Innovations

Diagnostic effectiveness of CBCT in Mandibular imaging – a systematic review

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Abstract

Aim: *To evaluate the diagnostic effectiveness of cone beam computed tomography and two-dimensional imaging modalities in mandible.* ***Objectives:*** *To identify, compare and assess the accuracy of the imaging modalities to diagnose anatomical structures, its variations and pathological conditions seen in the mandible.* ***Data sources and search methods:*** *Electronic search of the following database was performed: PubMed – Mesh, Cochrane central register of controlled trials, science direct, Google scholar and hand search. Articles were selected if there was a comparison between the imaging modalities and confined to the mandible. The electronic and hand search of studies published until December 2020, yielded a total of 9 meeting the inclusion criteria were selected.* ***Review methods:*** *Data extraction and collection from the included studies was conducted by the primary author and reviewed by the second author.* ***Conclusion:*** *Literature based evidence states that cone beam CT has a better diagnostic effectiveness over two-dimensional imaging. Hence, a proper benefit to risk ratio must be carried out prior to requisition of the imaging modality.*

Keywords: 1.*Cone beam computed tomography, 2.Panoramic imaging, 3.mandible*

Introduction:

Diagnostic imaging is an important addition along with clinical examination of a patient. Sir C Edmond Kells was the first person to use intra oral radiographs in dentistry. Further on the images were still a 2-D representation of a 3-D structure [1]. Intraoral periapical and orthopantomogram are the most popularly used 2D imaging techniques for dental examinations. Intra oral two-dimensional imaging includes periapical, occlusal, panoramic, cephalometric imaging. Orthopantomography (OPG) is the most widely advised radiographic procedure that reveals a complete image of maxillary and mandibular arch along with their surrounding structures. OPG is advantageous as it has relatively low radiation exposure, inexpensive equipment and broad coverage of oral structures whereas it possesses high distortion of images, phantom images and lower image resolution[2,3]. Due to distortion OPG fails in providing an accurate relationship between the anatomical structures[4].

Cone beam computed tomography (CBCT) has transformed diagnostic imaging in dentistry as it provides relays a three-dimensional volumetric data reconstruction of dental and maxillofacial structures with isotropic resolution and high dimensional accuracy[5]. Recently, CBCT has become the widely used imaging modality in clinical practice and is replacing medical CT as it provides requisite image quality with a lower exposure dose and good spatial resolution. Advantages include low cost of examination, faster scanning, least presence of artifacts and real-time imaging[6]. CBCT is also widely applied in implant placements, diseases of pulp and periapical tissues, cephalometric and orthognathic analysis and in maxillofacial surgery[7]. In anatomy, the mandible is the largest bone in the human facial skeleton and consists of the body, ramus, condylar and coronoid process along with alveolar sockets for the lower teeth. Small periosteal and endosteal vessels provide the blood supply. Periosteal vessels arrive from the inferior alveolar artery and supply the mandibular ramus. The endosteal vessels arise from the peri-mandibular branches of the maxillary artery, facial artery, ECA, and superficial temporal artery thereby supplying the body of the mandible[8].

A division of the trigeminal nerve called the inferior alveolar nerve (IAN) passes through the mandibular foramen and anteriorly in the mandibular canal branching for the lower teeth sensory nerve supply. At the mental foramen, the IAN divides into the incisive and mental nerve. The incisive passes through the incisive canal innervating the mandibular premolar, canine, and lateral and central incisors whereas the mental nerve leaves the mental foramen and provides sensation to the lower lip[9].

Imaging plays an important role as an essential tool along with clinical evaluation in diagnosing a wide spectrum of odontogenic and non-odontogenic lesions and thereby to manage treatment and its response. Panoramic radiographs and intraoral periapical radiographs form the foundation in the diagnosis of mandibular osseous changes. Conventional radiographs are used for imaging radiolucent, radiopaque, or mixed lesions of the mandible.

As panoramic radiographs are 2D projections of 3D structures, they have a limited merit for the assessment of lesion size, margins, and their involvement into adjacent anatomical structures or soft tissues. Cone beam CT, complement traditional radiographs overcoming the limitations and thereby giving more accurate information on diagnosis and treatment options[10].

Our research and knowledge have resulted in high-quality publications from our team[11–25]

Hence, this systematic review provides comparison of the imaging modalities in interpretation and diagnoses of both anatomical and pathological conditions seen in mandible

Structured question

What will be the effective imaging modality in assessing mandibular anatomical structures, its variations and pathological conditions?

PICO

P-Mandibular anatomy, variations and pathology of mandible

I - Cone beam computed tomography

C-Two-dimensional imaging

O-Diagnosticeffectivenes

Materials and methods:

a. SEARCH USED: We searched four databases for relevant studies published from January 2010 to December 2020. The sources included were PubMed – Mesh, science direct, hand search, Google scholar and Cochrane Central Register for Controlled Trials.

b. SEARCH METHODOLOGY:

Keywords used:

Population

Mandible, mandible/abnormalities, mandible/diagnosis, mandible/diagnostic imaging, mandible/pathology, mandibular condyle, mandibular condyle/abnormalities, mandibular condyle/diagnosis, mandibular condyle/diagnostic imaging, mandibular condyle/pathology, jaw cysts, jaw/abnormalities, jaw/diagnostic imaging, jaw/diagnosis, jaw/pathology, jaw abnormalities, jaw abnormalities/diagnostic imaging, jaw abnormalities/diagnosis, jaw abnormalities/pathology, jaw diseases, jaw diseases/diagnosis, jaw diseases/diagnostic imaging, jaw diseases/pathology, jaw fractures, jaw fractures/diagnosis, jaw fractures/diagnostic imaging, jaw fractures/pathology, jaw neoplasms, jaw neoplasms/diagnosis, jaw neoplasms/diagnostic imaging, jaw neoplasms/pathology, mental foramen, mental foramen/diagnostic imaging, mandibular nerve, nerve/diagnostic imaging, mandibular nerve/pathology

Intervention

Cone beam computed tomography, imaging, three dimensional, CBCT, Digital volumetric tomography, DVT, Volumetric tomography, VT

Comparison

Radiography, panoramic; radiography, occlusal; radiography, imaging; submentovertex view; water's view; posteroanterior cephalometric projection; reverse towne projection; radiography, interventional; radiography, dental, radiography; dental, digital, diagnostic imaging

Outcome

Predictive value of tests, sensitivity and specificity, reproduction/diagnostic imaging

c. Inclusion criteria

1. Articles that included only CBCT and two-dimensional imaging modality
2. Anatomical variations and pathological conditions confined only to the mandible.

d. Exclusion criteria

1. Articles that included other imaging modalities such as CT, MDCT, MRI
2. and ultrasound
3. Case reports
4. Articles that included both maxilla and mandible
5. In vitro studies

Data collection and analysis:

Study selection:

Search and study selection was done by the primary author and reviewed by the second author. After initial search, potentially eligible articles were selected based on title and abstract. Full text of selected articles was reviewed, and relevant studies were identified, which included studies published till December2020.

Chart 1- Search flow chart

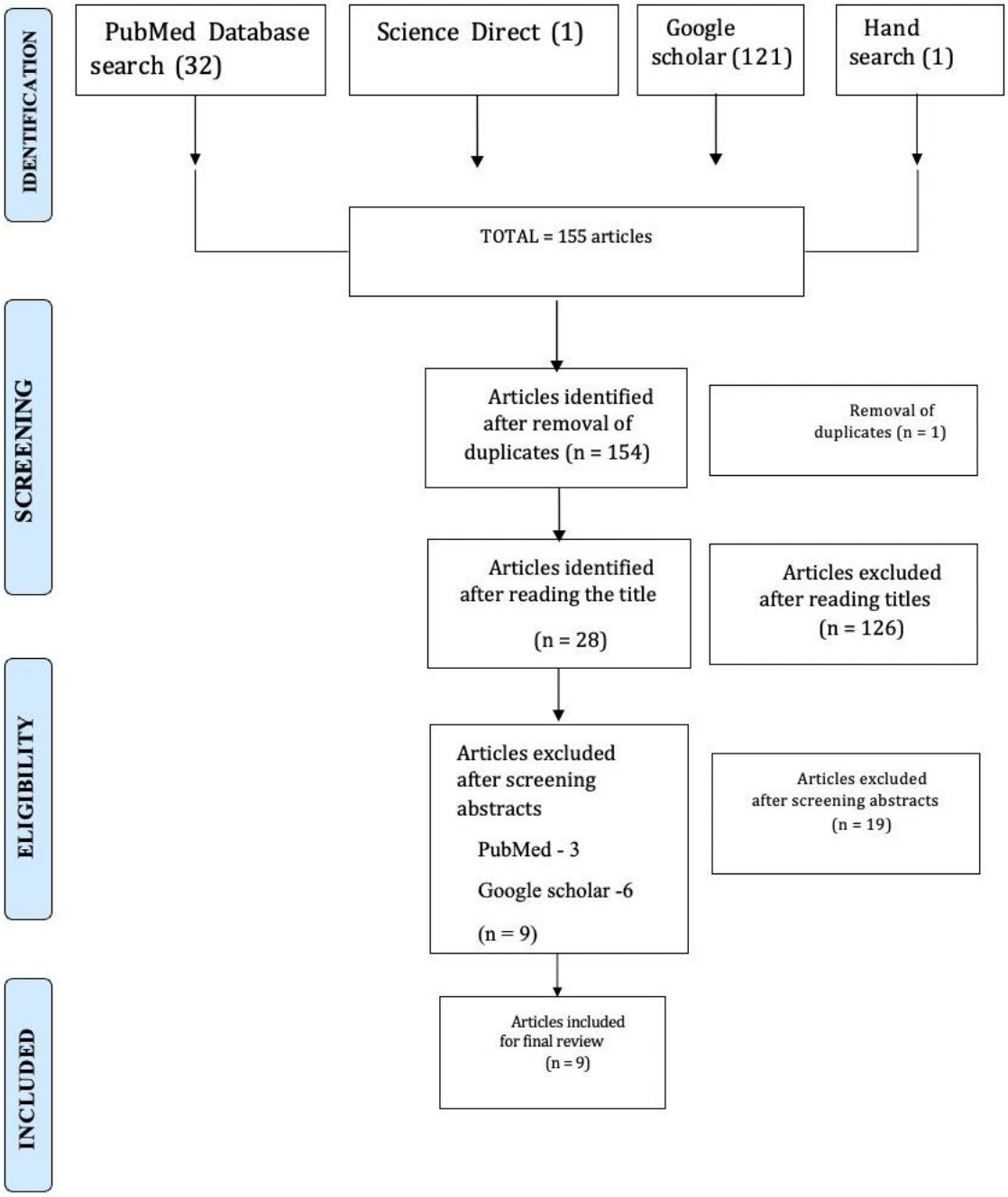

Table 1:generalcharecteristics of included study

SI.NO	Author	Year of study	Anatomical/ pathological	Purpose of the study	Number of study Images/patients	Imaging parameters	Outcome
1.	Shoaleh Shahidi et al.,	2018	Anatomical	Measure vertical bone height in different horizontal locations	508 images	CBCT - 66-85 kVp, 10-16 mA, 14.1 exposure time	Panaromic radiography-presurgical phase. CBCT-severe resorption
2.	Rakashree Chakraborty et al.,	2018	Anatomical	Location of the mandibular canal in mandibular posteriors	25 patients	CBCT - field of view with 0.3mm slice thickness and 26.9 seconds acquisition time was used.	Volumetric imaging-determine the precise anatomical relationship between the edentulous area and the mandibular canal.
3.	Michael M Bornstein et al.,	2011	Anatomical	1.Evaluate the detectability and dimensions of periapical lesions 2. Relationship of the mandibular canal to the roots of the respective teeth 3. Dimension of the buccal bone	40 patients	Periapical radiographs-paralleling technique – 65kV and 7mA CBCT - 3D Accuitomo XYZ - using a small field of view (4 x 4 cm)and a voxel size of 0.125 mm- 5mA and 80kV	1.15 (25.86%) PA lesions detected with sagittal CBCT slices were missed with PA radiography in mandibular molars. 2.Limited CBCT imaging as a valuable diagnostic method for the evaluation of posterior mandible before apical surgery.

4	Biyas Bhowmik et al.,	2018	Anatomical	Assess and compare the relationship of impacted third molar with IAC with the help of CR and DVT	48 patients	1.CBCT- the field of view being 50 mm × 37 mm and the voxel size 76.5 µm 70-74kV, 10mA and eexposure cycle of 10.8s 2.OPG- 68-74 kV,8-10mA with exposure cycle of 13.9-15.1s	1. DVT – better diagnostic information for images 2. Higher radiation dose 3. Secondary line of screening after OPG
5	Eduarda Helena et al.,	2018	Anatomical	Compare the detection of Juxta apical radiolucency in PAN and CBCT images	175 patients	PAN was obtained using an OP100D operating at 66 kVp, 2.5 mA and exposure time of 17.6 s. CBCT images were acquired using a Picasso-Trio unit parameters settings ranging from 80 kVp/3.5 mA to 85 kVp/3.7 mA	Juxta apical radiolucency allows higher detection and comprehension of variables in CBCT

6	Ramarathinum et al.,	2018	Pathological	Evaluate the diagnostic accuracy of DVT in contrast with OPG	21 patients	DVT imaging- slice thickness of 76 µm and 2mm Field of view is 50 * 37 mm. Constant scanning parameters were 85 kV and 28 mA.	1. DVT – better sensitivity and specificity in comparison to OPG 2. Valuable tool in detecting mandibular bone invasion
7	Cardoso et al.,	2020	Pathological	Comparing the diagnostic hypotheses obtained using images of panoramic radiographs and CBCT in cases of ameloblastoma, odontogenic keratocyst, and dentigerous cyst.	14 patients	CBCT – 0.3mm-0.4mm voxel acquisition protocol	Greater accuracy in diagnosis of characteristics ameloblastoma, odontogenic keratocyst

8	Shetty et al.,	2014	Pathological	Evaluate the efficiency of DVT in comparison with OPG in the assessment of bony condylar changes in patients of TMJ pain.	62 patients	1.Panoramic radiography is as follows: 70–74Kv, 14.3–15.1 mAs with scan time of 13.9–15.1 seconds. 2.Digital volumetric tomography is as follows: 70– 80 kv, 10 × 10.8 mAs with a scan time of 24 seconds	DVT provides more valid and accurate information on condylar bony changes.
9.	Peterson et al.,	2016	Pathological	Analyse possible differences in neuro- sensoric disturbances of the IAN between patients un-dergoing either panoramic imaging or CBCT before surgical removal of the mandibular third molar.	234 patients	CBCT examination with a field-of-view of 636 in an HD setting equalizing a voxel size of 0.133 and 451 single images.	Performing a CBCT examination before surgical re- moval of the mandibular third molar does not seem to prevent or reduce the number of post-surgical neuro-sensoric disturbances.

Table 02 - summary of outcome of excluded studies

Si.no	Title	Author	Reason for exclusion
1.	Is 3d-ct reformation using free software applicable to diagnosis of bone changes in mandibular condyles?	Oliveira et al.,	No comparison with OPG
2.	Detection accuracy of condylar bony defects in Promax 3D cone beam CT images scanned with different protocols	Zhang et al.,	No comparison with OPG
3.	Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography	Alkhander et al.,	Comparison with MRI
4	Diagnostic accuracy of cone beam computed tomography and conventional multislice spiral tomography in sheep mandibular condyle fractures	Sirin Y et al.,	Comparison with CT
5	Detection accuracy of condylar defects in cone beam CT images scanned with different resolutions and units	Zhang et al.,	No comparison with OPG

6	Evaluating the biomechanical effects of implant diameter in case of facial trauma to an edentulous atrophic mandible: a 3D finite element analysis	AyaliAysa et al.,	No comparison with OPG
7	Kissing molars: report of three cases and new prospective on aetiopathogenetic theories	Menditti et al.,	Not related to the main topic
8	Comparison of digital panoramic radiography versus cone beam computerized tomography for measuring alveolar bone	Tang zunan et al.,	Inclusion of maxillary bone
9	3D quantification of mandibular asymmetry using the SPHARM-PDM toolbox	Alhadidi et al.,	No comparison with OPG
10	Predictors of root resorption associated with maxillary canine impaction in panoramic images	Alqerban et al.,	Inclusion of maxillary bone
11	Comparison of methods for localization of impacted maxillary canines by panoramic radiographs	An S et al.,	Inclusion of maxillary bone
12	Availability of Software-Based Correction of Mandibular Plane for the Vertical Measurement of the Mandible in Cone Beam Computed Tomography	Han Sang sun et al.,	No comparison with OPG

13	Comparison of intraoral radiography and cone-beam computed tomography for the detection of periodontal defects: an in vitro study	Bagis N et al.,	Inclusion of maxillary bone
14	Evaluation of computer-assisted mandibular reconstruction with vascularized iliac crest bone graft compared to conventional surgery: a randomized prospective clinical trial	Ayob Nassim et al.,	No comparison with OPG
15	Finite element modelling of squirrel, guinea pig and rat skulls: using geometric morphometrics to assess sensitivity	Cox PG et al.,	Animal study
16	Cone-beam computed tomography study of root and canal morphology of mandibular premolars in a western Chinese population	Yu Xuan et al.,	No comparison with OPG
17	Prediction of detectability of the mandibular canal by quantitative image quality evaluation using cone beam CT	Takeshita et al.,	No comparison with OPG
18	Vestibulo-Oral inclination of maxillary and mandibular canines and bicuspids - a CBCT investigation	Hourfar et al.,	Inclusion of maxillary bone
19	Comparison of cone beam CT device and field of view for the detection of simulated periapical bone lesions	Hedisu et al.,	No comparison with OPG

20	Unified Heat Kernel Regression for Diffusion, Kernel Smoothing and Wavelets on Manifolds and Its Application to Mandible Growth Modeling in CT Images	Chung et al.,	Not related to the main topic
21	Clinical application of spharm-pdm to quantify temporomandibular joint osteoarthritis	Paniagua et al.,	Not related to the main topic
22	Diagnosis of alveolar and root fractures: an in vitro study comparing CBCT imaging with periapical radiographs	Kobayashi-velasco et al.,	Inclusion of maxillary bone
23	A comparative study of accuracy of detection of surface osseous changes in the temporomandibular joint using multidetector CT and cone beam CT	Alabdeen et al.,	Comparison with CT
24	The detection accuracy of cone beam CT for osseous defects of the temporomandibular joint: a systematic review and meta-analysis	Ma Ruohan et al.,	No comparison with OPG
25	Improving the prediction of the trabecular bone microarchitectural parameters using dental cone-beam computed tomography	Rong ting He et al.,	No comparison with OPG

26	Radiographic detection of artificially created horizontal root fracture using different cone beam CT units with small fields of view	Kamburogllu et al.,	No comparison with OPG
27	Automatic Craniomaxillofacial Landmark Digitization via Segmentation-guided Partially joint Regression Forest Model and Multi-scale Statistical Features	Zhang Jun et al.,	Not related to the main topic
28	The effect of horizontal X-ray beam angulation on the detection of furcation defects of mandibular first molars in intraoral radiography	Hishikawa T et al.,	Inclusion of maxillary bone
29	Optimizing Hybrid Occlusion in Face- Jaw-Teeth Transplantation: A Preliminary Assessment of Real-Time Cephalometry as Part of the Computer- Assisted Planning and Execution Workstation for Craniomaxillofacial Surgery	Ryan J Murphy et al.,	No comparison with OPG

Table 3: evidence level of selected articles

AUTHOR	YEAR	LEVEL OF EVIDENCE
Shoaleh Shahidi et al.,	2018	Level 3b
Rakashree Chakraborty et al.,	2018	Level 3b
Michael M Bornstein et al.,	2011	Level 3b
Biyas Bhowmik et al.,	2018	Level 3b
Eduarda Helena et al.,	2018	Level 3b
Ramarathinum et al.,	2018	Level 3b
Cardoso et al.,	2020	Level 3b
Shetty et al.,	2014	Level 3b
Peterson et al.,	2016	Level 2b

Based on Oxford Center for Evidence-based Medicine – Levels of Evidence (March 2009)

Results

Description of the studies:

The search identifies 155 publications out of which 126 were excluded reviewing the titles and 19 were excluded after reading the abstracts and a total of 9 studies were included in the study.

Discussion:

Orthopantomogram is a distinctive technique in the pre-surgical phase for measurement of the available bone height in edentulous ridges because of its cost-effectiveness, low exposure dose, and easy availability. The study done by Shahidi et al [26] aimed at the accuracy of conventional radiographs in measurement of vertical bone height precisely with respect to the horizontal bone alveolar crest. Findings from the study stated that there was a strong and linear relationship between the horizontal location of the alveolar crest related to the center of the mandibular canal and vertical height. The study states that Panoramic radiography can be used safely in the presurgical phase especially in the posterior mandibular regions and usage of CBCT only in situations with severe alveolar resorption.

Study done by Chakraborty et al[27] aimed at estimating the visibility of the inferior alveolar canal and the alveolar bone dimension in superoinferior and buccolingual dimensions. On visualizing mandibular canal CBCT revealed significantly better results when compared to OPG.Significant differences in mean distances between the two radiographic techniques for the superoinferior dimension was probably due to the magnification in OPG.

Observations from studies revealed that the mandibular canal was more inferiorly placed with respect to the superoinferior dimension in the mandible and have concluded that volumetric imaging as a best indicator to determine precise relationship area and mandibular canal.

For analysis of anatomical landmarks in mandibular molars and relationship of inferior alveolar canal to the lower teeth, Bornstein et al[28] compared Periapical radiography and CBCT. The study compared the efficacy of intraoral periapical radiography to that of the anatomy of the mandibular canal. Results revealed that diagnosis was statistically lower when compared to that of different CBCT sections, thereby underrating the real extent of the lesions. The present study showed that Periapical lesions detected using CBCT sagittal sections were completely missed in intraoral periapical radiographs and in about 44 radiographs the distance between the apical tips of mandibular molars and the superior border of the inferior alveolar nerve were not measured. CBCT imaging is thereby considered a valuable diagnostic imaging method of anatomically demanding area especially its relation to the inferior alveolar nerve in the mandible prior to surgeries.

Origin of neurosensory dysfunction is an aftermath post trans alveolar removal of impacted third molars. Study done by Bhowmik et al[29] compared the position of the mandibular canal to that of the third molars using CBCT and panoramic radiographs. The study revealed that there was no statistically relationship between the third molars and mandibular canal in vertical dimension but was highly significant while assessing the horizontal relationship. Study by Peterson et al[30]analyzed the differences in neuro-sensory disturbances of the IAN between patients who underwent orthopantomogram or Cone beam CT before surgical management of the mandibular third molar. Hence, CBCT examination prior to surgical extraction of mandibular third molar did not seem to change the outcome of neurosensory disturbances.
Article by Nascimento et al,[31]revealed for detection of juxta apical radiolucency using OPG and CBCT, selecting an imaging modality is the correlation between the effective dose related to it and the diagnostic details required. Differences in juxta apical radiolucency detection on panoramic and CBCT might be related to image acquisition combined with alveolar bone structure characteristics. CBCT is advised on if the added information can alter the course of treatment or the outcome for the patient.

The study done by Ramarathinum et al[32]for DVT in studying alveolar invasion of the mandible for patients with oral carcinoma revealed highest sensitivity and specificity proved to have maximum diagnostic ability in comparison to that of panoramic imaging. DVT aids as a beneficial tool in detecting the mandibular bone invasion and providing the extent of margins that are to be resected.

On comparison of the diagnostic effectiveness between panoramic and cone beam computed tomography in diagnosis of ameloblastoma, odontogenic keratocyst and dentigerous cyst, it was statistically insignificant in study done by Cardoso et al but with good diagnostic average for cases of ameloblastoma. Quantitative and qualitative features of odontogenic keratocyst and dentigerous cysts revealed no differences statistically[33].
Shetty et al[34] study evaluated the efficiency of CBCT to that of OPG in assessment of condylar changes in patients with temporomandibular disorders. The study revealed that gross bony changes such as flattening of condyle and pointed beak appearance of condylar head is best viewed in panoramic radiography whereas CBCT aids in detecting condylar alterations like erosion and osteophytes.

Conclusion:

Diagnostic effectiveness of CBCT in mandibular imaging plays a pivotal role in diagnosis as well as aids treatment planning. CBCT gives a better visualization of the mandibular anatomy and its variations when compared to that of two-dimensional radiographs which provides gross details. With the advancement in usage of Cone beam CT in dental practice, a proper assessment of benefit to risk ratio must be made to select the correct imaging modality for diagnosis.

References:

1. *Sethi P, Tiwari R, Das M, Singh MP, Agarwal M, Ravikumar AJ. Two Dimensional versus three dimensional imaging in endodontics - an updated review [Internet]. Vol. 5, Journal of Evolution of Medical and Dental Sciences. 2016. p. 6287–93.*
2. *Patel PS, Shah JS, Dudhia BB, Butala PB, Jani YV, Macwan RS. Comparison of panoramic radiograph and cone beam computed tomography findings for impacted mandibular third molar root and inferior alveolar nerve canal relation. Indian J Dent Res. 2020 Jan;31(1):91–102.*
3. *Spiotto MT, Juodzbalys G, Daugela P. Mandibular Third Molar Impaction: Review of Literature and a Proposal of a Classification [Internet]. Vol. 4, Journal of Oral and Maxillofacial Research. 2013.*
4. *Ghaeminia H, Meijer GJ, Soehardi A, Borstlap WA, Mulder J, Vlijmen OJC, et al. The use of cone beam CT for the removal of wisdom teeth changes the surgical approach compared with panoramic radiography: a pilot study. Int J Oral Maxillofac Surg. 2011 Aug;40(8):834–9.*
5. *Şekerci AE, Şişman Y. Comparison between panoramic radiography and cone-beam computed tomography findings for assessment of the relationship between impacted mandibular third molars and the mandibular canal [Internet]. Vol. 30, Oral Radiology. 2014. p. 170–8.*
6. *Neves FS, Souza TC, Almeida SM, Haiter-Neto F, Freitas DQ, Bóscolo FN. Correlation of panoramic radiography and cone beam CT findings in the assessment of the relationship between impacted mandibular third molars and the mandibular canal. DentomaxillofacRadiol. 2012 Oct;41(7):553–7.*
7. *Maloth K, Kundoor VR, Patimeedi A, Thakur M, Nomula R, Sunitha K. Objectivity and reliability of panoramic radiographic signs and cone-beam computed tomography in the assessment of a superimposed relationship between the impacted mandibular third molars and mandibular nerve: A comparative study [Internet]. Vol. 29, Journal of Indian Academy of Oral Medicine and Radiology. 2017. p. 100.*
8. *Saka B, Wree A, Henkel KO, Anders L, Gundlach KKH. Blood supply of the mandibular cortex: an experimental study in Göttingen minipigs with special reference to the condyle [Internet]. Vol. 30, Journal of Cranio-Maxillofacial Surgery. 2002. p. 41–5.*
9. *Lee M-H, Kim H-J, Kim DK, Yu S-K. Histologic features and fascicular arrangement of the inferior alveolar nerve. Arch Oral Biol. 2015 Dec;60(12):1736–41.*
10. *Avril L, Lombardi T, Ailianou A, Burkhardt K, Varoquaux A, Scolozzi P, et al. Radiolucent lesions of the mandible: a pattern-based approach to diagnosis. Insights Imaging. 2014 Feb;5(1):85–101.*
11. *Kumar SP, Girija ASS, Priyadharsini JV. Targeting NM23-H1-mediated inhibition of tumour metastasis in viral hepatitis with bioactive compounds from Ganoderma lucidum: A computational study. pharmaceutical-sciences [Internet]. 2020;82(2).*
12. *Manickam A, Devarasan E, Manogaran G, Priyan MK, Varatharajan R, Hsu C-H, et al. Score level based latent fingerprint enhancement and matching using SIFT feature. Multimed Tools Appl. 2019 Feb 1;78(3):3065–85.*
13. *Ravindiran M, Praveenkumar C. Status review and the future prospects of CZTS based solar cell – A novel approach on the device structure and material modeling for CZTS based photovoltaic device. Renewable Sustainable Energy Rev. 2018 Oct 1;94:317–29.*

14. *Vadivel JK, Govindarajan M, Somasundaram E, Muthukrishnan A. Mast cell expression in oral lichen planus: A systematic review. J Investig Clin Dent. 2019 Nov;10(4):e12457.*
15. *Ma Y, Karunakaran T, Veeraraghavan VP, Mohan SK, Li S. Sesame Inhibits Cell Proliferation and Induces Apoptosis through Inhibition of STAT-3 Translocation in Thyroid Cancer Cell Lines (FTC-133). Biotechnol Bioprocess Eng. 2019 Aug 1;24(4):646–52.*
16. *Mathivadani V, Smiline AS, Priyadharsini JV. Targeting Epstein-Barr virus nuclear antigen 1 (EBNA-1) with Murrayakoengii bio-compounds: An in-silico approach. Acta Virol. 2020;64(1):93–9.*
17. *Happy A, Soumya M, Venkat Kumar S, Rajeshkumar S, Sheba RD, Lakshmi T, et al. Phyto-assisted synthesis of zinc oxide nanoparticles using Cassia alata and its antibacterial activity against Escherichia coli. BiochemBiophys Rep. 2019 Mar;17:208–11.*
18. *K M P, Johnson P, Ganesh M, Subhashini AS. Evaluation of Salivary Profile among Adult Type 2 Diabetes Mellitus Patients in South India. J Clin Diagn Res. 2013 Aug;7(8):1592–5.*
19. *Paramasivam A, Priyadharsini JV. Novel insights into m6A modification in circular RNA and implications for immunity [Internet]. Vol. 17, Cellular & Molecular Immunology. 2020. p. 668–9.*
20. *Ponnanikajamideen M, Rajeshkumar S, Vanaja M, Annadurai G. In Vivo Type 2 Diabetes and Wound-Healing Effects of Antioxidant Gold Nanoparticles Synthesized Using the Insulin Plant Chamaecostuscuspidatus in Albino Rats. Can J Diabetes. 2019 Mar;43(2):82–9.e6.*
21. *Priyadharsini JV, Vijayashree Priyadharsini J, Smiline Girija AS, Paramasivam A. In silico analysis of virulence genes in an emerging dental pathogen A. baumannii and related species [Internet]. Vol. 94, Archives of Oral Biology. 2018. p. 93–8.*
22. *Anita R, Paramasivam A, Priyadharsini JV, Chitra S. The m6A readers YTHDF1 and YTHDF3 aberrations associated with metastasis and predict poor prognosis in breast cancer patients. Am J Cancer Res. 2020 Aug 1;10(8):2546–54.*
23. *Vigneshwaran S, Sundarakannan R, John KM, Joel Johnson RD, Prasath KA, Ajith S, et al. Recent advancement in the natural fiber polymer composites: A comprehensive review. J Clean Prod. 2020 Dec 20;277:124109.*
24. *Nambi G, Kamal W, Es S, Joshi S, Trivedi P. Spinal manipulation plus laser therapy versus laser therapy alone in the treatment of chronic non-specific low back pain: a randomized controlled study. Eur J Phys Rehabil Med. 2018 Dec;54(6):880–9.*
25. *Mohanavel V, Ashraff Ali KS, Prasath S, Sathish T, Ravichandran M. Microstructural and tribological characteristics of AA6351/Si3N4 composites manufactured by stir casting. Journal of Materials Research and Technology. 2020 Nov 1;9(6):14662–72.*
26. *Shahidi S, Zamiri B, Abolvardi M, Akhlaghian M, Paknahad M. Comparison of Dental Panoramic Radiography and CBCT for Measuring Vertical Bone Height in Different Horizontal Locations of Posterior Mandibular Alveolar Process. J Dent. 2018 Jun;19(2):83–91.*
27. *Chakraborty R, Panchbhai A, Bhowate R, Sen S. Comparison Between Conventional Radiography and 3D Volumetric Imaging for Location of Mandibular Canal: In Vivo Study [Internet]. Vol. 29, Journal of Indian Academy of Oral Medicine and Radiology. 2017. p. 267.*
28. *Bhowmik B, Naikmasur V, Guttal K. Efficacy of digital volume tomography in the preoperative assessment of position of inferior alveolar canal with impacted mandibular third molars in a subset of Indian population [Internet]. Vol. 10, Indian Journal of Dental Sciences. 2018. p. 153.*
29. *Petersen LB, Vaeth M, Wenzel A. Neurosensoric disturbances after surgical removal of the mandibular third molar based on either panoramic imaging or cone beam CT scanning: A randomized controlled trial (RCT). DentomaxillofacRadiol. 2016;45(2):20150224.*
30. *Nascimento EHL, Oenning ACC, Freire BB, Gaêta-Araujo H, Haiter-Neto F, Freitas DQ. Comparison of panoramic radiography and cone beam CT in the assessment of juxta-apical radiolucency. DentomaxillofacRadiol. 2018 Jan;47(1):20170198.*
31. *Ramarathinum D, Rao G, Kumar N, Anehosur V, Desai AK. Digital volume tomography in the assessment of mandibular invasion in patients with squamous cell carcinoma of the oral cavity - A prospective study. Saudi Dent J. 2019 Jan;31(1):93–8.*

32. *Cardoso LB, Lopes IA, Ikuta CRS, Capelozza ALA. Study Between Panoramic Radiography and Cone Beam-Computed Tomography in the Diagnosis of Ameloblastoma, Odontogenic Keratocyst, and Dentigerous Cyst. J Craniofac Surg. 2020 Sep;31(6):1747–52.*
33. *Shetty US, Burde KN, Naikmasur VG, Sattur AP. Assessment of condylar changes in patients with temporomandibular joint pain using digital volumetric tomography. Radiol Res Pract. 2014 Sep 21;2014:106059.*

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