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TITLE : Relationship of impacted third molar radiographic predictors on Orthopantomogram (OPG) with Cone Beam Computed Tomography (CBCT) images-A systematic review.

RUNNING TITLE: Relationship of impacted third molar radiographic predictors on Orthopantomogram (OPG) with Cone Beam Computed Tomography (CBCT) images.

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ABSTRACT

AIM & OBJECTIVE: To find correlation of panoramic radiographic indicators with CBCT images &compare the diagnostic accuracy of CBCT and digital OPG in assessing the relationship between the mandibular nerve canal (MNC) and impacted third molars(ITM).

MATERIALS & METHOD: Articles identified through database searching (PUBMED,MEDLINE, SCOPUS) were 17 & included articles were 11. Retrospective studies, prospective studies, comparative studies, studies comparing diagnostic accuracy of CBCT and OPG for relationship of ITM with that of MNC, Studies published from 1/01/2012 to 15/07/2023 were included. Studies in which relationship of ITM with that of MNC are diagnosed using methods other than CBCT or OPG, Studies comparing CBCT and OPG for the injury of MNC, Studies reporting relationship of MNC with ITM in only CBCT or OPG only were excluded.

RESULTS: The sensitivity across the studies for CBCT was 97.4% while it was between 67.8% and 98.55% for OPG radiography. The specificity for CBCT was 85.7% and for OPG was 43.39%. Similarly, the positive predictive values were demonstrated in only one study with 92.7% for CBCT and 97.6% for OPG.Negative predictive value for CBCT was 94.7%.

CONCLUSION: CBCT is superior diagnostic accuracy compared to OPG in assessing the proximity and relationship of ITM to the MN. Panoramic radiographic indicators are reliable to predict position of ITM and MN in CBCT.

Keywords: OPG , CBCT, mandibular canal, impacted third molar.

INTRODUCTION

Impaction, from the Latin for "organ or structure prevented from assuming its normal position," refers to a mechanical state that is abnormal. A third molar that is impacted is one that does not erupt at the proper location in the oral cavity during its normal development period.[1] The maxilla and mandible had the highest rates of impacted third molars, with documented frequencies ranging from 16.7% to 73.82% of cases in the Indian population.[2]. Although many studies have indicated a higher prevalence of impaction in females than in males, there is currently no conclusive evidence of a sexual propensity for third molar impaction.[3].

It has been discovered that impacted third molars can cause harm to neighboring teeth and are linked to a number of pathologic disorders, including cystic lesions, root resorption, neoplasia, pericoronitis, and periodontitis. According to reports, an impacted third tooth weakens the mandibular angle and increases the risk of mandibular fracture. As a result, extracting an impacted third molar continued to be standard procedure.[1] Careful pre-operative examination is necessary before extracting such a tooth, as skipping it can result in complications like discomfort (2.1%), bleeding (2.4%), swelling (2.1%), and inferior alveolar nerve paresthesia. Rizqiawan A et al. (2022) report that the prevalence rate of these problems ranges from 2.6% to 30.9%.[5]

A persistent sensory deficiency and/or altered sensation of the lower jaw, mental area, and lower lip of the affected side might be observed among the documented sequelae of inferior alveolar nerve paresthesia. These symptoms can be temporary or chronic.[1] Research indicates that between 0.8% and 0.4% of patients experience inferior alveolar nerve paresthesia after third molar surgery.[6]

Clinicians can choose the optimal surgical procedures, such as where to remove bone, how to partition the tooth, and which direction to raise the roots, by using pre-operative clinical and radiographic examination to help them assess the complexity of the treatment.

The proximity of impacted mandibular third molar (IMTM) roots to the mandibular canal can be measured using radiographic imaging techniques such as intraoral periapical radiography (IOPAR), orthopantomography (OPG), computed tomography (CT), cone-beam CT (CBCT), etc. Pre-operative extraction of the mandibular third molar, the standard imaging approach used is 2D view, or panoramic radiography, because it is quick, inexpensive, easy to achieve, and covers a wider range of oral structures with relatively little radiation exposure.[6]

Using orthopantomography (OPG), many authors have examined the appearance of impacted third molars and their relationship to the inferior alveolar canal. Rood and Shehab report that seven radiographic signs on panoramic radiography imaging have been found, which may indicate a close connection between the inferior alveolar nerve canal and the third molar root tips. Interruptions of the radiopaque wall of the canal ,narrowing of canal,deviation of canal, darkening of the tooth roots, deflection of roots, narrowing of the roots and bifid root apex are among these radiographic signs.[7]

For a precise analysis of the buccolingual relationship of the molar, cone beam computed tomography (CBCT) is the alternative radiographic technique that is advised.[3] For preoperative localization of the IAN, CBCT is a relatively new diagnostic three-dimensional (3D) imaging technique. Accurate 3D volumetric images in the axial, sagittal, and coronal planes are produced by CBCT in comparison to the two-dimensional panoramic radiograph. When the panoramic radiograph shows that the impacted third molar and the inferior alveolar canal are near together, CBCT is advised.[8] Therefore, these studies would provide clinicians the ability to choose between doing a coronectomy, changing their surgical strategy, and keeping an impacted third molar that is asymptomatic.[9]

Many studies have been conducted to compare the proximity and anatomic correlation of impacted third molar to vital structures radio graphically using OPG & CBCT.Comparison of Orthopantomography (OPG) and Cone beam computed tomography (CBCT), was carried out to analyse relation of impacted tooth, relation to apices of root tips, impaction status, Inferior alveolar nerve canal, presenceor absenceof corticalization etc.

This systematic review aims to compare the diagnostic accuracy of cone beam computedtomography (CBCT) and Digital Orthopantomogram (OPG) for evaluation of relation of mandibular canal with impacted third molar.

MATERIALS & METHODS

The current systematic review was conducted and written according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA Statement) checklist Recommendations.[10] and filed under Protocol number on PROSPERO CRD42023479544 (the International Prospective Register of systematic Reviews). The eligibility criteria were based on PICO (population, intervention, comparators and outcomes) as follows: where patients with impacted mandibular third molar were considered as population for the review. Diagnostic accuracy assessed through CBCT was considered as the intervention. Diagnostic accuracy assessed through OPG was considered as the comparator. With outcome as Diagnostic accuracy of detecting the relationship of impacted mandibular third molar with the inferior alveolar canal when assessed through CBCT and OPG.

Inclusion crieteria were retrospective studies, prospective studies, comparative studies, were included in the review,Studies done only on human species were included ,The studies comparing diagnostic accuracy of CBCT and OPG for relationship of impacted mandibular third molar with that of inferior alveolar canal were included , Studies in English language or studies in other languages where translation to English was possible were included , Studies published from 1st January 2012 to 15th July 2023.

Exclusion crieteria were studies in which relationship of impacted mandibular third molar with that of inferior alveolar canal are diagnosed using methods other than CBCT or OPG , Studies comparing CBCT and OPG for the injury of mandibular canal or mandibular nerve , Studies reporting relationship of mandibular canal with impacted third molar in only CBCT ,Studies reporting relationship of mandibular canal with impacted third molar in only OPG ,Reviews , Case reports ,Case series ,Conference proceedings , Letters to editor , Short communications if no required data is provided.

A search strategy was developed using keywords related to impacted mandibular third molar, CBCT, OPG, and diagnostic accuracy. Data was searched through the database, PubMed-Medline and Google scholar from 1st January 2012 till 15th July 2023. Cross references for pertinent papers were verified, and grey literature on CBCT, OPG, and diagnostic accuracy was also searched. When the full texts of the pertinent research were not accessible through an electronic database, a manual search in the institutional library was performed.

The comprehensive data search was performed in PubMed-Medline and Google scholar. While carrying out the search through PubMed the following filters were put:

1. Article type- Observational study and comparative study.
2. Publication date- 1st January 2012 till 15th July 2023
3. Best match option
4. Keywords are given in tabular form in the last after reference.

- The search strategies developed using Boolean operators for PubMed-Medline were as described in last after reference part.
-

STUDY SELECTION

One review author (TK) with 20 years of experience independently screened the titles and abstracts obtained by search strategy and included them if they met the inclusion criteria. Later full texts of all the included studies were obtained. After obtaining the full texts of the articles they were screened by reading the whole article and then decided if they met the inclusion criteria. Whenever there was uncertainty regarding any study to be eligible for inclusion, the problem was resolved by discussing it with the second author (SB) with 3 years of experience. Finally, the search yielded 11 studies which were included in the systematic review process.

The screening process of studies is presented in the form of PRISMA flow-chart (Figure1). This systematic review resulted in a total of 17 articles using PubMed search and 14 articles using Google scholar search engine. Nine studies were excluded based on the title screening. Further 22 studies underwent duplication removal. Four of the articles were duplicates that kept turning up in various search strategies. Three of the 18 articles that remained after reading their abstracts were excluded. The final choice of whether to include or remove the studies was made after reading the entire texts of the remaining 15 articles. Four articles were further excluded after reading the whole text. One article was not available full text and another three articles did not focus on providing relationship of mandibular 3rd molar with mandibular canal. The studies in this systematic review report only those studies that are comparing CBCT with OPG with respect to relationship of mandibular 3rd molar with mandibular canal. The characteristics of the articles included in this systematic review are presented in the result section.

DATA COLLECTION PROCESS

A standardized data extraction form also called as a pilot form was prepared in Microsoft Excel with the help of an expert. Initially 2-3 entries were made in the Excel and it was reviewed by an expert. Any disagreement between the authors was resolved by discussion.

DATA ITEMS

Data items included for extracting the data were:-

1. Study Id- Number given to each included study
2. Author's name- Name of the author
3. Year of publication- Year in which the study was published
4. Study design- Whether the study was retrospective or prospective comparative study
5. Sample size- Number of ,mandibular third molar teeth included in the study
6. Age: Age of the patients included in the study
7. Intervention- CBCT details
8. Comparator- OPG details
9. Exposure time- Exposure time for CBCT and OPG radiographs
10. Impacted third molar detail- classification of third molar considered in the study
11. Outcome- findings on CBCT, findings on OPG, correlation present, correlation absent, diagnostic accuracy details (sensitivity, specificity, positive predictive value, negative predictive value)
12. Other findings- Any other findings relevant to the review
13. Inference- The conclusion of the study
14. Remark- The remarks by the author (…..)

RESULTS

The present systematic review was conducted to compare the diagnostic accuracy of CBCT with OPG technique in assessing the relationship of mandibular impacted 3rd molar with mandibular canal. The screening process was undertaken in three steps that included screening of titles followed by screening of abstracts and finally screening of full text for inclusion in the review. The characteristics of the 11 included studies [11,12,13,14,15,9,16,17,6,8,7] included in the systematic review are presented in the below tables.

Table no.1,2,3,4 with figure-details are given in the last next to reference

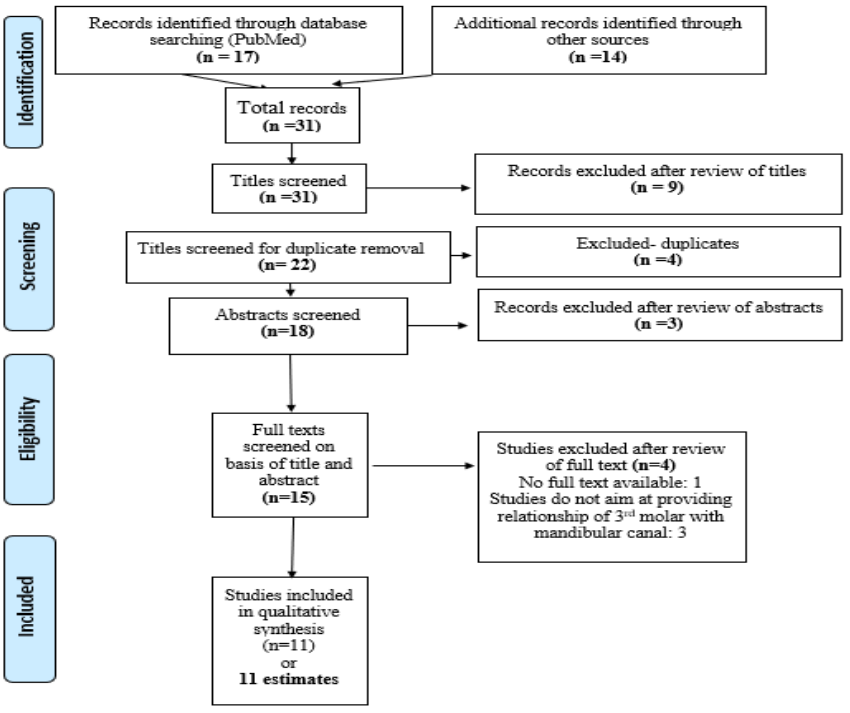
Keywords

Primary keywords	Secondary keywords
Impacted teeth (P)	Impacted third molar tooth Impacted third molar
Cone beam computed tomography (I)	Cone-Beam Computerized Tomography Cone-Beam CT Cone-Beam Computer-Assisted Tomography Volumetric Computed Tomography Volumetric CT CT scans CBCT
Panoramic Radiography (C)	Pantomography Pantomographies Orthopantomography Orthopantomographies Panoramic Radiographies OPG
Diagnostic accuracy (O)	Diagnostic imaging Canal relation Canal proximity Accuracy Sensitivity Specificity Positive predictive value Negative predictive value
Study (S)	Comparative study Observational study

Search strategy

Strategy
(impacted third molar tooth OR impacted third molar teeth OR impacted third molar) AND (cone beam computed tomography OR cone-beam computerized tomography OR cone-beam CT OR Cone-beam computer-assisted tomography OR volumetric computed tomography OR volumetric CT OR CT scans OR CBCT) AND (pantomography OR pantomographies OR orthopantomography OR orthopantomographies OR panoramic radiography OR panoramic radiographies OR OPG) AND (diagnostic accuracy OR accuracy OR sensitivity OR specificity OR canal proximity OR canal relation) AND (comparative study OR observational study)
("cone beam computed tomography'" OR CBCT) AND (orthopantomography OR "OPG" OR "panoramic radiograph") AND (mandibular canal OR "inferior alveolar nerve") AND "impacted third molar"

Figure 1-PRISMA Flow chart representing screening process of studies



Study Id	Title	Authors name	Publication year	Study design
1	Correlation of panoramic radiographs and cone beam computed tomography in the assessment of a superimposed relationship between the mandibular canal and impacted third molars	Jung YH et al.	2012	Retrospective observational study
2	Correlation of panoramic radiography and cone beam CT findings in the assessment of the relationship between impacted mandibular third molars and the mandibular canal	Neves FS et al.	2012	Retrospective case-control study
3	Comparison between panoramic radiography and cone-beam computed tomography findings for assessment of the relationship between impacted mandibular third molars and the mandibular canal	Sekerci AE et al.	2013	Retrospective comparative observational study
4	Diagnostic value of cone beam computed tomography and panoramic radiography in predicting mandibular nerve exposure during third molar surgery.	Hasani A et al.	2017	Prospective clinical series
5	Determination of proximity of mandibular third molar to mandibular canal using panoramic radiography and cone-beam computed tomography	Nayak DS et al.	2017	Comparative observational study
6	Accuracy of panoramic radiographic predictor signs in the assessment of proximity of impacted third molars with the mandibular canal	Elkhateeb SM et al.	2018	Retrospective observational study
7	Assessment of Roods and Shehab criteria if one or more radiological signs are present in orthopantomogram and position of the mandibular canal in relation to the third molar apices using cone beam computed tomography: a radiographic study	Pandey R et al.	2018	Prospective radiographic study
8	Correlation of panoramic radiograph and CBCT findings in assessment of relationship between impacted mandibular third molars and mandibular canal in Saudi population	Nasser A et al.	2018	Retrospective study
9	. Orthopantomography and Cone-Beam Computed Tomography for the Relation of Inferior Alveolar Nerve to the Impacted Mandibular Third Molars	Saha N et al.	2019	Retrospective observational study

Study Id	Title	Authors name	Publication year	Study design
10	Comparison of panoramic radiograph and cone beam computed tomography findings for impacted mandibular third molar root and inferior alveolar nerve canal relation	Patel PS et al.	2020	Retrospective study
11	Reliability of panoramic radiography in predicting proximity of third molars to the mandibular canal: A comparison using cone-beam computed tomography	Nunes WJP et al.	2021	Observational, cross-sectional, descriptive study

Table 2- Details of the study participants, intervention, and comparator of the studies included in the systematic review

Study Id	Authors name	Sample size	Age	Intervention	Comparator	Exposure time	Impacted third molar details
1	Jung YH et al.	175 teeth	29.3 years	CBCT (PaX-Zenith 3D, Vatech Co., Hwaseong, Korea)	OPG (Proline XC (Planmeca Co., Helsinki, Finland)	CBCT: 24 seconds	Not reported
2	Neves FS et al.	142 teeth	27.2 years	CBCT: Classic i-CAT CBCT unit, Imaging Sciences International, Inc., Hatfield, PA)	Digital OPG (Orthopantomograph® OP100 D unit, Instrumentarium Corp., Imaging Division, Tuusula, Finland)	OPG: 17.6 seconds	Not reported
3	Sekerci AE et al.	781 teeth	33.9 years-34.4 years	CBCT (NewTom VG; QR SRL Company, Verona, Italy)	Digital OPG (Instrumentarium OP200D; Instrumentarium Corp., Tuusula, Finland)	CBCT: 5.4 seconds OPG: 14.1 seconds	Pell and Gregory: Vertical, horizontal, mesioangular, distoangular
4	Hasani A et al.	59 teeth	26.1 years	CBCT (Promax-3D unit, Planmeca)	OPG (Proline XC; Planmeca, Helsinki, Finland)	CBCT: 18 seconds	Pell and Gregory: Meioangular, vertical, horizontal
5	Nayak DS et al.	40 teeth	20.3 years	CBCT (Planmeca Promax3D, Helsinki, Finland)	Not reported	Not reported	Not reported

Study Id	Authors name	Sample size	Age	Intervention	Comparator	Exposure time	Impacted third molar details
6	Elkhateeb SM et al.	210 teeth	25 ± 1 years	CBCT (CS 9300 PREMIUM 3D CBCT device, Carestream SM 749, Rochester, NY, USA)	Digital OPG (CS CS9000, select 3D Extraoral Digital Imaging System, SM749, Rochester NY, USA)	CBCT: 11.3 seconds OPG: 14.3 seconds	Winter's classification: Mesioangular, distoangular, vertical, horizontal
7	Pandey R et al.	47 teeth	Not reported	CBCT (PlanmecaRomexis device, Planmeca System, Helsinki, Finland)	Not reported	CBCT: 15 seconds	Not reported
8	Nasser A et al.	270 teeth	Not reported	CBCT (Planmeca ProMax 3D Plus, Planmeca Co., Helsinki, Finland)	OPG (Planmeca ProMax 2D S3)	Not reported	Pell and Gregory's classification: Vertical, Mesioangular, Horizontal, Distoangular, Buccal deflection, Lingual deflection
9	Saha N et al.	30	26.8 ± 8.9 years	CBCT (SCANORA 3D, SOREDEX)	Digital OPG (Sirona Orthophos XG 5 DS/Ceph digital)	CBCT: 15 seconds OPG: 14.1 seconds	Not reported
10	Patel PS et al.	200 teeth	45.5 years	CBCT PaxI3D Smart machine (Vatech Co Ltd, Hwaseong-si, Gyeonggi-do, Korea)	Digital OPG PaxI3D Smart machine (Vatech Co Ltd, Hwaseong-si, Gyeonggi-do, Korea)	CBCT:18 seconds OPG: 10 seconds	Winter's class: Vertical, mesioangular, distoangular, horizontal, others
11	Nunes WJP et al.	148 teeth	Not reported	CBCT (ICAT® Next Generation device, Imaging Sciences International, Hatfield, PA, USA)	OPG (Orthopantomograph® OP300 machine, Instrumentarium Dental, Tuusula, Finland)	CBCT: 26.9 seconds	Winter's classification: Vertical, mesioangular, distoangular, horizontal, inverted, transverse

Table 3 –Details regarding the radiographic findings and diagnostic accuracy of CBCT and OPG.

Study Id	Authors name	Findings on CBCT	Findings on OPG	Correlation present	Correlation absent	Diagnostic accuracy details	Other findings	Inference
1	Jung YH et al.	Absence of cortication/presence of interruption in 72.7% in relation to darkening of roots	Darkening of roots	Darkening of roots	Not reported	Not reported	Not reported	Panoramic radiographic signs were statistically associated with CBCT findings. Contact between the mandibular third molar and canal and a lingually positioned canal could be more frequently observed in cases of the interruption of the white line of the mandibular canal.
2	Neves FS et al.	Absence of cortication in relation to darkening of roots (13.4%), in relation to diversion of canal (2%), in relation to narrowing of canal (0.7%), in relation to interruption of white line (12%)	Darkening of roots (17.6%), diversion of canal (4.2%), narrowing of canal (3.5%), interruption of while line (20.4%)	Darkening of roots and interruption in white line, darkening of roots + interruption in white line	Diversion of canal, narrowing of canal	Not reported	Not reported	Panoramic radiography is an effective method for pre-operative assessment of mandibular third molars. In case of darkened roots and interruption of white line observed on panoramic radiographs CBCT is required to confirm proximity of canal with the 3rd molar.
3	Sekerci AE et al.	Absence of cortication leading to canal contact in relation to darkening of the roots (6.7%) and deviation of the mandibular canal (2.6%)	Interruption of the white line (71.3%), darkening of the roots (37.9%), deviation of the mandibular canal (11.8%), narrowing of the mandibular canal (7.8%), narrowing of the mandibular third molar root apex (5.1%), diversion of the mandibular third molar roots (3.3%)	Darkening of the roots and deviation of the mandibular canal	Interruption of the white line, narrowing of the mandibular canal, narrowing of the mandibular third molar root apex, diversion of the mandibular third molar roots	Not reported	Not reported	Darkening of the roots, deviation of the mandibular canal, and interruption of the white line observed on panoramic radiographs, both as isolated findings and in association, were effective for determining the risk relationship between the roots and the mandibular canal, requiring three-dimensional evaluation of such cases.
4	Hasani A et al.	Not reported	Discontinuation of the upper border of canal (68.3%), narrowing of the canal (19.5%), canal diversion (7.3%), darkening of the root (2.4%), superimposition of root on canal (2.4%)	None	None of the signs on OPG were significantly associated with presence of inferior alveolar nerve exposure	Sensitivity 97.4% (for CBCT) 67.8% (for OPG) Specificity 85.7% (for CBCT) PPV 92.7% (for CBCT) 97.6% (for OPG)	The signs with the highest sensitivity were interruption of the mandibular canal border and abrupt canal narrowing.	CBCT may have excellent diagnostic accuracy. However, panoramic also showed excellent PPV by evaluating atleast one risk factor of inferior alveolar nerve exposure during surgery.

Study Id	Authors name	Findings on CBCT	Findings on OPG	Correlation present	Correlation absent	Diagnostic accuracy details	Other findings	Inference
						NNV 94.7% (for CBCT)		
5	Nayak DS et al.	57.5% showed a true relationship with the mandibular canal Narrowing of the canal observed in 17.4% and darkening of apex in 56.5%	Darkening of the apex (52.5%), deflection of apex (10%), narrowing of apex(15%), deviation of canal (5%), narrowing of canal (15%), island-shaped apex (2.5%)	None	None of the signs on panoramic radiography could significantly predict a true relationship on CBCT	Not reported	Not reported	The presence of any of panoramic radiographic signs cannot definitely predict a true relationship. all patients with a close relationship on panoramic radiography should be referred for CBCT.
6	Elkhateeb SM et al.	Absence of cortication leading to contact between tooth and canal was 52.2% in relation to interruption of white line, 9.8% in relation to darkening of root apex, 9.8% in relation to narrowing of canal	Interruption of the IAC white line, darkening in root apex, narrowing of the canal, diversion of canal and root	Interruption of the canal, interruption and narrowing, then darkening of roots and narrowing of the canal	Not reported	Not reported	Not reported	CBCT is useful to assess the risk relationship of the IAN and the impacted mandibular third molars, and to reduce the occurrence of postoperative injury to the IAN.

Study Id	Authors name	Findings on CBCT	Findings on OPG	Correlation present	Correlation absent	Diagnostic accuracy details	Other findings	Inference
7	Pandey R et al.	Absence of cortication in 9 in relation to darkening of root, 5 in relation to deflection of root, 5 in relation to interruption of white line of canal, 1 in relation to narrowing of canal, 1 in relation to diversion of canal	Darkening of root (14), deflection of root (9), interruption of white line of canal (11), narrowing of canal (2), diversion of canal (2)	Darkening of root, interruption of white line of canal, deflection of root	Narrowing of canal, diversion of canal	Not reported	Not reported	CBCT has advantages of visualizing the exact topographic relationship of the mandibular canal to the tooth structure thus, CBCT is recommended for all cases showing two or more signs in OPG.
8	Nasser A et al.	Absence of cortication in 78 in relation to darkening of roots, 32 in relation to root deflection, 14 in relation to narrowing of roots, 21 in relation to narrowing of mandibular canal, 98 in relation to interruption of white line, 64 in relation to darkening of roots + Interruption of	Darkening of roots (117), Root deflection (60), Narrowing of roots (34), Narrowing of mandibular canal (36), Interruption of white line (156), Darkening of roots + Interruption of white line (93)	Darkening of roots, Interruption of white line, darkening of roots + Interruption of white line	Root deflection, narrowing of roots, narrowing of mandibular canal	Not reported	Not reported	Panoramic radiographic markers were statistically associated with CBCT findings.

Study Id	Authors name	Findings on CBCT	Findings on OPG	Correlation present	Correlation absent	Diagnostic accuracy details	Other findings	Inference
		white line						
9	Saha N et al.	Presence of corticalization in relation to darkening of root (15.4%), 0%in relation to deflection of roots, 3.8% in relation to bifid root apex, 15.4% in relation to interruption in white line,	Darkening of root (30.0%), deflection of roots (6.7%), bifid root apex (3.3%), interruption in white line (96.7%), Darkening of roots, deflection of roots, narrowing of roots, bifid root apex, diversion of canal, narrowing of canal, and interruption in the white line of the canal	Darkening of root, interruption in white line	Deflection of roots, bifid root apex	Not reported	Not reported	There was poor reliability of radiographic signs of OPG on predicting the involvement of mandibular third molar root with the mandibular canal thus indicating CBCT as an additional diagnostic tool for assessing relationship of third molar with mandibular canal.
10	Patel PS et al.	Absence of cortication in relation to superimposition (30.7%), interruption of white line (76.5%), darkening of canal (100%), darkening of root (83.3%), diversion of canal (80%), deflection of root (85.7%), narrowing of canal (90.4%)	Superimposition (6.5%), interruption of white line (32%), darkening of canal (1%), darkening of root (3%), diversion of canal (2.5%), deflection of root (3.5%), narrowing of canal (10.5%)	Superimposition	Interruption of white line, darkening of root, darkening of canal, diversion of canal, deflection of root and narrowing of canal with presence of corticalization	Sensitivity 98.55% (for OPG) Specificity 43.39% (for OPG)	Fryback and thornbury model score CBCT: 5.63 OPG: 2.58	Modified Fryback and Thornbury model proved that CBCT is a better radiographic modality as compared to OPG for evaluation of impacted mandibular third molars.
11	Nunes WJP et al.	Interruption and diversion of the mandibular canal and root deflection	Interruption of the mandibular canal (37.2%), darkening of the root (27.2%), narrowing of canal (9%), diversion of canal (4%), bifid apices (2%), narrowing of root apices (3%), deflection of root apices (9%), absence of proximity signal (7.5%)	Root deflection, interruption of canal, and diversion of the mandibular canal	Narrowing of canal, bifid apices, narrowing of root apices, absence of proximity signal	Not reported	Darkening, deflection, and narrowing of the root and interruption of the mandibular canal predicted proximity between the third molar and mandibular canal	Darkening, deflection, and narrowing of the root, in tandem with interruption of the mandibular canal on panoramic radiographs, indicate that CBCT should be performed when planning the extraction of an impacted mandibular third molar.

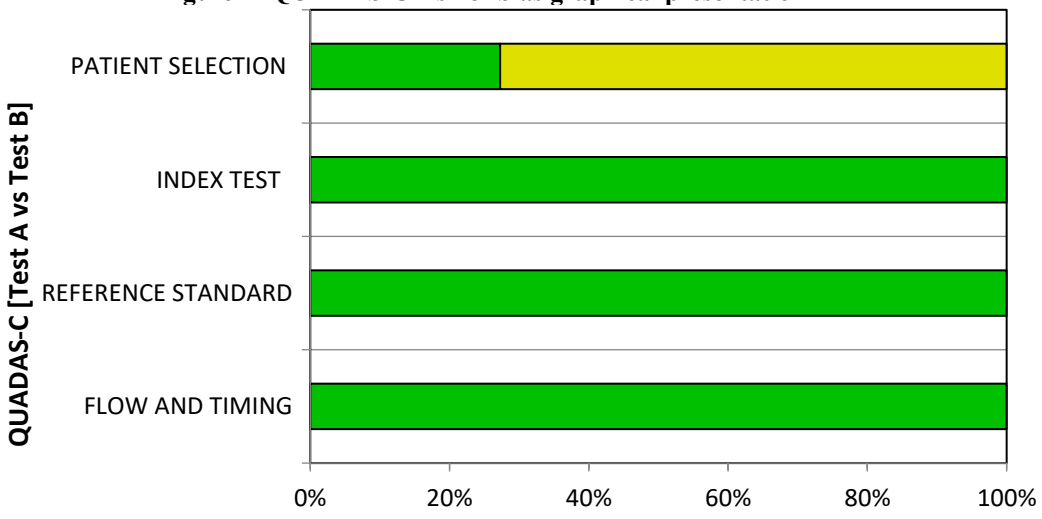
The table represents the details about the diagnostic accuracy of CBCT and OPG in the studies included in this review.

For reference standards domain and theflow and timing domain, all studies had low risk of bias. (Table 4, Figure 2)

Table 4- QUADAS-C risk of bias of individual studies

Authors name	Patients selection	Index test	Reference standard	Flow and timing
Jung YH et al. 2012	Low	Low	Low	Low
Neves FS et al. 2012	Unclear	Low	Low	Low
Sekerci AE et al. 2013	Low	Low	Low	Low
Hasani A et al. 2017	Unclear	Low	Low	Low
Nayak DS et al. 2017	Unclear	Low	Low	Low
Elkhateeb SM et al. 2018	Unclear	Low	Low	Low
Pandey R et al. 2018	Unclear	Low	Low	Low
Nasser A et al. 2018	Unclear	Low	Low	Low
Saha N et al. 2019	Unclear	Low	Low	Low
Patel PS et al. 2020	Unclear	Low	Low	Low
Nunes WJP et al. 2021	Low	Low	Low	Low

Figure 2- QUADAS-C risk of bias graphical presentation



DISCUSSION

The proximity of an impacted mandibular third molar to the mandibular canal is assessed using various criterias based on dental imaging.

- The distance between the root of the impacted tooth and the mandibular canal is a crucial factor. If the distance is minimal, there's a higher risk of the root encroaching upon or even being in direct contact with the canal, which increases the risk of nerve injury[9].
- The thickness of the cortical bone between the impacted tooth's root and the mandibular canal. Increased cortical bone thickness acts as a buffer and lowers the risk of nerve damage during extraction[34].
- A radiolucency between the tooth's root and the mandibular canal might indicate proximity which is observed in OPG. This is a sign of a potential space between the structures and can help indicate the risk level.
- If the root of the impacted tooth overlaps with or penetrates the outline of the mandibular canal on imaging, there's an increased risk of nerve contact during extraction.[35]

The main panoramic signs identified in the included studies of this review are darkening of roots, diversion of canal, narrowing of canal, interruption of white line, narrowing of the mandibular third molar root apex, discontinuation of the upper border of canal, superimposition of root on canal, and deflection of apex.[11,12,13,14,15,9,16,17,6,8,7]These signs indicate that the impacted third molar is close to the mandibular canal and has a risk of injury to the alveolar nerve during surgical procedure.

In the present review, **darkening of roots** on OPG in seven studies.[1,2,3,6.7,8,9] was interpreted as absence of cortication leading to canal contact in CBCT.

In contrast to studies reported on darkening of root only one study [9] reported presence of corticalization (a process that changes the structure of bone , where the trabecular bone is replaced by cortical bone[37])as a finding in CBCT in relation to the darkening of roots on OPG.

In terms of darkening of roots in studies by Hasani A et al.[14] and Nayak DS et al.[15] aimed to evaluate diagnostic accuracy of OPG and CBCT. It was concluded that no observations were correlated between the two imaging techniques i.e. radiographic findings observed on OPG can not predict a true relationship with interpretations observed on CBCT.

This implies that panoramic imaging does identify the proximity, however, the CBCT findings confirms this proximity thereby indicating its superiority over the panoramic radiograph.

Another finding reported across two studies[5,6] signifying a close proximity between third molar and mandibular canal was **darkening of apex** in OPG where CBCT was interpreted as absence of cortication for it. However, the finding did not demonstrate a positive correlation between the two radiographic techniques to predict the proximity of mandibular molar and mandibular canal.

On OPG, the **deviation of mandibular canal** was reported in nine studies where out of nine, five studies[2,3,7,10,11] on CBCT showed absence of cortication. Of these , four studies [2,3,7,10] out of nine presented the finding as absence of cortication and one study presented a diversion of the canal leading to canal and mandibular molar contact in CBCT. Only two studies[3,11] could show statistical correlation between two radiographic techniques and while other studies could not show any correlation.

Narrowing of canal as a sign of close proximity between mandibular molar and mandibular canal was observed on OPG in ten studies. In CBCT the finding of narrow canal was interpreted as absence of cortication. However, the statistical correlation of the finding between the two radiographic techniques(OPG & CBCT) was not observed in five [4,5,8,9,11]out of ten of the studies while two studies [6,10] demonstrated a positive correlation between the techniques.

Only one study[11] analysed **interruption of mandibular canal** as a finding of close proximity of mandibular molar and canal. This finding showed a positive correlation with both techniques.

Interruption of white line observed on the OPG was presented as absence of cortication in CBCT in ten of the studies while a single study[9] demonstrated the presence of corticalization in relation to the interruption of white line in CBCT. The correlation for interruption of white line was present in five studies[2,5,7,8,9] while two studies[1,6] demonstrated absence of correlation between the two radiographic techniques.

In majority of the studies included in this review, CBCT was found to be efficient in accurately determining the proximity of impacted third molar with mandibular canal. The reason is its three-dimensional image analysis aid that enables the practitioner to visualize the exact spatial relationship between the impacted tooth, the mandibular canal and surrounding structures. Because of its higher resolution and finer details over OPG, it allows for precise evaluation of root positions, cortical bone thickness, and the position of the mandibular canal. CBCT eliminates the problem of overlapping by providing cross-sectional images that separate structures. Further, CBCT images are easier to interpret in cases where accurate anatomical assessment is critical. The detailed three-dimensional representation leaves less room for interpretation error compared to two-dimensional images.[36]

It should be noted that, while CBCT offers numerous advantages in accurately determining the proximity of a third molar to the mandibular canal, it's important to balance these advantages with the consideration of radiation exposure. CBCT does expose the patient to a higher radiation dose compared to an OPG.[46] Therefore; the decision to use CBCT should be made based on the clinical necessity of the case and considering the potential benefits and risks involved.

The review does have few limitations:

- The sample size of the included studies was small to give concrete results.
- The studies included had differences in CBCT and OPG imaging protocols that might affect the comparability and generalizability of the findings.

CONCLUSION

Within the limitation of this review it can be concluded that CBCT generally offers superior diagnostic accuracy compared to OPG in assessing the proximity and relationship of impacted third molars to the mandibular canal. Theenhanced visualization is particularly relevant in complex cases, where precise anatomical information is crucial for treatment planning and risk assessment. CBCT could be particularly valuable in cases where accurate assessment of the relationship between impacted third molars and the mandibular canal is critical for treatment planning, such as in cases of close proximity that carry a higher risk of nerve damage as indicated by OPG findings. However, in cases where the risk of nerve proximity is lower and the need for three-dimensional visualization is not as crucial, OPG might remain a viable and more cost-effective option.

The following summary chart can guide to correlate findings on OPG with CBCT images, especially when this advance modality is not readily available:

Radiographic signs on OPG and interpretations on CBCT

OPG SIGNS	CBCT INTERPRETATIONS
Darkening of roots	Absence of cortication, Loss of cortical lining between root apex & mandibular canal (Corticalization)
Deviation of mandibular canal, Diversion of canal, Narrowing of canal, Deflection of root	Absence of cortication
Interruption of mandibular canal	Proximity of molar & Canal
Bifid root apex, Interruption of white line	Loss of cortical lining between root apex & mandibular canal (Corticalization)

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