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THE APPLICATION OF CONE BEAM COMPUTED TOMOGRAPHY IN ORTHODONTICS

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ABSTRACT

The recent advances in dentistry have noted to prove very advantageous in comparison to the conventional techniques such as radiographs. One such advancement is Cone Beam Computed Tomography (CBCT), a medical imaging technique comprising of X-Ray computed tomography. This imaging modality is extremely useful as an advanced, and now preferred method for detailed diagnosis and treatment planning for patients requiring Orthodontic treatment. CBCT imaging provides accuracy while measuring and analyzing, improves the conception of impacted teeth, aids in identification of airway abnormalities, helps in quantifying asymmetries, viewing periodontal structures, evaluation of endodontic complications, planning sites for temporary anchorage devices/implants and to observe anomalies in the temporomandibular joint and surrounding structures. This paper aims to review the role of CBCT in the diagnosis and treatment planning of orthodontic cases as well as to emphasize the need for adopting CBCT as a diagnostic tool in orthodontics thereby replacing or acting as an adjunct tool in conjunction with radiographs in Orthodontics.

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INTRODUCTION

The prevalence of malocclusion and the number of children and adolescents seeking orthodontic treatment often raises a major issue, i.e. the exposure of these children to high doses of ionizing radiation for the diagnosis, treatment planning and follow up of Orthodontic treatment (Olsson, 1967; Seelentag *et al*., 1958). A large amount of consideration has been assigned to this issue owing to the increased risk and ability of ionizing radiation to cause mutation of DNA and increased risk of cancer(Seelentag *et al*., 1958). Also, children tend to retain the ionizing radiation exposure for longer periods than adults, since they are more sensitive to radiation effects (Andriska *et al*., 1958; Seelentag *et al*., 1958). Children may also express increased susceptibility to environmental hazards, chronic infection, and inflammation, dietary factors, and long term medication due to differences in the uptake, metabolism and excretion of potential mutagens(Andriska *et al*., 1958; Seelentag *et al*., 1958).

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Currently, two-dimensional imaging modalities are being replaced by three-dimensional imaging techniques. The Cone Beam Computed Tomography (CBCT) has a similar resolution to that of Computed Tomography, but at a lower cost and radiation dose (Rinkel *et al*., 2007; Siewerdsen and Jaffray, 2001). Taking into consideration these advantages, CBCT is now widely used in the field of dentistry for diagnosis and treatment planning and to monitor the treatment progress and outcome (Ghoneima and Kula, 2013). Gribel *et al*.(Gribel *et al*., 2011a; Gribel *et al*., 2011b) stated that conventional cephalometric radiography has limited application owing to the projection of three-dimensional structures as two-dimensional images. As a result of this, superimposition of the anatomical landmarks takes place, which makes identification of the exact location of anatomical structures difficult. Conventional imaging techniques also may lead to magnification and distortion of the image obtained. CBCT allows the three-dimensional structures to be viewed accurately in all planes – sagittal plane, coronal plane and transverse plane. Identification of landmarks and simultaneous viewing of bilateral landmarks are possible with CBCT images. Van Vlijmen *et al*. (van Vlijmen *et al*., 2009a; van Vlijmen *et al*., 2009b; van Vlijmen *et al*., 2009c; van Vlijmen

et al., 2010; van Vlijmen *et al*., 2012) conducted a comparative study between CBCT and conventional radiographs as well as a series of studies and concluded that CBCT scans gave more accurate readings and measurements. Studies conducted by Neiva *et al*. (Neiva *et al*., 2015)reported that anatomical landmark identification on CBCT multiplanar and 3D reconstructions values were more reliable than conventional imaging techniques. However, the area of interest of the practitioner decides the most reliable imaging modality as lower reliability was found in the area of the condyles and higher reliability in the mid sagittal plane.

CBCT

CBCT was designed to overcome the shortcomings of conventional radiography and reduce the patient exposure to ionizing radiation. Cone Beam technology was introduced for the first time in Europe in 1996 and the US in 2001.
During CBCT, the scanner rotates around the patient's head, obtaining up to nearly 600 distinct images. It uses a cone shaped X-Ray beam that generates two-dimensional images that are converted to three-dimensional images using computer software.

Advantages of cbct over conventional imaging techniques

- It is cheaper and a smaller system is involved.
- The X-ray beam is limited.
- Accurate images are obtained.
- Rapid scan time.
- Less radiation exposure.
- Exclusive dentofacial imaging display mode.
- There are fewer imaging artifacts.

CBCT for oral and maxillofacial imaging

Kobayashi *et al*. (Kobayashi *et al*., 2013) evaluated the accuracy of linear measurements obtained in CBCT images using the dentomaxillary structures alone. They found that the measurement error with CBCT ranged from 0.01 to 0.65 mm as compared to conventional CT, where the error ranged from 0 to 1.11 mm. The other disadvantages of CT scan involved high cost, long scanning time, extensive machinery, high exposure to radiation and low resolution in the longitudinal direction. Most of these shortcomings were overcome with the introduction of CBCT.

CBCT systems can be classified into three distinct categories:

- Systems that image large portions of the cranial complex in one exposure
- CBCT systems with smaller FOV
- Systems with separate mechanisms for both the functions.

Radiation Exposure of CBCT

A number of studies were carried out to monitor the radiation exposure with CBCT scans. Ludlow *et al*. (Ludlow *et al*., 2006; Ludlow *et al*., 2007; Ludlow, 2008; Ludlow *et al*., 2009; Ludlow *et al*., 2015a; Ludlow *et al*., 2015b)stated that the radiation dose that a patient was exposed to during CBCT scans is significantly lower than that during conventional CT scans. Schulze *et al*. (Schulze *et al*., 2004; Schulze, 2015; Schulze *et al*., 2017) reported that CBCT produced almost four times lesser radiation than conventional CT. Parameters such as peak kilovoltage and milliampere are some of the factors which affect the effective radiation dose. Any alteration in these parameters can alter the image quality.He also further reported that dose reduction by means of a commercial lead apron was significant in all other regions, particularly in the region of the female breast.

Orthodontic Applications of CBCT

All these years, Orthodontics relied on two-dimensional images of three-dimensional structured. CBCT has made three-dimensional visualization of craniofacial structures possible.

CBCT in Orthodontic Diagnosis

Assessment of skeletal and dentofacial structures

As mentioned earlier, CBCT imaging is more accurate for landmark identification as it eliminates superimposition in the images. The values obtained from CBCT images are more accurate than conventional imaging techniques.

Three-dimensional localization of impacted teeth

CBCT is routinely used to evaluate impacted teeth and their position. Accurate localization of impacted teeth can be done in three-dimensional CBCT images. CBCT is also a helpful tool in providing information regarding the presence of pathology and root resorption, which makes diagnosis and treatment planning easy (Katheria *et al*., 2010).

Growth assessment

CBCT also proves helpful in the evaluation of skeletal maturity by assessing the cervical vertebrae maturity (Joshi *et al*., 2012).

Pharyngeal airway analysis

Lateral cephalograms have been frequently used to assess the airway using techniques involving both tissue and soft tissue points. Reconstructed 2D CBCT images and Conventional radiography helps in providing similar assessments of the airway. The pharyngeal airway is more clearly visible in axial CBCT cuts compared with conventional radiographs, thereby enhancing airway assessment, thus facilitating diagnosis and treatment planning of patients with complex anomalies of the airway(Agarwal and Marwah, 2016; Alsufyani *et al*., 2012; Edwards *et al*., 2014).

Assessment of the temporomandibular joint (TMJ)

CBCT imaging of the TMJ is more accurate and reliable in diagnosing morphology disturbances and erosion of the condyles. CBCT is more accurate than conventional CT and panoramic radiographs as stated by M. Hilgers *et al* (Hilgers *et al*., 2005). CBCT imaging is used for complete bilateral examination of TMJ which is less time consuming and involves less radiation exposure than conventional tomographic sections (Al-Saleh *et al*., 2016; Ma *et al*., 2016).

Cleft palate assessment

CBCT for patients with cleft lip and palate is useful for both preoperative and subsequent follow up evaluations. It is useful for the evaluation of the volume, exact location of the bone defect, position of supernumerary teeth, status of permanent teeth and alveolar bone morphology. CBCT imaging aids in treatment planning and during rehabilitation of a patient with cleft palate (Agarwal and Marwah, 2016; Kula *et al*., 2016).

CBCT in treatment planning

Orthognathic surgical planning

CBCT imaging in combination with software and virtual patient's dental models helps in examination of hard and soft craniofacial tissues and their relationships(Choi *et al*., 2014; Terzic *et al*., 2013). With the help of CT volumes virtual anatomical models can be fabricated and correlate with other available 3D image data(Paniagua *et al*., 2011). Thus, the generated virtual models can be used to check or recreate various treatment options, to create anatomically correct substitute grafts, and can be a useful tool during the surgical procedure.

Planning the placement of temporary anchorage devices (TAD)

Three-dimensional scans are especially useful in evaluating the amount and quality of bone available in the desired site of placement Therefore, with this single diagnostic imaging method, information about root proximity, surrounding structures, and the morphology of the inferior alveolar nerve canal and maxillary sinuses can be obtained, all of which are important in determining stability and success of TAD(Vassar *et al*., 2016). In a study conducted by Shilpa K *et al*., (Kalra *et al*., 2014)complex anatomy such as expanded sinuses or alveolar bone loss requires CBCT data for adequate planning before implant placement.

Accurate estimation of the space requirement for unerupted/impacted teeth

CBCT scans can help in getting accurate localization of impacted teeth, which will help decide the best method for surgical access. CBCT scans provide the valuable information of root proximity of neighboring teeth. This information can then be used to avoid untoward changes during traction path of the impacted tooth (Gurler *et al*., 2017; Jawad *et al*., 2016). The main advantage of CBCT imaging is to obtain accurate size of an impacted tooth.

Fabrication of custom Orthodontic appliances

Custom lingual Orthodontic appliance fabrication has been demonstrated using CBCT image data with three-dimensional printing technology(Kwon *et al*., 2014). This method appears to be rapid and results in effective and efficient treatment.

CBCT in Treatment Progress

Dentofacial orthopedics

CBCT helps in the assessment of treatment and growth changes. Identification of maxillary and mandibular bone remodeling and positional changes can be made. Evaluation of Rapid Maxillary Expansion treatment outcomes can also be evaluated using CBCT imaging.Overlapping of anatomical structures is able to be circumvented using 3D scans, therefore skeletal and dental changes can more accurately be evaluated(Garrett *et al*., 2008).

CBCT in Risk Assessment

Orthodontic-associated sensory disturbances

Sensory nerve disturbances of the lip and chin are frequently seen after dentoalveolar surgery, orthognathic surgery and third molar surgery a less common cause is Orthodontic treatment. One of the few ways of diagnosing orthodontic treatment induced mental nerve paresthesia is CBCT imaging. Campbell *et al*., (Campbell *et al*., 1987) mental nerve paresthesia induced due to orthodontic treatment showed the importance of CBCT imaging as the only technique helps in obtaining an exact diagnosis of this clinical condition

Orthodontic induced root resorption

CBCT images can be used to evaluate pre and post treatment root resorption because of better visualization of the roots. A study conducted by Alexander Dudic *et al*. (Dudic *et al*., 2009) stated that the amount of root resorption was underestimated when evaluated from conventional radiographs. Significant differences were found between the two methods. On Conventional radiograph examination, 56.5% of the teeth showed no resorption, 33.5% mild resorption and 8% showed moderate resorption. The statistics on CBCT evaluation were 31%, 49% and 19% respectively. Orthodontics induced dentoalveolar bone resorption can also be assessed and quantified accurately using CBCT imaging(Misch *et al*., 2006)

Conclusion

CBCT is beneficial to both the patient as well as the practitioner. It requires less scanning time and involves less radiation exposure. It also provides high resolution images and hence aids in good diagnosis and treatment planning. Because of its ability to capture the entire anatomy, it proves to be helpful especially in Orthodontics. If recorded correctly, the data received is more accurate than othrr imaging modalities. CBCT imaging may also be applied to other types of cases in which it is likely to provide valuable diagnostic information following verification of a positive benefit.

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