Imaging Techniques in Periodontics: A Review Article
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ABSTRACT
For many years radiograph have been a valuable aid in the diagnosis of periodontal disease and evaluation of treatment effects. Computer based image acquisition and processing technique now increase the importance of radiography in periodontal diagnosis. Radiographs can provide critical information for diagnosis and treatment planning and can also serve as baseline information for the assessment of treatment outcomes. Traditional radiographic aids are inadequate for determining the sites showing active tissue destruction & monitoring the response to therapy, as well as to measure susceptibility to future periodontal breakdown. Various modalities have been evolved to overcome these limitations, graphic diagnostic techniques used in periodontics.

1. Introduction
Diagnostic testing has been a great challenge in Periodontology. It is primarily derived from information obtained from the patient’s medical and dental histories combined with findings from thorough oral examination. The entire constellation of signs and symptoms associated with disease and the additional information provided by radiographic imaging and laboratory tests is taken into consideration before arriving a diagnosis (1). Radiographs are broadly classified as intraoral and extraoral (Fig: 1).

Traditional radiographic-aids are inadequate for determining the sites showing active tissue destruction & monitoring the response to therapy, as well as to measure susceptibility to future periodontal breakdown. The use of radiographs as a diagnostic tool has become an indispensable routine in dentistry. With the electronic era, more specialized equipments are introduced into different phases of the imaging procedures (1).

2. Discussion:
2.1. Conventional Radiographs:
A conventional radiographic image consists of the arrangement of silver grains in the photographic emulsion. The density of the silver grains depends on the intensity of the X-Ray beam. When a radiograph is viewed on a light box using transmitted light, the pattern of the different densities of the silver grains is transferred to the eyes and perceived as different shades of gray (2).

It is the traditional method to assess the destruction of alveolar bone associated with periodontitis. It can be used to evaluate bone loss even or angular patterns I-intra(infra)bone defects, root morphologies / topographies, Furcation radiolucencies, endodontic lesions, endodontic misshapes, developmental anomalies and root length and shape remaining in bone.

2.2. Intra oral periodical radiographs
Two common techniques used to take conventional radiographs are Paralleling and Bisecting angle techniques. X-ray film is placed parallel to the long axis of tooth and central ray of x-ray beam is directed at right angle to teeth and film in paralleling and central ray is directed at right angles to a plane bisecting the angle between long axis of teeth and film in bisecting techniques (3).

2.3. Advantages of intraoral periapical radiographs:
Gives assessment of periodontal status and apical infection, teeth and alveolar bone condition after trauma, unerupted teeth and detailed evaluation of apical cysts and other lesions in the alveolar bone.
2.4. Bitewing radiographs

Records the coronal part of upper & lower dentition along with periodontium. It is used to study the height and contour of interdental alveolar bone, interproximal calculus and caries, periodontal changes, gingival margins of approximal fillings. There are two common types one is horizontal and the other is vertical. Horizontal bitewing radiographs are useful for proximal caries detection. But it has limited use in periodontal treatment and treatment planning if bone loss is advanced. In vertical bitewing radiographs the film is placed with its long axis at 90° to the placement for horizontal bitewing radiography and is helpful in evaluating periodontium. (4)

2.5. Occlusal radiographs

It enables viewing of a relatively large segment of dental arch. This type of radiographs are taken in patients with trismus, impacted canines and third molars. It is also used to localize foreign bodies in the jaws, determining the extent of diseases like cysts and to measure the changes in size and shape of the mandible.

2.6. Extraoral radiographs

Chen et al in 2007 developed a sensor beam alignment aiming device for performing radiographs using this technique. Extra-oral radiographs are taken when large areas of the skull or jaw must be examined when patients are unable to open their mouths for film placement. It is not adequate for detection of early stages of dental caries or periodontal disease.

2.7. Conventional panoramic imaging (pantamography)

Oral pantomography is used as substitute for full mouth IOPA. It can be used in follow-up treatment, progress of pathology, postoperative bony healing and prior to any surgical procedures (extraction of impacted teeth, enucleation of cyst) (5). It is also used to view of the alveolar bone levels and evaluation of vertical height of alveolar bone before inserting osseo–integrated implants (Fig.2).

2.8. Advantages of pantamography

It has got a low exposure dose compared to full mouth IOPA. Broad anatomic region is imaged by this study. Anatomical structures are most identifiable and proper orientation of adjacent structures and generalised bone loss can be detected.

2.9. Limitations of OPG

OGP has got limitations of image distortion, lingual structures projection higher than buccal surfaces. Use of screen film combination results in less details than introral images. Overlapping of teeth and artifacts misinterpretation are its limitations.
2.10. Advanced radiographic techniques

Advances in basic periodontal research have transformed our understanding of almost all species of the periodontal disease process. These developments have translated into meaningful clinical applications improving the way we prevent, diagnosis and treat periodontal disease. In comparison the impact of radiographic imaging on the management of the periodontal has essentially remained unchanged for decades.(6)

Substantial advances in X-ray generator and X-ray technology have resulted in significant dose reduction and improved image quality. However, the basic information content of oral radiographic images has changed very little. Relatively few new technologies have emerged to address the critical needs in periodontal diagnosis. Digital imaging has been hailed as a panacea for many of the limitations associated with traditional film based radiography. However most of these limitations are associated with X-ray transmission and image interpretation and not with the choice of image receptor.

2.11. Radiovisiography (RVG)

The RVG system is capable of rapidly displaying a digital radiographic image on a monitor which results in a lower patient radiation. The "Radio" component is the conventional x-ray generator with a timer, capable of very short exposure time, along with image receptor. The "Visio" portion converts the output signal from a CCD to a digital format and displays it on a monitor. The "Graphy" component consists of data storage unit connected to a video printer.(7)

Duret F et al (1988) described RVG based on use of CCD. A filmless environment allows rapid image acquisition, less expensive storage, multiple viewing, and remote exchange of images. Development of a filmless environment also facilitates the teaching and research responsibilities incumbent in an academic environment.

Electronic teaching files, electronic conferences, teleconsultation, and other communication processes are enabled with the availability of electronic images. It can be used in dental caries detection, intra bony defects and periapical pathologies detection (8).  

2.12. Digital Image

The electric signal that is produced by the sensor is a voltage that is varying as a function of time. The sensor is connected to a special board in the computer, called a frame grabber; the function of this board is to sample the signal at short intervals, thus converting the analog signal into a digital signal. The output of the measurements is stored in the computer as numbers(9). When the image is captured and digitized by means of an electronic sensor system, the radiation intensities are measured along a rectangular two-dimensional grid of sensor elements, called pixels. The outcome of the measurement of each sensor elements transferred to the computer and stored as a number between 0 and 255. To display the image, the numbers are read out and used to control the intensities of the pixels on the monitor screen. Several methods exist to acquire a digital image.(10)

(A) Conventional Radiograph Digitized, Using a Flat-Bed Scanner and Transparency Adapter

This procedure assumes that a conventional radiograph is available. The radiograph is scanned, using a flatbed scanner with a transparency adapter. Usually the spatial resolution can be chosen such that the diagnostic details are preserved in the digital image.

(B) Semi direct Digital Image, Acquired Using Photo stimulable Phosphor Plates

Photo stimulable phosphor plates can hold a latent x-ray image for some time. The latent image is the result of excitation of electrons in the phosphor crystals by the x-ray photons. Later a laser beam scans the image
plate. The electrons return to the original energy level; during this process, energy is emitted in the form of light, which can be captured by a photo-multiplier device. The output of the photo-multiplier is converted into pixel values, comprising the image information. This technology is called semidirect because of the intermediate phase of the latent image. Photostimulable phosphor plates are available in sizes comparable to conventional dental film.\(^{(11)}\)

(C) Direct Digital Image, Acquired Using a Charge Coupled Device, Complementary Metal-Oxide Semiconductor, or Other Electronic Device

In this method, the intensity of the radiation in the x-ray beam is measured directly by an electronic device consisting of a large number of light-sensitive elements. The output of these elements is transferred to the computer as an electric signal and digitized in the frame grabber board. A scintillation layer (such as a screen phosphor material) is put on top of the sensor array. X-ray photons are converted into light photons, increasing the efficiency of the detector. The size of the electronic sensors has been considerably smaller than a No. 2 dental film, but currently sensors with an active area that approaches the dimensions of standard intraoral film are available.

2.13. Intraoral Detector

Direct sensor systems are capable of real-time imaging; an image is displayed on the monitor in a few seconds. The systems are built around a CCD sensor. CCDs are arrays of x-ray-sensitive or light-sensitive pixels.\(^{(11)}\)

ACCID is made up of a large number of photodetector cells (several thousand) that generate voltage in proportion to the amount of light or x-rays striking them. The CCD charge is read by transferring the collected charge in each pixel, in a serial fashion to a read out amplifier. The same photon-generated charge collected at each pixel site is transferred pixel by pixel (similar to a bucket brigade) in a predesigned sequence that cannot be interrupted. When the pixel charge is transferred to the readout amplifier, it is destroyed.

**Advantage of CCD:** Lowest noise of any competing technology.

**Disadvantages of CCD devices:** Blooming—Blooming is similar to allowing too much light through a viewbox, blinding the operator and washing out radiographic information in the excessively bright image. This blooming occurs in CCD systems by excess charge leakage to other pixels. Because commercial grade CCDs contain some flaws, regions of bad pixels result in a partially or a totally bad column or row of pixels.

The output from the CCD is to be digitized. A special hardware converter (Analog-To-Digital converter [ADC]) then takes the voltages generated by the individual elements of the CCD and rounds them off into the number of alternative values to be used to represent the image digitally. If 256 shades of gray are to be represented, the signal from each CCD element is converted to the appropriate value within this range. Initial sensor systems captured the image using this gray scale from 0 to 255.

2.14. Complementary Metal Oxide Semiconductor

**CMOS**—Based sensors are now finding their way into intraoral sensory stems. The first advantage of CMOS technology is design integration. The major advantages of CMOS image sensors are integration, lowpower, manufacturability, and lowcost. Another advantage of CMOS technology is the ability to benefit from the high-volume manufacturing capacity already in place to support the CMOS semiconductor industry. A CMOS chip is already in every computer in the world. CMOS sensors also permit the integration of control circuitry, including ADC, directly into the sensor. The Schick CDR
sensor (Schick Technologies, LongIsland, NY) is an example of the application of this new technology. On the downside, although they perform well in bright light conditions (e.g., digital photographic cameras), CMOS sensors may not perform well in lowlight conditions or with the rigorous demands of medical imaging systems. They have more fixed pattern noise and use some of the chip or area for other operations, leaving less active area for image acquisition.

2.15. Digital subtraction radiography

In 1935 Zeidse des Plantes first demonstrated this technique, who used a photographic technique. It is the technique by which images not of diagnostic value in a radiograph, are reduced so that the changes in the radiograph can be precisely detected. Digitalisation achieved by taking a picture of radiograph using video camera. This technique facilitates both qualitative & quantitative visualization of even minor density changes in bone by removing the unchanged anatomic structures from image. Digital subtraction radiography (DSR) has been developed to enhance the visualization of mineral changes that have occurred overtime. To show these changes against a homogeneous background of unchanged anatomy, a high level of standardization in projection geometry and image density needs to be achieved.

The application of substraction radiography in dentistry was facilitated by the development of micro computer, allowing conventional radiographs to be digitized and subtracted. When two images of the same objects are registered and the image intensities of corresponding pixels are subtracted, a uniform difference image will be produced.

If a change in the follow up image has occurred, this change will show up as a brighter area when the change represents gain and as a darker area when the change represents loss. The strength of the DSR that it cancels out the complex anatomical background against this changes occurs. (13) (Fig:3)

Advantages of DSR

It can able to detect small osseous lesions. There is high degree of correlation between changes in alveolar bone. The overall contrast is improved, trabecular marrow spaces can be visualized with enhancement of low and high density images.

Disadvantages of DSR

DSR is not capable to give an objective description. Presence of high standardization of x rays, no reduction in exposure, not an economical and time consuming process. It also needs for identical projection alignment during exposure of sequential radiographs.

2.16. Computer Assisted densitrometric image analysis system

It is introduced by Urs Brägger et al 1988. A video camera measures the light transmitted through a radiograph then the signals are converted to grey scale images. Camera is interfaced with computer and image processor for storage and mathematic manipulation of image. It offers an objective method for studying alveolar bone changes quantitatively. This gives a high degree of sensitivity, accuracy and reproducibility. (14)

2.17. Computer-Based Thermal Imaging

It compares the re-warming rates of normal and inflamed human gingiva. Aid in gingival temperature measurement. Valuable objective method for the diagnosis of periodontal diseases. Infra-red thermograph provides a non-invasive method.

2.18. Conventional tomography

It is designed to image a slice or plane of tissue accomplished by blurring the images lying outside the plane of interest. It consists of an x ray tube and radiographic film rigidly connected which moves about a fixed axis and fulcrum.
Fig 3: Application of DSR for detection and quantification of periodontal bone healing
(a) baseline image (b) 1-year follow up (c) subtraction image showing bone gain.

Fig 4: (a) Rotating the ray source with a wide fan beam (b) CT scan taken for oral implant planning.

Fig 5: (a) Panoramic cross sectional view (b) CBCT image showing periodontal alveolar bone loss, apical lesion and external root resorption in the incisor.

Fig 6: An example for dental CT scan.
As exposure begins tube and film move in opposite direction simultaneously. Objects located within the fulcrum remain in fixed positions and are viewed clearly. It is used less frequently with the introduction of MRI, CT and Cone beam imaging.

2.19. Computed tomography

Godfrey Hounsfield and Allan MacLeod Cormack (1979) shared Nobel prize .It consists of a x ray tube emitting finely collimated x-ray beam directed through the patient to a series of scintillating detectors or ionizing chambers . Detectors form a continuous ring and x-ray tube moves in a circle with in the ring. Patients lie stationary and x ray tube rotates one turn .Then the table will move 1 to 5 mm to next scan (15). The three dimensional information has led to exploring the value of CT for the assesment of alveolar bone height. CT machines use a rotating fan beam to image one thin slice (fig 4a).

2.20. Helical CT

Introduced in 1989. The gantry containing x ray tube and detectors continuously revolve around the patient where as patients table advances through the gantry. Result is acquisition of a continuous helix of data. The detectors are gas filled ion chambers of xenon and solid state detectors of cadmium tungstate . (16)

Advantages:
It eliminates superimposition of images of structures outside area of interest. It has got wide field of view, operator independent, good soft tissue discrimination, sensitive for soft tissue calcification and bone involvement. It gives a high contrast resolution differences between tissues that differ in density. Images can be viewed in axial coronal and sagittal planes.

Disadvantages:
The main disadvantages are high radiation dose, difficult to scan in planes other than axial planes, require intravenous contrast for best results and costly.

2.21. Cone Beam Computed Tomography

CBCT developed in 1982 for angiography. Utilizes cone shaped source of ionizing radiation & 2D area detector fixed on a rotating gantry. Multiple sequential images are produced in one scan. It rotates 360° around the head. Scan time typically < 1 minute. Image acquisition involves a rotational scan of a x ray source and reciprocating area detector moving synchronously around patients head. Many exposures are made at fixed intervals to form basic images. Software programs are used to reconstruct 3D images. (17)

It is indicated in evaluation of the jaw bones, Implant placement and evaluation of TMJ, Bony & soft tissue lesions, periodontal assessment, endodontic assessment alveolar ridge resorption , airway assessment. It also aid in diagnosing periodontal pathologies like gingival hyperplasia, gingival recession, pathologies related to alveolar bone. (18) Two dimensional imaging techniques are routinely used for the assessment of alveolar bone defects in periodontology. An example for CBCT for periodontal pathology (fig:5)

(A) Small Volume CT

It is a form of CBCT utilizes small field high resolution detector to generate high resolution 3D volume. Generally comparable to size of intraoral radiographs. Van Daatselaar 2003 based on comparison made between a full CT geometry and a local CT geometry implies “local CT of dental structures appears to be a promising diagnostic instrument.”

(B) MicroCT

Microtomography known as Industrial CT Scanning technique where, uses X-rays to create cross-sections of a 3D-object. The term micro means the pixel sizes of the cross-sections are in the micrometer range. It is indicated in animal studies - analysis of bone biopsies without destruction of samples.
(C) Denta CT scan

DentaScan is a unique computer software program provides computed tomographic (CT) imaging of the mandible and maxilla in three planes of reference: axial, panoramic, and oblique sagittal. Provides visualization of internal bone morphology in three dimensions; precise treatment planning. In cross-sectional view, observation regarding bone quality, density can be made. Pre-operative planning of endosseous dental implants and sub-periosteal implants (19). Denta scan CT provides information of the internal structures that cannot even be gained by direct intra-operative visualization, the bony structures visualization. It gives precise location of the mandibular canal and the floor of the maxillary sinuses.

It has the advantages of minimum additional cost; Low radiation dose; Multi planer reformation; Eliminates streak artifacts; Exact information about alveolar bone dimensions and Location of mandibular canal and maxillary sinus. In implant imaging, it helps in measuring Bone quantity: Height and buccolingual dimension of implant site; Bone volume: Extent of bone resorption; Bone quality and precise location of vital structures.(fig 6)

2.22. Simplant

It is a computer program for assessing oral implant site. Uses raw data from CT along with advanced computer graphics. The advantages are assessment of bone volume, bone height & quality, Proper length of implant can be selected and clear visualization of inferior alveolar canal.

2.23. Digital tomosynthesis (DTS)

Circular tomosynthesis has been described as a technique filling the continuum between transmission radiography and CT. The principle of tomosynthesis is based on selective focusing of an arbitrary slice through the object by shifting and adding a set of basis projections.

The basis projections are conventional transmission radiographs of the object taken from different angles with the x-ray focus moving in a fixed plane. Based on a discrete set of basis projections any slice through the object can be generated. By this method Pocket morphology, and attachment level are digitally recorded. Quantitative information of thickness and character of the gingiva, root surface irregularities, and the distribution of subgingival calculus.

2.24. Magnetic resonance imaging (MRI)

It does not involve the use of ionizing radiation. It involves the behaviour of protons in a magnetic field. The image itself is another example of a tomograph or sectional image that at first glance resembles a CT. Used for imaging intracranial and soft tissue lesions. In head and neck region mit is used for the assessment of intracranial lesions involving particularly the posterior cranial fossa, the pituitary and the spinal cord. For investigation of the salivary glands & Tumour staging, investigation of the TMJ to show both the bony and soft tissue components and implant assessment. Schara et al 2009 in an in vitro study evaluated the used the use of MRI to characterize inflammation and healing process in periodontal tissues and it was concluded that MRI can characterize the type and healing process of inflammation (20)

Advantages of MRI:

Non ionizing radiation is used, there is no biological effects. It gives higher soft tissue contrast. Blood vessels clearly seen. High resolution images can be constructed in all planes. MRI image before and after intial periodontal therapy is useful.

Disadvantages of MRI:

It is an expensive procedure time consuming. Metallic objects in the oral cavity produce artifacts.
2.25. Bone scanning or Radionuclide imaging

In contrast to X-ray, CT, MRI which require structural or anatomic changes to be recorded, this technique assesses biochemical alteration in body. It is a nuclear scanning test that identifies new areas of bone growth or breakdown. It can be done to evaluate damage to the alveolar bones, and monitor conditions that can affect the periodontium (including infection and trauma)

2.26. DICOM Standard

The Digital Imaging and Communications in Medicine. It facilitates communications between imaging devices and systems. By dictating specific data and interface requirements, DICOM ensure that devices, particularly devices made by different suppliers, can communicate with one another.

3. Summary and Conclusion

The adoption of advances in the radiographic modality of the future, when based on sound scientific evidence, has the potential to transform the way we visualize the periodontal tissues. Digital image standardization, subtraction radiography, 3D imaging and quantitative image analysis are already a reality. There is little doubt that periodontists of the future will be using more advanced imaging modalities, either directly as a chair side procedure, or indirectly through the services of an oral and maxillo facial radiologist. Dentists should have knowledge of the working principles, requirements, clinical benefits and hazardous effects of these systems for proper usage.

4. REFERENCES


