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RESEARCH ARTICLE

DIAGNOSTIC EFFICACY OF CONE BEAM COMPUTED TOMOGRAPHY (CBCT) IN CHRONIC PERIODONTITIS - A SYSTEMATIC REVIEW AND META ANALYSIS

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Abstract

Aim: To evaluate better diagnostic efficacy between cone beam computed tomography (CBCT) and other conventional imaging techniques for periodontal parameters in chronic periodontitis (CP)

Methods: Review adhered to with Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines and registered in PROSPERO- CRDXXXX. Databases were searched from January 2000 to May 2024 for studies evaluating the diagnostic efficacy or accuracy of CBCT compared to conventional radiographic techniques and evaluating outcome in terms of periodontal parameters like furcation width, horizontal bone loss, vertical bone loss and bone defects. Quality assessment was evaluated using Cochrane risk of bias (ROB) -2 tool for randomized controlled trials (RCTs) through its domains using Review manager (RevMan) software version 5.3.

Results: Eight studies were included in qualitative synthesis and four studies for meta-analysis. Quality assessment revealed a moderate to low risk of bias. The results of meta-analysis, showed that for furcation width -0.59 (-1.87 – 0.69), horizontal bone loss 1.56 (-2.11 – 5.24), vertical bone loss 1.62 (-1.94 – 5.19) and bone defects -0.78 (-2.19 – 0.64) were detected better by CBCT imaging. Also, funnel plot did not show any asymmetry indicating absence of possible publication bias in meta-analysis.

Conclusion: CBCT overall was more accurate and provided more quantitative data with greater precision and lesser deviations compared to conventional imaging techniques in chronic periodontitis. However, furthermore studies showed be conducted with robust methodology with proper standardization protocols to validate the study findings.

Clinical Significance: The study highlights the clinical significance of CBCT in diagnosing chronic periodontitis, emphasizing its superior accuracy, precision, and three-dimensional imaging capabilities compared to conventional radiographs. These advantages are critical for accurately detecting periodontal defects, guiding treatment decisions, and improving outcomes in complex cases. The study also calls for further research with standardized protocols to validate these findings and support CBCT's broader clinical application**.**

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Introduction:-

Periodontitis is characterized by periodontal bone loss and clinical attachment loss (CAL).[1] Clinical and radiographic examinations are essential for determining periodontal diagnosis, prognosis and treatment plan.Early detection of periodontal disease is important to prevent tooth loss.[2] The incidence of this disease has increased and has been estimated to be about 30% in the western countries.[3]

Radiographs have played a major part in the analysis of patients affected by periodontitis for many years.[4] As one of the most frequent chronic diseases in the world, the appearance of periodontitis in the human mouth shows multiple variations concerning the presence and structure of defects in older and younger people.[3,4] In order to stop the progression of disease, especially within the younger population, it is important to detect these defects early.[4]Therefore, it is vital to assess the structure of the defects accurately, in order to choose adequate therapeutic interventions.[5]

At present, intraoral radiography (IOR) including periapical and bitewing radiographs are widely used for evaluating the level and pattern of alveolar bone destruction.[6] It is simple to acquire with relatively low cost and low radiation dose. However, a major limitation of IOR is the two-dimensional (2D) nature of the images that often obscures and underestimates periodontal bone loss.[1–3] Therefore, an imaging technique thatallows three-dimensional (3D) visualization of teeth and periodontal bone defects could be of great benefit for an accurate assessment of periodontal bone loss.[7]

CBCT is an advanced imaging technique that enables cross-sectional and 3D analysis of bony structures in the head and neck region.[8] Unlike conventional CT scanners, which must provide sufficient contrast to visualize differences in soft tissues, CBCT is mostly used to differentiate bone from soft tissue.[9]

Use of cone-beam computed tomography (CBCT), an advanced application of computed tomography (CT), has increased rapidly in the dental field since its inception in 2004.[10] CBCT provides the ability to collect data at higher resolutions and generate 3D data at both lower cost and lower absorbed doses than conventional techniques.[11]

Currently, CBCT has been widely used in dentistry for complex diagnostic evaluation and treatment planning such as those related with dental implants, craniofacial fractures and orthodontics.[10] However, the applications of CBCT in periodontics appear to be limited. Routinely, IOR is seemingly adequate for periodontal diagnosis and treatment planning.[11] Nevertheless, in the area with complex anatomical structures, e.g. multirooted teeth, floor or border of maxillary sinus and also infrabony defects, a radiographic interpretation by means of IOR seems to be insufficient to provide accurate information. This leads to the poor clinical decision-making in complicated cases.[10]

CBCT apparently enables to provide 3D information which may overcome the drawback of the original 2D image acquired from IOR.Success of periodontal regeneration depends mainly on the size, shape and angle of the defect.[5–7] Therefore, it is important to correctly identify and classify the defect to select the appropriate treatment.[11]

Looking at the evidences, it is clear that no study till date, has provided a comprehensive, qualitative and quantitative analysis on assessing and evaluating the overall better diagnostic efficacy between CBCT and other conventional imaging techniques. Hence, we improvised our research by including relevant literature and carried out a systematic review aiming to evaluate better diagnostic efficacy between CBCT and other conventional imaging techniques for periodontal parameters through meta-analysis

Methodology:-

Protocol development

This reviewwas conducted and performed in according to the PRISMA 2020 statement[12]and registered in Prospective Registration of Systematic Review (PROSPERO)- CRDXXXXX.

Study Design

The research question “Is there any difference in the diagnostic efficacy ofCBCT and conventional radiographic modalities in chronic periodontitis patients? was put out in the Participants (P), Intervention (I), Comparison and Outcome (O) framework.

P (population): patients with chronic periodontitis (CP)

I (intervention): imaging through CBCT
C (comparator): imaging through conventional radiographic modalities
O (outcome): better diagnostic efficacy in terms ofdetecting periodontalparameters like furcation width, horizontal bone loss, vertical bone loss and bone defects

Eligibility Criteria
Inclusion Criteria:
1) English language articles
2) Studies published fromJanuary 2000 – May2024 and having sufficient and relevant data on thediagnostic efficacy or accuracy of CBCT compared to conventional radiographic techniques
3) Studies reporting diagnostic efficacy in terms of periodontal parameters like furcation width, horizontal bone loss, vertical bone loss and bone defects
4) Studies reporting quantitativeand qualitative data in terms of mean, standard deviation and frequency
5) comparative studies, in vitro studies, randomized controlled trials (RCTs) were included
6) Articles from open access journals

Exclusion Criteria:
1) Any studies conducted before 2000
2) Articles in other than English language
3) Reviews, abstracts, letter to the editor, editorials, animal studies and were excluded
4) Articles not from open access journals
5) Articles not reporting the study outcomes in terms of mean and standard deviation

Search Strategy
Electronic database search was performedfrom 2000 tillMay 2024through following databases: PubMed, google scholar and EBSCOhostto retrieve articles in the English language.

Proper keywords and Medical Subject Heading (MeSH) terms were selected and combined with Boolean operators like AND/ORusing the following keywords and their combinations: “CBCT” (MeSH term) AND “intraoral periapical imaging” (MeSH term); “panoramic radiography” (MeSH term) AND “chronic periodontitis” (MeSH term); “diagnostic accuracy” (MeSH term) AND “periodontal bone loss” (MeSH term) AND “bony defects”(MeSH term); “wall defects” (MeSH term) AND “hard tissue diagnosis” (MeSH term) AND “periodontal bone loss imaging” AND“randomized controlled trials” (MeSH term); “in vitro study” AND “comparative study”.

Search Strategy according to PICO Format:

	Strategy
Population	("chronic periodontitis"[MeSH Terms] OR "periodontal disease AND “alveolar bone loss" OR "periodontal bone defect" OR "dental radiography"[MeSH Terms] OR "diagnosis AND prognosis" OR "intrabony defect"[MeSH Terms]AND " clinical attachment loss"
Intervention	"Cone-beam computed tomography"[MeSH Terms] OR "diagnosis" AND "3 -dimensional imaging" AND " hard tissue diagnosis" OR "bone defect" OR "furcation involvement" OR "horizontal bone loss"[MeSH Terms] OR "vertical bone loss" AND “2 wall defect AND 3 wall defect" OR "fenestration AND dehiscence"[MeSH Terms]
Comparator	"Conventional radiography techniques"[MeSH Terms] OR "intraoral peripaical"[MeSH Terms] OR "panoramic radiography"[MeSH Terms] OR "diagnosis" AND "3 -dimensional imaging" AND " hard tissue diagnosis" OR "bone defect" OR "furcation involvement" OR "horizontal bone loss"[MeSH Terms] OR "vertical bone loss" AND “2 wall defect AND 3 wall defect" OR "fenestration AND dehiscence"[MeSH Terms]
Outcome assessed	("diagnostic accuracy"[MeSH Terms] OR "defect measurement" OR ("periodontal bone loss imaging"[MeSH Terms] OR "diagnostic tool" AND "comparative study” OR ("in vitro study"AND "randomized controlled trial" AND "retrospective study" OR "prospective study")

Screening process
Search and screening were done by two authors. The process of choosing of articles was divided into two phases. Two reviewers looked over the titles and abstracts of every article in first round. Articles that didn’t fit into the inclusion were removed. Phase-two, involved independent screening and review of few full papers by the same

reviewers. Discussions were held to settle by any disputes. A third reviewer was bought in to make the ultimate decision when two reviewers could not agree upon something. All three authors came to agreement on choice in the end. When more information was needed, the studies corresponding authors were contacted by email.

Data extraction

For all included studies, the following headings were included in the final analysis: author(s), country of study, year of study, sample size, study design, outcome assessed, parameters evaluated and conclusion.

Evaluation of methodological quality

The methodological quality among included clinical trials or randomized controlled trials (RCT) was executed by using Cochrane collaboration risk of bias (ROB) -2 tool[13] through its various domains in Review Manager (RevMan) 5.3 software.

Statistical analysis

Statistical analysis was conducted using RevMan 5.3 with standardized mean difference(SMD)[14] serving as the summary measure. Significance was determined at the threshold of $p<0.05$.

Assessment of heterogeneity

The Cochranes test for heterogeneity was employed to assess the significance of any differences in treatment effect estimations among trials.[15] Heterogeneity was deemed statistically significant if the P-value was <0.01.

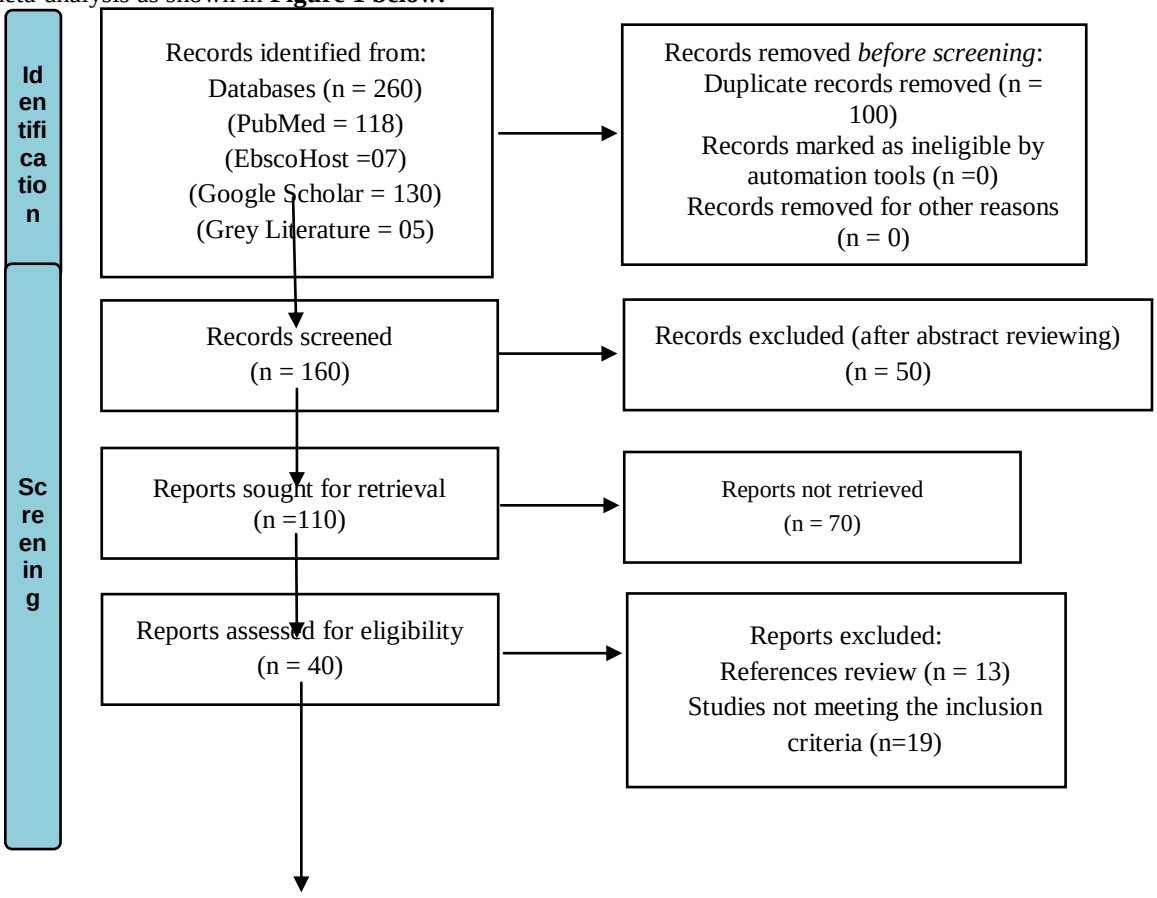
Investigation of publication bias

The study assessed publication bias using Begg's funnel plot, which plots the effect size against standard error. Asymmetry in the funnel plot may indicate potential publication bias.[16]

Results:-

Study Selection

After copies evaluation, reference rundown of all included examinations was screened. Of which 160 examinations were barred. After this full text articles were evaluated for qualification and articles that didn't meet consideration rules were barred. Eightstudiesfitted into inclusion criteria and were subjected to qualitative and four studies for meta-analysis as shown in **Figure 1 below.**



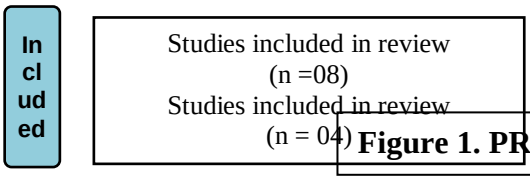


Figure 1. PRISMA 2020 Flow Diagram

Study Characteristics

As shown in **Table 1,** data was evaluated from eight studies[17-24] from an aggregate of total of 1428sites in chronic periodontitis patients with bone loss.All the included studies had randomized controlled trial (RCT) study design and compared the diagnostic efficacy between CBCT and conventional imaging modality (periapical radiography (IOPA) and panoramic radiography (PA) for detecting periodontal parameters and reporting outcomes in terms of furcation width, horizontal and vertical bone loss and bone defects. Among the included studies, four studies[17-20] was conducted in USA and one study each in China[21], Egypt[22], Thailand[23] and Germany[24].From the results of the study, it was found that all soft and hard tissue defects were easily identified by CBCT and CBCT overall was more accurate and providedmore quantitative data with greater precision and lesser deviations.

A) Furcation Width -was evaluated by two studies[17-21]from an aggregate of 27 teeth. It was found thatMengel et al., 2005[17] reported a greater furcation width of (0.06)from the actual width by CBCT compared to conventional imaging (0.24) while Qiao et al., 2014[21]reported an increased width of (1.39) from the actual width by CBCT compared to conventional imaging (1.41).

B) Horizontal Bone loss-was evaluated by two studies[19,21]from an aggregate of 156 teeth. It was found that Mol et al., 2008[19]reported a greater horizontal bone loss of (0.82) from the actual bone loss by CBCT compared to conventional imaging (0.45) while Qiao et al., 2014[21]reported an increased width of (2.11) from the actual width by CBCT compared to conventional imaging (2.48).

C) Vertical Bone loss - -was evaluated by two studies[19,21]from an aggregate of 156 teeth. It was found that Mol et al., 2008[19]reported a greater vertical bone loss of (0.82) from the actualbone loss by CBCT compared to conventional imaging (0.45) while Qiao et al., 2014[21]reported an increased width of (2.11) from the actual width by CBCT compared to conventional imaging (2.48).

D) Bone defect- -was evaluated by two studies[19,21]from an aggregate of 156 teeth. It was found that Mol et al., 2008[19]reported a greater bone loss of (0.06) from the actual bone loss by CBCT compared to conventional imaging (0.55) while Qiao et al., 2014[21]reported an increased width of (0.01) from the actual width by CBCT compared to conventional imaging (0.5).

Table 1:- Showing descriptive study details of included studies.

Author, years of study	Country	Study design	Sample size	Modalities used	Parameters evaluated	Conclusion
Mengel et al., 2005[17]	USA	RCT	07	CBCT, PA, IOPA	Furcation, fenestration, dehiscence, 2 and 3 wall defects	CBCT showed better diagnosing ability
Misch et al., 2006[18]	USA	RCT	200	CBCT, PA	Periodontal osseous defects (infrabony buccal, lingual and interproximal defects	All defects were easily identified by CBCT due to its 3d imaging property
Mol et al., 2008[19]	USA	RCT	146	CBCT, conventional radiography	Bone loss	Better overall diagnostic and quantitative information was shown by CBCT
Leung et al., 2010[20]	USA	RCT	334	CBCT, PA	Alveolar bone height loss, dehiscence and fenestration	CBCT overall has good diagnostic potential compared to other modalities

Qiao et al., 2014[21]	China	RCT	20	CBCT, 2D imaging modality	Vertical bone loss, horizontal bone loss, furcation involvement	High accuracy was seen by CBCT for periodontal bone loss
Dehglani et al., 2016[22]	Egypt	RCT	218	CBCT, IOPA, PA	buccal and lingual infra-bony, inter proximal, horizontal, crater, dehiscence and fenestration defects	CBCT overall has higher accuracy than other radiographic modalities
Suphanantachat et al., 2017[23]	Thailand	RCT	666	IOPA, CBCT	1,2 and 3 wall defect, infrabony defect	Better overall detection was provided by CBCT
Ruetters et al.,2020[24]	Germany	Germany	117	CBCT, PA	Periodontal bone defect, vertical bone loss	CBCT overall has higher accuracy and lesser deviations than PA

CBCT: cone beam computed tomography; IOPA: intraoral periapical radiography; PA: panoramic radiography technique; RCT: randomized controlled trial

Evaluation of methodological quality

The greatest risk of bias (ROB) was observed in random sequence generation followed by blinding of participants and personnel. However, all the studies included in the analysis reported moderate to the lowest levels of ROB overall. Domains such as blinding of outcome assessment, incomplete outcome data, selective reporting and other biases were assigned the lowest levels of ROB. Detailed assessments of ROB across various domains and individual studies are visually represented in **Figures 2 and 3 below**.

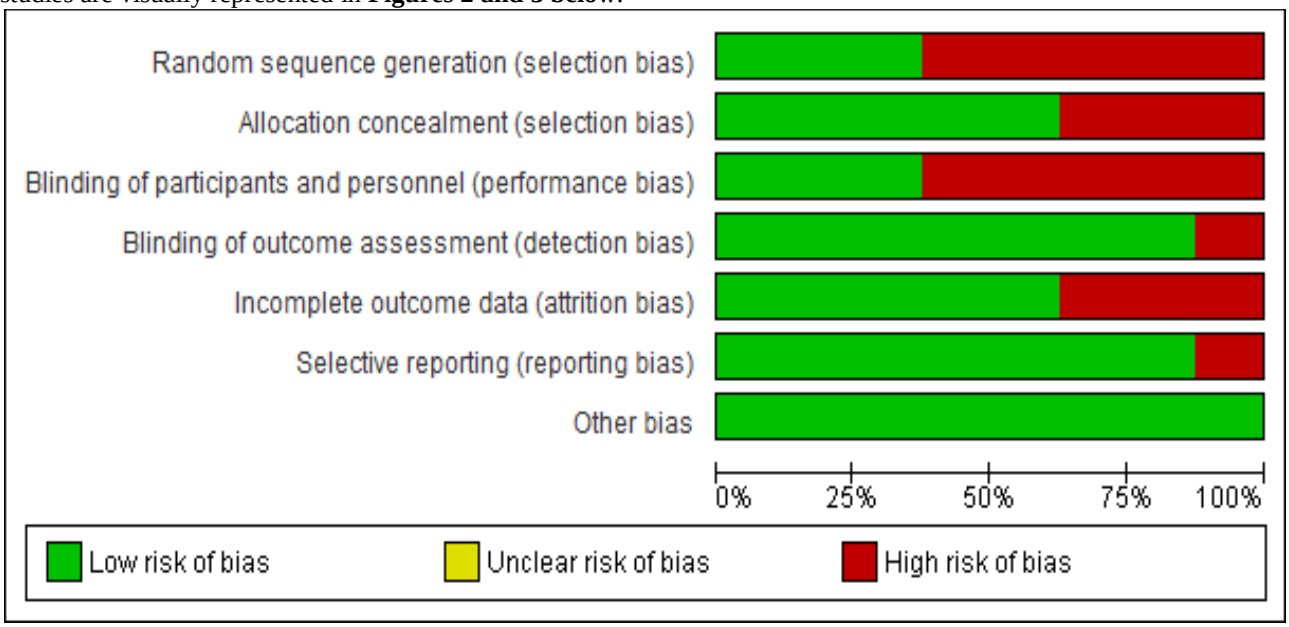


Figure 2:- Showing ROB graph: presented as percentages across all included studies.

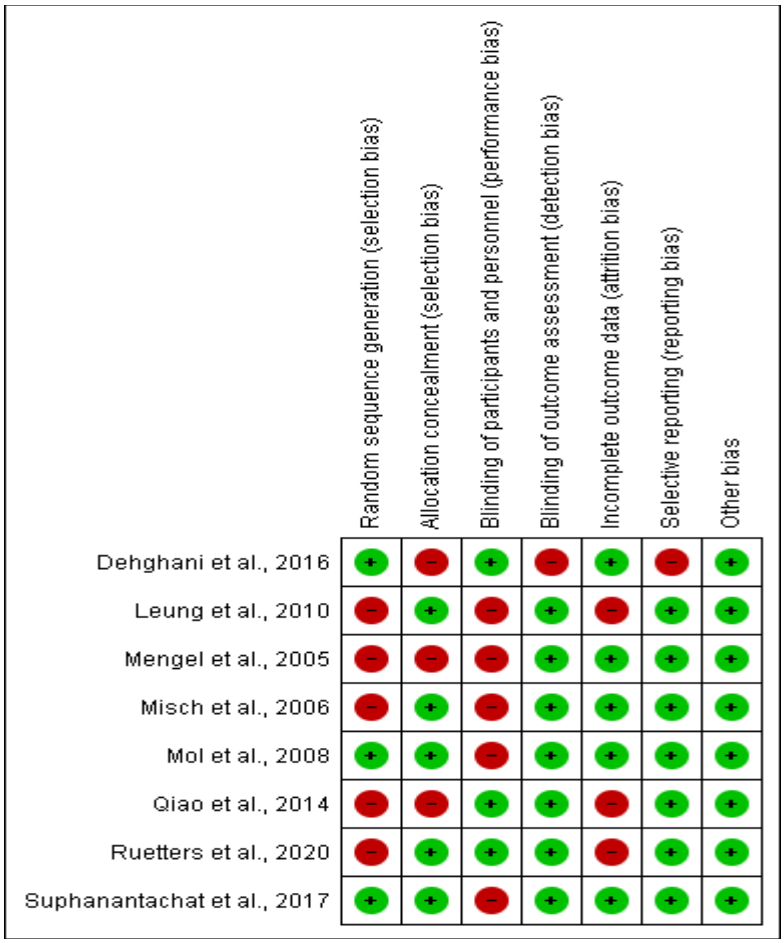


Figure 3:- Showing ROB summary: for each included study.

Synthesis of results

The meta-analysis was performed for evaluating the better diagnostic efficacy between the two imaging modalities among chronic periodontitis (CP) patients in terms of diagnosing furcation width, horizontal bone loss, vertical bone loss and bone defects **as shown in figures 4 - 11 below.**

Furcation width

Two studies[17,21]containing data on 44 patients with CP, of which (n=22) patients were evaluated by CBCT imaging and (n=22) patients by conventional imaging modality for evaluation of better diagnostic efficacy in terms of furcation width diagnosis. As shown in **Figure 4.** the SMD is -0.59 (-1.87 – 0.69) and the pooled estimates favours CBCT imaging signifying that overall mean diagnosisof furcation width on an average was 0.59 times lesser in conventional imaging modality ($p<0.05$).

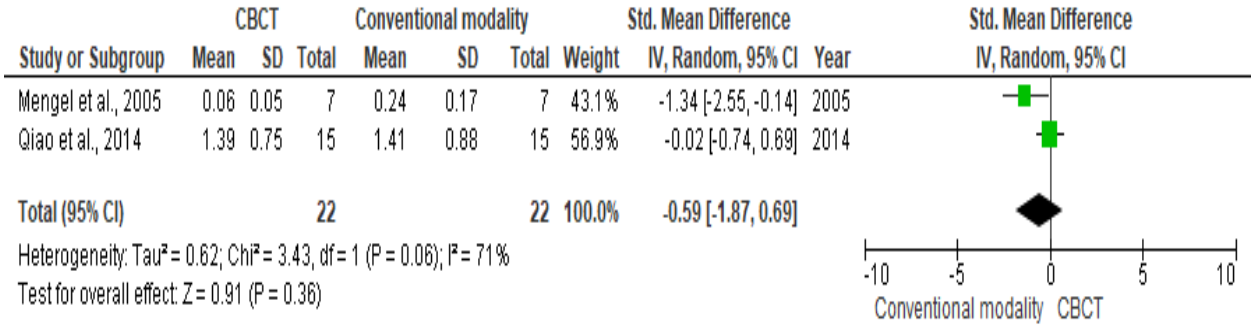


Figure 4:- Comparison between CBCT and conventional imaging for furcation width diagnosis.

The funnel plot did not show significant asymmetry, indicating absence of publication bias as shown in **Figure 5.**

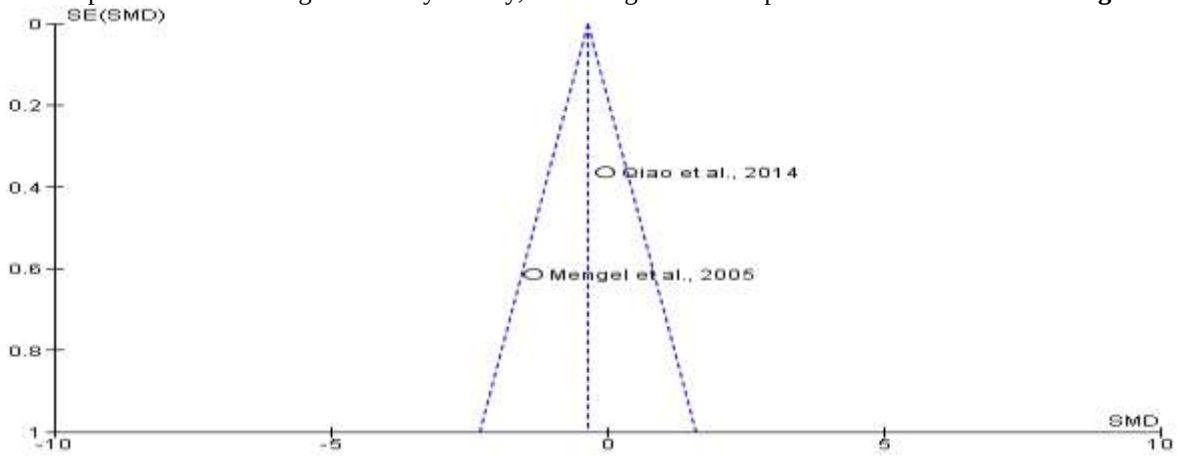


Figure 5:- Funnel plot showing an absence of publication bias in the meta-analysis.

Horizontal bone loss

Four studies[19,21]containing data on 322 patients with CP, of which (n=161) patients were evaluated by CBCT imaging and (n=161) patients by conventional imaging modality for evaluation of better diagnostic efficacy in terms of horizontal bone loss diagnosis. As shown in **Figure 6.** the SMD is 1.56 (-2.11 – 5.24) and the pooled estimates favours CBCT imaging signifying that overall mean diagnosis of horizontal bone loss on an average was 1.56 times more in CBCT imaging ($p<0.05$).

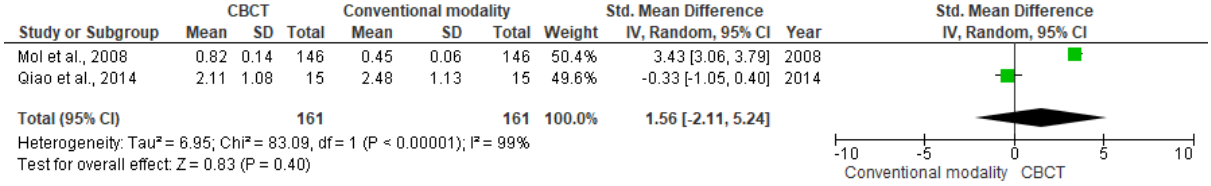


Figure 6:- Comparison between CBCT and conventional imaging for horizontal bone loss diagnosis.

The funnel plot did not show significant asymmetry, indicating absence of publication bias as shown in **Figure 7.**

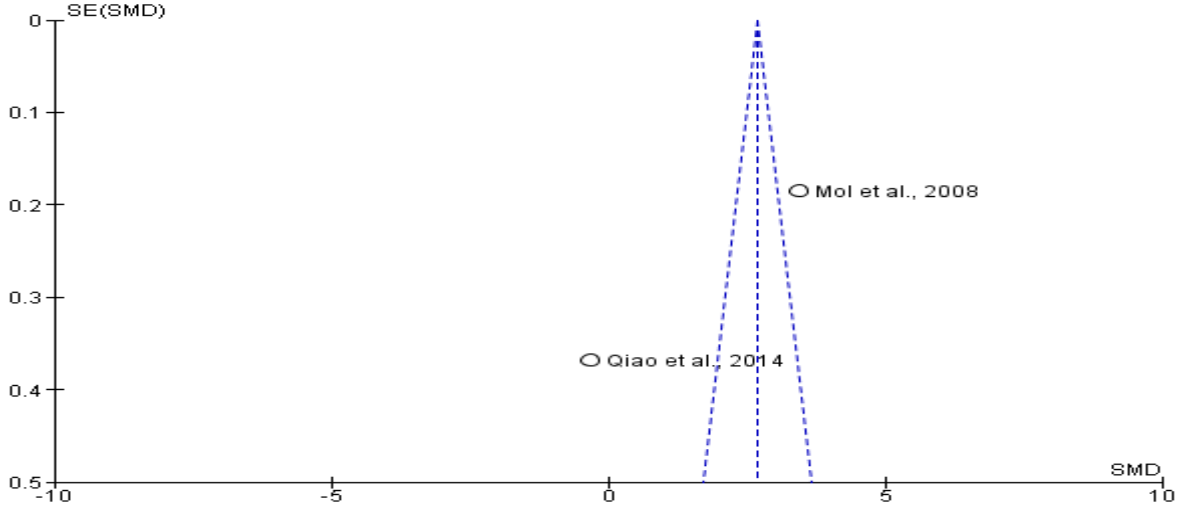


Figure 7:- Funnel plot showing an absence of publication bias in the meta-analysis.

Vertical bone loss

Four studies[19,21]containing data on 44 patients with CP, of which (n=22) patients were evaluated by CBCT imaging and (n=22) patients by conventional imaging modality for evaluation of better diagnostic efficacy in terms of

vertical bone loss diagnosis. As shown in **Figure 8.** the SMD is 1.62 (-1.94 – 5.19) and the pooled estimates favours CBCT imaging signifying that overall mean diagnosis of vertical bone loss on an average was 1.62 times more in CBCT imaging ($p<0.05$).

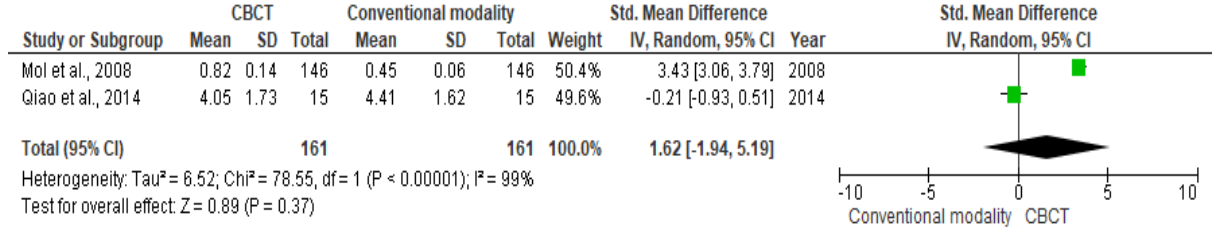


Figure 8:- Comparison between CBCT and conventional imaging for vertical bone loss diagnosis.

The funnel plot did not show significant asymmetry, indicating absence of publication bias as shown in **Figure 9.**

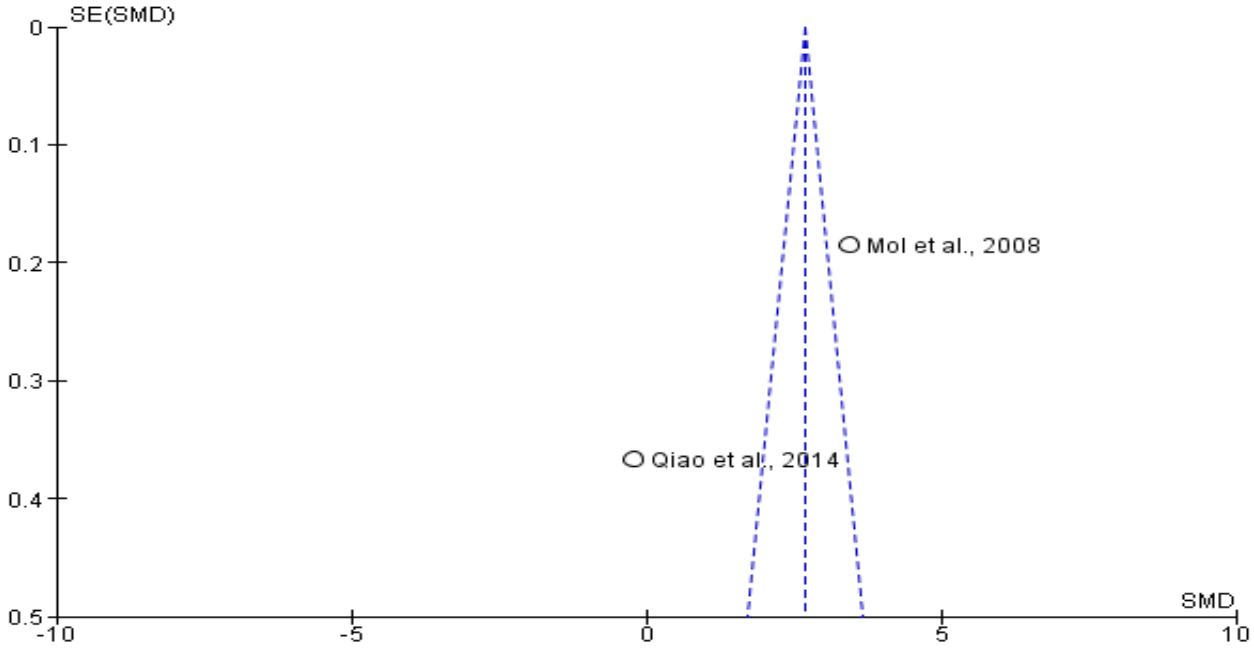


Figure 9:- Funnel plot showing an absence of publication bias in the meta-analysis.

Bone defect

Twostudies[17,22] containing data on 450 patients with CP, of which (n=225) patients were evaluated by CBCT imaging and (n=225) patients by conventional imaging modality for evaluation of better diagnostic efficacy in terms of bone defect diagnosis. As shown in **Figure 10.** the SMD is -0.78 (-2.19 – 0.64) and the pooled estimates favours CBCT imaging signifying that overall mean diagnosis of bone defect on an average was 0.78 times lesser in conventional imaging modality ($p<0.05$).

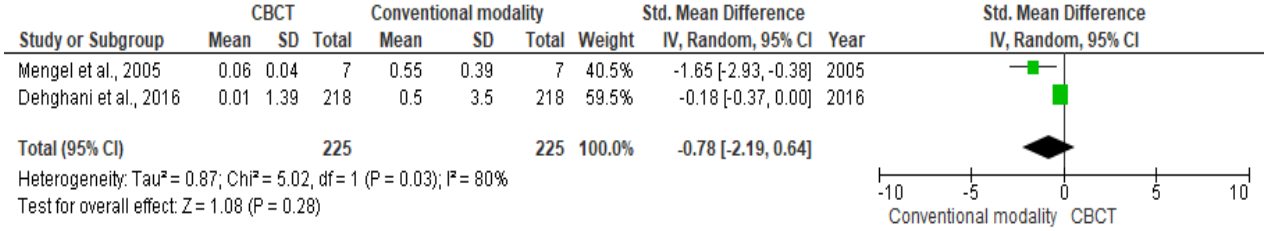


Figure 10:- Comparison between CBCT and conventional imaging for bone defect diagnosis.

The funnel plot did not show significant asymmetry, indicating absence of publication bias as shown in **Figure 11.**

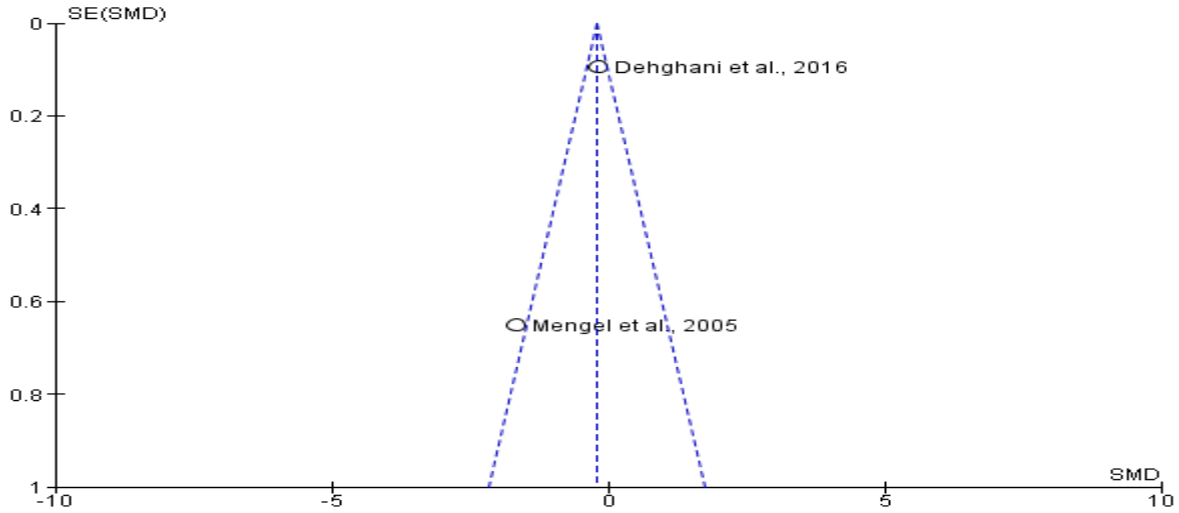


Figure 11:- Funnel plot showing absence of publication bias in the meta-analysis.

Discussion:-

Anter et al., 2016[25]conducted systematic review to assess the accuracy of CBCT as a diagnostic tool for alveolar bone loss in periodontitis. Databases were searched from 2000 to 2015 yielding 14 studies. From the results of the included studies, it was found that CBCT provided diagnosis of alveolar bone loss in periodontal defect with a minimum error of 0.19 +/- 0.11 mm and a maximum error of 1.27 +/- 1.43 mm. It was concluded that CBCT is an ideal imaging modality for detecting periodontal hard tissue loss.

Choi et al., 2018[26]carried out systematic review of existing literature of studies evaluating the diagnostic efficacy of CBCT and conventional imaging modality for periodontal parameters like infrabony defects, furcation involvement, alveolar bone crest height and periodontal ligament space. Electronic databases were searched till 2017 for interventional and observational studies yielding 13 studies. From the results of the studies, it was found that all infrabony defects (100%) were identified by CBCT while only 67% of the defects were identified by periapical radiographs (IOPA). For bone crest height, it was found that CBCT images found that CBCT images found crest height to be 0.23 mm higher than the actual crest height while IOPA showed deviation of 1.17 mm. CBCT images had an accuracy of (78 – 88%) for diagnosing furcation involvement. It was concluded that CBCT is the best imaging method for detecting periodontal parameters.

Woebler et al., 2018[27]carried out systematic review of existing evidences to assess the accuracy and usefulness of CBCT in periodontology. Thirteen studies were taken for review, however due to presence of large amount of heterogeneity, meta-analysis was not possible to be conducted. From the results of the review, it was found that CBCT had shown high accuracy and usefulness in detecting periodontal structures and in periodontology field.

This systematic review and meta-analysis was conducted to provide an updated evidence on better overall diagnostic efficacy of CBCT compared to other conventional imaging modality for periodontal parameters like furcation width, horizontal bone loss, vertical bone loss and bone defect. Electronic databases were searched till May 2024 for observational and experimental studies comparing these two imaging modalities. Eight studies[21-28]were included in review after going through selection process and four studies[21,23,25,26] for meta-analysis. Through the results of meta-analysis, it was found that for furcation width -0.59 (-1.87 – 0.69), horizontal bone loss 1.56 (-2.11 – 5.24), vertical bone loss 1.62 (-1.94 – 5.19) and bone defects -0.78 (-2.19 – 0.64) were detected better by CBCT imaging modality. Also, funnel plot did not show any asymmetry indicating absence of possible publication bias in meta-analysis.

The adherence to PRISMA guidelines, thorough literature search, and rigorous methodology, including Cochrane risk of bias assessment, underscored the credibility of these systematic reviews. With high overall study quality and minimal bias across the included studies, the evidence base supporting therapeutic recommendations for optimizing the use of CBCT imaging is robust and actionable.

However, there were also some limitations. A review of the evidence shows that the literature on comparative evaluation of CBCT with other conventional imaging modality is sparse when evaluating outcomes as mentioned in study. Even after an unlimited search and eligibility criteria, there were very few studies with qualitative synthesis and quantitative synthesis. Only eight studies were included in the final assessment. More prospective or follow-up studies comparing these two imaging modalities are needed to evaluate the above-mentioned results to show a better efficacy between the two imaging modalities and to validate our study findings.

A systematic review is a transparent and repeatable procedure for identifying, selecting and critically assessing published or unpublished data to address a well-defined research question. Meta-analyses, a statistical analysis that incorporates numerical data from related studies, are frequently paired with systematic reviews. The best evidence is generally regarded as systematic reviews and meta-analyses. However, the calibre of the included studies has an impact on how strong the evidence is. In the present review, sufficient studies with a brief observation period and a known risk of bias were included. As a result, the presently available evidence is sufficient to make therapeutic recommendations in response to the current systematic review's focus question.

Conclusion:-

From the results of the study, it was found that CBCT overall was more accurate and provided more quantitative data with greater precision and lesser deviations compared to conventional imaging techniques. However, furthermore studies showed be conducted with robust methodology with proper standardization protocols to validate the study findings.

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