REVIEW ARTICLE

Paradigm shift in dental imaging concepts – an insight view from basic to advance

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Abstract

One of the most recent breakthroughs in the world of dentistry is digital imaging. It allows dentists to deliver better care and treatment to their patients by making diagnostic and treatment planning easier, reducing wait times, enhancing patient satisfaction, and increasing efficiency. Dental care is changing around the world because to digital dentistry, which gives patients access to high-quality health care when they need it most. The transition from analogue to digital radiography has simplified and sped up not only the process but also image storage, processing (brightness/contrast, image cropping, etc) and retrieval. To solve the challenges associated with traditional procedures, modern imaging technologies like Cone beam computed tomography (CBCT), Magnetic resonance imaging (MRI), ultrasound imaging, laser scanning, Intra-oral scanning, 4D imaging and video Stereophotogrammetry have been introduced for the advancement in the field of dentistry. The purpose of this review is to provide an overview of the recent breakthroughs in imaging technology and their applications, advantages and disadvantages in several dental disciplines.

Introduction

Dentist and researches are dependent on x-rays for better and accurate diagnosis and treatment planning. Imaging techniques are considered as a corner stone in the field of dentistry to determine any changes that occur in the teeth or the periodontium in general. Wilhelm Roentgen, a physicist, discovered the x-ray in 1895. The first dental x-ray was taken by Dr. Otto Walkhoff in 1896.[1] Since then, the imaging techniques in clinical dentistry has evolved and with the advancement in digital radiography, precise and detailed information of specific cases are possible.

The advancement from analog imaging technique to digital imaging is considered as a revolution in dental radiology. Imaging technique plays a pivotal role in endodontics for diagnosis of various disease involving both maxilla and mandible, its treatment and follow-up.

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INDICATIONS OF IMAGING IN ENDODONTICS

- To examine hard tissue morphology and pathological variations.
- To detect and look for changes in tooth shape, root canal number, pulp chamber calcification, and root curvature.[2]
- Detect any break in Crown and root structure.
- To determine the root canal's working length
- To assess the prepared canal's post-obturation and sealing
- To evaluate any periapical changes after treatment.
- Forethought for any surgical considerations.
- Evaluating tooth resorptive lesions.

TECHNIQUES USED FOR DENTAL RADIOGRAPHY

I. Bisecting Angle Technique:
The sensor is placed at an angle behind the target tooth. The x-ray beam's central ray is angled at the right angle to an imaginary line that bisects the angle created by the tooth's long axis and the film.[3]

II. Paralleling Technique:
The sensor is positioned behind the desired tooth and the x-ray beam's central ray is directed at the right angle to the tooth and the film.[3]

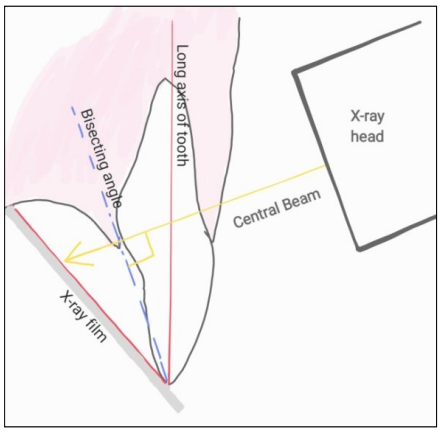

Fig 1: Diagrammatic representation of Bisecting Angle technique.

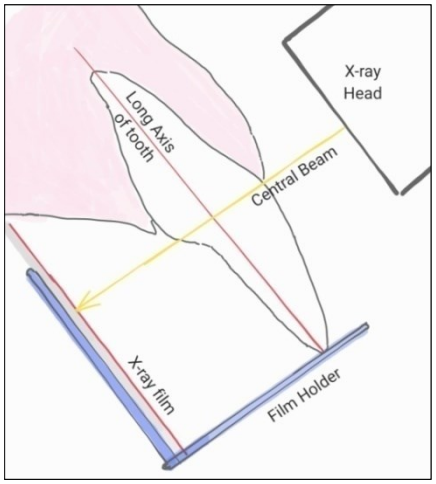

Fig 2: Diagrammatic representation of Paralleling technique.

CONVENTIONAL RADIOGRAPHY

The conventional film - based radiographs are exposed to x-ray beam and is then processed chemically to produce the images. The conventional x-ray consists of an x-ray film and is used as common practices in many clinics and education institutes. Dental x-ray films consist of intraoral and extra oral films and are available in different sizes according to the requirements.[4]

Most dentists still prefer conventional radiography equipment as it is inexpensive, easy to use, and widely available. But there are certain limitations of analog or conventional radiographs over digital radiographs such as lower contrast resolution, superimposition of different overlying tissues on the image etc.[7] Benefits of digital radiographs include the short processing time, *i.e.*, the ability to view the image more rapidly, elimination of the darkroom and processing chemicals. It allows manipulation of the image produced by adjusting the contrast, density, sharpness and image orientation, without any additional radiation exposure to the patient or the operator.[5]

Intraoral radiographs

A. **Periapical radiograph**:
Periapical view aid in recording the structures surrounding the apex of the root of the tooth and are available in three different sizes.
Size 0 - 22×35mm (children)
Size 1 - 24×40mm (Anterior teeth- Adult)
Size 2 -This is a standard size of 31×41mm used in Anterior & Posterior teeth- Adult.[3]

B. **Bitewing radiograph/ Interproximal radiograph**:

Bitewing film helps in recording both maxillary and mandibular teeth simultaneously and are used in identifying any interdental caries, secondary caries, bone loss etc. bitewing films are available in four size based on the location and age of the patient.[3]
Size 0 - 22× 35mm (Anterior teeth- Children)
Size 1 - 24×40mm (Posterior teeth- Children, Anterior teeth- Adult)
Size 2 - 31×41mm, standard size (Posterior teeth- Adult)
Size 3 - All posterior teeth are seen in one film, 27×54mm (Posterior teeth- Adult).

C. **Occlusal radiograph**

Viewing the maxilla or jaw from the occlusal surface is done with occlusal films. The occlusal films come in sizes ranging from 57mm to 76mm.[4]

INDICATION OF OCCLUSAL RADIOGRAPHS

- To keep track of the number and location of extra teeth and impacted teeth.
- In maxillary and mandibular fractures, to determine the extent of shattered fragments.
- To detect the presence of foreign bodies and their location. In case of Sialoliths in the ducts of sublingual and submandibular glands.
- To detect disease in the palate or floor of the mouth and determine the medial and lateral extent of cyst, osteomyelitis or malignancies.
- To examine the area of cleft palate.[5]

INDICATION OF INTRAORAL X-RAYS

- Identification of periapical infection or inflammation.

- Detection of impacted/unerupted teeth.
- Evaluation of implant and surgical cases.
- Endodontic procedures
- Evaluation of periodontal status.
- Detection of any trauma or fracture to the teeth and associated alveolar bone.[5]

Extraoral radiograph

These are larger x-ray films used to view the oral cavity and its surrounding structures in a single film. The main focus of the extra-oral films is the jaws and skull.

Orthopantamography (OPG):
These are used to record a two-dimensional view of maxilla and mandible including the jaws and surrounding structures. The size of film used in OPG is 5× 12 inch, 6×12 inch.[3]

Cephalometric radiograph:

These extra-oral radiographs are used to record the radiographic view of the jaws and skull permitting measurement. The size of film used is 5×7 inch, 8× 10 inch.[3]

INDICATION OF EXTRA-ORAL X-RAYS
- Locate impacted teeth.
- Evaluate the growth and development of jaws.
- Detect any TMJ disorders.[5]

DIGITAL IMAGING

Digital imaging system consist of sensor, computer and software associated with hardware system to produce a digitized image that can be manipulated by a computer and displayed on screen.[6]
The radiovisiography (RVG) is the first system that was developed in digital imaging. The digitized images can be acquired either directly by intraoral sensor or charge-coupled device, or indirectly by scanning the analog radiographs and transferring them to the computer to get an indirect digital image.[2]
The digital x-ray system use several technologies that incorporate sensors using solid-state detectors such as charge-coupled device(CCD), complementary metal oxide semiconductor (CMOS) or storage phosphor detectors such as Photostimulable phosphor (Fig 3).[7,8,9]

Digital X ray

1. Solid state detector
   A. Charge coupled device CCD
   B. Complementary metal oxide semiconductor CMOS

   ⇩

   Direct image obtained by sensor

2. Photostimulable phosphor

   ⇩

   Semi direct digital image obtained

Fig 3: Flowchart showing types of digital x-ray systems

ADVANCEMENT IN 3D IMAGING TECHNIQUES:

1. **Computed Tomography**:
   Computed tomography uses a narrow fan-shaped collimated x-ray beam to generate 3D images of an object by multiple exposure around an 2D image data. Computed tomography was first developed by Sir Godfrey N Hounsfield in 1972.[7]

INDICATION
- Assessment of trauma and malignancies.
- Implant planning.
- Detecting vertical root fracture.
- Evaluating root canal anatomy (missed canals or extra canals).
- Research purpose.
- Resorption of roots.
- Presurgical assessment.
- Detection of apical periodontitis.[10,11]

Advantages of CT scan in dentistry include precise and detail image of the bone, soft tissue and blood vessels at same time, painless and non-invasive.[12] Limitations for the use of CT scan include high radiation exposure and are expensive.[13]

2. **Cone Beam Computerized Tomography (CBCT)**

CBCT also known as digital volume tomography (DVT) is digitalized imaging technique in which a cone-shaped x-ray beam is centered on a 2D x-ray sensor to scan one rotation around the object and produce multiple 2D images that are reconstructed in 3D.[14]

A voxel is the smallest 3D element of a volume2, and it's usually depicted as a cube or box with height, width, and depth. Each x-ray absorption is represented by a three-dimensional voxel. On CBCT images, the voxel size is isotropic, which implies that all sides have the same dimension and resolution in all directions. CBCT units also come in a variety of voxel sizes, including 0.2 mm, 0.3 mm, and 0.4 mm.

Fig 4: CBCT Machine. (Image courtesy: gdental.com)

INDICATION

- Assessment of root fractures.
- Detection of bone loss.
- Analysis of root canal morphology.[2]
- Evaluation of bony lesions.
- Complex endodontic procedures.
- Implant assessment.
- Evaluate alveolar bone grafts in cleft lip and palate patients.

Advantages of CBCT include high resolution, accuracy, reduced scanning time, low radiation, and it is cost effective than CT scan. There are certain disadvantages of CBCT such as artifact results in weak images, limits the imaging of soft tissue. Therefore mainly advised for imaging hard tissues, require more space than conventional x-ray unit, unwanted patient movement leads to image distortion etc.[15]

3. Magnetic Resonance Imaging (MRI)

MRI is a specialized non-invasive imaging technique that uses magnetic field as well as radio-wave in viewing of soft tissues in the body. MRI has high contrast sensitivity to tissue differences and is useful in detecting soft tissue lesions. This is considered the vital reason MRI have replaced CT scan for imaging soft tissues.[12]The strength of the magnet in MRI equipment is measured in Tesla units.[5]

Fig 5: MRI Machine (Image courtesy: my.clevelandclinic.org)

INDICATION

- Evaluate root resorption.
- Detect TMJ problems.
- Investigate soft tissue lesions in salivary glands.[5]
- Differentiating solid and cystic lesions.
- Tumors and fractures.
- Assessment of bone height and bone density for implant dentistry.
- Monitoring the growth of facial skeleton.

Advantages of MRI include non-invasive, radiation free imaging and can be used in pregnant patients and children.[16] There are some limitations of MRI also which include high cost, contraindicated in Cardiac patients, time consuming, differentiating benign and malignant tumors are difficult and they are contraindicated in Claustrophobic patient.[16]

4. Ultrasound Imaging

This is a non-invasive, soft imaging technique based on the propagation and reflection of ultrasound waves in the tissues. Ultrasound is also known as Echography or real-time Echotomography. The frequency used in dental imaging is between 3MHz & 12MHz.[17]

A transducer or an electronic device converts electrical impulses to high frequency sound waves or also called as Echo. The echo is transmitted into the tissue and part of it is absorbed within the medium and remaining part of it continues to travel through the tissues. Lastly, a portion of echo is reflected back to the transducer and small amount of it is scattered. The reflected echo is reconverted into electrical impulses, processed and transformed as light spot using grey scale images on a computer screen.[17]

Fig 6: Ultrasound imaging machine. (Image courtesy: pocketdentistry.com)

INDICATION

- Detect the presence of endodontic lesions and the vascular supply in the bone.

- TMJ disorders.
- Space infections.
- Ultrasound guided core needle biopsy.
- Diagnosis of oral submucous fibrosis.[4]
- Salivary gland disorders.
- Detection of benign and malignant tumors.
- Assessment of Lymphadenopathies.
- Periodontal bony defects.
- Maxillofacial fractures.[2]

Advantages of Ultrasound imaging technique is that it is non-invasive and painless, non-ionizing radiation,[5] can be used in MRI contraindicated conditions like patients with cardiac pacemaker, claustrophobic etc and ultrasound is well tolerated and cause less discomfort for patient during the procedure. Limitations of Ultrasound imaging include operator- equipment dependent, images are difficult to orient and interpret and ultrasound is not effective in visualizing bone or travel through air.[17]

MODERN 3D IMAGING TECHNIQUES:

1) Laser Scanning (3D Laser Scanning)

Laser scanning is considered to be non-invasive, rapid and automated method to acquire 3D digital data using laser light.[18] 3D laser scanning technology is widely being accepted and effectively growing in the field of dentistry to provide the best possible treatment and satisfaction to the patient.

Fig 7: Laser scanning device. (Image courtesy: citydentist.com)

INDICATION

- Cosmetic dentistry.
- Surgical planning.
- Research purpose.
- Orthodontic treatment planning- make appliance to correct teeth alignment.
- To fabricate accurately fitting crown and bridge.
- Provide 3D color model for education and teaching purpose.
- Reconstructive surgery like designing of implant.[19]

Advantages of Laser scanning device include time and cost effective, patient comfort, effective and simplified treatment planning, 3D view of dental anatomy, reduced risk and increased success rate.[19] Some of the limitations are that the laser scanners are impossible to detect or measure surfaces out of scanners line of sight, ambient light may blend with the laser and interfere with the accuracy of the scan. Hence, separate room recommended where light can be monitored and finally initial high cost. But, if planning to use on regular basis then 3D laser scanning is beneficial.

2) Intra Oral Scanning

Intra oral scanners play an important role in the field of dentistry and this fast growing technology provides an accurate 3D mapping of the oral cavity.[13] 3D scanner captures the data by protecting light source onto the desired object and converting the physical model into the digital 3D CAD file.

Fig 8: Intraoral scanning device. (Image courtesy: 3dnatives.com)

Advantages of intraoral scanners are effective patient communication, implementation of highly accurate models, traditional work flow simplification, possibility to create periodically update data base of dentitions for future interventions, possibility to simulate surgery interventions on the digital model and reduced patient discomfort.[20]Drawbacks of intraoral scanning device include, difficult to detect deep margins in prepared teeth or in case of bleeding, high purchase and cost management related to upgrade of software.

3) 4D Imaging and Video Stereophotogrammetry (Video Camera)

Video camera or 4D imaging and video stereophotogrammetry is a non-invasive 4D video that records the dynamic movements of human face and

provide better understanding of dynamics of facial expressions.[13] Virtual patients can be created by superimposing the facial skeleton onto the 3D model of the patient's head.[21] This allows the clinicians to practice their skills in a risk-free environment and help them to better prepare for real-life situations.

Fig 9: 4D imaging and video stereophotogrammetry. (Image courtesy: researchgate.net)

Conclusion

Dental imaging has been around for more than a century, but it is only in the last few decades that it has advanced significantly. The digital imaging system is a new technology that has the potential to improve the quality of dental care and offers an alternative to traditional film-based methods, which are associated with high radiation exposure, retake and processing time .The development of advancements in dental imaging paves way for new diagnostic and treatment planning procedures. Dentists must have acquired knowledge of these new techniques to use them effectively.

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