CONE BEAM COMPUTED TOMOGRAPHY IN DENTISTRY - AN EVIDENCE BASED REVIEW

Deepak Narang[1], Sunit Jureil [2], Rajdeep Kaur[3], Prabhjot Kaur[4], Vikram Bali[5], Amandeep Singh[6].

[1]Reader Department of Oral Medicine and Radiology, Deshbhagat Dental College, Punjab, India.

Additional Professor Department of Prosthodontics, King George Government Dental College, Lucknow, Uttar Pradesh, India. [3] Assistant Professor, Department of Orthodontics, [4] Reader, Department of Oral and Maxillofacial Pathology, [5] Professor, Department of Periodontics, [6] Professor & HOD, Department of Public Health Dentistry, Deshbhagat Dental College, Punjab, India.

ABSTRACT

In this era of advanced technology, cone-beam computed tomography (CBCT) has gained popularity in the field of oral radiology due to its advantages over conventional radiography. . A 3-dimensional analysis of head and neck anatomy allows practitioners to plan appropriately, operate with confidence, and assess results post-operatively. The use of CBCT is profoundly increasing for diagnosis and treatment planning in different specialties of dentistry. Cone Beam Computed Tomography (CBCT) is a valuable imaging technique in dentistry that can help direct a dentist's approach to a variety of conditions. Furthermore, CBCT overcomes certain limitations of 2-dimensional imaging, such as distortion, magnification, and superimposition.

The 3D imaging has made the complex craniofacial structures more accessible for examination. Early and accurate diagnosis of deep-seated lesions is possible. CBCT provides a high-spatial resolution of bone and teeth which allows accurate understanding of the relationship of the adjacent structures.

CBCT has helped in detecting a variety of cysts, tumours, infections, developmental anomalies, and traumatic injuries involving the maxillofacial structures. However, CBCT lacks the detailed depiction of soft tissue conditions for evaluation of pathologic conditions, head and neck infections, and temporo-mandibular joint (TMJ) disc evaluation.

This review evaluates the evidence-based research supporting the application of CBCT in the various fields of oral Medicine and radiology, including Oral lesions, Dental abscess, Periodical lesions, Cysts, Tumours, Oral carcinoma and Salivary gland pathology.

Additionally, the significant limitations of CBCT and potential areas for future research will be discussed.

KEY WORDS: **Cone-beam computed tomography, dentistry, diagnostic imaging**

INTRODUCTION

The introduction of Cone Beam Computed Tomography (CBCT) in dentistry provides a three dimensional view of oral and craniofacial structures aiding as an eminent diagnostic tool.Due to the reduced radiation exposure when compared to conventional CT, CBCT plays its main role in diagnosis and treatment planning in Dentistry [1,2]

First commercial CBCT unit marketed to the dental use was introduced in Europe in 1999. Use of CBCT in oral and maxillofacial imaging was initiated in the past decade in several countries; however, in India, its use was limited due to the cost of procuring the machine. Currently, the availability of this technology is increasing in many dental institutions and diagnostic centres across the country.

Applications of CBCT imaging include dental measurements, diagnostics of the temporomandibular joint, 3D cephalometry, evaluation of root resorption after tooth movement, airway assessment, periodontal bone level assessment before orthodontic treatment, pre-surgical assessment of the jaw, and predicting the

diameter of the unerupted tooth, analyses on reconstructed of 3D surface models of the craniofacial skeleton, soft tissues, and teeth [3] .

Advances in CBCT imaging technology provide sufficient detail of small areas in the jaws. This allows accurate measurements to be made and thereby to assess which areas of the jaws are most likely to provide sufficient thickness of cortical bone for anchorage. For use of appliances such as mini-implants, CBCT images of the head and jaws are needed to carry out measurements in specific areas.[4,5].

Cone-beam computed tomography (CBCT) introduction in maxillofacial imaging heralds a true paradigm shift from two-dimensional (2D) imaging to 3D imaging in dentistry. CBCT has emerged as an alternative to medical CT for diagnosing and treatment planning of oral and maxillofacial lesions. This imaging modality is a boon to dentistry due to its advantages over conventional 2D techniques and medical CT. [6,7]

Thus, CBCT is providing the dental clinician a modality for 3D representation of the maxillofacial structures, which in turn has reduced the dependence on the CT and super specialty setups for 3D imaging of oral and maxillofacial region.[8,9]

Initially, in the field of dental implantology, CBCT gained popularity for its crucial role. Currently, the utility of CBCT encompasses field orthodontics, oral and maxillofacial surgery, Endodontics, Temporomandibular joint (TMJ) disorders, Periodontics, Sleep disorders, Airway analysis along with dental implantology.[10 – 14]

TWO-DIMENSIONALIMAGING TO THREE-DIMENSIONAL IMAGING IN DENTAL PRACTICE

Imaging is a very important aspect in the diagnosis and management of a patient. Although new imaging techniques have been introduced, conventional 2D radiographs such as periapical radiographs, panoramic, and occlusal remains as a commonly used modality for the primary diagnosis and treatment planning in dentistry. However, 2D imaging techniques have got limitations such as magnification, distortion, and superimposition.[15]

Multiplanar imaging has provided the best diagnostic approach for dental practitioners. The volume of data that is acquired during a CBCT scan is stored, reformatted, and realigned. Several different types of images can be synthesized according to the requirements of the diagnostician. Elimination of superimposition of the area under investigation with other neighbouring structures is the major advantage of CBCT imaging compared to the 2D imaging. [16,17]

ANALYSIS OF CONE-BEAM COMPUTED TOMOGRAPHY IMAGES

Practitioners deciding to use CBCT for their patients need to take responsibility for the interpretation of the entire volume encompassed in the scan. Methodical, diagnostic approach is required. [16,17]

Formal reporting done by the oral and maxillofacial radiologist helps referring dentist to review the CBCT volumes. The most important in reviewing a CBCT scan is to apply a systematic approach to ensure that no available diagnostic feature is missed. [16,17]

An example of such an approach might be dividing the imaging volume into several smaller sections based on anatomical locations such as maxilla and maxillary teeth, mandible and mandibular teeth, nose and paranasal sinuses, TMJs, neck, cervical spine, and skull base, other findings.

In reviewing each of the anatomical regions, special attention is paid to the reason for the scan acquisition.

The review of a CBCT scan is a step-by-step analysis of all abnormal radiographic findings in the various image reconstructions. The diagnostician should check for any irregularities in the appearance of the region of interest along with changes in the shape, size, and density. Protocol can be adapted by the diagnostician for reviewing the CBCT volume. [18]

In the axial section, viewing from the most inferior slice to the most superior and identifying structures and comparing right and left can be done. Further, determine the nature of the structure as anatomic or pathologic. [18]

In coronal sections, viewing from the most anterior to the posterior section can be followed, similarly, for sagittal sections, view from one side to the other. Evaluation of reconstructed panoramic section and cross sections can be carried out. [18]

Due to the oblique angle of the mandibular condyles with midsagittal plane, the standard MPR images are not ideal for evaluating the TMJs. TMJ view is used to evaluate TMJs. Finally, 3D volumetric renderings can be reviewed. If abnormality is detected in the scan volume, determining whether normal variant or pathology is necessary. [18]

Lesions detected on CBCT should be evaluated for the following features: location, periphery, shape, internal structure, and effects of lesion on adjacent structures. After a thorough evaluation of the above features, clinician need to provide radiographic diagnosis/differential diagnosis and decide regarding further investigations, biopsy, observation for some period, other specialty referral or treatment.[18]

APPLICATIONS

The clinical applications of CBCT imaging in the oral and maxillofacial region are vast. Multiplanar imaging in CBCT has provided a highly useful technique for oral and maxillofacial radiologist for the diagnosis of any bone pathology and developmental anomaly in the orofacial region. [19]

This technique is a boon for diagnosis and the evaluation of fractures in oral and maxillofacial region, to determine size, extent, and location and to assess their relation to vital structures in cases of cysts and tumours in the orofacial region. [19]

CBCT is preferred for object localization, impacted teeth, supernumerary teeth and to assess their relation to vital structures, osteomyelitis, soft-tissue calcifications, cleft palate, developmental anomalies, presurgical planning, and postoperative evaluation. [19]

CBCT IN ORAL CANCER

In oral cancer cases, CBCT is useful in detecting osteolysis with sensitivity 89%–93% and specificity 60%–96.5%.35 The accuracy of CBCT is comparable to magnetic resonance imaging (MRI), CT and bone scintigraphy and is more accurate than panoramic radiography. Increasing use of CBCT in day-to-day practice results in improved detection of bone involvement in cases of oral cancers. However, poor soft-tissue assessment is the limitation in oral cancer cases. [20,21]

Czerwonka et al. conducted a CBCT study to assess the bone invasion in oral cancer cases and compared it with conventional computed tomography and concluded that CBCT offers marginally improved sensitivity at the cost of reduced specificity for assessment of bone invasion compared to CT. [20,21]

The technique of choice for visualization of tumour size in the soft tissues and for evaluation of cervical lymph node involvement is MRI, while CT is the technique of choice for evaluation of the presence and extent of bone invasion. The introduction of CBCT represents an alternative for the preoperative study of patients with oral cancer to evaluate the extent of jaw bone invasion. [20,21]

Closmann and Schmidt described the use of CBCT as a complementary examination for the preoperative evaluation of three patients with malignant lesions of the oral cavity (two squamous cell carcinomas and one osteosarcoma. [20,21]

Examination by CBCT was superior to that of OPG and MRI for evaluation of mandibular invasion and the extent of the lesion in the hard tissues, with the added advantage of lower cost and lower radiation dose than CT. The authors concluded that CBCT could be useful for the preoperative staging of oral cancer and for determining the extent of surgical resection necessary, as well as for planning reconstruction techniques.However, CT and/or MRI remain essential for lymph node staging and for the detection of soft-tissue involvement [20,21,22]

CBCT IN PERIAPICAL DISEASE

Conventional radiographic techniques provide limited information about the origin, size, and situation of periapical lesions. Superposition of adjacent anatomical and dental structures makes it necessary to perform a number of images from different angles[23]. It should be noted that the effective dose of radiation of two periapical radiographs in the area of the molars is of between 0.01 and 0.02 μSv[24], whereas the dose with limited CBCT is between 0.006 and 0.012 μSv[25].

Experimental studies have shown that CBCT is superior to digital or conventional intraoral radiography for the detection of chemically[26] or mechanically [27] induced periapical lesions. ***Lofthag-Hansen et al***demonstrated the utility of limited CBCT

for the detection of periapical pathosis not identified by conventional intraoral radiography. With CBCT, these authors found a larger number of teeth and roots involved and a larger number of lesions extending toward the maxillary sinus than on periapical radiographs. [28]

In 70% of the cases studied, the examiners considered that CBCT provided relevant additional diagnostic information in comparison with intraoral radiographs. The authors recommend the use of CBCT when there is a clinical suspicion of periapical disease and no pathology is detected on conventional radiographic techniques, as well as to plan periapical surgery for multi-rooted teeth. On the same subject, ***Estrela et al***. demonstrated that panoramic and periapical radiographs underestimated both the number and size of periapical lesions in comparison with CBCT. [29,30]

After performing a descriptive study using CBCT to visualize the regional anatomy of the area of the upper first molars, ***Rigolone et al***. suggested the possibility of using a small vestibular access for apicoectomy of the palatal root of the maxillary first molars[31].

CBCT IN SALIVARY GLAND PATHOLOGY

Non-tumour salivary gland diseases are common in adults and include sialadenitis, sialadenosis, stones, ductal strictures, dilatation and anatomical abnormalities. Before undergoing endoscopic or surgical treatment, patients require radiological diagnosis and an accurate map of the salivary ducts to be generated.[32,33]

3D-CBCT sialography allows us to demonstrate the presence of stones mucous plugs, strictures and dilatations and to explore the normal glands. As with CT scanning or CBCT, 3D-CBCT sialography can determine the number and the precise location of salivary stones, including those smaller than 2 mm in diameter. The main advantage of this technique is that it allows accurate mapping of salivary ducts and injuries via 3D reconstruction and MPR. [34,35,36]

3D-CBCT sialography is suitable for establishing an indication and guide a therapeutic endoscopic procedure[34]. Moreover, the cannulation of the salivary glands for radiological uses remains essential to our understanding of sialoendoscopy. [34,35,36]

CBCT IN ORAL LESIONS, OBJECT LOCALIZATION & FOREIGN BODY DETECTION

CBCT plays an important role in the analysis of benign and malignant lesions of the oral and maxillofacial region. Benign lesions of the jaws have varied radiographic appearances. Plain radiographs along with advanced imaging help the practitioners in arriving at a diagnosis and planning treatment for the lesion. CBCT imaging is highly beneficial for the evaluation of the location, size, extent, expansion, and involvement of any surrounding vital structures due to the disease process. CBCT is the technology of choice for fracture assessment and treatment planning in the oral and maxillofacial region. It, thus, eliminates usage of multiple 2D radiographs to do the same.

For object localization CBCT is the preferred technique. Recent studies have shown that CBCT is a more accurate and precise examination method for the localization of impacted teeth and impacted supernumerary teeth. It also aids in the assessment of the effect of these impacted teeth on the adjacent teeth and other vital structures. CBCT evaluation is, therefore, recommended for accurate treatment planning in thesecases. [34,35,36]

Retained foreign body in the maxillofacial region following trauma may pose a diagnostic difficulty for dental practitioners. CBCT helps in foreign-body localization. As an incidental finding radio opacity was noticed in the mandibular anterior region in a panoramic radiograph. Patient revealed that he had sustained a road traffic accident 10 years back and was unaware of any foreign body. CBCT confirmed the presence of foreign body in the soft tissues below the lower lip. Foreign bodies in the maxillofacial region may cause functional, allergic, and infective complications. [34,35,36]

CBCT IN FORENSIC ODONTOLOGY

Dental age estimation of living or deceased individuals is considered an important aspect in the field of forensic science. CBCT serve as non invasive method for dental age assessment. Various dental age estimation methods were reported in the literature.[36-40]A previous study showed that CBCT images of the face could be used for measuring soft-tissue thickness in the facial region.[41]

CBCT IN TEMPOROMANDIBULAR JOINT DISORDER

Magnetic Resonance Imaging (MRI) remains the gold standard for comprehensive intra-articular evaluation of the temporomandibular joint, including disc anatomy, position, and movement, as well as the joint capsule, surrounding soft tissues, and musculature. However, while MRI provides invaluable information, it remains inferior to computed tomography in providing detailed analysis of bony architecture[42].

CBCT has been shown to improve overall diagnostic accuracy for internal derangement when used as a supplement to MRI. Mohammed compared the interpretation of TMJ disorders when evaluated by MRI alone versus CBCT in addition to MRI and found that inter-examiner and intra-examiner consistency was higher when CBCT was used in addition to MRI when compared to MRI alone[43].

The limitations are CBCT is unable to evaluate inflammatory changes of the TMJ, especially in the acute setting. [44,45] Additionally, bone density estimation is poor due to Hounsfield unit distortion. Accordingly, CBCT should only be used when assessing the cortical surface area and dimensions of the condyle and temporal bone. [44,45]

The advantages of CBCT in the evaluation of the TMJ include an increased diagnostic capability of the bony articular derangements, especially when used to supplement other imaging techniques, such as MRI. [44,45]

CBCT IN OROFACIAL PAIN

One frequent problem dentists face is how to deal with a patient who has an atypical toothache. This is a persistent toothache without definitive evidence of dental-pulpal disease such as periapical radiolucency and/or a thermal or electrical pulp test that shows complete nonresponsiveness (an indicator of nonvitality) of the tooth to stimulation. [44,45]

CBCT devices can routinely detect incomplete vertical tooth cracks and fractures has not been proven yet. CBCT can be used to detect more substantial tooth complete fracture cases (those where the teeth components have some physical separation). [44,45]

No much study has yet been performed using CBCT imaging to find its sensitivity and specificity for detecting orofacial pain & incomplete vertical fractures in vivo. In such a research project, the gold standard would have to be teeth either examined with a microscope during endodontics treatment or after careful extraction to see if the CBCT prediction was correct.[44,45]

CONCLUSION

The role of CBCT in dentistry is variable, due to the significant breadth of the specialty. Ultimately, CBCT provides the depth dimension that cannot be visualized with 2-dimensional films. Although CBCT offers the advantages of a 3-dimensional view with minimal scatter at a low cost and radiation dose when compared with CT and MRI, it is lacking in soft tissue definition and differentiation. [44,45]

This review confirms that CBCT provides additional information to the clinician in a variety of clinical scenarios. In dentoalveolar surgery, CBCT helps visualize relevant anatomic structures, however limited data exists to suggest a significant change in treatment outcome. Bone volume and linear measurements can be calculated accurately with CBCT, which is useful when preparing for an implant surgery or when assessing osseous lesions. [44,45]

CBCT can also accurately depict bony infections, such as osteomyelitis and osteonecrosis, but falls short to more superior radiographic methods when viewing soft tissue. While some studies advocate the use of CBCT for orthognathic or TMJ surgery, systematic reviews have failed to support their universal application. [44,45]

CBCT is used for many purposes, including routine oral surgical procedures, such as removal of impacted teeth and placement of dental implants. However, the quality of literature supporting its use and demonstrating superiority over other imaging methods is quite varied. Although CBCT has now been available for decades, there are many significant opportunities to expand the existing literature and support new applications of this valuable imaging technology. [44,45]

REFERENCES

1. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreais IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8:1558-1564.
2. Sharon L. Brooks. CBCT Dosimetry: Orthodontic Considerations. Seminars in Orthod 2009; 15:14-18.
3. NiansongYe,a Fan Jian,aJunjieXue. Accuracy of in-vitro tooth volumetric measurements from cone-beam computed tomography Am J Orthod Dentofacial Orthop. 2012;142:879-87
4. Cassetta M, Sofan AA, Altieri F, Barbato E. Evaluation of alveolar cortical bone thickness and density for orthodontic mini-implant placement. Journal of Clinical and Experimental Dentistry. 2013; Dec 1; 5(5):e245-52.
5. Cha J, Kil J, Yoon T, Hwang C. Miniscrew stability evaluated with computerized tomography scanning. American Journal of Orthodontics and Dentofacial Orthopedics. 2010; 137:73-9.
6. Miracle AC, Mukherji SK. Conebeam CT of the head and neck, part 2: Clinical applications. AJNR Am J Neuroradiol 2009;30:1285-92.
7. Jaju PP, Jaju SP. Clinical utility of dental cone-beam computed tomography: Current perspectives. ClinCosmetInvestig Dent 2014;6:29-43.
8. Kumar M, Shanavas M, Sidappa A, Kiran M. Cone beam computed tomography-know its secrets. J Int Oral Health 2015;7:64-8.
9. Aditya A, Lele S, Aditya P. Current status of knowledge, attitude, and perspective of dental practitioners toward cone beam computed tomography: A survey. J Oral MaxillofacRadiol 2015;3:54-7.
10. Dhillon JK, Kalra G. Cone beam computed tomography: An innovative tool in pediatric dentistry. J Pediatr Dent. 2013;1:27-31.
11. Kiarudi AH, Eghbal MJ, Safi Y, Aghdasi MM, Fazlyab M. The applications of cone-beam computed tomography in endodontics: A review of literature. Iran Endod J 2015; 10:16-25.
12. Kapila S, Conley RS, Harrell WE Jr. The current status of cone beam computed tomography imaging in orthodontics. Dentomaxillofac Radiol 2011;40:24-34
13. James K. Mah and Stefan Alexandroni. Cone-Beam Computed Tomography in the Management of Impacted Canines. SeminOrthod 2010; 16: 199-204.
14. Greenberg AM. Cone beam computed tomography scanning and diagnosis for dental implants. Oral Maxillofac Surg Clin North Am 2015;27:185-202
15. Da Silva Santos LM, Bastos LC, Oliveira-Santos C, da Silva SJ, Neves FS, Campos PS, et al. Cone-beam computed tomography findings of impacted upper canines. Imaging Sci Dent 2014; 44: 287-92.
16. Angelopoulos C. Anatomy of the maxillofacial region in the three planes of section. Dent Clin North Am 2014; 58: 497-521.
17. Llena C, Fernandez J, Ortolani PS, Forner L. Cone-beam computed tomography analysis of root and canal morphology of mandibular premolars in a Spanish population. Imaging Sci Dent 2014;44:221-7
18. Brooks SL. Diagnosis of jaw pathologies using cone beam computed tomography. In: Sarment D, editor. Cone Beam Computed Tomography: Oral and Maxillofacial Diagnosis and Applications. Chichester: Wiley-Blackwell; 2014. p. 43-64.
19. Shukla S, Chug A, Afrashtehfar KI. Role of cone beam computed tomography in diagnosis and treatment planning in dentistry: An update. J Int Soc Prev Community Dent 2017;7:S125-36
20. Closmann JJ, Schmidt BL. The use of cone beam computed tomography as an aid in evaluating and treatment planning for mandibular cancer. Journal of Oral and Maxillofacial Surgery. 2007; 65: 766-771.
21. Linz C, Müller-Richter UD, Buck AK, Mottok A, Ritter C, Schneider P, et al. Performance of cone beam computed tomography in comparison to

conventional imaging techniques for the detection of bone invasion in oral cancer. International Journal of Oral and Maxillofacial Surgery. 2015 Jan;44(1):8-1
22. Shoha RR, Downson J, Richards AG. Radiographic interpretation of experimentally produced bony lesions. Oral Surgery, Oral Pathology, Oral Medicine, Oral Radiology and Endodontology. 1974;38:294-303 Usefulness of Cone Beam Computed Tomography for the Diagnosis and Treatment of Oral... http://dx.doi.org/10.5772/intechopen.68313 183
23. Lofthag-Hansen S, Huumonen S, Gröndahl HG. Limited cone beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg Oral Pathol Oral Med Oral Radiol Endod. 2007;103:114-119
24. Ekestube A, Thilander-Klang A, Lith A, Gróndahl HG. Effective and organ doses from scanography and zonography: A comparison with periapical radiography. Dentomaxillofac Radiol. 2004;33:87-92
25. Iwai K, Arai Y, Hashimoto K, Nishizawa K. Estimation of effective dose from limited cone beam X-ray CT examination. Japanese Dental Radiology. 2000;40:251-259
26. Özen T, Kamburoglu K, Cebeci ALI, Yüskel SP, Paksoy CS. Interpretation of chemically created periapical lesions using 2 different dental cone-beam computerized tomography units, an intraoral digital sensor, and conventional film. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009;107:426-432
27. Stravropoulos A, Wenzel A. Accuracy of cone beam dental CT, intraoral digital and conventional film radiography for the detection of periapical lesions. An ex vivo study in pig jaws. Clinical Oral Investigations. 2007;11:101-116
28. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod. 2008;34:273-279
29. Estrela C, Bueno MR, Azevedo BC, Azevedo JR, Pécora JD. A new periapical index based on cone beam computed tomography. J Endod. 2008;34:1325-1331
30. Simon JHS, Enciso R, Malfaz JM, Rogers R, Bailey-Perry M, Patel A. Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy. J Endod. 2006;32:833-837
31. Rigolone M, Pasqualini D, Bianchi L, Berutti E, Bianchi SD. Vestibular surgical access to the palatine root of the superior first molar:"Low-dose cone-beam" CT analysis of the pathway and its anatomic variations. J Endod. 2003;29:773-775
32. Iro H, Zenk J, Escudier MP, Nahlieli O, Capaccio P, Katz P, et al. Outcome of minimally invasive management of salivary calculi in 4,691 patients. Laryngoscope 2009; 119: 263–8. doi: https://doi. org/10.1002/lary.20008
33. 2. Katz P. New techniques for the treatment of salivary lithiasis: sialoendoscopy and extracorporal lithotripsy: 1773 cases. [In French.] Ann Otolaryngol Chir Cervicofac. 2004; 121: 123–32.
34. Kroll T, May A, Wittekindt C, Kahling C, Sharma SJ, ¨ Howaldt HP, et al. Cone beam computed tomography (CBCT) sialography—an adjunct to salivary gland ultrasonography in the evaluation of recurrent salivary gland swelling. Oral Surg Oral Med Oral Pathol Oral Radiol 2015; 120: 771–5. https://doi.org/10.1016/j.oooo.2015.09.005
35. Linz C, Müller-Richter UD, Buck AK, Mottok A, Ritter C, Schneider P, et al. Performance of cone beam computed tomography in comparison to conventional imaging techniques for the detection of bone invasion in oral cancer. Int J Oral MaxillofacSurg 2015;44:8-15.
36. Pałasz P, Adamski Ł, Górska-Chrząstek M, Starzyńska A, Studniarek M. Contemporary diagnostic imaging of oral squamous cell carcinoma-A review of literature. Pol J Radiol 2017; 82:193-202.
37. Yang F, Jacobs R, Willems G. Dental age estimation through volume matching of teeth

imaged by cone-beam CT. Forensic SciInt 2006;159 Suppl 1:S78-83.
38. Gulsahi A, Kulah CK, Bakirarar B, Gulen O, Kamburoglu K. Age estimation based on pulp/tooth volume ratio measured on cone-beam CT images. DentomaxillofacRadiol 2018;47: 20170239.
39. Koh KK, Tan JS, Nambiar P, Ibrahim N, Mutalik S, Khan Asif M, et al. Age estimation from structural changes of teeth and buccal alveolar bone level. J Forensic Leg Med 2017;48:15-21.
40. Rai A, Acharya AB, Naikmasur VG. Age estimation by pulp-to-tooth area ratio using cone-beam computed tomography: A preliminary analysis. J Forensic Dent Sci 2016;8:150-4.
41. Fourie Z, Damstra J, Gerrits PO, Ren Y. Accuracy and reliability of facial soft tissue depth measurements using cone beam computer tomography. Forensic SciInt 2010;199:9-14.
42. Westesson, P. Reliability and validity of imaging diagnosis of temporamandibular joint disorder. Adv. Dent. Res. 1993, 7, 137–151. [CrossRef]
43. Al-Saleh, M.; Punithakumar, K.; Lagravere, M.; Boulanger, P.; Jaremko, J.L.; Major, P.W. Three-Dimensional Assessment of Temporomandibular Joint Using MRI-CBCT Image Registration. PLoS ONE. 2017; 12, e0169555.
44. Hussain, A.M.; Packota, G.; Major, P.W.; Flores-Mir, C. Role of different imaging modalities in assessment of temporomandibular joint erosions and osteophytes: A systematic review. Dentomaxillofac. Radiol. 2008;37:63–71.
45. Al-Saleh, M.A.Q.; Alsufyani, N.A.; Saltaji, H.; Jaremko, J.L.; Major, P.W. MRI and CBCT image registration of temporomandibular joint: A systematic review. J. Otolaryngol. Head Neck Surg. 2016, 45, 261.

Corresponding Author
Dr. Deepak Narang
Deshbhagat DC, Punjab
Mobile No. : 7318085073
Email: parasitology1979@gmail.com

How to cite this Article:
Narang D, Singh P, Kaur R, Kaur P, Pushpa, Singh A. Tooth morphological variations in crown & root among dental graduates in lucknow – a descriptive cross sectional study. Journal of Interdisciplinary Dental Sciences, July-Dec 2021;10(2):28-35