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Conebeam Computed Tomography a New Light to Dentistry - A Review

Abstract

It describes the different 3D techniques of imaging and uses of Conebeam Computed Tomography (CBCT) in dentistry and specially in orthodontics, CBCT equipment has a greatly reduced physical footprint and is approximately one quarter to one fifth the cost of conventional CT. CBCT provides images of highly contrasting structures and is therefore particularly well suited for the imaging of osseous structures of the craniofacial area. Uses of cbct is increase in different branch in dentistry, it is use in RCT, impacted teeth, cephlometic, air way analysis.

Key Words

3D images; study models; RCT; cephlometric;
visual treatment objective

Ashwani[1], Biswaroop Mohanty[2], Aditya Chaudhary[3], Sateesh Bhatele[4], Anju Aggarwal[5], Himanshu Gupta[6]

[1]Assistant Professor, Department of Orthodontics & Dentofacial Orthopaedics, Maharana Pratap Dental College & RC, Gwalior, Madhya Pradesh, India
[2]Assistant Professor, Department Of Orthodontics & Dentofacial Orthopedics, Kalinga Institute of Dental Sciences, KIIT University, Bhubaneswar, Odisha, India
[3]Assistant Professor, Department Of Orthodontics & Dentofacial Orthopedics, ITS Dental College, Greater Noida, Uttar Pradesh, India
[4]Post Graduate Student, Department Of Oral & Maxillofacial Surgery, SGT Dental College & Hospital & Rc, Gurgaon, Haryana, India
[5]Assistant Professor, Department Of Orthodontics And Dentofacial Orthopedics, ITS Dental College, Greater Noida, Uttar Pradesh, India
[6]Post Graduate Student, Department Of Oral & Maxillofacial Surgery, Maharaja Gangasingh Dental College & Research Centre, Sriganganagar, Rajasthan, India

COMMON DIAGNOSTICS RADIOGRAPH

‘‘Cephalometric’’ images constructed from CBCT scans have been shown to be as accurate as, or in some cases more accurate than, conventional 2D lateral cephalometric radiographs. Additionally, lateral cephalometric radiographs constructed from the CBCT scans can use the information from the right and/or left half of the skull. Constructing these images using one half of the skull can overcome the problem faced with superimposition of the right and left ramus, body, molars, and mandibular condyles. CBCT scans allow an infinite number of focal troughs to be specified and reformatted, compensating for arch variations. Also, separate ‘‘panoramic’’ radiographs can be obtained from the CBCT data, focusing on the maxillary arch and the mandible. Linear and angular dimensions have been shown to be more accurate using the CBCT panoramic images, compared with traditional panoramic radiographs, which is also true when viewing the condyles. Several other views, projectional and tomographic, are used in orthodontics, but not as frequently. Most of these images can be reconstructed from the CBCT data if a CBCT scan has been acquired.[1-10]

IMPACTED CANINE

Possibly the most recognized need for CBCT imaging in orthodontics is that of impacted canine evaluation. The prevalence of impacted maxillary canines is approximately 0.9% to 3.0%. The ratio of palatal to labial impactions has been shown to be as high as 9:1. In the past, orthodontists have used the tube shift technique to compare two periapical radiographs taken at different beam angles to determine the facial/lingual position of the impacted canine. This same lingual, opposite buccal rule is helpful in determining whether the impacted canine is labial or lingual to the incisor roots; however, the degree of displacement is difficult to determine. CBCT imaging is precise in determining not only the labial/lingual relationship but also a more exact angulation of the impacted canine. These 3D images

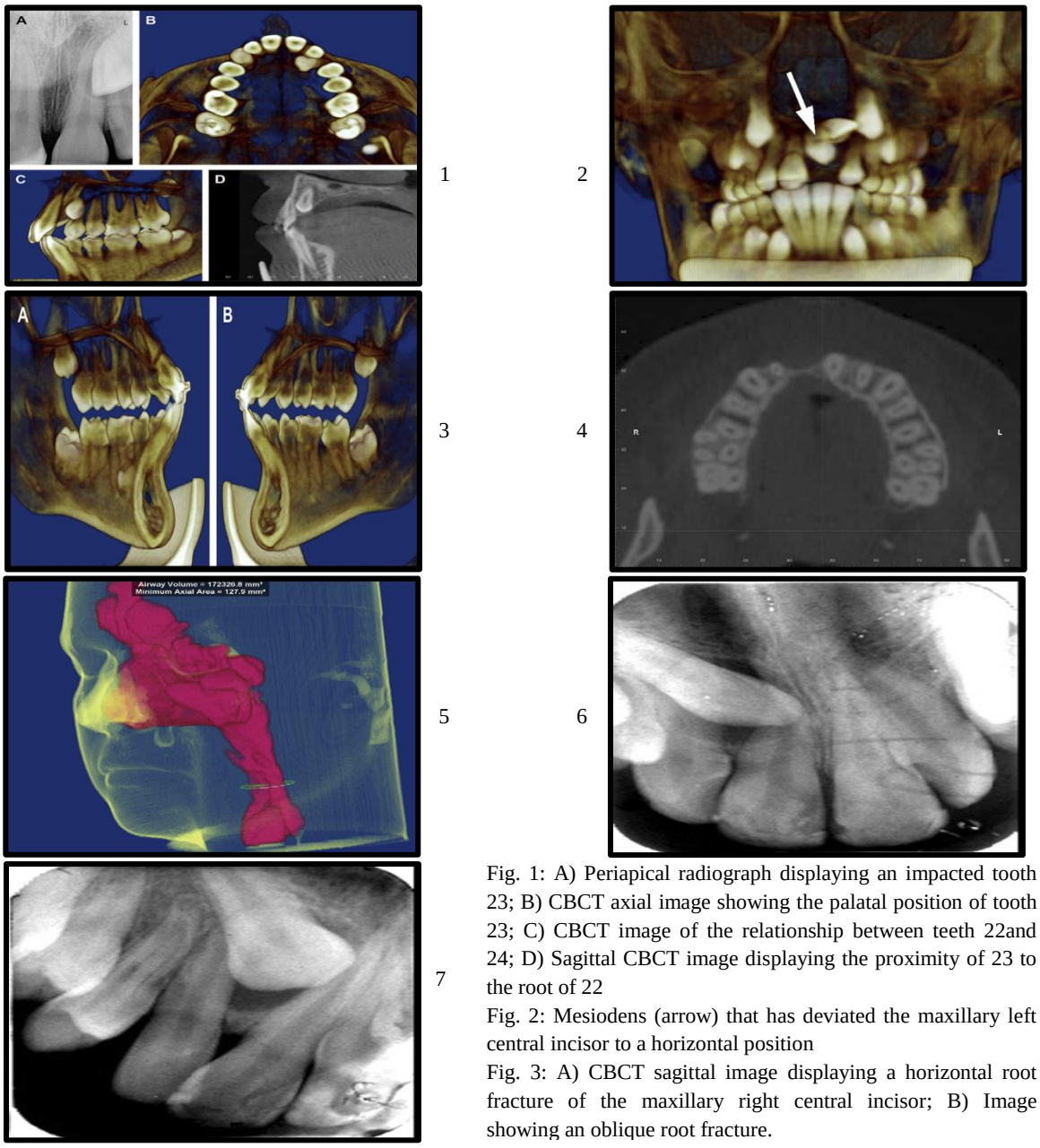

Fig. 1: A) Periapical radiograph displaying an impacted tooth 23; B) CBCT axial image showing the palatal position of tooth 23; C) CBCT image of the relationship between teeth 22and 24; D) Sagittal CBCT image displaying the proximity of 23 to the root of 22

Fig. 2: Mesiodens (arrow) that has deviated the maxillary left central incisor to a horizontal position

Fig. 3: A) CBCT sagittal image displaying a horizontal root fracture of the maxillary right central incisor; B) Image showing an oblique root fracture.

Fig. 4: Axial CBCT image of a patient who has a unilateral cleft and missing central incisor

Fig. 5: CBCT image showing airwayFig. 2: Mesiodens (arrow) that has deviated the maxillary left central incisor to a horizontal position

Fig. 6: A) Periapical radiograph of the impacted right canine shows superimposition of the crown of the canine on the distal part of the root of the lateral incisor; B) Periapical radiograph of the impacted right canine obtained from a more distal angle than that shown in A that eliminates the superimposition and confirms that the canine crown is palatal to the central incisor root. These findings suggest that the impacted tooth should be exposed surgically and orthodontic traction should be performed from the palatal side

are beneficial in determining the proximity of adjacent incisor and premolar roots, which can be invaluable in determining the ease of uncovering and bonding and the vector of force that should be used to move the tooth into the arch with a lesser chance of adjacent root resorption.[11-15]

OTHER IMPACTED TEETH

Various other teeth become impacted less often than canines but still pose a significant orthodontic challenge. Maxillary central incisors can be impacted and displaced subsequent to the presence of a mesiodens. Never before have we been able to determine an exact position of these displaced and impacted central incisors. The position of these

teeth and the root and crown morphology can be evaluated. This knowledge can help determine the desirability of retaining and placing traction on these impacted teeth. Many times, the orthodontist is the first to recognize the presence of supernumerary teeth or odontomas in the young patient. Two-dimensional radiographs, especially panoramic ones, can make definitive diagnosis of an early-forming supernumerary tooth difficult. Second molars can also become impacted and malpositioned, which can be caused by ectopically positioned adjacent third molars or second molar follicles that are inexplicably tipped in an oblique or horizontal orientation. Using these images, the orthodontist and oral surgeon can combine their knowledge to establish a treatment plan that directs attention to the timing of mesiodens removal.[4,14]

ROOT RESORPTION

Most root resorption involved in orthodontic treatment can be readily viewed on periapical radiographs. However, resorption that occurs on thefacial or lingual side of the tooth is difficult to ascertain and quantify with this 2D view. CBCT scanning allows for better viewing of resorption on either of these surfaces. However, the most important relationship of CBCT imaging to root resorption may be that of determining maxillary canine eruption position and its possible relationship with future spontaneous resorption of the adjacent lateral and central incisors.[4,15,16]

FRACTURED ROOT

In the past, periapical radiographs have proved to be the best diagnostic images for evaluating a patient for fractured roots. To view these fractures radio graphically may be difficult if the fracture is in an oblique direction and not parallel to the beam of radiation supplying the radiograph image. Periapical radiographs can be difficult to take immediately post trauma because of swelling, bleeding, and discomfort experienced by these patients. On the contrary, CBCT scans can be acquired quickly and the teeth of interest may be viewed from various angles and directions. The ability to view the cut of a single tooth of interest in the three planes of space makes determining if the involved tooth displays fracture much easier.[4,15]

ORTHODONTIC TAD

The temporary anchorage device (TAD) has gained popularity of late for use in orthodontic treatment. Many tooth movements that were mechanically difficult to accomplish in the past have become achievable with the use of these mini-implants. The placement of TADs by the orthodontist is becoming more common, although TADs will continue to be placed by the oral surgeon. In either case, the knowledge of the root positioning can greatly enhance the opportunity for proper placement and success of TADs. CBCT images allow more accurate and dependable views of the interradicular relationships than panoramic radiographs. These images allow not only more successful placement but also better treatment planning of where these TADs should be placed so that proper force vectors can be used during orthodontic treatment. CBCT data can be used to construct placement guides for positioning mini-implants between the roots of adjacent teeth in anatomically difficult sites .The quality of the bone in the proposed placement sites can be evaluated before insertion of the mini-implants. Quantifying the thickness of the palatal bone can aid in determining the size and location of any TADs that may be treatment planned for the palate. CBCT images have been shown to be an accurate way to assess the volume of bone present at the proposed location. The use of TADs will continue to increase in orthodontics, and retention of these mini-implants will be important to the successful outcome of treatment. The number of orthodontists using CBCT scans and TADs will increase significantly in the near future.[4,16,17]

ASYMMETRY EVALUATION

It can be difficult to evaluate the bony asymmetry of orthodontic patients using cephalometric and panoramic radiographs. Superimposition of structures, patient positioning, and distortion can be frustrating and unreliable. For instance, the comparison of the condyle and ramus lengths can be important to the occlusion of an orthodontic patient. Direct measurements can be made of these structures with CBCT imaging by comparing the right and left sides. Software companies are adding the ability to extract (segment) the mandible or maxilla from the CBCT image and evaluate the bone independent of the other structures. In addition, the unilateral nature of posterior cross bites can be diagnosed more specifically. The determination as to the presence of a truly unilateral cross bite versus one subsequent to a shift of the mandible into centric occlusion can be enhanced. A determination of an asymmetric maxilla or mandible can be accomplished more easily by viewing and measuring the bones in 3D.[4,18]

TEMPOROMANDIBULAR JOINT DEGENERATIVE CHANGES

Panoramic radiography is an acceptable initial tool for the assessment of temporomandibular joint (TMJ) osseous structures. But because of the known limitations of panoramic radiography, the absence of radiographic findings in a symptomatic patient does not rule out obscured osseous changes; moreover, radiographic findings, if present, may not be revealed in full. Conventional tomography has been used extensively for the evaluation of TMJ hard tissues; however, technique sensitivity and the length of the examinations made it a less attractive diagnostic tool for the dental practitioner. CBCT images not only can be taken in the office but also viewed from many different angles and from an almost infinite number of slices. CBCT images of the TMJ have been shown to provide greater reliability and accuracy than tomographic or panoramic views in detecting condylar erosions.[4,19]

CLEFT LIP AND PALATE

Estimates of the size (dimensions) of the osseous defects and the spatial relationship of the defect to other important anatomic structures are difficult to obtain in 2D images. CBCT can provide the cleft's exact anatomic relationships and bone thickness around the existing teeth in proximity to the cleft or clefts. This information is invaluable for the grafting procedures planned and for possible tooth movement in the existing dentition.[4]

SOFT TISSUE

In the past, soft tissue evaluation was difficult using 2D photographs and radiographs. The patient's profile has been the most common soft tissue projection evaluated using photographs and lateral cephalometric radiographs. The profile is visualized using photographs; however, tracings and landmark analysis of the profile are quantified using the soft tissue observed on the lateral cephalometric radiograph. Frontal photographs are used to judge symmetry, but without numerous views from different angles, it is difficult to gain a good feel of facial symmetry. Using the soft tissue data gathered in the CBCT scan, it is possible to rotate and tilt the head in an infinite number of positions to evaluate symmetry of the soft tissue. The positioning of the nose, the alar base fullness, and the inferior border of the mandible are only a few of the items easily studied. Surface area and volume analysis will surely be used in the future to aid in evaluating facial symmetry. It is difficult to gain a good view of the nose with some CBCT machines because this area is at the edge of the image package. Recently, various companies have offered photographic imaging packages to coordinate with the CBCT data, using multiple camera locations. These systems are not widely used, but their use may increase as the cost decreases. Anatomage (Anatomage Inc., San Jose, California) currently has a process to take a common 2D digital facial photograph and map it to the CBCT image without the use of numerous cameras.[4,19]

AIRWAY

Using lateral cephalometric radiographs, the orthodontist may evaluate the airway in a 2D manner. All this evaluation, however, is limited by the fact that we are looking at a flat projection seen in a sagittal or coronal plane. A 3D view of the airway can be readily available with CBCT imaging. Using CBCT images filtered to show airway, it is possible to quantify the volume of the airway and sinuses. The most constricted location of the airway can be found, and the axial view of this region can be quantified. Orthodontists who are keenly interested in studying the patient's airway will surely continue to enhance the analyses that are available using the 3D information.[4,19-21]

OTHER APPLICATIONS OF CONE-BEAM CT [21-25]

Technology is constantly changing, and new applications arise almost daily.

VIRTUAL STUDY MODEL

Virtual models Plaster casts have been used in orthodontics for more than 100 years. They have been used to evaluate the patient's alignment, arch width, occlusion, tooth mass, and soft tissue. Smaller voxel size and innovative software have led to the ability to reconstruct virtual orthodontic study models without the need to obtain alginate impressions. These virtual models can be composed with or without roots evident. For many orthodontists, the presence of roots could be a major improvement over commonly used plaster casts, which only display the crowns. Also, these virtual models can be studied and measurements made on the computer, as is possible with those fabricated currently by the OrthoCad system. If ''hardcopy'' models are needed, these can be fabricated from wax, starch, and plaster, using rapid prototyping technology.

INVISALIGN

The Invisalign (Align Technology, Santa Clara, California) tooth movement system was introduced to orthodontics in 1999. A series of clear

thermoplastic trays are used to gain the desired tooth movement. These removable, computer-generated trays are changed every 2 weeks until the desired alignment and occlusion are gained. Currently, the orthodontist supplies the Invisalign laboratory polyvinyl siloxane impressions and a bite registration. The laboratory uses a computer linked to a destructive scanner to assemble this information into 3D renderings of the patient's teeth. These virtual models are adjusted on a computer per the orthodontist's detailed prescription of tooth movement. Once approved, the computer images are converted to ''hardcopy'' models using stereolithography and the clear trays are fabricated from these models.

CBCT ALIGNER

It may be possible in the future to execute the entire fabrication process of the aligners using CBCT digital data. The CBCT images could be used to create the virtual models, thus negating the need to take and mail impressions and a bite registration. This information could be transferred electronically to certain laboratories (e.g., Align Technologies), and the desired virtual tooth movement can be accomplished by way of e-mail communication between the orthodontist and the laboratory. Even the retainers could be fabricated by the data in the laboratory computer database of the final tooth positions

INDIRECT BONDING OF BRACKETS

Indirect bonding of fixed orthodontic brackets is used by many orthodontists to place these brackets on the teeth more accurately. Currently, in this technique, brackets are adhered to accurate stone models in the desired position. This bracket set-up is then transferred from the models to the patient using various types of trays and composite material. This laboratory fabrication is done either in the orthodontic office or at an outside facility. Construction of ''hardcopy'' models from the CBCT images could allow this indirect bonding to occur in either of these laboratory sites. If accomplished in an outside laboratory, the digital image could be electronically transferred to this laboratory with no pouring up or mailing of impressions involved. The same CBCT file used for the virtual models described earlier could be used for the indirect bonding procedure.

INSIGNIA

The Insignia process (Ormco Corporation, Orange, California) uses 3D imaging data and precision manufacturing to custom make orthodontic brackets and wires for an individual patient. Using an accurate impression taken by the orthodontist, the Insignia laboratory digitally constructs a virtual model of the teeth using specialized 3D scanners. Insignia software integrates these precision images with the orthodontist's prescription to calculate the optimum alignment and occlusion. The bracket for each tooth is then custom fabricated, taking into account the shape of the labial surface of the tooth and its root angulation and overall anatomy. An indirect bonding transfer mechanism is then fabricated so that each bracket may be placed at a specific location on each individual tooth. Wires are fabricated by the laboratory to work closely with the custom brackets to supply the desired orthodontic tooth movement. It is anticipated that an accurate CBCT scan will replace the impression currently taken by the doctor.

SURESMILE

Suresmile technology (OraMetrics, Inc., Richardson, Texas) uses the precision wire-bending capability of robots, combined with digital 3D scanning of teeth, computer simulation, and special wire materials to facilitate orthodontic tooth movement in an accurate fashion. This system uses a handheld, 3D white-light scanning device to gain a virtual image of the patient's dentition. This procedure, done either through intraoral scanning or scanning of dental models, can be achieved with or without orthodontic brackets in place. These virtual images, along with the orthodontic prescription, are then used to position the dentition in its most aligned and interdigitated state. Wires are made by the Suresmile robot from a high-tech and flexible material to reposition the teeth orthodontically to the desired occlusion and alignment. Additional scans are usually taken during treatment to refine the tooth movement. In the future, CBCT images could take the place of current orthodontic impressions and white-light scanning.

CLINICAL IMPLICATION [24-30]

CBCT is a 21st century modality, and it offers an accurate one-to-one measurement that can be made on the images and transferred directly to the surgical field.

1) A 3-D image can show the surgeon an exact picture of what will be seen in the operating room when the flap is opened and the impacted tooth is laid bare.
2) Given the greater degree of precision and clarity that CBCT exhibits, it has advantages over plain film radiography in that it offers 3-D imaging

that adds depth which may be viewed in the full 360-degree range and in any desired plane around the immediate area of interest.

3) Unexpected anatomical or pathological findings that are not noted in plain film radiographs and that may obstruct or delay orthodontic treatment until they are eliminated may be found when CBCT is used. Clinical diagnosis of existing pathology can be assessed accurately by using CBCT.
4) In addition, 3-D imaging contributes to more accurate and less traumatic surgical exposure, as well as to more efficient and directionally appropriate orthodontic traction, than does traditional 2-D imaging and thus contributes to faster resolution and better overall tooth prognosis.
5) The use of CBCT occasionally can be the difference between the success and the failure of the treatment plan

Clinical Implications In Impacted Teeth

The indications for CBCT in relation to the treatment of impacted teeth are particularly in terms of anatomical detail, root resorption and the labiolingual relationships of the impacted tooth with the roots of neighboring teeth, in addition to determining the pathway for biomechanical resolution.

Cone-Beam Presentation Portfolio

CBCT scanning involves a single rotation of thecone-beam source around the patient's head. Ittakes five to 40 seconds and uses a voxel (volumetric pixel) size of 0.1 to 0.4 millimeters, depending on the CBCT unit being used. For a patient with bilaterally impacted maxillary canines, the scanning needs to encompass the anterior maxilla from the left second premolar to the right second premolar to provide the practitioner with good clinical orientation. The presentation portfolio needs to provide the maximum of information for the orthodontist and surgeon to use. The information should include the following:

1. **Axial (horizontal)** slices from the level of the cementoenamel junction of the erupted teeth progressing superiorly at 1-mm intervals to the level of the apexes of the unerupted canines;
2. **Transaxial (vertical)** slices at 1-mm intervals and cut radially in an arc from the left second premolar to the right second premolar;
3. **Coronal slices** at 1-mm intervals from the first labial cut that touches the incisors to the second premolars;
4. Ideally, a selection of 3-d images;
5. A video of the 3-D image rotating both horizontally and in the vertical plane around the dentition, if the CBCT unit includes this option. A single scan can offer all of these options.

Clinical Implication In Office Setting

The decision to invest in digital radiographic equipment should be a simple one for dental practitioners. Although digital x-ray sensors have long equaled analog film for diagnostic tasks, they have several advantages over film radiography, including immediate image production with solid-state devices; interactive display on a monitor with the ability to enhance image features and make direct measurements; integrated storage with access to images through practice management software systems; security of available backup and off-site archiving; perfect radiographic duplicates to accompany referrals; security mechanisms to identify original images and differentiate them from altered images; the ability to tag information such as a patient identifier, date of exposure and other relevant details; and interoperability of the Digital Imaging and Communications in Medicine file format.[31]

Clinical Implication In Implant

The integration of chair side CAD/CAM software and CBCT provides dentists with a combined data set they can use for implant planning. This method may allow dentists more flexibility for delivering implant prosthetics both milled custom abutments and milled crowns chair side. The digital work flow for implant dentistry and chair side CAD/CAM offers new approaches to the way dentists can practice implant dentistry.[17,30]

CONCLUSION

Cone beam computed tomography (CBCT) is a diagnostic imaging technology that is changing the way dental practitioners view the oral and maxillofacial complex. CBCT uses radiation in a similar manner as does conventional diagnostic imaging and reformats the raw data into Digital Imaging and Communications in Medicine (DICOM) data. DICOM data are imported into viewing software that enables the manipulation of multiplanar reconstructed slices and three-dimensional volume renderings. DICOM data also may be used in third-party software to aid in dental implant placement, orthognathic surgery and orthodontic assessment.

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