Review Article

Recent advances in dental radiography for pediatric patients: An unstructured review

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ABSTRACT

Dental radiography is considered to be a diagnostic tool for a proper treatment planning of the disorders of oral cavity such as periodontal diseases, different oral pathologies, and dental caries. In pediatric dentistry, radiography is a part of daily practice because of its unusual and unique role. As the child is brought in the clinic for the first time, radiology has been proven to be an acceptable and a painless method to introduce a child for dental treatment. The confidence of the patient can be, thus, successfully achieved through radiographs. The main objective of the review is to find the advances in dental radiograph to give a brief overview of dental radiography in children including specialized radiographic techniques and different modifications that can successfully be used in infants, young and handicapped children, children with gag reflex, and mentally disabled children.

KEY WORDS: Dental radiograph, Handicapped children, Pediatric patients

INTRODUCTION

Dental radiology is considered to be best and a useful diagnostic aid for a proper and thorough examination of the oral cavity of a child. It is considered to be the most reliable and valuable diagnostic tool, especially for infant, children, adolescent, and patients with special health-care needs. It helps to arrive at a correct diagnosis, followed by a proper treatment planning. Before undergoing any procedure for taking radiograph, a thorough medical, dental, and clinical examination of the patient should be performed.

Childhood is the period of life's greatest physical, psychological, and emotional growth; the child we see today is no longer the same tomorrow. The child patient presents a challenge to the dentist, who must solve the problems of today with an eye to the future and dental health of an adult. Diagnosis is a process by which the practitioner distinguishes one disease from another, differentiates between normal and abnormal, and determines the etiology of abnormal conditions (Forrester). Accurate diagnosis can only be achieved by systematic and methodical collection of data. The present article illustrates the various diagnostic aids that can be used clinically in pediatric dentistry for the detection and evaluation of commonly seen dental diseases.

The major reasons for taking radiographs of teeth and supporting tissue in pediatric dentistry are as follows:
1. Detection of caries
2. Dental injuries
3. Disturbances in tooth development
4. Examination of pathological conditions other than caries.

In the past 10 years, different film types and processes became available for non-digitized image observation. White and McMullan (1986) concluded that both ultra-speed film and xeroradiography (XR) were somewhat preferable to extra speed film. More recently, the possibilities of digitizing and computer processing of images (DRI) became the subject of research. Images can be digitized fast and accurately with charge-coupled device (CCD) detectors. This is possible by the use of a regular radiograph and a CCD-equipped video camera. Alternatively, an X-ray-sensitive CCD detector can be used in the place of the radiographic

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film. This is called radiovisiography (RVG). The dose required for RVG is substantially less than that required for photographic X-ray film. Several techniques are available for post-exposure computer treatment of the images. The simplest is contrast enhancement of the gray levels of interest. An alternative is color coding of contrast, in which (slightly) different gray levels are depicted as different colors on the display screen. So-called filter techniques can be used to emphasize borderlines between areas with different gray levels. Wenzel *et al*. (1991a, b) compared conventional film radiographs, digitized film radiographs, and RVG for the detection of occlusal caries in non-cavitated extracted teeth. Histologic sections served as the validation criterion. The two digital methods with contrast enhancement tended to perform better than, although not significantly different from, the other three methods. Average likelihood ratios (true positive/false positive) were 4.3 (conventional film radiographs), 4.4 (RVG with contrast enhancement), 3.6 (RVG with × function), 4.9 (digitized radiographs with contrast enhancement), and 3.7 (digitized radiographs with filtering procedures). These authors conclude that radiography can much improve diagnosis compared with clinical inspection. They also conclude that digital techniques, no matter which, improve the sensitivity without substantial loss of specificity. Advanced digital techniques such as edge enhancement do not seem to lead to further improvement (Wenzel *et al*., 1991a). A similar conclusion was reached by Russell and Pitts (1993), but it is to be noted that their sensitivities are strikingly low. Quantization of proximal lesions from radiographs by means of a computer-produced lesion contour has been developed by Pitts *et al*. This work has been reviewed before Bosch and Angmar-Mnsson, 1991, and seemed to have promise for quantitative longitudinal studies (Pitts and Renson, 1987). As far as we know, follow-up on this work is yet to come. Although quantization of lesion changes over time would seem simple with digitized images, such a development is hampered by the requirement that X-ray tube, tooth, and film have to be repositioned at each exposure. This has appeared to be a real problem. Previous efforts by Webber *et al*. (as reviewed before by ten Bosch and Angmar-Mansson, 1991) to overcome this problem by computerized tooth tomography have not yet led to a clinical application. In a recent paper, Wenzel and Sewerin (1991) described and tested a simple personalized repositioning system that seems to combine adequate and simplicity.

MODIFIED PROJECTION TECHNIQUES

Radiographs being a valuable tool are essential to diagnose oral diseases and to timely monitor the development of dentofacial structures and the results of the treatment outcomes. As each patient is unique, initially a proper medical and dental history of the patient is required for determining the need for dental radiograph along with a complete clinical examination and assessing the patients' vulnerability to environmental factors that affect oral health. There are certain modifications for taking radiographs in infants, young and handicapped children, children with gag reflex, and special cases. Several radiographic techniques may be used to obtain films of these patients. For example, intraoral radiographs may be made with the parent or guardian holding the films in place. Film holding devices such as bite blocks or a hemostat extended through a rubber stopper may also be employed to retain the film. In addition, a film can be retained with the patients' occlusion, thus not being dependent on digital fixation.

DIAGNOSIS OF DENTAL CARIES

Dental caries is a chronic disease that involves destruction of tooth structure, which can lead to loss of masticatory function and unesthetic appearance of affected enamel. The boundaries of caries diagnosis and caries interventions are changing. Dentists currently use visual, tactile, and radiographic information to detect relatively advanced changes in the dental hard tissues. Diagnosis of dental caries is often regarded as synonymous with the detection of clinical signs of tissue damage caused by the disease, i.e., carious lesions and cavities.

RADIOGRAPHIC METHODS

Radiographs can be classified into the conventional and advanced techniques. Although conventional radiographs such as bitewing and intraoral periapical radiograph are most frequently used for the detection of caries, they may cause overlapping of teeth due to faulty angulations and may also miss the initial lesion. During the primary dentition, the occlusal surface is most susceptible to caries attack, but with the eruption of first permanent molars, the incidence of proximal lesions greatly increases. In such situation, bitewing radiographs are absolutely required to detect proximal lesions in primary molars. The advanced radiographic techniques include digital radiography and XR. Digital radiography is a digital, filmless technique for intraoral radiography, utilizes very little of the radiation to which the patient has been exposed, and avoids the need for developing films.[1] XR has the advantages of producing less radiation and edge enhancement along with its wide latitude of exposure.

ANALYSIS OF DIAGNOSTIC RECORDS

1. Cast analysis: Mixed dentition model analysis
2. Cephalometric analysis

3. Diagnostic radiographs and photographs
4. Orthodontic classification.

MIXED DENTITION MODEL ANALYSIS

Model analysis is a valuable tool in orthodontic diagnosis and treatment planning as it provides a three-dimensional (3D) view of arches and helps in early assessment of available space. Mixed dentition model analysis evaluates the amount of space available in the arch for succeeding permanent teeth and the necessary occlusal adjustments. Non-radiographic method includes Moyer's analysis, IOWA prediction method, Johnson and Tanaka's analysis, Boston University Approach, regression equation, and Ballard, Wyllie, and Owen's analysis. Radiographic methods include Nance analysis, Hixon–Oldfather analysis, Staley–Kerber's analysis, and Huckaba analysis.

CEPHALOMETRIC ANALYSIS

Radiographic cephalometry is the measurement of the head from bony and soft tissue landmarks on the radiographic image.[2] Lateral cephalograms reveal the details of skeletal and dental relationships that cannot be observed in other ways, and they allow a precise evaluation of the response to treatment.

ORTHODONTIC CLASSIFICATION

Angle's 1899 classification was based on identifying occlusal relationships and classifying a malocclusion according to the position of the mandibular first molar and its relationship to the opposing maxillary first molar. It classifies malocclusion into Angle's Class I, Class II (Div 1, Div 2, and subdivision), and Class III relations (pseudo Class III and subdivision).

Maturity Indicators

1. Neural age helps us to understand that the patient is mentally developed to understand the need for the treatment and to what extent he can cooperate and follow instructions.
2. Mental age is an index of maturation of the mind and increases at a rate that depends on many intrinsic and environmental factors. Some of the performance tests used to measure intelligence are the Stanford–Binet test and Wechsler scale.
3. Physiological and biochemical ages are a series of physiological and biochemical changes occurring during growth, which can be correlated to skeletal land chronological age.
4. Chronological age is determined by the passage of time since birth, which is a poor indicator of maturity.
5. Sexual/pubertal age is the stage of the development of secondary sexual characteristics and provides a physiological calendar of adolescence that correlates with the individual's physical growth status.
6. Dental age is determined by formation or eruption of teeth.
7. Skeletal/radiological/anatomic age is considered to be the most reliable age for growth assessment for orthodontic purposes. It is closely related to the growth of the individual.

Mentally Disabled Children

For patients with limited ability, to control film position, an intraoral film with bitewing tabs is used for all bitewing and periapical radiographs. An 18-inch length of floss is attached through a hole made in the tab (to facilitate retrieval of the film). The patient should wear a lead apron with a thyroid shield, and anyone who helps hold the patients and films or sensor should wear lead-lined apron and gloves.[3]

CHILDREN WITH GAG REFLEX

Occasionally, the child may express his apprehension by an increased tendency to gag. Gagging has been interpreted as an effort by the child to defend himself consciously otherwise against the invasion of the oral cavity. For this reason, it is necessary to acquaint the patient thoroughly with the radiographic procedure before filming. One of the most effective methods of reducing gagging is a distraction. The child is asked to concentrate intensely on something spatially removed from the oral cavity. The task may be to raise one leg and his toes, make a fist, or hold his breath. Furthermore, it is advisable to perform the examination in the morning when the individual is well rested, rather than in the afternoon or evening.[4] Furthermore, it has been observed that the chance of gagging is reduced when the stomach is empty or half filled. Pharmacological techniques for managing gag response include the use of sedative and topical anesthetic. Few agents that have been recommended for decreasing the gag reflex include phenothiazines derivatives, antihistamines, barbiturates, and nitrous oxide. For temporary relieving the gag reflex, the use of local anesthetics such as xylocaine or dyclone in topical or rinse form appears to be effective. General anesthesia is generally not considered as an approach for obtaining radiographs.[4] Film size positioning and manner of placement may also be varied to accommodate the child who gags during radiography. Children have smaller jaws, shallow lingual vestibule, which requires the use of smaller films. It is sometimes useful to place posterior film toward the front of the mouth initially and allow the child to move the film posteriorly into position himself.

Handicapped Children

Many mentally handicapped children will not allow an intraoral film to be placed in their mouths. Intraoral radiographs of these children are usually obtained with the parent holding the film in position. A holding device that fixes the film in position while the patient occludes is more effective than trying to hold the film by digital placement. Such patients cannot or will not open their mouth for radiographic procedures. In these cases, extraoral radiographs such as panoramic, lateral jaw, or 45° projections are used.[5] The use of intraoral holder at times becomes difficult in handicapped children or young patients, wherein Rinn SnapA-Ray is used instead of the use of conventional holders. With the help of these modifications, holding the film in the oral cavity becomes easier in handicapped and young children.[6]

Modification in Film Packets and Holder

Film packets can be modified in patients to reduce the anxiety level or to minimize the local discomfort and gagging associated with the placement of the film. This modification includes the bending of the film (occlusal), using the smallest possible film, or either bending of the corners of the film to decrease the irritation, especially in the sublingual area of the oral cavity.[5,7,8] Lewis[14] suggested the use of cotton rolls, which are taped with the packet of the film for maintaining the plane of the film.[9] For patients with gagging reflex, handicapped children, or young children, certain modifications of the film or film holder position are advocated. One technique includes the "reverse" bitewing in which the film is placed in the buccal vestibule, and the beam is directed through the jaws from the opposite side of patients' head.[6] Alternative to intraoral periapical radiographs, extraoral techniques may be a good and reliable alternative when it is not possible or practical due to many factors, for example, handicapped children, young patients, or patient with a gag reflex. The most common and frequently used substitute for intraoral radiography includes lateral jaw or lateral oblique and the panoramic films.

SPECIALIZED RADIOGRAPHIC TECHNIQUES

Ultrasonography

It is used widely in dental scanning. Most solids, including enamel and dentin, can be penetrated by ultrasound, and it is possible to detect caries and cracks that can usually hardly be observed in conventional film radiography.[10]

Ultrasound refers to the acoustic waves with frequencies >20 KHz, which correspond to the upper limit of sound audible to humans. (1) For most medical applications, wave generation is based on electromechanical transducers using piezoelectric materials. (2) Benefits of ultrasound modalities include the relative low costs, as well as real-time abilities of most diagnostic devices, and the assessment of mechanical material characteristics such as bulk or shear moduli. Ultrasound waves transmit energy, as X-ray does, but while X-rays pass readily through a vacuum, sound requires a medium for its transmission. (3) In general, the speed of sound is faster in solids, intermediate in liquids, and slow in gases. In an ideal liquid, the bulk modulus of shear is zero. Most real liquids behave like an ideal liquid, which means that the energy transportation is dominated by longitudinal waves too. The propagation speed of the ultrasound wave in a liquid relies on the particle density and the bulk modulus of compression. As a first approximation, soft tissues can be considered as a viscous fluid. Due to the fact that densities and compression modulus of most soft tissues are similar to that of water at 37 C, a mean propagation speed of 1540 m/s is assumed for the most common case of brightness modulated (B-mode). More complex cases arise if hard tissues, like tooth and bone, are in the focus of interest. Hard tissues show a much higher speed of sound variation than soft tissues. Furthermore, shear modulus dependent waves can occur in addition to the longitudinal wave mode. Interface effects should be considered, and energy loss inside of high-attenuating tissues, like bone, may be a limiting factor for the B-mode imaging.[11] Nevertheless, variations in the speed of sound either due to the heterogeneous soft tissue distribution or even local temperature differences can cause distance measurement errors and refraction-based image distortion. More complex cases arise if hard tissues, such as tooth and bone, are in the focus of interest. Hard tissues show a much higher speed of sound variation than soft tissues. Furthermore, shear modulus-dependent waves can occur in addition to the longitudinal wave mode. Interface effects should be considered, and energy loss inside of high-attenuating tissues, such as bone, may be a limiting factor for the B-mode imaging.

Computed Tomography (CT)

CT scanner was first developed in the field of medicine by Hounsfield. It is also known as computed axial tomography scanning. The attenuation of an X-ray beam in the body is used in conventional radiography to project a shadow onto an image receptor. These shadowgraphs record a two-dimensional (2D) representation of a 3D object. Small lesions are, therefore, not readily identified because of overlapping and underlying anatomy, image distortion occurs because of unequal magnification effects and low contrast masses are poorly delineated since scatter contributes substantially to the image data.[12] It is a radiographic technique that blends the concept of thin-layer radiography (tomography) with computer synthesis. CT is a digital and mathematical imaging technique that creates tomographic sections where the tomographic layer is not contaminated by blurred structures from adjacent anatomy. It enables differentiation and is a non-invasive procedure.[13] CT examinations are quicker and more patient-friendly. Tremendous research and development have been made to provide excellent image quality for diagnostic confidence at the lowest possible X-ray dose. It is mainly indicated for the investigations of intracranial diseases, pre-operative assessment of maxillary alveolar bone height and thickness before inserting implants, investigations of suspected intracranial and spinal cord damage investigation and assessment of fractures involving the orbits and nasoethmoidal complex, cranial base and cervical spine fractures, tumor staging assessment of site, size, and extent of benign and malignant tumor investigations of tumors and tumor-like discrete swelling intrinsic and extrinsic to the salivary glands, and investigation of the temporomandibular joint (TMJ).[13] It eliminates superimposition of images of structures outside the area of interest; normal hidden surfaces can be examined in detail. It has the ability to rotate images and to add or subtract structural components permiting relationships to be studied. Structural relationships of hard and soft tissues can be observed directly.[12] Although CT scan provides many above-mentioned advantages, it offers certain limitations for its usage. In CT imaging, the effect of blurring is much greater than in conventional radiographic systems. The detail of a computed tomographic image is not as fine as that obtainable on other radiographs. Furthermore, the metallic objects such as fillings produce marked streak artifacts across the CT image. The equipment is very expensive.[14] Clinical application of CT in children includes diagnosis of neonatal maxilla and disorders involving the auditory ossicles and TMJ. It also provides a detailed view of the dental arches and positioning of the supernumerary teeth. The extent of the cyst and tumors can be identified. In orthodontic cases, both skeletal and a dental relationship can be assessed. Proper evaluation of the trauma involving the face can be made with the use of CT.[15]

XR

XR is a highly accurate electrostatic imaging technique that uses a modified xerographic copying process to record images produced by diagnostic X-rays. The xerographic process was invented and first used in 1937.[16] The most common application of XR in medical field is mammography, but it has also been successfully applied to imaging other body parts such as the skull, larynx, respiratory tract, TMJ, mandible, para osseous soft tissues, and dental structures. In 1955, the first recorded use of XR for alveolar structures took place. It was a lateral oblique view of the mandible.[10] The main advantage of XR includes simultaneous evaluation of multiple tissues, i.e., tissues with different thickness and densities can be easily viewed under one film. Accidental film exposure is impossible. It has excellent characteristics of the forces around the electrostatic charges, which form the latent image, i.e., it provides a high-resolution images. So far as no special skills are required for office copying machine, even more so is the XR process. Furthermore, dark room requirements are unnecessary, and the entire XR process may be completed within 60 s. The process also allows multiple copies simultaneously. It is the most cost-effective method compared to either automatic processing or manual processing.[17] Periapical xeroradiographs were made using a smaller plate when compared with the plate size of conventional X-ray film.[18] Xeroradiograph shows a well-defined and a sharp delineated bone details as well as soft tissue imaging on the same picture. These features offer advantage orthognathic surgery and in cephalometrics tracing, especially in children.

Cone-beam CT (CBCT)

CBCT also called as dental volumetric tomography, cone-beam volumetric tomography, dental CT, and CB imaging is a recent technology initially developed for angiography in 1982 and subsequently applied to maxillofacial imaging. It is only since the late 1980s that it has become possible to produce clinical systems that are both inexpensive and small enough to be used in the dental office. The principal feature of CBCT is that multiple planar projections are acquired by rational scan to produce a volumetric dataset from which inter-relational images can be generated.[18,20] Cone-beam scanners use a 2D digital array providing an area detector rather than a linear detector as CT does. This is combined with a 3D X-ray beam with circular collimation so that the resultant beam is in the shape of a cone, hence the name “CB.” As the exposure incorporates the entire region of interest, only one rotational scan of the gantry is necessary to acquire enough data for image reconstruction.[17] As CBCT requires only a single scan for capturing the necessary data, the time required for CBCT scanning is substantially less (<30 s) as compared to conventional CT. CBCT data reconstruction and viewing are performed on a personal computer. Furthermore, some manufacturers provide software with extended functionality mainly requiring for orthodontic analysis and for implant placement.[18] CBCT can be used in pediatric patients having malocclusions and craniofacial anomalies, including cleft lip and palate. It is also proven to be helpful for the proper assessment and correct determination of the position of the unerupted teeth, especially for the canines in upper arch, and to determine the extent of root resorption. CBCT also provides a proper relationship between the dentition and for the assessment of treatment planning and its outcome.[20] This technology has limitations related to the CB projection geometry, detector sensitivity, and contrast resolution that produces images that lack the clarity and utility of conventional CT images.[20]

Magnetic Resonance Imaging (MRI)

An MRI scan is a radiology technique that uses magnetism, radio waves, and a computer to produce images of body structures. The MRI uses non-ionizing radiation from radiofrequency band of electromagnetic spectrum (9–10 mm of wavelength). It is a non-invasive imaging modality that uses electrical signals generated from response of hydrogen nuclei to strong magnetic field and radio wave/radiofrequency pulses to produce an image to allow specialists to explore inner working of human body, to detect and define the difference between healing and diseased tissue without the use of X-ray.[20] MRI scan can be used as an extremely accurate method of disease detection throughout the body. It is mainly indicated for assessing intracranial lesions, especially those involving the posterior cranial fossa, pituitary, and spinal cord. In the head, trauma to the brain can be seen as bleeding or swelling. It is also used for staging the tumor, i.e., evaluating the size, site, and extent of all soft tissue tumors and tumor-like lesion involving all areas, including salivary gland, pharynx, larynx, and orbit and also used for imaging the tongue mainly for lingual tumor for the definition of boundaries and degree of vascularity. MRI is also used to study the extent of soft tissue tumours and tumour like lesions involving, salivary gland, the pharynx, and the larynx.[1,3,11,19,20] Being a non-invasive technique, MRI successfully helps in 3D visualization of the carious lesion and determines its extent and its relationship with the adjacent surrounding tooth structures.[9]

CONCLUSION

The use of proper and innovative radiographic techniques can help the dentist to obtain diagnostic radiographs with minimum harm and maximum comfort for the pediatric patient. There are many modifications available for both intraoral and extraoral techniques. It depends on the type of patient and the situation for the use of these modifications. All these modifications can act as a substitute for the conventional radiographic method.

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