Review Article

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CBCT In Orthodontics

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ABSTRACT

Background: The aim of orthodontic diagnosis is to identify dento-alveolar, skeletal and functional alterations in the maxillo-facial complex. Diagnosis and treatment planning are based on a combination of study models, intra-oral and extra-oral images, and radiographs, traditionally consisting of panoramic and cephalometric radiographs. Cephalometric analysis (CA) plays an important role in diagnosis and treatment planning. Traditional CA is based on three different X-ray projections: latero-lateral teleradiography, postero-anterior teleradiography and axial projection. However, conventional radiographs are limited because they provide a 2-D representation of 3-D structures. The traditional system, analysing the three dimensions separately, is insufficient because dento-facial alterations often take place in 3-D space. The recent introduction of CBCT in combination with computer software allows the application of this new methodology to different fields of dentistry,including its successful use in orthodontics. Cone beam CT (CBCT) has become an increasingly important source of three dimensional (3D) volumetric data in clinical orthodontics since its introduction into dentistry in 1998. The purpose of this manuscript is to highlight the current understanding of, and evidence for, the clinical use of CBCT in orthodontics, and to review the findings to answer clinically relevant questions.

Keywords: CBCT, dentistry, orthodontics.

INTRODUCTION

Diagnosis in orthodontics forms a very important basis for treatment planning. The aim of orthodontic diagnosis is to identify dento-alveolar, skeletal and functional alterations in the maxillo-facial complex. Diagnosis and treatment planning are based on a combination of study models, intra-oral and extra-oral images, and radiographs, traditionally consisting of panoramic and cephalometric radiographs.[1]Cephalometric analysis (CA) plays an important role in diagnosis and treatment planning. They are performed to determine deviations in the skeletal and dentoalveolar structures by identifying specific landmarks on both hard and soft tissues and consecutively calculating the spatial and angular relationship between them. The reliability of cephalometric analyses depends on projection and identification errors.[2,3]However, conventional radiographs are limited because they provide a 2-D representation of 3-D structures. The traditional system, analysing the three dimensions separately, is insufficient because dento-facial alterations often take place in 3-D space. Earlier the three dimensional representation was limited to plaster casts and more recently the digital models but the introduction of cone beam computed tomography (CBCT) has enhanced the effectiveness of diagnostic procedures in specific situations. The present article gives an insight into the advantages and uses of the cone bean computed tomography in orthodontics.

CBCT- a brief history and advantages

CBCT was introduced in dental radiology in 1998 with the NewTom QR-DVT 9,000 (NIM, s.r.l., Verona, Italy).[4] After an initial period of slow adoption and the emergence of other CBCT manufacturers,[5,6] this technology has become

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widely accepted in recent years Many different names have been suggested for this technology.[7]Although functional nomenclature, such as digital volume tomography or cone beam volumetric tomography (or simply volumetric tomography or cone beam imaging), have been proposed in an effort to differentiate it from its high-radiation, conventional medical computed tomography (CT) counterpart, the original CBCT label seems to have been largely adopted by most users, albeit it is somewhat of a misnomer. During a CBCT scan, many single 2D snapshot images are captured from predefined angles as the machine moves through a single isocentric rotation of the x-ray source/sensor unit. These raw images are then computationally compiled into a 3D dataset with the use of specialized reconstruction algorithms. The volume is often referred to as the "3D image," although technically this is still a misnomer because the views on the computer screen are in reality still planar and not holographic projections. Nevertheless, the resultant overlap-free "3D image" still offers many advantages over standard 2D x-ray radiographs, such as:

- 3D representation of dental and craniofacial structures;
- custom image reformatting to provide optimal visualization from different angles and perspectives;
- orthogonal images that do not contain magnification errors or projection artifacts
- management of superimpositions;
- interoperability in Digital Imaging and Communications in Medicine (DICOM) format;
- generation of data that can be used in other diagnostic, modeling, and manufacturing applications, and
- radiation exposure within a similar range of other dental radiographic imaging devices, which is generally an order of magnitude lower than that of medical CT devices.[8-11]

Current scientific status of the use of CBCT

Technology assessment

Radiation exposure and comparisons between CBCT and other forms of imaging: CBCT has substantially lower radiation, but lower resolution than spiral CT.[12] The currently available CBCT units have variable radiation exposure in the range of 87 to 206 mSv for a full craniofacial scan.[13,14] Thus, when compared with the combined radiation exposure of conventional orthodontic images including a panoramic radiograph (14.2–24.3 mSv), a lateral cephalogam (10.4 mS) and a fullmouth series (13–100 mS), CBCT radiation exposure is equivalent to or slightly higher than traditional imaging.

Accuracy of CBCT-derived cephalograms and measurements vs gold standard: Cephalograms reconstructed from CBCT data have no statistically significant difference in linear and angular measurements relative to traditional cephalograms,[12]whereas measurement error from CBCT images are lower than those from cephalograms.[15] 3D measurements from CBCTs can be made in several visualization modes, including multiplanar (MPR), volume rendered (VR) and shaded surface display (SSD).[16,17] Of these, point-to-point measurements made in the MPR mode are highly accurate when compared with physical skull measurements, whereas the surface anatomy measured in VR and SSD modes have a measurement error of 2.3% as compared with direct physical measurements. The error in VR and SSD display modes results are due to the fact that the surface contours are estimated in these modes. These findings suggest that identification and targeting of landmarks should be done using the digital imaging and communications in medicine (DICOM) volume in an MPR display mode.

Comparison of CBCT vs panoramic radiography

A subjective comparison of images from two CBCT units(NewTom 9000, QR s.r.l., Verona, Italy and Arcadis Orbic 3D, Siemens Medical Solutions, Erlangen, Germany) and routine panoramic radiography demonstrated that CBCT provides more information than the radiographs for localizing impacted and retained teeth, root resorption, cleft lip and palate (CLP), and third molar evaluations but not for changes in the TMJ.[18]

Uses in Orthododntics

Supernumerary Tooth

Supernumerary teeth are those that develop in addition to the normal complement and occur in 1% to 4% of the population. They occur frequently in the anterior maxilla (mesiodens), maxillary molar, and premolars and may interfere with normal tooth eruption or cause a diastema in the upper incisors.[19]

Impacted Tooth

Although CBCT imaging clearly enhances the visualization of normal and abnormal anatomy and pathologies, the impact of the additional information obtained from these scans in refining or changing treatment plans in various situations is less clear. CBCT has been shown to enhance the ability to accurately localize the canine, evaluate its proximity to other teeth, examine the follicle size and assess resorption of the adjacent teeth.[20]

Root morphology and resorption:

Root length, root form and root resorption have traditionally been assessed via periapical radiographs. However, CBCT could provide enhanced visualization of roots, making it a valuable tool for assessing pre-orthodontic or postorthodontic root resorption.[21]

TMJ anatomy in health and disease:

Little information is currently available on the efficacy of CBCT scans in enhancing the diagnosis of TMJ disorders over routine radiography. It has, however, been reported that little additional information on gross morphological changes in TMJ structures is derived from CBCT relative to an orthopantamogram in the majority of cases (86%).[22] In contrast, in a more refined

study, interactive and static CBCT scans demonstrated cortical erosions more accurately (95% and 77%, respectively) than normal panoramic projections (65%), thereby providing more diagnostic accuracy for detailed assessment of the articular surface of the TMJ. [23]

Bone quality and quantity assessments:

With the widespread use of temporary anchorage devices (TADs), the determination of bone volume, bone quality, and the location of adjacent structures have become important in providing orthodontic treatment. It has been shown that a location 4 mm palatal to the incisive foramen provides excellent bone volume for palatal bone screws.[24,25]

Sinuses and Airway Evaluation

Use of CBCT for the assessment of the sinuses and airway is emerging as a major application for the technology.[26] This information is particularly relevant to the orthodontist because mouth breathing and consequent airway obstruction is considered an etiology of malocclusion. Unfortunately, the traditional orthodontic records do not allow for comprehensive evaluation of the airways Detailed views of the sinuses and the maxillary osteum are readily available.

Cleft Lip and Palate (CLP)

CBCT offers many unique advantages for imaging of patients with CLP. The rapid acquisition time ranging from 5.7 to 40 seconds is a tremendous advantage for young patients and for patients who have difficulty remaining stationary. The much lower radiation dose for the patient is favorable for subsequent imaging sessions and decreases the total cumulative radiation dose compared with serial medical CT scans. Medical

CT has been used for visualization of cleft palates.[27] and other anomalies but there is concern for single and cumulative exposure to young patients.[28] Recent improvements in CBCT features of resolution, soft-tissue contrast, and specialized reconstruction algorithms for the head and neck region, along with a significantly reduced radiation exposure, make it a preferred maging modality of choice for CLP patients. In addition, the image quality is generally superior to that of medical CT allowing for detailed visualization of the cleft region. CLP patients often have supernumerary teeth and malformed teeth in the anterior maxilla. This region is very difficult to image with traditional dental films. For osteoplasties, CBCT provides valuable information on the morphology of the bone defect, the proximity of adjacent teeth, and assessment of the size and volume of the bony defect, allowing clinicians to estimate the amount of bone required to repair the defect. This aspect can play a decisive role in surgical treatment planning, especially in cleft patients requiring autologous bone graft and other surgical procedures.

Orthognathic surgery and distraction osteogenesis:

CBCT imaging offers the ability to capture images and to analyze the craniofacial hard and soft tissues and their spatial relationships using virtual patient-specific models and appropriate software. Virtual anatomical models can be constructed from CT volume and co-registered with other available 3D image data. The virtual models can then be used to simulate or test treatment options, construct anatomically correct replacement grafts and ultimately be an important tool during the surgical procedure. Databases also can be linked to anatomical models to provide the modelled tissues with attributes that simulate tissue responses to growth, treatment and function. For example, facial soft tissues can be attributed with viscoelastic properties and linked to the underlying hard tissues so that simulated manipulation of the hard tissues (teeth and skeleton) produce an appropriate deformation response in the associated soft tissues. This process can provide a clearer representation of expected changes following treatment when compared with less sophisticated modelling.[29]

CONCLUSION

In conclusion, over the past decade since the introduction of CBCT into dentistry several studies have accumulated valuable data on technology assessment, craniofacial morphology in health and disease, treatment outcomes and efficacy of CBCT images in diagnosis and treatment planning. Although CBCT continues to gain substantial popularity, its use is recommended primarily in select cases in which conventional radiography cannot supply satisfactory diagnostic information, including cleft palate patients, assessment of unerupted tooth position, supernumerary teeth, identification of root resorption caused by unerupted teeth, evaluating boundary conditions and planning orthognathic surgery. CBCT imaging will find increasing acceptance and application in the diagnosis and treatment, with a subsequent phasing out of conventional radiographs. Ongoing development of 3D imaging promises to enhance the precision and effectiveness of our diagnosis and treatment planning.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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