipulation ability. • Convenience of NO Processing. • Long term image archiving.	• Resolution comparable to conventional. • Sensor Size is limited. • Sterilization concerns. • Expensive.
Lateral Cephalograms	**Occlusal radiographs**
Benefits • Provide 1:1 image of the relation of maxilla to mandible and skull base. • Known magnification 7% - 12% • Axial inclination and dento alveolar relation at the midline assessed. • Cross section of midline visualized.	**Pitfalls** • Maxillary projections are oblique - hence distorted. • Shows the widest width of bone then bone width at the crest. • Degree of mineralization, trabecular pattern not appreciable.

Panoramic Radiography: Uses conventional tomographic techniques to create an over view of the patient's maxillary & mandibular dentition.

Benefits	Pitfalls
• Screening. • Opposing landmarks easily identified. • Initial vertical bone height measurement.	• Poor Resolution and Sharpness. • Distortion. • Vertical plane and Horizontal plane magnification.



Panoramic Radiography

Tomography:

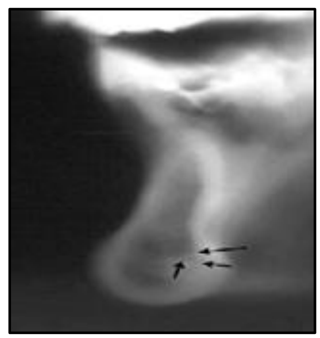
Conventional tomography: The x-ray source and image receptor move simultaneously in a controlled way resulting in blurring of structures outside the desired image layer. Different types of motion of the x-ray tube and the film are employed - Linear (the simplest), circular, trispiral, elliptical and hypocycloidal.

Blurring of objects outside the focal plane, producing streak artifacts being the pitfall.

Complex motion tomography/Multidirectional tomography: Tube and cassette motion is controlled by a computer, and is also called computer assisted tomography.

Benefits	Pitfalls
• Relatively sharp. • Bone width bucco- lingually assessed. • Bone Height – measurements from Alveolar crest. • NO superimposition. • Fixed uniform image magnification caused by metallic dental restorations and amalgam.	• Poor contrast - in thin slices.

Conventional tomography



Complex motion tomography

IMAGING:

Computed Tomography: Introduced in the mid 1970's CT scanners produce digital data measuring the extent of x-ray transmission through an object and the information may be transformed into a density scale and used to generate or reconstruct a visual image. Axial and coronal CT images were only marginally helpful because of streak artifacts.[4,5]

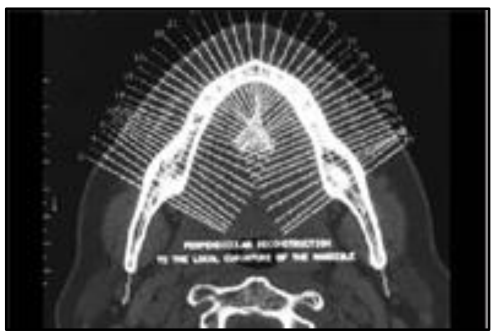
Benefits	Pitfalls
• Gold Standard. • Very high image quality - contrast & spatial resolution. • No blurring. • Free from magnification & distortion. • Quantitative assessment of bone density. • Ideal for multiple implant sites.	• High radiation dose. • Artifacts. • Expensive.

Bone	CT Hounsefield Units
D1 – Dense Cortical	> 1250 HU
D2- Porous Cortical	850 – 1250 HU
D3 – Coarse Trabecular	350 – 850 HU
D4 – Fine Trabecular	150 – 350 HU
D5 – Immature non mineralized	< 150 HU

Misch Bone Density Classification[6]

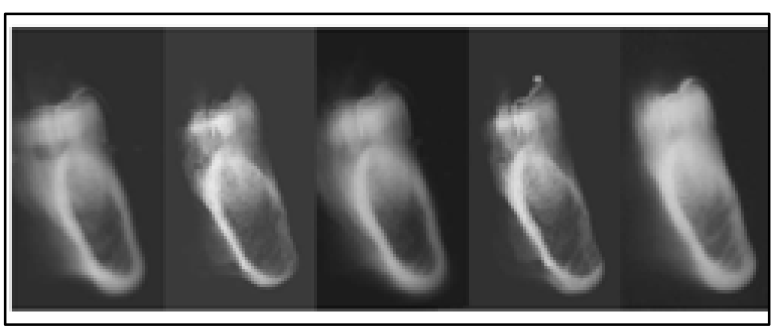
Reformatted/Multiplanar CT: To avoid the above problems with plain CT, in the 1980's specialist software was developed to produce virtual panoramic and cross-sectional images by reprocessing or "reformatting" axial CT slices.

Much of this software is based on the original Denta Scan program which is a computed tomography (CT) software program that allows the mandible and maxilla to be imaged in three planes: axial, panoramic and cross-sectional.



Reformatted/Multiplanar CT

Tuned Aperture Computed Tomography: An alternative to both conventional tomography and CT for dental implant imaging, tuned aperture computed tomography TACT is a new and promising imaging modality based on the principles of digital tomosynthesis. Tomosynthesis is a radiographic technique used to generate an image of a slice or a plane through an object. Multiple images of the objects are made from different angles. These images are superimposed to produce a tomosynthetic reconstruction of the desired plane.



Tuned Aperture Computed Tomography

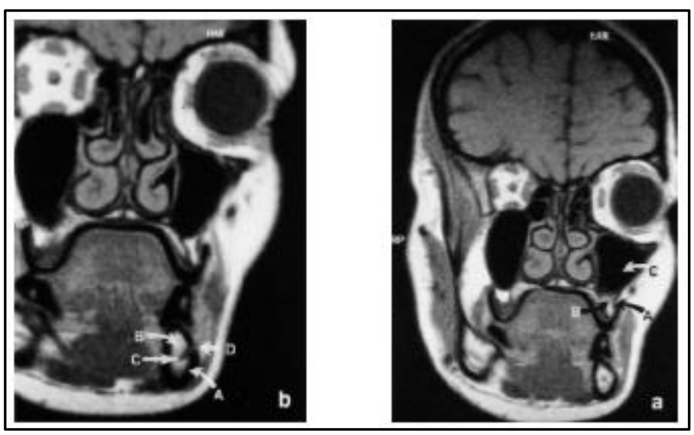
Radiation Dose: CT delivers a relatively large dose of ionizing radiation. It is important to maximize the diagnostic yield while simultaneously limiting the field of view to the region of interest.

Effective dose of;

- 10μSv is attained from a single periapical film exposure;
- 26μSv from a panoramic projection;
- 150μSv from a full-mouth survey;
- 61μSv from the CT of the mandible;
- 104μSv from the CT of the maxilla.
- Effective dose per slice when using the Scanora linear tomography system (Orion, Helsinki, Finland) to be in the range of 1–30 μSv[7];

Magnetic Resonance Imaging: Uses electrical and magnetic radiofrequency pulses rather than ionizing radiation to produce an image. Operate at 0.5-1.5 Tesla (1T = 20,000 Earth's Mag Field).Images of choice are T1 wt images with Gadolinium as Contrast in radiographic guides.

Benefits	Pitfalls
• Non Ionizing. • Lesser artifacts. • In Autologous bone grafts can differentiate regions of bone healing.	• Expense. • Availability. • Definition of bone inferior to CT.

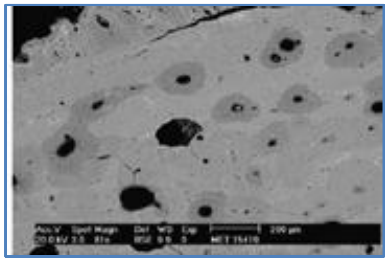


Magnetic Resonance Imaging

ADVANCES IN RESEARCH:

I. Evaluation of Osseointegration using Advanced Imaging:

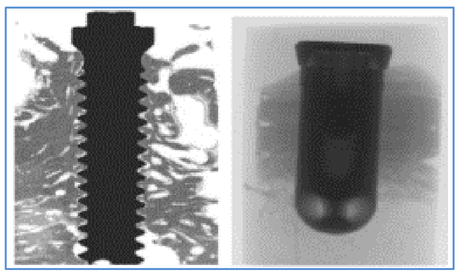
Back scattered Emission Technology: BSE is a method for assessing bone mineral content. The specimen's surface is bombarded with electrons, many of which are scattered back from the specimen. These backscattered electrons are collected by digital sensors that measure voltage and thus create a 0 to 256 gray level mage.



Back scattered Emission Technology

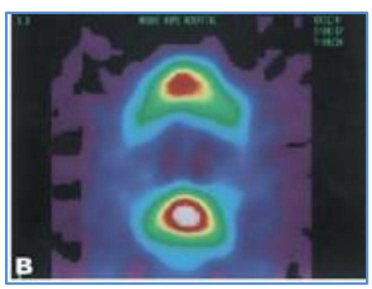
Micro CT and Micro Radiography: Modified radiography of sections of the implant with adjacent bone with decreased exposure factors allows for assessment of bone formation around the implant is Micro radiography.

Micro-computed tomography is introduced as the probable successor to routine histological sectioning and microradiography for assessing bone modeling and remodeling activity in mineralized tissues.



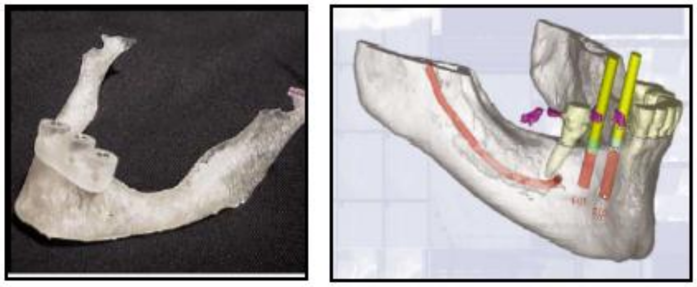
Micro CT and Micro Radiography

Scintigraphic Methods SPECT: Bone scintigraphy is a well-established imaging technique that accurately reflects osteoblastic activity Evaluation of bone metabolism in the peri-implant zones, provides anatomic images and functional dynamics information on the osteointegration process.



Scintigraphic Methods SPECT

II. **Advances in Real time Imaging during Implant Placement:** Materialize NV of Leuven, Belgium, pioneered the automatic fabrication (in acrylic) of exact replicas of the patient's maxilla or mandible complete with templates or "drill guides" to assist with the actual drilling at the time of surgery. It also produces an interactive 3-D representation of the patient's bone structure.[8]



Stereolithography

It is one of several Rapid Prototyping (RP) techniques whereby a physical model can automatically be fabricated from computer data.

Surgical Drill Template Using CT: Enables surgeon to view the precise underlying anatomic structures and to plan the implant placement taking these into account. With the CT derived densities (Hounsefield values) the surgeon can orient the implants towards the denser bone.[8]

Surgical Drill Template Using CT

Real Time Imaging with Optical Sensors: The system guides the surgeon "on-line" on the CT-scan image into the appropriate implant position, according to the treatment.

Real Time Imaging with Optical Sensors

CONCLUSION: The excellent imaging modalities that exist today can enhance the success of implant placement. Selection of projections should be made with consideration to the type and number of implants, location and surrounding anatomy individual to each patient. A feasible imaging protocol which could be practiced for various indications for osseointegrated prosthesis could be as follows.

IMAGING PROTOCOL?

SITE	Screening	Acceptable	Accurate	Not of optimal use
Single anterior	IOPA	IOPA+TSS	IOPA+CT	Panoramic
Multiple anterior	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)
Single posterior	IOPA	IOPA+TSS	IOPA+CT	Panoramic
Multiple posterior	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)
Entire mandible (less than 6 sites)	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)
Entire mandible (more than 6 sites)	Panoramic	-	Panoramic+CT	TSS IOPA (only used in areas of suspected residual pathology)

Mandible[9]

SITE	Screening	Acceptable	Accurate	Not of optimal use
Single anterior	IOPA	IOPA+TSS	IOPA+CT	Panoramic
Multiple anterior	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)
Single posterior	IOPA	IOPA+TSS	IOPA+CT	Panoramic
Multiple posterior	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)
Entire mandible (less than 6 sites)	Panoramic	Panoramic+ TSS	Panoramic+CT	IOPA (only used in areas of suspected residual pathology)

Maxilla

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AUTHORS:

1. Prasanna H. R.
2. A. Rajesh
3. Sadananda M. P.
4. H. J. Jayakrishna

PARTICULARS OF CONTRIBUTORS:

1. Professor, Department of Periodontics, KGF Dental College.
2. Reader, Department of Periodontics, KGF Dental College.
3. Senior Resident, Department of Periodontics, KGF Dental College.
4. Professor, Department of Periodontics, Shyamala Reddy Dental College.

NAME ADDRESS EMAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Prasanna H. R,
Suraksha Dental Clinic,
Opp. Bhaskar Clinic,
Shankarmatt Road, 1st Cross,
K. R. Puram, Hassan-573201.
E-mail: drprasannahr@gmail.com

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