ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 7, Issue – 2, March – 2024, Page No. : 55 - 65

Contribution of Cone Beam Computerized Tomography in Contemporary Orthodontics

[1]Dr. J. Preethi, [2]Dr. R. Chandrasekar

[1-2]Sri Ramakrishna Dental College and Hospitals, Peelamedu, Coimbatore

Corresponding Author: Dr. J. Preethi, Sri Ramakrishna Dental College and Hospitals, Peelamedu, Coimbatore

Citation of this Article: Dr. J. Preethi, Dr. R. Chandrasekar, "Contribution of Cone Beam Computerized Tomography in Contemporary Orthodontics", IJDSIR- March – 2024, Volume –7, Issue - 2, P. No. 55 – 65.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

It's been fascinating to see how novel technologies are being used in dentistry and orthodontics of particular significance is the development of cone-beam computed tomography (CBCT) as the primary imaging modality for full-mouth orthodontic therapy. The data derived from CBCT imaging offers a number of noteworthy benefits. According to the practitioner's knowledge at the time of orthodontic diagnosis, CBCT imaging, for instance, improves the localization of impacted teeth, visualizes airway abnormalities, identifies and quantifies asymmetry, assesses periodontal structures, identifies endodontic problems, plans placement sites for temporary skeletal anchorage devices, and views condylar positions and temporomandibular joint (TMJ) bony structures. Moreover, compared to integrated diagnostic current digital panoramic and cephalometric imaging, CBCT imaging only slightly increases radiation exposure. This article's goal is to give a thorough introduction to CBCT imaging, covering its methods, benefits, and uses in orthodontics.

Keywords: Cone beam computed tomography, Orthodontic applications

Introduction

CBCT is gaining its importance in the field of dentistry in current period. It is a 3-dimensional diagnostic aid of craniofacial structures, CBCT is not only used for diagnosis, it is being used for treatment planning also. Full form of CBCT is Cone-beam computed tomography. It is an efficient aid to manage and educate the patient and to provide improved treatment outcomes, and provides patient satisfaction. It is a milestone evolution in diagnostic aids which has evolved from 2 dimensional to 3 dimensional.

Computerized tomography (CT) scans were developed by Sir Godfrey Hounsfield in 1967[1]. CT was prologue for CBCT and this CBCT was upgraded from CT by Kau et al., 2005; Palomo et al., 2005[3]; Kapila et al., 2011[4]. CBCTs were designed to counter some of the limitations of conventional CT scanning devices. The object to be evaluated is captured as the radiation source falls onto a two-dimensional detector. This simple difference allows a single rotation of the radiation source

to capture an entire region, as compared to conventional CT devices where multiple slices are stacked to obtain a complete image in CBCT. It allows an infinite number of focal troughs to be specified and reformatted, compensating for arch variations.

CBCT has grown progressively important in treatment planning and diagnosis in implant dentistry5, ENT6, orthopaedics, and interventional radiology (IR). CBCT provides additional characteristic information, clear views of anatomizing, relative density information, and an easy- to- understand complete radiographic view. CBCT imaging in orthodontics8 used for root resorption, supernumerary teeth, canine impaction, surgical planning, or upper airway block. The application of CBCT is gaining identical significance of cephalometer which is being still used since 20th century.

Regarding the properties of CBCT, it is high in image quality, completeness, and versatility and it has clear advantages over the cephalometer. In accordance with the "as low as reasonably achievable" (ALARA) principle, if ionising radiation were reduced below that of current orthodontic radiographic series, it is possible that orthodontists would take CBCT scans on most, the cephalometer would become disused. However, its higher ionising radiation results in a benefit/risk ratio that is not always weighted positively toward CBCT[9,10,11].

The purpose of this article is to provide a quick overview of the application of CBCT in orthodontics.

Impacted and transposed teeth

Dental anomoly that is frequently seen and requires orthodontic treatment is tooth impaction. Mandibular wisdom teeth were the most commonly impacted teeth, followed by maxillary and mandibular canines.(12) When diagnosing impacted teeth and planning their treatment, radiographic examinations are more important than clinical examinations. These teeth were radiographically evaluated for a number of years utilizing lateral, occlusal, periapical, or panoramic cephalograms. The location, angulation, spatial position, and connections of the impacted tooth cannot be adequately visualized in three dimensions using these traditional two-dimensional radiographs. Thus, the presence of impacted and transposed teeth is the most compelling reason to employ CBCT in orthodontics.

In addition to identifying the best direction for the teeth to extrude into the oral cavity, CBCT improves the management of impacted teeth by improving the ability to accurately localize these teeth, assess their proximity to other teeth and structures, measure the size of the follicle and alveolar width, detect pathology, and evaluate the root resorption of neighboring teeth.(13) It would be able to ascertain the alveolar boundary conditions in addition to the position of the tooth and dilacerated root in cases of impacted teeth, particularly if exposure or forced eruption is planned. Furthermore, since CBCT scans may be used to determine an impacted tooth's precise size, it would be considerably simpler to prepare the space required for it.

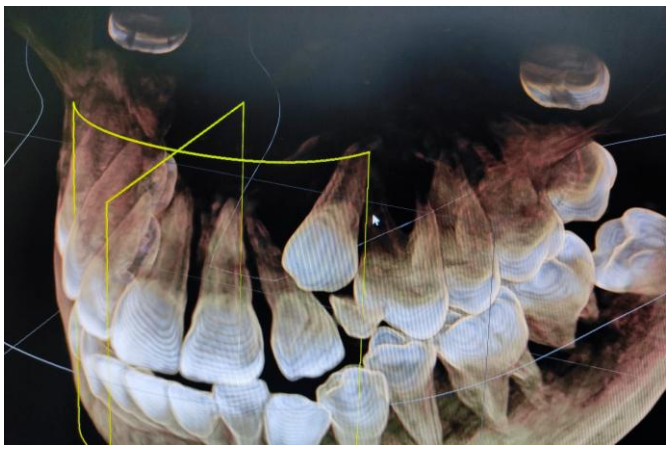

Figure 1: Orthodontic applications revealing evaluation of impacted canine by CBCT

Figure 2: CBCT images used for assessment of orthodontic treatment involving impacted canines

Since CBCT is useful in establishing the surgical access site, bond position, and mechanics design, it increases the clinician's confidence in diagnosis and treatment plan. Different from other professionals, orthodontists are able to locate an impacted tooth in three planes of space in the least amount of space and without causing harm to nearby teeth.(14)

Overall, when the procedure and biomechanics are examined using CBCT, it may be believed to improve accuracy and success rates for the treatment of impacted teeth.

Supernumerary teeth

Supernumerary teeth are those which are not part of the regular permanent or deciduous dentition sequence. They could appear anywhere in the oral cavity. They could show up as one tooth or several, bilaterally or unilaterally erupted, impacted, or in the mandible, maxilla, or both jaws. Between 0.1 and 3.8% of teeth are supernumerary, and this condition is more common in the permanent dentition.(15,16,17)

Before the invention of three-dimensional Cone Beam Computed Tomography (CBCT), several x-rays taken from various angles might be used to approximate the precise location of impacted supernumerary teeth. It is frequently challenging to precisely localize an object on the desired tooth due to distortion, projectional effects, and superimposition of surrounding structures [5]. It has been demonstrated that CBCT offers better three-dimensional imaging than "plain films" and gives the physician exact anatomic truth when locating impacted teeth (18, 19)

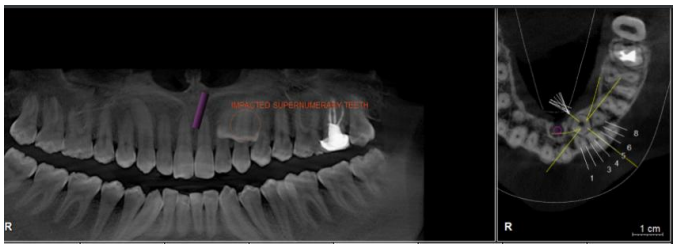

Figure 3: Examination of the images from the CBCT shows the palatal location of tooth.

Root resorption

A condition known as "root resorption" causes the loss of dentin, cementum, or bone in response to a number of different stressors. The diagnostic effectiveness of panoramic radiography in identifying external root resorption is only week. Therefore, periapical radiographs have typically been used to assess root resorption. However, current research indicates that CBCT, as opposed to 2D radiography, can identify finely detailed pictures of minor root abnormalities with higher sensitivity and specificity.(20)

Inaccuracies brought on by inaccurate projection and magnification can be reduced by using CBCT images to offer 3D information on tooth movement, including its direction and magnitude. Furthermore, having access to 3D data offers details on every tooth, not just the movement of the central incisor as revealed by lateral cephalograms.(21)

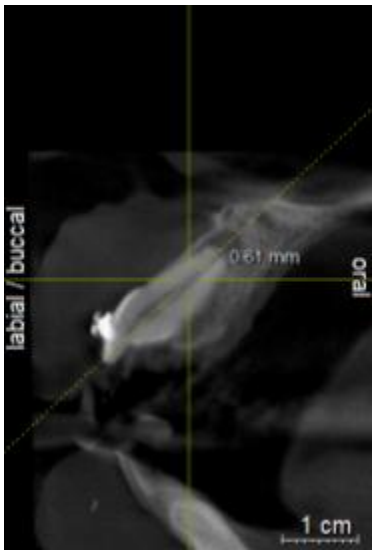

Figure 4: Measuring root resorption and tooth

CBCT is a valuable tool for identifying resorption lesions because of early treatment planning and improving prognosis result from avoiding to root resorption. Tomography produces three-dimensional pictures that let the doctor see resorption in its early phases.(22,23)

According to Alqerban et al., there was not a significant difference in the CBCT systems' ability to detect the degree of root resorption, and all of the methods they employed in their investigation shown good accuracy in identifying root resorption. The detection of tiny resorptions in the apical third and the high radiation dose necessary are the limitations of employing CBCT for external root resorption.(24)

Evaluation of root angulation and length

Orthodontists have embraced CBCT imaging because of its three-dimensional (3D) rendering capability, which is perfect for imaging 3D abnormalities such as skeletal and dental malocclusions. Furthermore, a much more comprehensive image of how the teeth grow, erupt, and assume their final positions as the primary and permanent occlusions arise can be obtained by integrating 3D radiographs with clinically evident dental crowding, spacing, or abnormalities. The correction of malocclusion involves more than just aligning the crowns, therefore this information is essential for both orthodontic diagnosis and treatment planning.

Two factors make root position and morphology crucial for the best orthodontic treatment: parallelism and root position are thought to be essential for a stable, ideal occlusion and one of the rare common adverse side effects of orthodontic treatment is external apical root resorption (EARR). One risk factor for EARR that will be covered is the amount of apical root movement, which can only be measured by radiography. The ability to precisely assess root angulation and length both before and after orthodontic treatment makes CBCT radiographs extremely important. We will evaluate the measurement accuracies of 2D and 3D radiographs since angular and linear root measurements are crucial for orthodontic diagnosis, treatment planning, and outcomes evaluation.(24,25)

Figure 5: Measurement by cone-beam computed tomography

A study was carried out to compare the accuracy of tooth length estimations obtained using various imaging modalities with real lengths measured using a Verniercaliper. The findings showed that CBCT is the

most accurate radiography technique for measuring tooth length. The average underestimation of the real tooth length was ~0.2 mm, while the average magnification provided by IOPA was 0.82 mm, and tooth lengths were found to be 0.8 mm shorter on OPG.(26)

Tooth-bone relationship

The morphology of the maxillary and mandibular alveolar cortex is crucial in orthodontic treatment planning, particularly when there is a significant difference between tooth volume and available space in the dental arches. Teeth that migrate and tilt toward the oral vestibule frequently cause the external cortex to become thinner or to become discontinuous, resulting in fenestrations and/or dehiscences. This type of treatment results in decreased thickness of keratinized gingiva due to increased tissue strain caused by orthodontic forces. It might thus become too thin for the progenitor cells that give rise to new bone. Gingival recessions are a potential problem that are more prevalent in the vicinity of the mandibular incisors(27)

Periodontal surgery is advised to thicken the thinned maxillary and mandibular alveolar cortex before beginning any orthodontic growth of the tooth arch. Transplanting the hard palate mucosa or subepithelial connective tissue is the foundation of this type of surgery.(28)

Cone-beam computed tomography (CBCT), a new advancement in radiological imaging, offers a more accurate way to view anatomical structures and identify pathological lesions. Due to its high resolution and very low exposure dose (in comparison to medical CT), CBCT has shown to be extremely helpful in the field of dentistry [29]. The planning of orthodontic and implantological treatments frequently makes use of CBCT scans. Therefore, we reasoned that using CBCT could provide important insights into the connections between the dentate anterior mandible's morphology and tooth positions. The objective of this research is to assess the impact of inferior incisor and canine position on the cortical and spongious bone dimensions of the front mandibular alveolar process.

Figure 6: CBCT showing tooth bone relationship

Cleft lip and palate (CLP) cases

Patients with CLP are treated by interdisciplinary teams from infancy to adulthood. Rebuilding the alveolar ridge, dentofacial area, lips, and nasal anatomy involves a variety of surgical techniques. Regarding the radiation dose, the SEDENTEXCT Consortium reported that, in the field of dentistry, "the application of CBCT in cleft lip and palate patients was found to be the simplest to support." To ascertain the impact of this novel 3D facial imaging technology on treatment planning, treatment outcome, and treatment evaluation, more research is deemed necessary.(30)

Preoperative CBCT can help select an appropriate autogenous graft donor site prior to surgery, provide accurate estimates of the amount of expansion and graft material required, and allow visualization of the three-dimensional morphology of the bone bridge and its relationship to the neighboring teeth's roots. The use of

CBCT is advised for alveolar bone transplant success and for determining the buccal-palatal breadth of the bone in CLP instances.(31) A post-treatment CBCT can assess pharyngeal space, the outcome of bone grafting, and the impact of nasoalveolar reshaping.

Temporomandibular joint (TMJ) morphology and pathology contributing to malocclusion

In dentistry, cone-beam computed tomography (CBCT) was introduced more extensively in Europe in 1998 and the USA in 2001 (32) . Its current applications include imaging the temporomandibular joint's (TMJ) bone structures and has become the standard approach for identifying and assessing TMJ degenerative lesions . The temporomandibular joint's CBCT is also used to quantify the articular eminence (height and inclination), joint space, and the position and volume of the condylar process.(33)

CBCT has been used to assess condylar variations following orthodontic treatment in addition to TMJ issues. It enables more accurate landmark recognition on curved surfaces, such as the condyle, and permits volumetric measurement of the TMJ (34,35). To ascertain how the TMJ would react to mandibular advancement or extraction treatment, as well as the outcomes of distraction splint therapy in cases of mandibular asymmetry, CBCT assessment was suggested.(36)

Figure 7: CBCT showing left TMJ with condylar hypoplasia

Airway morphology and obstructive sleep apnea (OSA)

Obstructive sleep apnea (OSA) is a sleep-related breathing disorder characterized by upper airway obstruction that causes oxygen desaturation and sleep fragmentation (1). It is linked to several possible detrimental health outcomes, including hypertension, heart failure, stroke, diabetes mellitus, and neurocognitive impairment, as well as a notable reduction in quality of life.(37)The treatment of open bite asymmetry (OSA) involves the use of mandibular advancement appliances and the planning of orthognathic surgery in appropriate patients. Evaluating the dimensions changes in the airway obstruction and nasopharyngeal region in CLP is also very important. Orthodontists can precisely estimate the patient's airway's cross-sectional area, minimum cross-section, and total volume with CBCT. Additionally, it has been used to research the outcomes of orthognathic surgery and orthodontic treatments.(38)

Studies of the upper airway based on CBCT scans are considered to be reliable in providing important information about the morphology of the pharyngeal airway; however, they have limitation in distinguishing different types of soft tissues.(39) Variations in airway dimensions and morphology due to patient's swallowing movement and head posture are also among the limitations of this technique .(40)

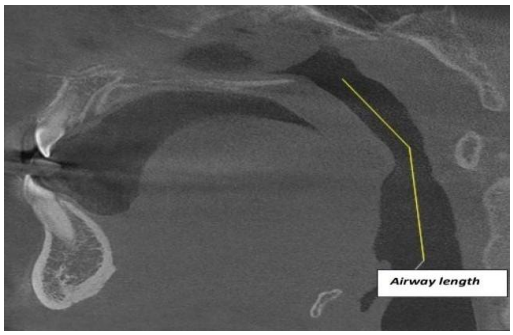

Figure 8: CBCT image of airway length

Temporary anchorage device (TAD) placement:

Orthodontics has long faced the difficulty of anchoring as resistance against undesirable displacement of one or more dental components. Due to oral problems, expectations for aesthetics, and most importantly, patient compliance, the use of conventional anchorage with extraoral equipment frequently becomes unfeasible.(41) Temporary anchoring devices (TADs) are being used more and more because they make orthodontic treatment easier and offer more clinical options. Its primary benefits are associated with the smaller devices, which free up more space for installation; also, it is inexpensive, doesn't rely on patient compliance, and is simple to install and remove.(42)

CBCT technology allows us to assess interradicular distance and thickness, transverse bone thickness, bone density and thickness, and cortical bone dimensions and quality. Although the front palate has the thickest bone, Holm et al. advised a CBCT assessment to determine the maximum screw length because bone thickness varies greatly amongst individuals. In addition to defining alveolar border conditions, CBCT can be used to identify even cranial and caudal boundaries prior to miniscrew placement, hence reducing the possibility of bone and root perforations.(43) Utilizing CBCT images to build surgical guides can assist prevent any harm to the maxillary and root sinuses. By simulating stress, finite element analysis built with CBCT will help direct the assessment of the mechanical benefits or drawbacks of the orthodontic appliances with TADs.

Dentofacial deformities and craniofacial anomalies:

Craniofacial abnormalities are heterogenic developmental deformities that affect the bones of the face and skull. Craniosynostosis, micrognathia, cleft lip and alveolus with or without extension to the hard and soft palate, hemifacial malformations, tooth developmental defects, and defects involving other body parts are common features observed in such anomalies. Global reports of these anomalies have been made. A multidisciplinary team comprising experts from various fields, such as pediatricians, geneticists, ophthalmologists, nurses, speech pathologists, otolaryngologists, orthodontists, oral surgeons, prosthodontists, and social workers, is necessary for the early detection and management of craniofacial anomalies. This team provides the child, who has a craniofacial anomaly, and the family with tremendous assistance.(45)

Several research were undertaken to select reference planes, construct cephalometric analysis, evaluate measurement accuracy, establish mean normalcy values, and assess gender and ethnic group differences for 3D evaluations. In addition to morphological examination, the spatial link between the neighboring structures is assessed using these photos. The model surgery can be performed thanks to CBCT technology. The design and manufacture of the occlusal surgical splints are therefore made possible by computer assisted orthognathic surgery. It is possible to generate anatomically perfect replacements and grafts by using virtual models. Following orthognathic surgery, the soft tissue response to the changes in the hard tissue can be more accurately predicted thanks to the CBCT data.(46)

CBCT is suggested for evaluating preoperative orthodontic decompensation of the maxillary and mandibular incisors. This is supplemental data from CBCT that is used to plan orthognathic surgery; it is not the primary reason for CBCT use. Additionally, CBCT shows to be a useful technique for evaluating the TMJ following orthognathic surgery, especially in cases where there is a significant risk of condyle resorption.(47)

Conclusion

1. The use of CBCT imaging is justified when the advantages of the diagnosis and/or treatment plan outweigh the possible dangers of radiation exposure in the presence of individual anamnesis, clinical examination, and available radiographs. Any decision about radiographic imaging should be made with the ALARA principle in mind. Only when the expected information has the potential to alter a patient's course of treatment or result can CBCT be justified.

2. When there is disagreement over whether conventional radiographs or 3D imaging are more adequate, CBCT can be utilized. These instances include individuals with cleft palates, evaluations of unerupted tooth positions, detection of root resorption brought on by unerupted teeth, and scheduling of orthognathic surgery.

3. In order to avoid multiple imaging, it is important to carefully evaluate if conventional radiographs are still necessary if the clinical examination indicates that a CBCT scan is required for an accurate diagnosis and/or treatment planning.

References

1. Hounsfield GN. Computerized transverse axial scanning (tomography): Part 1. Description of system. Br J Radiol. 1973;46(552):1016-1022. doi:10.1259/0007-1285-46-552-1016
2. Kau CH, Richmond S, Palomo JM, Hans MG. Three-dimensional cone beam computerized tomography in orthodontics. J Orthod. 2005;32(4):282-293.
3. Palomo JM, Rao PS, Hans MG. Influence of imaging parameters on radiation dose for effective dose reduction in cone beam computed tomography (CBCT) for dental diagnostics. Med Phys. 2008;35(7):3199-3207. doi:10.1118/1.2948342
4. Kapila SD, Nervina JM. CBCT in orthodontics: assessment of treatment outcomes and indications for its use. Dento maxillofac Radiol. 2015;44(1):20140282. doi:10.1259/dmfr.20140282
5. Patel S, Dawood A, Whaites E, Pitt Ford T. New dimensions in endodontic imaging: part 2. Cone beam computed tomography. IntEndod J. 2009;42(6):463-475. doi:10.1111/j.1365-2591.2009.01588.x
6. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008;52(4):707-730.
7. Loubele M, Bogaerts R, Van Dijck E, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol. 2009;71(3):461-468. doi:10.1016/j.ejrad.2008.04.057
8. Rudolph DJ, Willes C, Yuan F, Huang JC. Orthodontic applications of cone-beam volumetric tomography. J ClinOrthod. 2007;41(10):628-634. PMID: 18062788.
9. Ludlow JB, Timothy R, Walker C, Hunter R, Benavides E. Effective dose of dental CBCT—a meta-analysis of published data and additional data for nine CBCT units. DentomaxillofacRadiol. 2014;44(1):20140197. doi:10.1259/dmfr.20140197
10. Schulze D, Heiland M, Thurmann H, Adam G. Radiation exposure during midfacial imaging using 4- and 16-slice computed tomography, cone beam computed tomography systems and conventional radiography. DentomaxillofacRadiol. 2004;33(2):83-86. doi:10.1259/dmfr/68019960
11. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral

Pathol Oral RadiolEndod. 2008;106(1):106-114. doi:10.1016/j.tripleo.2008.03.018

12. Alling CC, Helfrick JF, Alling RD. Impacted Teeth. Philadelphia, Pa: W.B. Saunders; 1993
13. Haney E, Gansky SA, Lee JS, Johnson E, Maki K, Miller AJ, Huang JC. Comparative analysis of traditional radiographs and cone-beam computed tomography volumetric images in the diagnosis and treatment planning of maxillary impacted canines. American Journal of Orthodontics and DentofacialOrthopedics. 2010;137(5):590-597
14. Walker L, Enciso R, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. American Journal of Orthodontics and DentofacialOrthopedics 2005;128(4):418-42
15. Yusof WZ (1990) Non-syndromal multiple supernumerary teeth: Literature review. J Can Dent Assoc 56: 147-149. [Crossref]
16. Rajab LD, Hamdan MA (2002) Supernumerary teeth: Review of the literature and a survey of 152 cases. Int J Pediatr Dent 12: 244-254. [Crossref]
17. Brook AH (1974) Dental anomalies of number, form and size: Their prevalence in British school children. J IntAssoc Dent Child 5: 37-53. [Crossref]
18. Brauer HU (2010) Case Report: Non-syndromic multiple supernumerary teeth localized by cone beam computed tomography. Eur Arch Paediatr Dent 11(1): 41-43. [Crossref]
19. Walker L, Enciso R, Mah J (2005) Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J OrthodDentofacialOrthop 128(4): 418-23. [Crossref]
20. Brezniak Wasserstein A.Rootresorption after orthodontic treatment: part 1. Literature review. Am J OrthodDentofacialOrthop. 1993;103:62–66
21. S. Baumrind, E.L. Korn, R.L. Boyd Apical root resorption in orthodontically treated adults Am J OrthodDentofacialOrthop, 110 (1996), pp. 311-320
22. Patel S, Wilson R, Dawood A, Focchi F, Mannocci F. The detection of periapicalpathosis using digital periapical radiography and cone beam computed tomography – Part 2: a 1-year post-treatment follow-up. IntEndod J 2012; 45: 711–723.
23. Patel S, Wilson R, Dawood A, Focchi F, Mannocci F. The detection of periapicalpathosis using digital periapical radiography and cone beam computed tomography – Part 2: a 1-year post-treatment follow-up. IntEndod J 2012; 45: 711–723.
24. Alqerban A, Jacobs R, Fieuws S, Nackaerts O, SEDENTEXCT Project Consortium, Willems G. Comparison of 6 cone-beam computed tomography systems for image quality and detection of simulated canine impaction-induced external root resorption in maxillary lateral incisors. American Journal of Orthodontics and DentofacialOrthopedics. 2011;140(3):129-139
25. Pejicic A, Bertl M, Čelar A. Extent and prognosis of apical root resorption due to orthodontic treatment. Int J StomatOcc Med. 2012;5:147–154. doi: 10.1007/s12548-012-0056-5
26. Adarsh K, Sharma P, Juneja A. Accuracy and reliability of tooth length measurements on conventional and CBCT images: An in vitro comparative study. J Orthod Sci. 2018 Sep 6;7:17. doi: 10.4103/jos.JOS_21_18. PMID: 30271762; PMCID: PMC6144757.
27. Joss-Vassalli I, Grebenstein C, Topouzelis N, Sculean A, Katsaros C (2010) Orthodontic therapy and gingival recession: a systematic review. Orthodontics Craniofac Res 13:127–141

28. Alhulaimi HA, Awartani FA (2013) Periodontium biotype modification prior to an orthodontic therapy: case report. King Saud Univ J Den Sci 4:91–94
29. Song JM, Lee JY, Kim YD (2015) CBCT morphologic analysis of edentulous posterior mandible for mandibular body bone graft. J Oral Implantol 41:477–482
30. European Commission. Radiation protection no 172. Cone beam CT for dental and maxillofacial radiology (evidence based guidelines). 2012. Available: http://www.sedentexct.eu/files/radiation_ protection_172.pdf. [Accessed 2014 Mar 16]
31. Hamada Y, Kondoh T, Noguchi K, Iino M, Isono H, Ishii H, et al. Application of limited cone beam computed tomography to clinical assessment of alveolar bone grafting: a preliminary report. The Cleft Palate-Craniofacial Journal. 2005;42(2):128-137
32. D. C. Hatcher, "Operational principles for cone-beam computed tomography," Journal of the American Dental Association (1939), vol. 141, Supplement 3, pp. 3s–6s, 2010.
33. M. Ahmad, L. Hollender, Q. Anderson et al., "Research diagnostic criteria for temporomandibular disorders (RDC/TMD): development of image analysis criteria and examiner reliability for image analysis," Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics, vol. 107, no. 6, pp. 844–860, 2009.
34. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in Orthodontics. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2013;116(2):238-257
35. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dental Clinics of North America. 2008;52(4):707-730
36. Alhammadi MS, Fayed MS, Labib A. Three-dimensional assessment of condylar position and joint spaces after maxillary first premolar extraction in skeletal Class II malocclusion. Orthodontics & Craniofacial Research. 2017. doi: 10.1111/ocr.12141
37. Epstein, L.J., et al. ; Adult Obstructive Sleep Apnea Task Force of the American Academy of Sleep Medicine. (2009) Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. Journal of Clinical Sleep Medicine: JCSM, 5, 263–276.
38. Badran, M., Yassin, B.A., Fox, N., Laher, I.and Aya s, N. (2015) Epidemiology of sleep disturbances and cardiovascular consequences. The Canadian Journal of Cardiology, 31, 873–879.
39. Massie JP, Runyan CM, Stern MJ, Alperovich M, Rickert SM, Shetye PR, Staffenberg DA, Flores RL. Nasal septal anatomy in skeletally mature patients with cleft lip and palate. JAMA Facial Plastic Surgery. 2016;18(5):347-353
40. Lenza MG, Lenza MM, Dalstra M, Melsen B, Cattaneo PM. An analysis of different approaches to the assessment of upper airway morphology: A CBCT study. Orthodontics & Craniofacial Research. 2010;13(2):96-105
41. Antoszewska J, Papadopoulos MA, Park HS, Ludwig B. Five-year experience with orthodontic miniscrew implants: a retrospective investigation of factors influencing success rates. Am J OrthodDentofacialOrthop. 2009;136:158 e1–10.

42. Kang S, Lee SJ, Ahn SJ, Heo MS, Kim TW. Bone thickness of the palate for orthodontic mini-implant anchorage in adults. Am J Orthod Dentofacial Orthop. 2007;131:S74–81.
43. Holm M, Jost-Brinkmann PG, Mah J, Bumann A. Bone thickness of the anterior palate for orthodontic miniscrews. The Angle Orthodontist. 2016;86(5):826-831
44. Archak Chakraborty , LaraMoyu Fu , Rumpa Gangu ly & Snehlata Oberoi (2023) The Benefits of CBCT Imaging in the Diagnosis of Individuals with Craniofacial Anomalies, Journal of the California DentalAssociation, 51:1, DOI: 10.1080/19424396.2 023.2244704
45. Porto OC, de Freitas JC, de Alencar AH, Estrela C. The use of three-dimensional cephalometric references in dentoskeletal symmetry diagnosis. Dental Press Journal of Orthodontics. 2014;19(6):78-85
46. Sun B, Tang J, Xiao P, Ding Y. Presurgical orthodontic decompensation alters alveolar bone condition around mandibular incisors in adults with skeletal Class III malocclusion. International Journal of Clinical and Experimental Medicine. 2015;8(8):12866-12873
47. Cevidanes LH, Bailey LJ, Tucker SF, Styner MA, Mol A, Phillips CL, Proffit WR, Turvey T. Three-dimensional cone-beam computed tomography for assessment of mandibular changes after orthognathic surgery. American Journal of Orthodontics and Dentofacial Orthopedics. 2007;131(1):44-50