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EXCECUTION OF CBCT IN ORTHODONTIC DIAGNOSIS AND TREATMENT PLANNING- A REVIEW ARTICLE

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ABSTRACT

Since a precise diagnosis and well-thought-out treatment plan are essential to any medical intervention, cone beam computed tomography (CBCT) was developed and is now extensively utilized. With the use of CBCT technology, one may view images in three dimensions and determine the precise location and size of lesions in any anatomical region. For the same reason, CBCT can be utilized for optimal treatment planning and efficient dental care not only in surgical disciplines but also in fields like endodontics, prosthodontics, and orthodontics. This review's objective is to provide dental professionals with up-to-date information on CBCT applications across all dental specialties, enabling them to make better informed diagnoses and consistent treatment decisions.

KEYWORDS: CBCT, Orthodontics.

INTRODUCTION

Imaging is an important diagnostic tool that complements the clinical evaluation of the dental patient. With the advent of panoramic radiography in the 1960s and its broad use in the 1970s and 1980s, dental radiology made significant advancements as a single, all-encompassing image of the jaws and maxillofacial structures was made available to clinicians. However, the basic limits of all planar two-dimensional [2D] projections—magnification, distortion, superimposition, and misrepresentation of structures—apply to both intraoral and extraoral methods, whether used separately or in combination.[1]

Various attempts have been attempted to provide three-dimensional [3D] radiographic imaging, such as stereoscopy and tunable aperture CT. Although CT has been around for a while, its usage in dentistry has been restricted due to issues with cost, accessibility, and dosage. Cone-beam computed tomography [CBCT], which is especially designed to examine the maxillofacial region, represents a real paradigm change in data collecting and image reconstruction from a 2D to a 3D approach.[2] The revolution in maxillofacial imaging that CBCT has brought about has sparked unprecedented interest from all dental fields. It has made it easier to move from 2D to 3D images for dental diagnosis, and it has expanded the role of imaging beyond diagnosis to include image guidance for operative and surgical procedures through the use of third-party applications software.[3]

The purpose of this article is to provide an overview of this CBCT technology and an understanding of its application on treatment planning, treatment progress and outcome and treatment risk assessment

1. Application of cbct in treatment planning:

1.1 Orthognathic surgical planning:

Following diagnosis confirmation, the surgical operation is planned and simulated using three-dimensional anatomical models. Corrective interventions in orthognathic surgery refer to techniques that don't call for an extrinsic graft, while reconstructive interventions are reserved for instances where a graft is necessary.*[4]* Determining the precise position of the surgical incisions, organizing the movements of the bone segments in relation to each other, and achieving the intended realignment intraoperatively are crucial during corrective treatments. The challenge in reconstructive surgery is to choose the ideal shape for the implant or graft. The challenges with implants and prostheses are choosing the right device, shaping it, or creating a custom device out of a suitable biocompatible material. Selecting the harvesting site, sculpting the graft, and positioning the implant or graft in the right spot are the challenges associated with grafting. The intrinsic complexity of the cranial anatomy can be taken into consideration when planning virtual osteotomies. Additionally, inner structures, such as the mandibular nerve canal, are frequently included in the surface model, and areas of thin or absent bone, like the maxillary sinus anterior wall, cause abrupt discontinuities in the mesh. Following the virtual osteotomy, the intended surgical movements can be quantified and the bone segments relocated via a virtual surgery.[5] For every bone fragment, the six degrees of freedom [DOF] of anatomical segment relocation are monitored. This makes it possible to simultaneously follow measurements of translation and rotation around each of the X, Y, and Z axes and rectify the skeletal discrepancy for a particular patient. The generated segment relocation can serve as the surgeon's starting point when discussing the 3D orthodontic procedure and the surgical treatment objectives for every patient; additionally, if high-resolution dental structure scans are registered to the CT or CBCT and the software tool has an occlusion detection feature that allows it to identify occlusal contacts, conflicts, and the exact occlusion in the virtual simulations, it may be used for printing surgical splints.[6]

1.2 Planning for placement of temporary anchorage devices [TADs]:

More accurate measures of alveolar bone structure have been made possible by recent advancements in three-dimensional X-ray diagnostics.[7] Moreover, CBCT offers a reduced radiation dosage in comparison to spiral CT. The radiation dose during the CBCT examination was the subject of only four of the reviews that were included. According to current standards, CBCT is typically not suggested for orthodontic treatment planning when it comes to TAD placement. For patients with borderline measurements, this assessment is required prior to surgery in order to insert miniscrews. Different root lengths, the structure of the maxilla and maxillary sinus, the transverse inclination of the neighbouring teeth, and the height of the alveolar process were all linked to a high degree of variability in the outcomes.[8]

It appears that the only way to obtain information regarding the quantity of bone, the potential location of an IZC miniscrew, and the preferable insertion path is through CBCT with sufficient parameters.[9] It appears that each patient should have their own IZC TAD inserted; a single site is apparently insufficient for all patients. As a result, to properly install IZC miniscrews, CBCT could be required. It makes it possible to create a customized TAD insertion technique for every patient in order to lower the risk of complications and provide the desired primary stabilization for orthodontic anchorage. Considerations for insertion height and depth, as well as bone thickness, amount of cortical bone, and various transversal and sagittal angulations, should be made.[10]

The use of CBCT for IZC miniscrew placement planning appears reasonable when taking into account a good risk-benefit ratio. However, radiation shielding is required, particularly for young patients, during this kind of assessment. [11]The research suggests that measuring alveolar bone can be done more accurately by reducing the CBCT voxel size. A 0.2-mm voxel size examination yields an average spatial resolution of 0.4 mm. As a result, it can detect things at a minimum distance of 0.4 mm. It offers sharper pictures, makes identifying alveolar crests simpler, and produces results that are closer to the gold standard [direct measurements].Due to inadequately precise measurements, the voxel size of about 0.4 mm may be a constraint. Conversely, demonstrated strong interclass reliability for both the 0.2 mm and 0.4 mm scans.[12]

1.3 Accurate estimation of the space requirement for unerupted/ impacted teeth:

To evaluate the position of an impacted tooth, CBCT is frequently utilized. Studies have demonstrated that CBCT can provide more accurate localization of canine teeth and more accurate estimates of the space conditions within the arch. These findings can have a significant impact on diagnosis and treatment planning, enabling a more clinically-oriented approach. When canine inclination in the panoramic X-ray exceeds 30°, when root resorption of neighboring teeth is suspected, and/or when the canine apex is not clearly discernible in the panoramic X-ray, implying dilaceration of the canine root, small volume CBCT is also justified as an addition to routine panoramic X-rays.[13]

Katheria et al. [2010] discovered that CBCT offers more details about treatment planning, root resorption presence, and pathology location when compared to conventional radiography. The advantages of CBCT imaging must be evaluated against the intricacy of the underlying pathology and the radiation risk to juvenile patients.

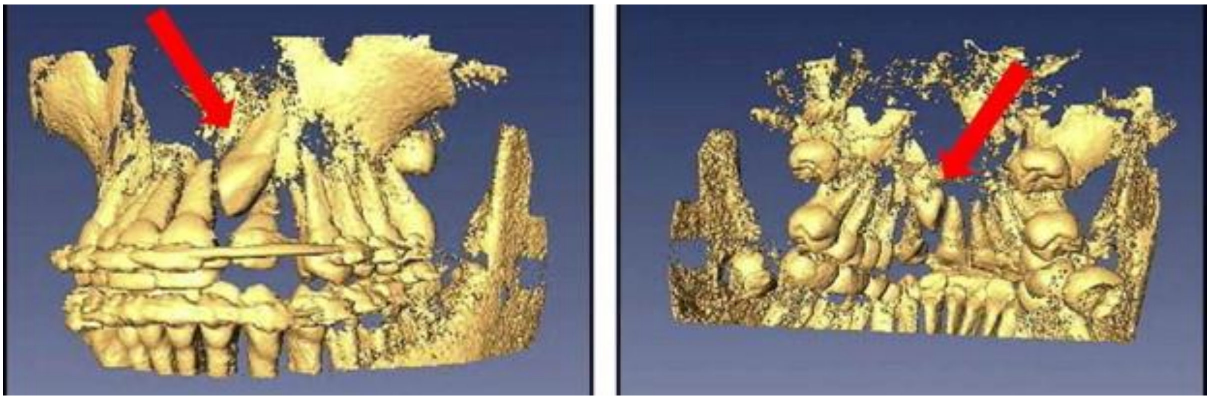

Figure 1 *(CBCT image of impacted upper left canine.)*

Accurate localization of impacted and/or transposed teeth is made possible by CBCT scans, which aids in choosing the most effective surgical access and bonding technique. In order to avoid or lessen collateral damage, it also aids in defining the best and most effective route for extrusion into the oral cavity. Moreover, CBCT scans give the orthodontist important details about the teeth's root proximity that surround the affected teeth. In order to prevent undesirable alterations in these teeth, this information can subsequently be used to position neighbouring teeth and their roots away from the impacted tooth's traction path.[14] A further benefit of CBCT over traditional radiography is its ability to provide exact measurements of an impacted tooth, which helps determine and create the space required to accommodate the tooth within the arch.

1.4 Fabrication of custom orthodontic appliances:

CT images were used for diagnostic and treatment planning. CAD and rapid prototyping were combined to create surgical templates for precise mini-screw placement. By employing CT imaging, damage to the surrounding tissues can be prevented. However, failing to take mechanical considerations into account before to mini-screw insertion may result in incorrect screw implantation and inadequate primary stability, which can cause screw loosening.[15] Therefore, if biomechanical analysis is combined with the creation of a customized surgical template to achieve the best mechanical performance and screw position insertion precision, mini-screw survival rate success can be increased.[16]

The CAD/CAM technology can accurately transmit design information from the lateral cephalogram to the final design of the appliance. This work uses combined three-dimensional [3D] model pictures and cephalograms to virtually construct unique lingual appliances with the goal of minimizing these inaccuracies. CAD/CAM technology has not only increased design accuracy but also made fabrication simpler by doing away with the need for soldering. To strengthen the appliance's bond, lingual pads are equipped with a mesh-like base. Furthermore, undercuts on the lingual pad base can be supported by fast prototyping technology, which is not achievable with traditional fabrication techniques.[17]

2. Application of CBCT in assessing treatment progress and outcome:

2.1 Dentofacial orthopaedics:

CBCT-based 3D craniofacial and dental morphometrics are vital for characterizing normal and aberrant 3D anatomy of structures, with the potential for long-term use in diagnosis and therapy progression. The capacity of CBCT to offer 3D volumetric, surface, and sectional information regarding the craniofacial structures is one of its main advantages over 2D radiography.[18] This has made it possible for orthodontists and related researchers to get around some of the significant drawbacks of 2D radiography, such as uneven head position, geometric distortion, overlaid structures, and magnification.[19] Researchers are currently looking at the use of CBCT pictures to evaluate dental connections in orthodontic patients. CBCT images are most commonly utilized to examine skeletal contributions to malocclusion.[20]

CBCT is expected to offer information that could result in one or more of the following outcomes. improved diagnosis, including accurate localization of impacted and extra teeth; measuring the extent of a malformation or deficiency, as in the case of individuals with abnormalities of the face or neck[21]; Enhancing the differential diagnosis of skeletal, dental, or combined malocclusions; this includes figuring out which jaw is contributing to the malocclusion and whether the discrepancy is unilateral or bilateral, as in cases of open bite, asymmetry, orthognathic surgery, and craniofacial anomalies; additionally, it aids in the identification of potential causes of the malocclusions, such as the contribution of TMJ abnormalities to asymmetry or an open bite. When comparing the 3D data from

CBCT to that from conventional 2D radiography, the anticipated results could eventually range from improved therapy [22]

2.2 Orthognathic surgery superimposition :

To achieve fully automatic voxel-based rigid registration, OnDemand3D's fusion module was utilized. The anterior cranial base anatomical structures in the CBCT volumes were chosen using axial, sagittal, and coronal slice views of the volumes. The rigid registration [translation and rotation] that best aligned the reoriented CBCT volume to the original CBCT volume was then carried out using the OnDemand3D automated registration tool. This tool used the intensity of the grey levels for each voxel in the anterior cranial base of the two CBCT volumes. Using the anterior cranial base as a reference, the same voxel-based superimposition technique was utilized to align the pre- and post-treatment CBCT volumes of growing patients undergoing RPE and adults undergoing orthognathic surgery. The procedure of superimposition required a total of 10 to 15 secs to complete.[23]

Following the registration process, the superimposed CBCT volumes were exported as DICOM files using the OnDemand3D program, and they were then loaded into the ITK-SNAP software program for segmentation and the creation of 3D virtual surface models of the skull in order to quantify the effects of the superimposition.[24] The ITK-SNAP algorithm automated segmentation of the mandible, maxilla, frontal bone/anterior cranial fossa, and middle cranial fossa for every CBCT volume in four stages.After creating a 3D virtual surface model of the skull, the STL to SGI Inventor 2.0 Utility Beta tool was used to convert the STL file to an Open Inventor file [IV]. This was done by exporting the STL file created by the ITK-SNAP program.[25] The Cranio-MaxilloFacial application software, which uses this IV extension to open the 3D virtual surface model of the skull, measures the closest point surface distance between thousands of surface triangles in the 3D surface models. The color-coded surface distance maps that are produced allow for the quantification of registration errors.[26]

3. Application of CBCT in risk assessment:

3.1 Investigation of orthodontic-associated sensory disturbances:

Orthodontic therapy requires complex three-dimensional tooth movements. In the buccal and lingual dimensions, an accurate evaluation of the root's closeness to the inferior alveolar nerve may not be achievable using traditional 2-dimensional panoramic radiographs. This suggests that in patients who may be at high risk, a cone-beam computed tomography [CBCT] scan is necessary. A CBCT scan is thought to be a reliable technique for determining the mandibular canal's location. Before attempting treatment in this area, CBCT should be performed to ascertain the inferior alveolar nerve bundle's course in order to reduce the risk of neuropathy.[28]

The most frequent causes of reported sensory abnormalities of the lower lip are lower jaw orthognathic surgery, internal rigid fixation of mandibular fractures, third molar extraction, dentoalveolar surgery, endodontic therapy, or tumors close to the mandibular canal.[28]Few case reports of paresthesia following tooth movement impinging on the inferior alveolar nerve exist to date.All of the documented reasons for nerve disruptions are categorized as neuropraxias18, or first-degree nerve damage.[29]A conduction blockage brought on by mild compression of the nerve trunk leads in neuropraxia. Because axonal continuity is preserved, there is a brief conduction blockage.19 Clinical reports from patients describe sensory abnormalities that typically resolve completely within hours to minutes.

3.2 Assessment of orthodontics-induced root resorption and periodontal tissues:

Orthodontically induced tooth root resorption [OITRR] is a pathological condition caused by orthodontic therapy that results in the irreversible loss of some or all of the dental tissues.Because orthodontic forces are the cause of OITRR, it is categorized as root resorption of iatrogenic origin. This type of resorption is inflammatory in that it results in inflammation of the periodontal ligament, which kills cementoblasts and causes cementoclasts and odontoclasts to develop. These cells stop alveolar dental ankylosis by inducing resorption.[30]

Cone Beam Computed Tomography [CBCT], periapical radiographs, and panoramic radiographs can all be used to diagnose OITRR. With CBCT imaging, radiation may be targeted to the anatomical region of interest while capturing all hard and soft tissues in three dimensions. This results in a greater amount of information and may help patients get less radiation overall [Jaykishan, 2019]. A scientific revolution has been sparked by sophisticated research apparatuses and the most recent diagnostic techniques.[31]

3.3 Treatment outcomes :

The use of CBCT in orthodontics is justified by its complex diagnostic and therapeutic properties, for which research has been conducted in a limited number of clinical problems, such as impacted teeth, CL/P, and orthognathic surgery.[32] Even in the lack of such evidence, a practitioner may still decide to use the technology if there is sufficient evidence to suggest that it will probably improve the diagnosis and/or treatment strategy. Based on existing research, we would predict that CBCT, when applied in any of these settings, is likely to yield information that may lead to one or more of the following outcomes: [1] improved diagnosis, like accurately locating extraneous and impacted teeth; [2] assisting in the identification of potential causes of malocclusions, such as the contribution of TMJ abnormalities to an open bite or asymmetry;[33] [3] quantifying the magnitude of a defect or deformity, such as in patients with craniofacial anomalies; [4] improving the differential diagnosis of skeletal, dental, or combined malocclusions, including identifying the jaw[s] contributing to malocclusion and determining whether the discrepancy is bilateral or unilateral, such as in orthognathic surgery, asymmetry, craniofacial anomaly, and open bite cases; and [5] determining whether the discrepancy is bilateral or unilateral. When comparing the 3D data from CBCT to that from conventional 2D radiography, the anticipated result could eventually range from a change of the treatment to a refining of it entirely.[34]

3.4 Evaluation of cervical vertebral maturation [CVM]:

This use of CBCT to monitor skeletal maturation in response to the advances in diagnosis and treatment planning made possible by three-dimensional imaging. Mature alterations can be seen in the sagittal plane as well as the coronal and transverse planes when imaging the cervical vertebrae with CBCT. The advantage of using CBCT to evaluate skeletal maturity could be that any new information could be used to improve and fortify existing techniques or create a brand-new, three-dimensional cervical vertebrae maturation approach. In the latter scenario, if a CBCT scan has previously been performed for other purposes, the patient may benefit from not being exposed to radiation via hand-wrist or lateral cephalometric radiographs needlessly.[35]

Skeletal maturation of patients is a crucial consideration when considering orthodontic therapy. The assessment of the teenage growth peak was done using the hand-wrist and CVM methodologies. While estimates of skeletal maturity may benefit from the use of CBCT images, this is not the only reason for which they should be put to use[37]. According to Shim et al.,[36] the cervical vertebrae's estimated maturation stages on CBCT offered a trustworthy assessment of pubertal growth support and had a high positive connection with hand-wrist radiographs and lateral cephalograms.

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