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Review Article

Impact of recent advances in radiology on orthodontic diagnosis and treatment planning - A review

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ABSTRACT:
Every medical, dental and surgical procedure is solely based on the diagnosis of the underlying pathology or disorder. In recent times there has been a tremendous advancement in scientific technology which has helped dental practitioners all over the world. The use of computers in cephalometry has made it easier to view and measure various readings. Computer aided design and computer aided manufacturing have increased the accuracy and quality of all dental materials. In the field of Orthodontics, there have been many advances. This article summarizes the recent advancements in diagnostic aids in Orthodontics which has helped revolutionize treatment planning for the Orthodontic fraternity.
Keywords Orthodontics, CBCT, Cephalometry.

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INTRODUCTION

Radiographs are considered essential for orthodontic treatment. Among other indications, radiographs and cephalometric analysis are used for assessing the interrelationships among the maxillofacial skeleton, dentition, and soft tissues.[1,2] However, diagnostic value of orthodontic radiographs and indications for their use are still debatable, and studies that investigated the validity of cephalometric analysis and its influence on orthodontic diagnosis and treatment planning showed inconsistent results. Moreover, the minimum set of records required for orthodontic diagnosis and treatment planning has never been solidly established or defined in the literature.[1-6] At the same time, exposure to radiation is associated with health risks for patients and staff. These risks, more specifically, the somatic stochastic effects, are widely acknowledged and no radiation exposure, even in small doses, is free of risk, particularly in children.[3,4] Consequently, the use of radiation by orthodontists is accompanied by a responsibility to ensure appropriate indication. It must always be justified and delivered in doses ‘as low as reasonably achievable.[5,6] The use of lateral cephalometric radiographs forms an important diagnostic tool in orthodontics treatment as well as orthognathic surgery. However, their 2-dimensional nature presents an inherent limitation to the clinician, as the human body is 3- dimensional.[7] In addition, a significant amount of radiographic projection error further limits their accuracy. Three-dimensional imaging of the human body via computed tomography has been available to the field of medicine for the last 30 years. However, the significant amount of radiation exposure associated with this technology, precluded its widespread use in dentistry.[8] With the development of Cone Beam Computed Tomography, there has been a drastic reduction in radiation exposure to the patient, which allows its use for safely obtaining 3-dimensional images of the craniofacial structures.[9] This should allow the clinician to visualize the hard and soft tissues of the craniofacial region from multiple perspectives, which could have far- reaching implications for treatment planning in orthodontics and orthognathic surgery.[10]

CONE BEAM COMPUTED TOMOGRAPHY

Craniofacial CBCT were developed to counter some of the limitations of conventional CT scanning devices. In craniofacial CBCT the object to be evaluated is captured as the radiation falls onto a two-dimensional retractor. This simple difference allows a single rotation of the radiation source to capture an entire region of interest as compared to conventional CT device where multiple slices are stacked to obtain a complete image. The cone beam also produces a more focused beam and considerably less scatter radiation compared to conventional fan shaped CT devices.This significantly increases x-ray utilization and reduces the x-ray tube capacity required for volumetric scanning. It is said that radiation exposure is 20% of conventional CT or equivalent to full mouth peri-apical radiographic exposure.[11]

ADVANTAGES OF CBCT

- Less cost
- Smaller in size
- Exposure chamber (head) is custom built and reduces the amount of radiation
- Images are comparable to conventional CT and are displayed as full head view, as skull View or as regional components**.**[12,13]

CLINICAL APPLICATIONS IN ORTHODONTICS

With CBCT Orthodontists have many images that are not possible with conventional radiographic measures.

- Impacted teeth and oral abnormalities
- Airway analysis
- Assessment of alveolar bone height and volume
- TMJ morphology
- Lateral and frontal Cephalogram views
- Skeletal views
- Facial analysis
- 3D review of dentition[14]

RADIATION EXPOSURE

CBCT provides three-dimensional images with up to four times less radiation than a conventional CT scan. The resultant radiation is dependent on the settings used (Kvp and mA). The use of lower mA and/or collimation are some of the ways to reduce the amount of radiation the patient receives, but at the same time produces lower image quality than by using higher settings. The patient's effective exposure from a resultant CBCT is as low as 45 μSv to as high as 650 μSv. Full mouth radiographs produce an exposure of 150 μSv and a round trip from Tokyo to Paris is about 135 μSv of exposure. The ADA Council on scientific affairs recommends the use of techniques that would reduce the amount of radiation received during dental radiography known as the ALARA principle (as low as reasonably achievable). This includes taking radiographs based on the patient needs, using the fastest film compatible with the diagnostic task, collimating the size of the beam to as close the size of the film as feasible and using lead aprons and thyroid shields.

DIGITAL CEPHALOMETRY

In 1922, Pacini described a rather primitive method for standardization of radiographic imaging of the head. He recommended positioning of the subject at a fixed distance of 2m from the x-ray source with a film cassette fixed to the head with a wrapping of gauze bandages [8,9]. Almost a decade later in 1931, Broadbent and Hoffarth (The United States and Germany) simultaneously published their own methods of obtaining standardized lateral head radiographs. Their methods published in the Angle Orthodontist in 1937, introduced the field of cephalometry to the orthodontic community. Cephalometry is a vital tool in orthodontic for evaluation of craniofacial complex, determination of morphology and growth, diagnosis of anomalies forecasting future relationship, planning treatment and evaluating the results of growth and effects of treatment. Cephalometrics remains the only quantitative method that permits investigation and examination of the spatial relationship between both cranial and dental structures. The lateral cephalogram provide information regarding skeletal, dental, and soft tissue morphology as well as relationship between these structures.[15]

The use of lateral cephalograms in research includes -

- Quantifying craniofacial parameters in individuals as well as a population of individuals
- Distinguishing normal from abnormal
- Comparing treated samples to untreated controls
- Differentiating populations as homogenous or mixed, and assessing the change of pattern over time

Since its advent in 1931, conventional cephalometry has remained unchanged. Digital radiography has been accepted in the dental community, but high cost delayed their progress. Recently with the development of cost effective radiography (extra oral) and increased utilization of computers in orthodontics has made digital cephalometric imaging a viable option. The paradigm shift is occurring in orthodontics from the widely accepted film based to digital cephalometry. The methodology and various techniques for the development of digital cephalograms are the same procedure as described earlier for digital radiography. To accept this scientific description various studies are being carried out to accept the reliability of these digital cephalograms. Rudolph et al. compared the reliability of digital and conventional cephalometric radiographs in terms of landmark identification error.[16] They concluded similar reproducibility and precision in landmark identification using both direct digital and conventional lateral cephalometric head films. Heiko vesser et al. studied and compared the radiation exposure and dose between conventional cephalometry and digital cephalometry.[17] They

concluded that digital cephalometric radiography cuts the radiation dose in half compared with the conventional screen film technique and that digital cephalometry is more advantageous than conventional cephalometry in that perspective. Jia Kuing Liu et al. studied the accuracy of computerized identification of landmarks using various angular and linear measurements.[18] They concluded that computerized identification of certain landmarks is questionable and further studies are needed to confirm their accuracy. Geelen et al. studied the reproducibility of cephalometric landmarks on conventional film, hard copy and monitor displayed images obtained by a storage phosphor technique. They concluded that the there was no clinically significant difference in landmark identification among the various methods.[19]
A plethora of software's is available to clinician to choose from -

- Vistadent
- Dolphin
- Quick ceph
- Dentofacial Planner
- Vixwin software
- Dr ceph
- Ortho plan
- Ceph x
- Orthoview ceph

Factors to be considered before going to purchase software are -

- Facility of integration of photographs and study models
- Windows based system available
- DICOM compatibility
- Lateral as well as posterio-anterior analysis should be possible

SOFTWARES DEVELOPED IN INDIA
DIGICEPH

Method for computerized digitization analysis and superimposition

- 13 cephalometric analysis
- Developed by the center for Bio-Medical Engineering, IIT Delhi and Dept of Dental Surgery AIIMS

DIGITAL IMAGING AND COMMUNICATIONS IN MEDICINE (DICOM)

American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) formed a joint committee in order to create a standard method for transmission of medical images and their associated information. DICOM defined information standardized not only for images but also for patients, students, reports and other data groupings. With the enhancement made in DICOM (version 3.0) came the development and expansion of picture archiving and communication system and its interfacing medical information systems.

DIGITAL STUDY MODELS

Study models have long been an essential part of the orthodontic process. They have traditionally been cast out of either plaster or stone and have served two main purposes:

- To provide information for diagnosis and treatment planning
- To provide a 3D record of the original malocclusion, any stages during correction and outcome of the treatment.[20,21]

ULTRASOUND IMAGING OF CONDYLAR MOTION [22]

Imaging of the temporomandibular joint in an effort to understand normal and abnormal function continues to be a challenge. The principal methods currently used to image the joint in the sagittal view are x-rays, magnetic resonance imaging, and arthroscopy. The main disadvantage of x-rays is that they provide a static view while exposing the surrounding structures to radiation. With magnetic resonance imaging, the patient's head position is abnormal, which can influence mandibular motion. It is a costly procedure and often requires the patient to travel to a special facility. Arthroscopy involves surgical invasion of the joint with attendant surgical risks as well as the significant likelihood of altering normal function by its presence. Ultrasound imaging has been recognized for some time as having several important advantages: it does not require special facilities and thus has the potential to become available in an orthodontic office, and it can be used to view the joint in a continuum without invasion, discomfort, alteration of the patient's normal head posture, or interference with condylar motion.
Audio frequencies greater than 1600 Hz (cycles per second) are considered ultrasonic. An ultrasonic sound wave passing through the tissue will have a portion of the sound wave reflected on transiting dissimilar tissues. This reflected energy is returned to the ultrasonic emitting device (transducer) where the location of the interface is determined, and an appropriate image is produced representing the interface contours. In earlier studies, ultrasonic transducers have been placed at various parts of the skin surfaces related to the temporomandibular joint area. This produced nonconventional images of the joint from the frontal, superior, or both aspects. Recently Hirt and Knupfer obtained images of the temporomandibular joint in the more conventional sagittal plane. These were images of the joints of cadavers. Until now, obtaining conventional (sagittal) images of the temporomandibular joint via sonography has been limited for several reasons. Ultrasound is unable to penetrate the relatively large mass of bone overlying the joint, and the size of the transducer has prevented its strategic placement in order to produce conventional sagittal images.

THREE-DIMENSIONAL ULTRASONOGRAPHY

Three-dimensional ultrasound imaging is a new technology that presents views of the fetal face with greater clarity than the conventional two-dimensional imaging described previously. The advantages include viewing of the face in a standard anatomic orientation, manipulation of planar views without concern for fetal movement, identification of the exact location of the planar images relative to the surface facial image, and easy interpretation of the lifelike rendered three-dimensional images by a non-trained observer. The sensitivity of three-dimensional imaging in diagnosing cleft lip and palate is considerably greater than two-dimensional imaging.

SURE SMILE

Recent advances in computer management 3D imaging of dentition, manipulation of complex 3D data, and robotics have resulted in a new approach to treatment.[23] A patient centred practice is one that delivers high-quality care with a minimum amount of patient discomfort, compliance demand and chair time and completes treatment on time.

BENEFITS OF SURE SMILE

- Reduce errors in treatment resulting from appliance management
- It provides image capturing, 3D visualization of tools for diagnosis, monitoring, and patient communication along with precision appliances that can help the orthodontist to deliver truly customized care in a patient oriented practice.

CLINICAL PROCEDURES

The process begins with a 3D scan of patients dentition using the oro-scanner (oro matrix) a hand held scanner, this captures in real time in vivo images of dentition. The dentition is prepared for scanning by applying a thin white film, similar to articulating spot spray. It uses structured white light to generate images in rapid succession by projecting a precisely patterned grid on to the teeth. As the hand held scanner is passed over the dentition, reflected images of dentition, reflected images of a distorted grid are recorded with a video camera built into the handle of the scanner. The scanner is passed over the dentition in a rocking motion to allow visualization of all tooth surfaces, including undercut areas. The entire process takes about 1½ minutes per arch. The image is reference independent; meaning the image capturing process is not affected by the movement of patient or scanner. The scanner is placed in a mobile care smile cart that rolls from chair to chair. During the scanning stage, the multiple and over lapping images go to the computer. With sophisticated data registration and management techniques, the images are processed and the computer model is created. The teeth are then compared with teeth in a library of dental morphology. Information voids in the scan are filled with data from the library to further refine models.[24] A full oral scan is taken and integrated with conventional photographs and x-rays and entered into the electronic patient chart. Once the process is complete the teeth can be moved like independent objects in 3 dimensions with software controls. The windows based software allows the operator to diagnose plan treatment and simulate the results. 3D viewing of models like frontal, lateral, posterior or occlusal views or different perceptive by using navigation tools. The teeth can also be viewed in individual arches. The operator can diagnose and plan the treatment with tools to measure tooth and arch dimensions and symmetric and asymmetric arch forms. A coronal cross section like a 3D CAT scan is also available for evaluation of 3rd order relationship. The clinician plans treatment on parameters such as midline, occlusal plane and arch dimensions, multiple plans are to be simulated for comparison. The final treatment plan is then represented in form of 3D diagnostic setup – the Target occlusion. The operator can get treatment alternative by moving the teeth with a mouse or selected menus by enhancing or reducing teeth mesially or distally to simulate inter-proximal disking. The changed in X, Y and Z coordinates can be done in individual teeth to show case difficulty and treatment changes. Inter-arch contact and relations, such as overbite and overjet can be viewed with a cutting plane tool, which displays an inter-proximal or a transverse view at any location along with the arch. Once the target occlusion is done the digital bonding system form library is selected. Then geometric calculation and incorporation of various forces into the wires and their impact in teeth can be calculated. The operator based on the amount of tooth movement and forces required can decide the optimal treatment plan. Any errors in positioning brackets and wire combination can be managed at any stage during the cycle. New oral scans can be used for designing finished wires and fixed 3-3 lingual retainers before deboning.

ADVANTAGES OF SURE SMILE [25]

- Undesirable tooth movement may be reduced
- Arch-wire selection errors may be reduced
- Bracket positioning errors may be reduced
- Bonding adhesive thickness errors can be reduced

ACCURACY OF SYSTEM [26]

- Oro scanner – unblurred images per second with as many as 3500 3D measuring points per image
- Greater accuracy of each points more than 50 microns, a linear error of 0.1 mm per tooth
- Wire bending – Bend positioning error ± 0.1mm, Angular/ torsional error ± 10
- Digital bracket movement ± 25microns; in vivo ± 1mm

CONCLUSION

The above mentioned technological advancements have helped not only the Orthodontists but the whole dental community. These advancements can be used in all branches of dentistry (Prosthodontics, Endodontic, Oral surgery etc). Diagnosis and treatment planning has become much more accurate, easier and less time consuming with these software's. Researchers and developers are striving hard continuously to make dentistry easier for all practitioners worldwide.

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