The Applications of Cone Beam Computed tomography in Dentistry

Rajiv Ahluwalia,[1] Parvinder Kaur,[2*] Sumita Giri,[3] Chetna Arora,[4] Puja Malhotra,[5] Mayank Singhal[6]

[1]Professor & HOD, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

[2]Professor, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

[3]Professor & HOD, Department of Conservative Dentistry and Endodontics, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

[4]Professor, Department of Conservative Dentistry and Endodontics, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

[5]Professor & HOD, Department of Prosthodontics and Crown & Bridge, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

[6]Professor, Department of Oral & Maxillofacial Surgery, Santosh Dental College & Hospital, Santosh Deemed to be University, Ghaziabad, Delhi NCR

***Corresponding author- Parvinder Kaur**

ABSTRACT

The diagnostic methodology employed in dentistry, and particularly in orthodontics, has undergone a substantial transformation as a result of the development of three-dimensional (3D) imaging technology. In cases of severe skeletal anomalies or tooth impactions, 3D imaging may be required even though standard imaging techniques such orthopantomography, lateral cephalometric analysis, and anteroposterior graphs can provide enough information in the case of mild to moderate orthodontic deformities. Despite its relatively high cost, poor vertical resolution, and significant radiation dose, computed tomography (CT) has frequently been used when precise 3D imaging is required. Contrary to traditional CT applications, the advancement of cone beam computed tomography (CBCT) technology has provided significant benefits over the traditional approach, including reduced radiation exposure, improved image quality, a quick scan time, fewer image artefacts, chair-side image display, and real-time analysis. These benefits have given dental professionals the chance to utilise 3D imaging more frequently by comparatively reducing radiation dose concerns, cost load, and availability, in particular. Therefore, the purpose of this review is to outline clinically pertinent circumstances and to emphasise the current understanding of CBCT practise in orthodontics.

Keywords: Cone beam computed tomography, orthodontics, 3D imaging.

INTRODUCTION

Treatment of malocclusions and facial discrepancies, which are related to dental and skeletal divergences, is the main goal of orthodontic treatment, and in particular, dentofacial orthopaedics. The major complaint of a patient and the skills of orthodontics are typically the foundation of the treatment strategy to accomplish this goal. The results of treatment are anticipated to be aesthetic, psychological, and functional. Detailed radiographic imaging of the face components is typically necessary for differential diagnosis and treatment planning of such defects. In particular, lateral cephalometric imaging and conventional radiography have long served as the foundation of the diagnostic process [1]. One of the causes of treatment failure and relapse has been identified as the limits of such conventional procedures caused by the transformation of three-dimensional (3D) anatomy to two-dimensional pictures [2]. These consist of rotational errors, linear projective transformations, superimposition of anatomical features, geometric distortion, and discrepancies in magnification [3] Cone beam computed tomography (CBCT), a more recent development, allows for 3D imaging of the anatomy, allowing for the identification of intricate relationships between nearby tissues [4]. This has improved with the advancement of computer software technology, which has made it possible to thoroughly evaluate these photographs for a variety of demands.

Modern Orthodontic Radiography Demands

When an orthodontist requests radiographs, they are typically utilised in conjunction with clinical diagnosis and evaluation of the effectiveness and result of the therapy. However, the need for these radiographs for each patient must be justified carefully based on the patient's primary complaint, medical history, physical examination, and potential treatment goals [5].

Choosing the best imaging technology, getting the image, and interpreting it are the three fundamental components of justifiable radiography practise. The least amount of radiation exposure and greatest amount of diagnostic value should be found in the ideal imaging procedure. Even in nations where standards specify algorithms based on patient age and clinical results, this practise is still debatable. According to the European Guidelines on Dental Radiology and the approved guideline in the United Kingdom, routinely ordering radiographs for all patients is categorically classed as contraindicated [6,7]. Although the American Dental Association Council on Scientific Affairs has released an advisory statement on the use of CBCT in dentistry, it is interesting that there is no implemented standard in the United States [8].

Knowledge on CBCT Imaging: Orthodontist and Patient

Because CBCT technology is still quite new and improving quickly, it can be challenging for a physician to keep up with new discoveries and to expand their clinical knowledge. However, the orthodontist should be very knowledgeable about the most recent advancements in this technology in order to properly diagnose the patient and advise the patient about the dangers of radiation exposure. For accurate and exact interpretation of the data produced from CBCT imaging, a high level of skill is required. In other words, inexperienced doctors run the risk of misreading CBCT pictures and missing or making false-positive diagnoses [9]. Only when the orthodontist is frequently updated with the appropriate knowledge and clinical experience is it feasible to prevent this risk.

Radiation Dose Considerations

The as-low-as-reasonably-achievable (ALARA) approach should be followed when making a decision regarding any radiographic imaging technique. Only if the anticipated information has the potential to alter a patient's treatment options or result can CBCT be justified. Calculating a CBCT scan's effective dose22 and comparing it to the following values has historically been the most common method for estimating radiation risk: 1) assessments from comparable imaging modalities, such as multiples of standard panoramic pictures or a multi-slice medical CT, 2) background equivalent radiation time, such as days of background radiation, or 3) radiation harm (stochastic-cancer rate). These comparisons frequently use variable and non-absolute base units (typical panoramic dose, background radiation, weighted probability of fatal and non-fatal malignancies). This suggests that the risk of CBCT may be stated either conservatively or generously compared to the danger of panoramic radiography, depending on the panoramic picture dose utilised for the comparison. In-depth explanations and disclosure to patients about radiation exposure risks, benefits, and imaging modality alternatives are essential and should be recorded in the patient records because CBCT exposes patients to ionising radiation that may pose elevated risks to some high-risk patients (pregnant or younger patients).

Radiation exposure and comparisons between CBCT and other forms of imaging: Compared to spiral CT, CBCT has significantly less radiation but inferior resolution. The radiation exposure for the currently accessible CBCT devices ranges from 11 to 674 Sv for dento-alveolar scans to 30 to 1073 Sv for complete craniofacial scans. Additionally, the multislice CT radiation dose ranges from 280 to 1410 Sv. 24 The following list provides an approximation of radiation doses for conventional imaging: a whole mouth series, 13-100 Sv, a lateral cephalogam, 2.7-24.3 Sv, and a panoramic radiograph [10].

Comparison of CBCT vs. panoramic radiography: CBCT can provide more information than conventional radiographs in localising impacted and retained teeth, root resorption, cleft lip and palate (CLP) evaluation, and third molar evaluations, but not for evaluating changes in TMJ, according to a subjective comparison of images from two different CBCT units (NewTom 9000, QR s.r.l.; Verona, Italy, and Arcadis Orbic 3D, Siemens Medical Solutions; Erlangen, Germany) [11].

Dose consideration in younger patients: The relative vulnerability of various tissues to the same level of radiation exposure is referred to as an effective dose. Depending on risk-weighting factors (differences in exposed tissue sensitivity, gender, and age) and absorbed radiation dose, the risk of carcinogenesis in particular tissues and organs varies. Multiplying organ doses by risk-weighting factors yields the effective dose [12].

How to Minimize Patient Radiation Exposure

The doctor who submitted the request for the conditions in which the image is to be taken is nonetheless responsible even if the judgement about the CBCT scan is appropriate. The radiation doses can be greatly changed depending on the radiography equipment and operator preferences. As a result, parameters for beam collimation [such as field of view (FOV)], picture quality [such as number of basis images, resolution, and arc of trajectory], and exposure [such as mA, kV] can all be changed. For an equal FOV exam, CBCT units from different manufacturers can differ in dose by up to 10-fold. Additionally, many CBCT machines include exposure factor modifications that can change patient doses by as much as seven times in order to improve image quality [13].

Accuracy of CBCT-derived Cephalograms and Measurements vs. Conventional Method

It has been demonstrated that cephalograms produced by CBCT imaging do not differ significantly from conventional cephalograms in terms of their linear and angular measurements, but their measurement errors are smaller [14]. A variety of visualisation techniques, including multiplanar (MPR), volume-rendered (VR), and shaded surface presentation, can be used to perform 3D measurements on CBCT images (SSD). 32,33 When compared to direct physical measurements of the skull, point-to-point measurements made in the MPR mode are said to be extremely accurate, whereas measurements made of the surface anatomy in the VR and SSD modes have been shown to have a measurement error of 2.3% [15, 16]. Surface contours that were approximated in these modes were thought to be the cause of the mistake in the results of the VR and SSD display modes. The identification and targeting of landmarks should be carried out utilising the digital imaging and communications in medicine (DICOM) volume in an MPR display mode, it might be expected given these findings.

Case Selection

According to certain criteria, such as facial asymmetry, sleep apnea, impacted teeth, intention to utilise dental mini-implants, consideration of rapid maxillary growth, and persistent TMJ complaints, and some researchers have suggested conducting CBCT scans [4]. Due to the possible availability of extra diagnostic data, some have argued for the routine use of CBCT in typical orthodontic diagnosis and treatment planning. When there is a realistic anticipation that a radiograph will have a positive clinical impact, using any imaging modalities prior to orthodontic treatment is appropriate.

Impaction: The use of CBCT imaging in orthodontics may be most frequently done because of impacted and transposed teeth [17-19]. The information obtained can aid plan surgical access and bond placement, localise impacted or transposed teeth, diagnose pathological diseases, and root resorption, as well as define the best and most effective route for extrusion into the oral cavity with the least amount of collateral damage.

Tooth-Bone Relationships: The volume (depth and height) and morphology of the alveolar bone in relation to the sizes, angles, and spatial positions of the tooth roots may be referred to as the boundary conditions for orthodontic treatment. The complicated anatomical boundary requirements may restrict or determine the desired final spatial position and angulation of the tooth in addition to any planned or probable tooth movement. Patients with compromised periodontium, gingival anatomy, or both, patients whose movement of the tooth or teeth may require translocation past another tooth or obstruction, and patients whose alveolar bone phenotypes clinically appear too narrow to accommodate significant labiolingual or buccolingual displacements or angulations of teeth may all benefit from CBCT scans for evaluating tooth-bone relationships [10, 19].

Recent Innovations

New improvements have emerged as a result of efforts to enhance image quality and reduce radiation exposure as imaging technology advances. These include adjustable FOV collimation, increased filtering, flat panel detectors with higher photon sensitivity, automatic exposure control using photon counting, and variable exposure parameters (such as mA and kV) and image quality settings (e.g., scan trajectory options and number of basis images). However, such advancements and their dependability with regard to image quality and patient safety should be confirmed by carefully planned investigations. The effectiveness of CBCT imaging for orthodontic diagnosis and treatment planning in terms of its impact on therapy choices and patient outcomes is still a topic of interest and requires in-depth investigation [20]. Undoubtedly, these issues and discussions could be resolved once breakthroughs give clinicians access to non-radiation imaging equipment for the anatomy. As of now, the medics involved in the acquisition or necessity of a picture are responsible. On the other hand, exact effective dose and precise indication may be helpful for reducing patient risk and increasing diagnostic benefit due to the driving force of developing technology (segmented volumetric measures, etc.).

CONCLUSIONS

The use of CBCT imaging is warranted when individual anamnesis, clinical inspection, and readily available radiographs are present and the advantages to the diagnosis and/or treatment plan outweigh any potential radiation exposure hazards. Any radiographic imaging decision should be made in accordance with the ALARA principle. Only when the anticipated information has the potential to alter a patient's treatment options or result can CBCT be justified. When there is disagreement regarding the suitability of traditional radiography and 3D imaging, CBCT can be used. Patients with cleft palates, evaluation of the location of erupting teeth, detection of root resorption brought on by erupting teeth, and planning of orthognathic surgery are some of these examples.

In order to visualise the area of interest as clearly as possible, it is required to limit the FOV, exposure (mA and kV), number of basis photos, and resolution. If CBCT results in a higher radiation dose, it is contraindicated to obtain simply a lateral cephalometric and/or panoramic radiograph. If the clinical examination outweighs the requirement for a CBCT scan for adequate diagnosis and/or treatment planning, the need for conventional radiography should be carefully considered in order to avoid repeated imaging.

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