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REVIEW ARTICLE

CBCT in Orthodontics: The Wave of Future

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ABSTRACT

Cone beam computed tomography (CBCT) has probably been one of the most revolutionary innovations in the field of dentistry in the past decade and it provides a novel platform for orthodontic diagnosis and treatment planning. Current imaging techniques are essentially two-dimensional (2D) representations of three-dimensional (3D) objects and suffer from several limitations. Hence, fulfillment of ideal imaging goals has been limited. Two-dimensional radiographs are insufficient, especially in complex cases like impacted teeth, supernumerary teeth and orthognathic surgeries. CBCT images provide far more detailed information than conventional 2D radiographs and are user friendly. Soft tissues, skull, airway and the dentition can be observed and measured on CBCT images in a 1:1 ratio.

Clinical significance: CBCT provides an excellent tool for accurate diagnosis, more predictable treatment planning, more efficient patient management and education, improved treatment outcome and patient satisfaction. This article focuses on various applications of cone beam CT technology in orthodontics.

Keywords: CBCT, 3D imaging technology, Orthodontic diagnosis, Virtual models.

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INTRODUCTION

Comprehensive visualization and records of the craniofacial complex have always been important goals in orthodontic imaging. These tasks have routinely been performed by means of plaster models, photographs and radiographs. Current imaging techniques in the dental office are essentially two-dimensional (2D) representations of three-dimensional (3D) objects. These 2D projections, suffer from several limitations like magnification, distortion, superimposition and misrepresentation of structures. However, cone-beam computed tomography (CBCT) has gained considerable acclaim worldwide in recent years as a viable 3D imaging modality.

The introduction of CBCT specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift. It has created a revolution in maxillofacial imaging expanding the role of imaging from diagnosis to image guidance of operative and surgical procedures with the help of various software applications.

CBCT in dentistry is high resolution, low distortion, digital imaging of the hard tissues of the head. Instead of pixels, the resolution is measured in voxels and often is sharper than a conventional CT. Cone-beam refers to the cone shape of the X-ray beam, unlike conventional CT, which uses a fan-shaped beam to create multiple thin slices, as shown in Figure 1 CBCT produces panorex and cephalometric projections, which become 3D when the data is reformatted in a volume. With CBCT technology all possible radiographs can be taken in under 1 minute. The orthodontist now has the diagnostic quality of periapicals, panoramic, cephalograms, occlusal radiographs, and TMJ series at their disposal, along with views that cannot be produced by regular radiographic machines like axial views, and separate cephalograms for the right and left sides.

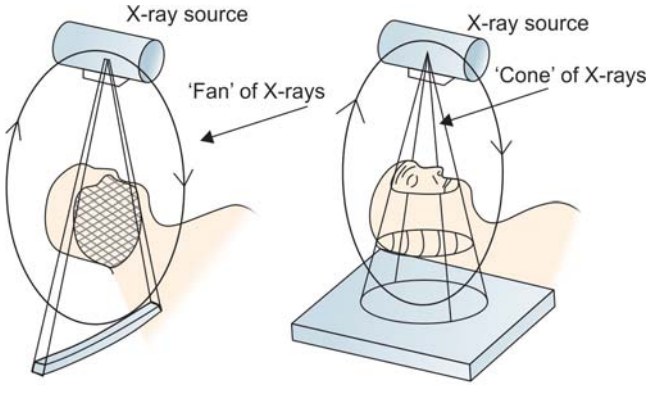


Fig. 1: Diagrammatic representation of image capture technique of CT and CBCT devices

Complexities of the craniofacial complex, dentition and airway present challenges in obtaining conventional images. CBCT has image-fidelity advantages over conventional imaging that can lead to improved visualization. CBCT is changing orthodontics with respect to clinically assessing patients and is evolving with respect to diagnosis, clinical techniques and outcomes.

This article discusses the application of CBCT in various orthodontic tasks, from simple to more advanced. It also takes a glimpse into the future to determine how CBCT may become a normal part of high-tech orthodontic treatment.

Practical Applications of CBCT in Orthodontics

Impacted Tooth Position

The most recognized need for CBCT imaging in orthodontics is that of impacted canine evaluation. CBCT imaging is precise in determining not only the labial/lingual relationship but also a more exact angulation of the impacted canine.[1,2] These 3D images are beneficial in determining the proximity of adjacent incisor and premolar roots (Figs 2A to C), which can be invaluable in determining the ease of uncovering and bonding. It also helps in deciding the vector of force that should be used to move the tooth into the arch with a lesser chance of adjacent root resorption.[3]

Root Resorption

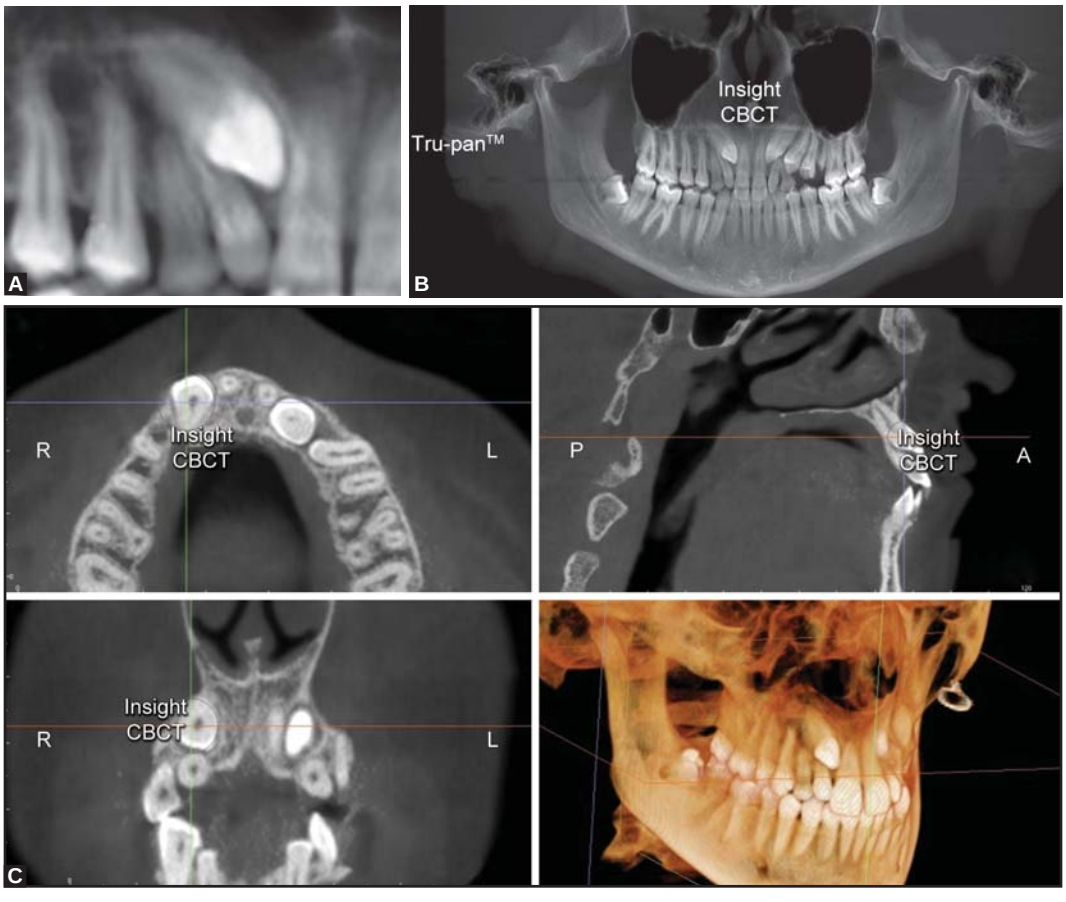
Routinely Orthopantomograms and intraoral periapical radiographs are used to view root resorption, but these radiograhs have certain limitations due to which they are unable to provide adequate information.[4] Root resorption can be observed readily in CBCT images, and the image clarity allows clinicians to classify the type of root resorption. For teeth with multiple roots, resorption can be localized to a specific root.

Fractured Roots

To view root fractures radiographically, it may be difficult if the fracture is in an oblique direction. With CBCT, the tooth of interest can be viewed in all the three planes of space making it easier to determine the site of root fracture and degree of displacement.[5]

Orthodontic Implants Placement

The knowledge of the root positioning can greatly enhance the opportunity for proper placement and success of orthodontic implants.[6]



Figs 2A to C: (A) Periapical view of a maxillary canine, (B) CBCT image showing panoramic view, (C) CBCT images showing the relationship of the impacted canine with adjacent teeth

CBCT images allow more accurate and dependable views of the inter-radicular relationships than panoramic radiographs.[7] CBCT data can be used to construct placement guides foe positioning mini-implants between the roots of adjacent teeth in anatomically difficult sites.[8] The volume and quality of the bone in the proposed placement sites can be evaluated before insertion of the mini-implants.[9,10]

Location of Anatomic Structures

Anatomic structures, such as the mental foramen, inferior alveolar nerve, maxillary sinus, and adjacent roots are easily visible using CBCT. CBCT images also allow precise measurement of distance, area and volume which helps the clinicians in treatment planning for sinus lifts, ridge augmentations, extractions and implant placements.

Asymmetry Evaluation

Three-dimensional visualization of the patient allows for a more accurate evaluation of both dental and skeletal asymmetries. Presence of a truly unilateral crossbite *vs* one subsequent to a shift of the mandible into centric occlusion can be determined more easily by viewing and measuring the maxillary and mandibular bones in three dimensions.[11]

Temporomandibular Joint Assessment

Conventional tomography has been widely used for TMJ evaluation; however, technique sensitivity and the length of the examinations made it a less attractive diagnostic tool for the dental practitioner. CBCT images of the TMJ have been shown to provide greater reliability and accuracy than tomographic or panoramic views in detecting condylar erosions.[12,13] Presence of temporomandibular dysfunction can complicate orthodontic treatment and hence requires carefull assessment of TMJ anatomy, before, during and after orthodontic treatment. Follow-up CBCT images made over an extended period of time can be important to the orthodontist in evaluating the process of any suspected degenerative changes.

Airway Analysis

Airway analysis has conventionally been carried out by using lateral cephalograms. The CBCT technology provides a major improvement in the airway analysis, allowing for its 3D and volumetric analysis (Fig. 3). Three-dimensional airway analysis will be an extremely useful tool in diagnosis and management of complex clinical conditions like sleep apnea and enlarged adenoids.[14,15]

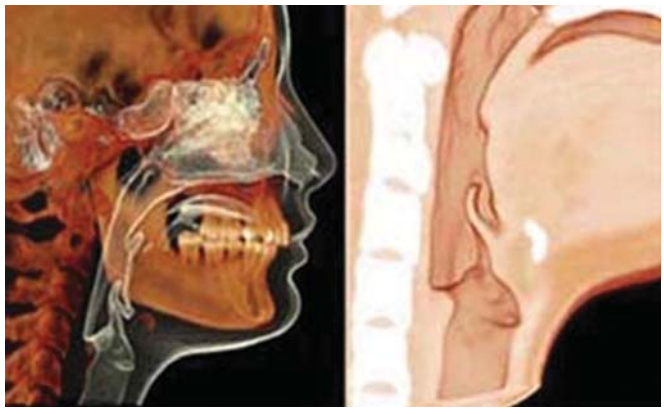


Fig. 3: Three-dimensional view of the airway with CBCT (*Courtesy:* Anatomage Inc. San Jose, CA, with permission)

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.[16,17]

CBCT generated Cephalograms

The CBCT data set can be reformatted to generate a CBCT-reconstructed lateral cephalogram so that conventional measurements can be made and compared with existing 2D norms.[18-20] These CBCT reconstructed lateral cephalograms (Fig. 4) offer the advantage of ability to digitally reorient the head position in cases in which the patient did not undergo scanning with the proper head position.

Fig. 4: CBCT reconstructed lateral cephalogram (*Courtesy:* Anatomage Inc. San Jose, CA, with permission)

The image quality can also be enhanced by virtually sculpting away extraneous superimposing skeletal structures. In addition, separate images can be created of the left and right sides for assessment of asymmetries.

Pathologies of Jaws

Presence of radiopaque lesions near the apexes of teeth, such as enostosis, condensing osteitis, dense bone island and focal apical osteopetrosis are not readily visualized on panoramic radiographs.[21,22] They appear to have no causative factors but can prevent tooth movement. Such lesions can be viewed easily using CBCT images.

Orthognathic Surgery

Several applications of CBCT in orthognathic surgery treatment simulation, guidance and outcome assessment have been developed. CBCT 3D surface reconstructions of the jawbones are used for preoperative surgical planning and simulation in patients with traumas and skeletal malformations.[23-25] Coupled with dedicated software tools, simulations of virtual repositioning of the jaws, osteotomies, distraction osteogenesis and other interventions can now be successfully implemented.

Superimpositions

The introduction of CBCT allows clinicians to perform superimpositions in three-dimensions and has eliminated some of the errors that occur with traditional lateral cephalometric superimposition. These 3D superimpositions help in better assessment of treatment outcomes.

Future uses for CBCT

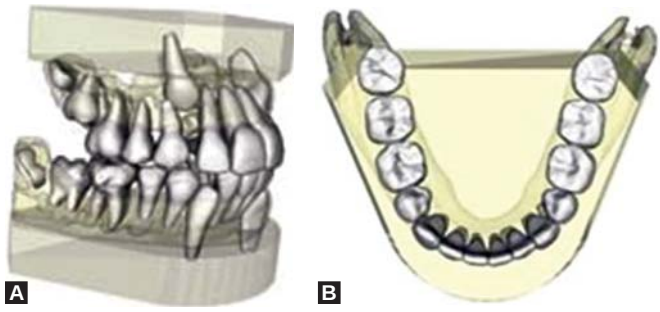
Technology is constantly changing and new applications arise almost daily. The following applications of CBCT technology gives a glimpse of what may be available in the near future.

Virtual Models

CBCT data can be used to produce 3D digital study models (Fig. 5A and B) without the need for alginate impressions. It avoids patient discomfort and saves orthodontist's valuable chair time. These models are of higher diagnostic value than other digital models because it includes not only the tooth crowns but also roots, impactions, developing teeth and alveolar bone.[26,27]

Invisalign Aligner

It may be possible in the future to execute the entire fabrication process of the aligners using CBCT digital data.[11]



Figs 5A and B: (A) AnatoModel* with transparent alveolar bone, allowing visualization of roots and developing teeth attached to plaster-like virtual bases, (B) AnatoModel created from scans of teeth with isolation of mandibular arch for occlusal view. (*Anatomage, Inc, 111N. Market St., Suite 800, San Jose, CA 95113; www. anatomage. com. *In vivo* Dental is a trademark)

The CBCT images could be used to create the virtual models, thus negating the need to take and mail impressions and bite registration. This information can be transferred electronically to laboratories 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

Construction of 'hardcopy' models from the CBCT image can be used for laboratory procedures required for indirect bonding.[11]

Custom-made Brackets and Wires

CBCT data can be used precisely to manufacture custom-made orthodontic brackets and wires for an individual patient.[11]

CONCLUSION

Three-dimensional CBCT based hard and soft tissue simulations, photographic integrations and superimpositions have ushered in a new era of dynamic CBCT imaging. Future developments in this field offer promises of even greater benefits in orthodontic diagnosis and treatment. The long awaited incorporation of the 3D to our radiographic records is soon becoming a reality. CBCT is the future of orthodontics and the applications in orthodontics seem almost limitless.

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