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Review

The accuracy of linear measurements in cone beam computed tomography for assessing intrabony and furcation defects: A systematic review and meta-analysis.

La precisión de las mediciones lineales en la tomografía computarizada de haz cónico para evaluar defectos intraóseos y de furcación: Una revisión sistemática y un metanálisis.

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Abstract: Objective: This study aims to assess the accuracy of the linear measurements of intrabony and/or furcation defect quantified by cone beam computed tomography (CBCT). Material and Methods: A systematic search of the literature was conducted by two authors independently from the PubMed, Scopus, and EBSCO for full articles published in journals between January 2003 and March 2017. Eligible studies were assessed for quality and heterogeneity using the QUADAS-2 tool. A meta-analysis was performed to identify the accuracy of CBCT in the measurement of intrabony defects. The effect size was estimated and reported as the standardised mean difference (SMD). Results: A total of 105 titles and abstracts were screened. Of those, 11 articles met the inclusion criteria for the systematic review while only four were selected for meta-analysis. The overall effects of standardized mean difference and 95% CI was -0.03 [95% CI -0.67 to 0.60] with a x^2 statistic of 0.49 with 3 degrees of freedom (p>0.05), I_2= 0.01%. Conclusion: CBCT is highly accurate and reproducible regarding linear measurements for assessing intrabony defects with a weighted standardized mean difference of 0.03mm. More randomised controlled trials are required to assess the accuracy of CBCT in assessing patients with periodontal defects.

Keywords: *Cone-beam computed tomography; furcation defect; periodontal diseases; databases, bibliographic; publications; data collection.*

Resumen: Objetivo: Este estudio tiene como objetivo evaluar la precisión de las mediciones lineales de defectos intraóseos y/o de furcación cuantificados por tomografía computarizada de haz cónico (CBCT). Material y Métodos: Dos autores, independientemente realizaron una búsqueda sistemática de la literatura en PubMed, Scopus y EBSCO, para obtener artículos completos publicados en revistas entre Enero de 2003 y Marzo de 2017. Los estudios elegibles se evaluaron para determinar la calidad y la heterogeneidad utilizando la herramienta QUADAS-2. Se realizó un metanálisis para identificar la precisión de CBCT en la medición de defectos intraóseos. El tamaño del efecto se estimó y se informó como la diferencia de medias estandarizada (DME). Resultados: Se seleccionaron un total de 105 títulos y resúmenes. De ellos, 11 artículos cumplieron con los criterios de inclusión para la revisión sistemática, mientras que solo cuatro fueron seleccionados para el metanálisis. Los efectos generales de la diferencia de medias estandarizada y el IC del 95% fueron -0.03 [IC del 95%: -0.67 a 0.60] con una estadística X^2 de 0.49 con 3 grados de libertad (p>0.05), I_2= 0.01%. Conclusión: CBCT es altamente preciso y reproducible con respecto a mediciones lineales para evaluar defectos intraóseos con una diferencia de medias estandarizada ponderada de 0.03 mm. Se requieren más ensayos controlados aleatorios para evaluar la precisión de CBCT en la evaluación de pacientes con defectos periodontales.

Palabras Clave: *Tomografía computarizada de haz cónico; defecto de furcación; enfermedades periodontales; bases de datos bibliográficas; recolección de datos.*

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INTRODUCTION.

Periodontitis is an infectious disease that exhibits inflammation of the supportive tissues of the tooth, that can inevitably lead to the destruction of the periodontal ligament and alveolar bone, and which may also result in tooth loss.[1] A recent systematic review has shown that periodontitis is highly prevalent, with approximately 10% of the global population affected by advanced periodontitis.[2] Therefore, it is crucial to diagnose and manage this condition at its initial or early stage.

After assessing the periodontal condition and disease from the patient's history and after clinical examination and diagnosis, a good and accurate assessment of periodontal bone loss or periodontal defects are needed for the proper formulation of a suitable treatment plan. Clinically, the periodontal probe continues to be one of the most useful diagnostic tools to determine the presence and severity of periodontal bone loss.[3,4] However, studies have shown that due to several factors, errors may contribute to the final estimated value during periodontal probing, due to such variables as the type of periodontal probe used, probing force, type of site, type of location of the tooth, inflammatory state of the tissues, and presence of subgingival calculus.[5-8]

Furthermore, dental radiographs are used as an adjunct diagnostic method for the management of periodontal patient.[9] Dental radiographs also provide information about the bone levels and pattern of bone loss that cannot be gained through routine clinical examination which can be measured as linear distances from the cemento-enamel junction (CEJ) to the bone defects.[10-12] A study has shown that bone loss should be considered if the radiographic bone height is greater than 1.9mm (95 % confidence interval: 0.4-1.9mm).[13] Moreover, by looking at the remaining bone support with the root length, radiographs can provide key information of relevance towards periodontal decision making which is not possible to be captured by clinical examination.[14]

Currently, two-dimensional planar images from intra-oral and panoramic radiography are the most frequent conventional imaging techniques used to identify the location, quantify the amount and determine the pattern of alveolar bone loss.[12] Intraoral radiographs, including bitewing (BW) and periapical (IOPA) views as well as panoramic radiograph, are considered to be the gold standard in radiographic tools for assessing alveolar bone status.[11-15] However, these techniques only provide two-dimensional (2D) images for the detection and quantitative assessment of 2-wall and 3-wall defects.

Therefore, a more accurate imaging technique is required to produce high quality images and reduce the inevitable limitations from the conventional radiography.

Cone beam computed tomography (CBCT) has recently emerged in the dental field and is being investigated as a possible complementary diagnostic tool in periodontal practice.[16-18] Interestingly, a recent paper reported that CBCT could be used in assessing periodontal defects such as localized intrabony defects, buccal cortical plate defects, molar furcation involvement, and periradicular pathologies.[12] Previous studies have also shown that in comparison with 2D imaging, CBCT generates images with excellent morphologic details, dimensional accuracy, and eliminates structural distortion and overlapping.[19,20]

The use of the best radiographic tools for treatment planning may also assist the periodontist in the decision-making process from the initial diagnosis until definitive treatment. This would be more significant especially when surgical procedures are involved as suggested by previous studies that recommended to take CBCT of molars with furcation involvement and teeth with deep intrabony defects.[18,21,22]

To date, there have been three systematic review articles discussing the role of CBCT in periodontitis.[22–24] The first article, by Walter *et al.,*[22] discussed the indications of CBCT for periodontal diagnosis and treatment planning in specific clinical situations, concerning the accuracy and potential benefit of dental CBCT. Further, this study concluded that CBCT provides high accuracy in detecting the morphology of vertical bony defects particularly in maxillary molars with furcation involvement.

In another article, Nikolic-Jakoba *et al.,*[24] reviewed the diagnostic efficacy of CBCT for the diagnosis of and/or treatment plan for intrabony and furcation defects using a well-known six-tiered hierarchical model for diagnostic efficacy. This study concluded that there was insufficient scientific evidence to justify the use of CBCT in the diagnosis and treatment plan for intrabony and furcation defects.

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Subsequently, Anter *et al.*,[23] questioned the accuracy of CBCT in the measurements of alveolar bone loss in periodontal defects in their systematic review study. They found that the mean CBCT measurement error in the included studies ranged between 0.19±0.11mm and 1.27±1.43mm. However, this study did not discuss furcation defects.

It is apparent that most of the previous studies agreed that CBCT provided better accuracy and had been verified in terms of detection and quantification of periodontal defects.[25–27] However, to the authors' knowledge, none of the existing studies measured the pooled effect of linear measurement in CBCT as compared to the clinical intrasurgical measurement when the accuracy is defined as "how close a measured value is to the actual value".[28] Hence, the objective of this study is to assess the accuracy between CBCT and the clinical intrasurgical linear measurements of intrabony and/or furcation defect.

MATERIALS AND METHODS.

This study followed a standard protocol based on the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines.[29] In the light of available evidence, the specific questions in this systematic review were addressed according to the PICO (Population, Intervention or exposure, Comparison, Outcome) criteria[30]: "How much of the CBCT's linear measurement (O) deviates from the clinical intrasurgical measurement /artificial osseous defect (C) for the assessment of intrabony and furcation defects (I) in periodontitis (P)?"

Type of studies included

All study designs were included except for case reports, case series, and systematic reviews.

Study selection

The studies were eligible for selection if the clinical or comparative CBCT studies were performed on humans. The studies that utilized CBCT with the presence of intrasurgical measurement to validate the true state of the disease were also included. However, studies were only included if the raw data of CBCT and clinical intrasurgical measurement in measuring intrabony and furcation defects were presented. Additionally, only English publications were selected for this study.

Types of outcome measures

The primary outcome measure was the standardised mean difference for the accuracy of dental CBCT compared to the clinical intrasurgical measurement (CBCT – intrasurgical measurements). Hence, the positive value will denote the overestimation of the CBCT measurement while negative value reflects an underestimation of the CBCT measurement. For each study included, at least the mean error and standard deviation must be documented.

Search strategy for identification of studies

A systematic search of the literature was conducted by two authors (NA and MYP) independently from the PubMed, Scopus, and EBSCO for the full articles published in journals between January 2003 and March 2017. The Boolean search was performed on each database using the search term: "cone beam computed tomography" OR "cone beam CT" OR "CBCT" OR "tomography" AND "furcation defects" OR "intrabony defects" OR "furcation" OR "furcations" OR "periodontal bone loss" OR "intrabony" OR "vertical defects" OR "vertical bone loss" OR "interradicular bone loss" OR "interradicular bone defects". The search was supplemented with a manual search based on the reference lists of the selected papers and other previous reviews including related journals. Accordingly, the search was regularly updated to prevent the inclusion of retracted articles.

Data selection

In the first sieve, the titles and abstracts were screened independently by the two authors (NAMY and MYPMY). Any irrelevant abstracts, identical abstracts in different databases and abstracts that did not satisfy the inclusion criteria were excluded. After screening the titles and abstracts, a second screening was performed where the full texts of potentially relevant articles were obtained to exclude articles with improper methodology along with selective reporting of results. Any disagreements were resolved by further discussion or arbitration with the third author (EN). After selecting articles for data extraction, the reference lists of the selected articles and related review articles were manually searched. Proprietary reference manager software was used to manage a large number of studies during this stage, and the reasons for excluding studies were recorded. The study selection was then documented in a detailed flow chart.

Data extraction

Information pertaining to the year of publication and diagnostic accuracy of CBCT used were extracted from each article by two independent reviewers (NAMY and MYPMY). Data extraction is based on the study design, sample size, CBCT image acquisition parameters, clinical intrasurgical measurements, and results. Furthermore, the linear measurement was evaluated and independently assessed by the two independent reviewers.

Assessment of methodological quality

The Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool[31] built on the original QUADAS tool[32] was used to assess the methodological quality of each of the included studies. The recommended QUADAS questions were used which provided a structured series of questions, each with a defined answer. The questions were designed to evaluate the presence of any bias related to multiple aspects of the methodology of the selected studies consisting of four key domains that discussed patient selection, index test, reference standard, and flow of patients through the study and timing of index tests and reference standard (flow and timing). Each study was reviewed by two of the three authors (NAMY and MYPMY), and any disagreement between the two review authors was solved by means of consensus. Next, the individual review author assessments and the agreed results of the QUADAS-2 tool were combined. The questions selected are listed in Appendix 1. This tool underwent piloting and calibration before being used to assess the selected articles.

Data analysis

Descriptive analyses of the characteristics of the selected studies including statistical tests were performed by summarising the studies in evidence tables to determine the quantity of data and checking for variations in the characteristics of individual studies. The evidence tables provided the framework to assess if the data is suitable for further quantitative analyses such as meta-analyses.

Meta-analyses were carried out using RStudio version 3.4.1 (2017-06-30) RStudio, Inc. Software and the metafor function package was used to develop the graphics and quantitative measurement in this analysis.[33] In the present study, the mean difference and standard deviations were obtained either directly from the paper or calculated where possible. Data entry was double checked by another author (EN). The weight of each study included in the meta-analysis for every effect estimate was determined by its standard deviation and sample size. The effect size was estimated and reported as the standardised mean difference (SMD) with the 95% confidence interval (CI) for linear measurements. Furthermore, a funnel plot serving as a visual means was carried out to assess any disproportionate representation of the study results according to both strength and precision.

RESULTS.

Study characteristics

A total of 105 titles were initially identified. However, after filtering for any duplicates, 70 titles and abstracts were reviewed, and only 28 articles were potentially related. Of these,[17] articles did not meet the inclusion and exclusion criteria, and a total of 11 articles were finally included in the systematic review. Only four studies with intrabony defects were included in the quantitative analysis. The exclusion was mainly due to papers that did not match the inclusion criteria.

Figure 1 summarises the selection process while the excluded studies and reasons for exclusion are presented in Table 1.

The included publications were published in the period between 2006 and 2016. The data extraction from the 11 included studies was completed and is presented in Table 2. Next, these studies were appraised as part of the methodological quality assessment using the previously mentioned checklist[31] (Appendix 2).

Among the included publications, three publications were in vitro studies[19,34,35] which used human skulls by creating artificial periodontal defects as a clinical intrasurgical measurement (gold standard) under a controlled environment and representing an almost ideal condition. The remaining articles were clinical studies.

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All the clinical studies performed clinical intrasurgical measurement as the gold standard where three studies were measured on furcation defects. Of these three studies, two assessed the accuracy of maxillary molars by comparing the severity of furcation involvement by the percentage agreement between the CBCT and intrasurgical findings that served as a gold standard.[26,27]

For the outcome measures, the accuracy of CBCT was observed from the data of the mean difference and standard deviation. The mean difference with a 'negative' value indicates that the CBCT measurement was underestimated when compared to the clinical intrasurgical measurement. Subsequently, the CBCT measurement was overestimated when the mean difference exhibited a 'positive' value. None of the primary studies presented a zero value of the mean difference. The risks of bias in individual studies were assessed accordingly as illustrated in Figure 2 and in Table 3. Consequently, the results of the clinical studies were analysed for meta-analysis.

Syntheses of results

The data from the included studies in this review was pooled and analysed to address the accuracy of CBCT in the linear measurement for assessing the vertical defects (n=4). As shown in Figure 3, there is no statistical significance at the study level except for Pahwa *et al.,*[20] (standardised mean difference = 0.07mm, [95% CI -0.66 to 0.80]).

However, a meta-analysis of all four studies suggested that the accuracy of CBCT in comparison with the clinical intrasurgical measurement was not statistically significant. Moreover, the overall effects of standardised mean difference was -0.03mm [95% CI -0.67 to 0.60] with a x^2 statistic of 0.4898 with 3 degrees of freedom (p>0.05), I_2= 0.01%. The funnel plot (Figure 4) did not indicate any evidence of publication bias.

Figure 1. Flow diagram of the selection process of the studies included based on PRISMA 2009.

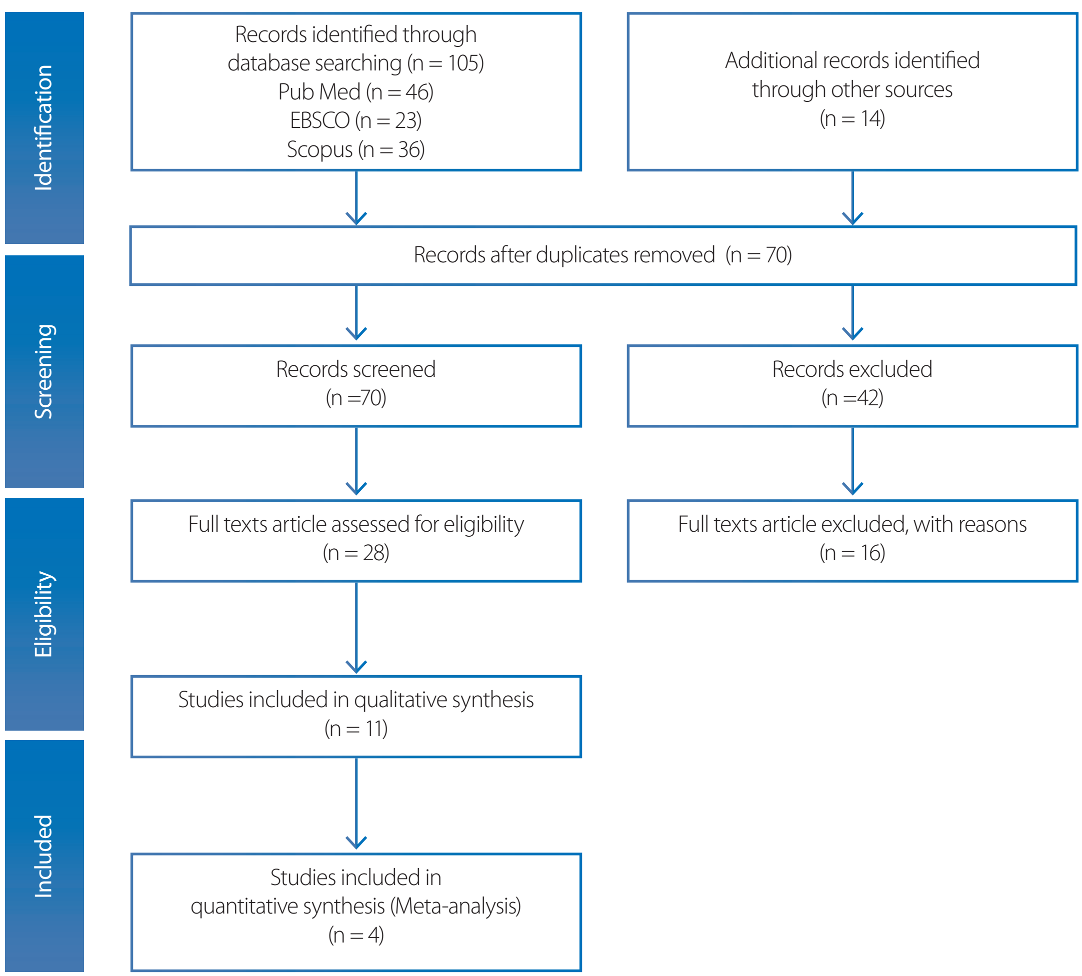

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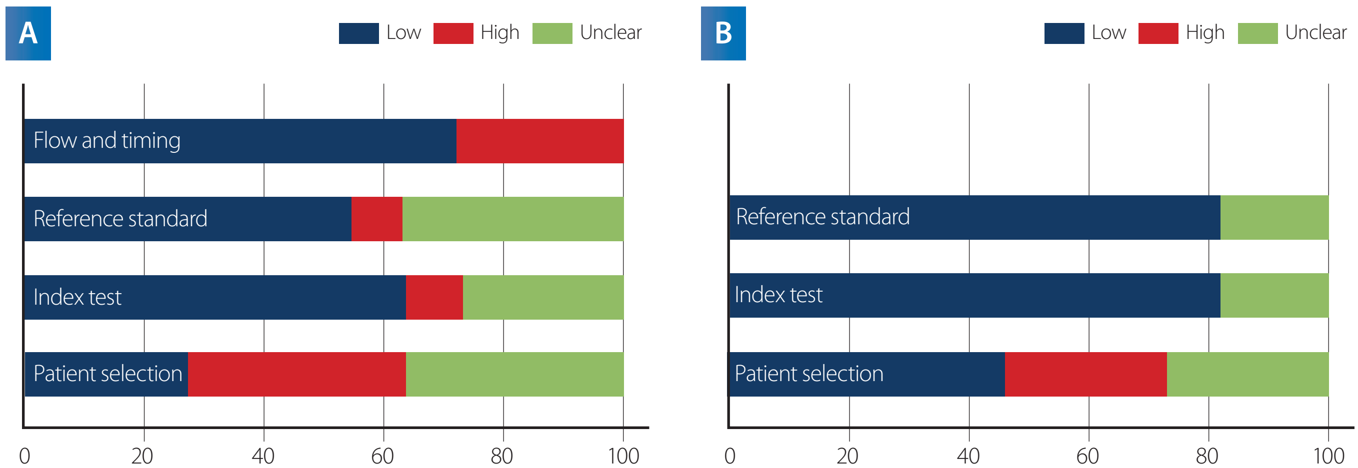
Figure 2. Risk of bias and applicability concerns graph: judgements about each domain are presented as percentages across included studies.



A: Proportion of studies with low, high, or unclear risk of bias, % . **B:** Proportion of studies with low, high, or unclear concerns regarding applicability, %.

Figure 3. Forest plot of standardised mean difference in accuracy of CBCT for assessing intrabony defects.

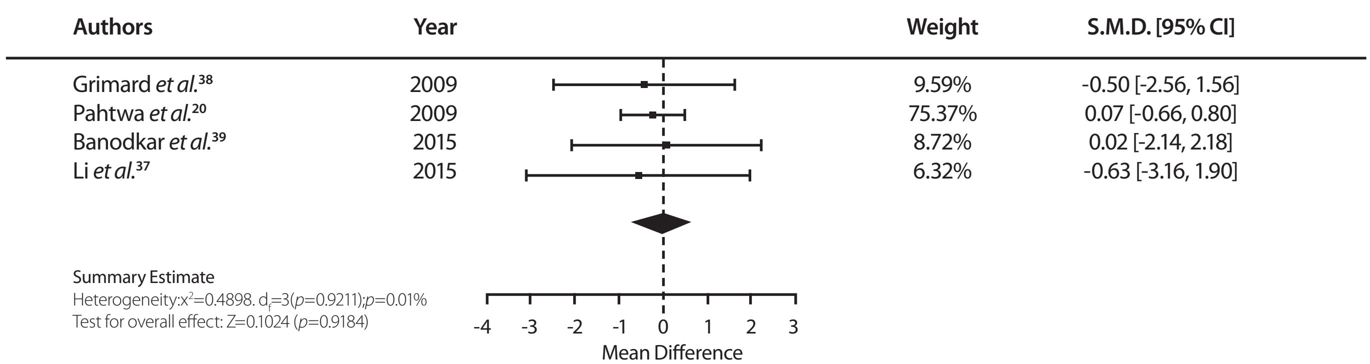


Figure 4. Funnel plot of accuracy of CBCT for assessing intrabony defects

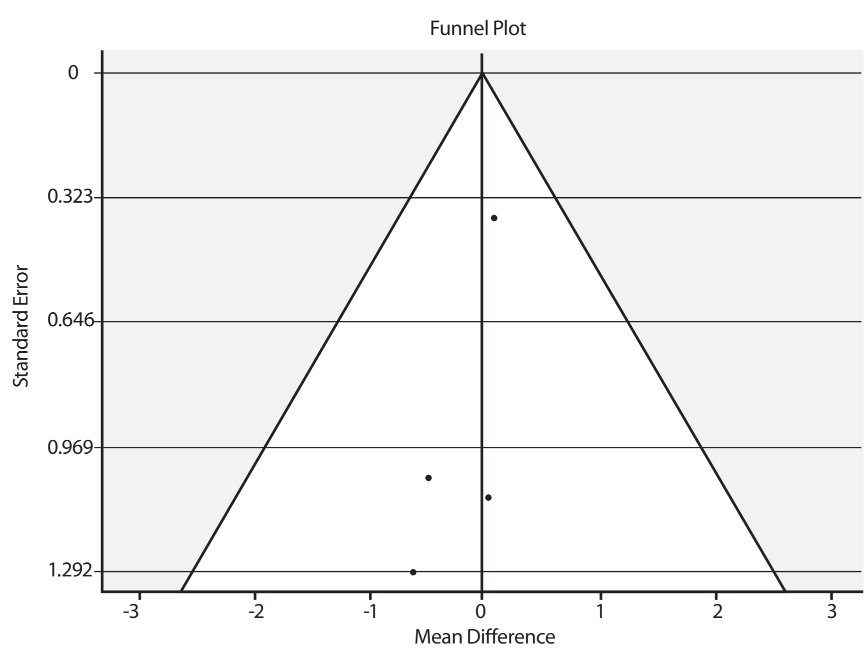


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Table 1. Excluded publications and reason for exclusion.

Study	Reason for exclusion
Zhu *et al.*,[43] 2017	E3
Jie *et al.*,[44] 2016	E1
Darby *et al.*,[45] 2015	E1
Allen *et al.*,[46] 2014	E1
Braun *et al.*,[47] 2014	E3
Vasconselos *et al.*,[48] 2014	E3
Songa *et al.*,[49] 2014	E3
Fleiner *et al.*,[50] 2013	E3
Laky *et al.*,[51] 2013	E1
Umetsubo *et al*[52] 2012	E3
El-Zoheiry *et al.*,[53] 2011	E1
Zhong *et al.*,[54] 2010	E4
Walter *et al.*,[55] 2009	E1
Noujeim *et al.*,[56] 2009	E3
Mol *et al.*,[57] 2008	E3
Vandenberghe *et al.*,[58] 2007	E3
Mengel *et al.*,[59] 2005	E2

E1, no Gold Standard; E2, animal studies; E3, no comparison data of CBCT and Gold Standard; E4, not published in English

Table 2. Summary of included studies.

Authors, year, aim of the study	Study design and sample size	CBCT parameters	Outcome parameters	Results (Accuracy)
Misch *et al.*,[34] 2006 To compare linear measurements of periodontal defects using CBCT to traditional methods.	Human, *ex vivo* study, using two dry human skulls and mandibles with 21 artificially made periodontal defects.	CBCT system: I-CAT Tube voltage: 120KVp Filament current: 47.74mAs Acquisition time : 20 s Voxel size: Unstated	Visualization of measurement of buccal, lingual, and interproximal intrabony defects.	The mean CBCT measurement error was: 0.41±1.19 mm for the height and 1±0.67mm for the width and both were not statistically significant.
Vandenberghe *et al.*,[35] 2008 To explore the diagnostic value of CBCT in the determination of periodontal bone loss, including the 3D topography of infrabony defects.	Human, *ex vivo* study, using one dry human skull and one human cadaver head with 71 periodontal defects.	CBCT system: I-CAT Tube voltage: 120KVp Filament current: 23.87mAs Acquisition time : 20 s Voxel size: 0.4mm	Four categories of image quality for assessing lamina dura delineation, contrast, and bone quality lity (lack of visibility, poor visibility, medium visibility, good visibility), linear bone measurements, intrabony craters, and furcation defects detection.	The average absolute CBCT measurement error of infra-bony defects for panoramic reconstructed view was 0.47mm while for cross-sectional images it was 0.29mm.
Takeshita *et al.*,[19] 2008 To evaluate the diagnostic accuracy of conventional periapical radiography taken with film holders Rinn and Han-Shin, digital periapical	Human, *ex vivo* study, using 70 teeth from macerated human mandibles.	CBCT system: I-CAT Tube voltage: Unstated Filament current: 36.2mAs Acquisition time : Unstated Voxel size: 0.125mm	Measurement of alveolar bone loss	The measurement error was not mentioned in this article; manual calculation was done resulted mean measurement error of -0.08mm

radiography with complementary metal-oxide semi-conductor sensor (CMOS), panoramic radiography, and CBCT in the mea-surement of alve-olar bone loss				
Grimard *et al.,*[38] 2009 To compare the measurements from digital intra-oral radiographs and CBVT images to direct surgical measurements for the evaluation of regenerative treat-ment outcomes.	Human, *in vivo* study, randomized, controlled clinical trial of 29 patie-nts with 35 periodon-tal defects	CBCT system: 3DX Accuitomo Tube voltage: unstated Filament current: unstated Acquisition time : 18 s Voxel size: unstated	Bone defect fill and bone defect resolution	The mean errors of CBVT measurements: For CEJ-AC initially, it was -0.1±1.2mm while for re-entry 0.01±0.7 mm. For initial CEJ-BD, it was -0.9 ± 0.8mm and for re-entry, it was -0.5±1.1mm
Walter *et al.,*[27] 2010 To assess the accuracy of cone beam computed tomography (CBCT) in detecting furca-tion involvement in maxillary molars.	Human, *in vivo* study, comprised of 14 patie-nts with 75 furcation entrances	CBCT system: 3D Accuitomo 60 Tube voltage: 74-90kV Filament current: 5-8mA Acquisition time : unstated Voxel size: 0.08-0.25mm	Furcation defects (Class I, II and III)	The measurement error was not mentioned in this article; they only reported of the agreement between CBCT and intra surgical findings. 84% CBCT findings were -firmed by the intra sur-gical findings, 14.7% were underestimated, and 1.3% overestimated compared with intra-surgical fibdings.
Raichur *et al.,*[36] 2012 To compare the linear measu-rements of radiovi-siography and di-gital volume tomo-graphy (DVT) to direct surgical mea-surements in the detection of perio-dontal infrabony defects.	Human, *in vivo* study, comprised of 7 patie-nts with 28 sites of in-frabony periodontal defects.	CBCT system: KODAK 9000C 3D Tube voltage: 70-74kV Filament current: 10mA Acquisition time : 10.8 s Voxel size: Unstated	CEJ-AC and CEJ-BD measurement	The measurement error was not mentioned in this article; manual calcu lation was done resulted mean SD measurement error for CEJ-AC = 0.16 and CEJ-BD = 0.06
Pahwa *et al.,*[20] 2014 To compare the diagnostic va-lues of radiovisio-graph and compu-ted tomography images in compa-rison with direct surgical measure-ments for the de-termination of pe-riodontal bone loss	Human, *in vivo* study, comprised of 15 pa-tients with 31 sites of vertical defects	CBCT system: Unstated Tube voltage: 120kV Filament current: Unstated Acquisition time : 1.5 s Voxel size: Unstated	Linear measurements of (1) Alveolar bone level distance from CEJ-BD (2) distance from CEJ-AC and (3) infrabony compo-nent was measured by subtracting (CEJ-AC) from (CEJ-BD).	The mean CBCT measure ment error was 0.07±0.14 mm.
Qiao *et al.,*[26] 2014 To investigate the	Human, *in vivo* study, comprised of 15 pa-	CBCT system: 3D Accuitomo 60	The degree of furcation involvement, horizontal	The measurement error was not mentioned in

accuracy of dental CBCT in assessing FI in maxillary molars.	tients with 51 of furcation defects	Tube voltage: 74-90kV Filament current: 5-8 mA Acquisition time : Unstated Voxel size: 0.125 x 0.125 x 0.125mm	and vertical bone loss.	this article; manual calculation was done resulted mean measurement error 0.37mm for horizontal bone loss and 0.36mm for vertical bone loss.
Banodkar *et al.*,[39] 2015. To evaluate the accuracy of CBCT measurements of alveolar bone defects.	Human, *in vivo* study, comprised of 15 patients with 100 of periodontal bone defects.	CBCT system: Planmeca Promax 3D Tube voltage: 90kV Filament current: 10 mA Acquisition time : 13s Voxel size: 400 µm	Measurement of horizontal and vertical bone defects	The measurement error was not mentioned in this article; manual calculation was done resulted mean measurement error -0.02mm for horizontal bone loss and 0.02mm or vertical bone loss
Li *et al.*,[37] 2015 To explore the relationship between CBCT measurement and direct measurements during the surgery to correct intrabony defects.	Human, *in vivo* study, comprised of 44 patients with 44 intrabony defects.	CBCT system: New tom VG Tube voltage: 110kV Filament current: 12-17 mA Acquisition time : Unstated Voxel size: Unstated	Parameters of intrabony defects including CEJ-BD level, depth of the defect, mesiodistal and buccolingual width of defect	The mean CBCT measurement error : CEJ-BD = 0.76 ± 1.40mm Depth of defect = 0.63 ± 1.67mm Mesiodistal width of defect = -0.17±0.67mm Buccolingual width of defect = -0.16 ± 0.65mm
Pajnigara *et al.*,[25] 2016 To evaluate the dimensions of furcation defects clinically (pre- and post-surgery), intrasurgically, and by CBCT (pre- and post-surgery).	Human, *in vivo* study, comprised of 40 patients with 200 grade II furcation defects.	KODAK 9000C 3D and KODAK 9000C, Carestream Health. Parameter setting was not mentioned	Vertical and horizontal component measurements of pre- and post-surgery clinical, intrasurgery and pre- and post-surgery CBCT	The measurement error was not mentioned in this article; manual calculation was done resulted mean measurement error -0.2mm for horizontal bone loss and -0.34mm for vertical bone loss

CBCT: Cone beam computed tomography. **CBVT:** Cone beam volumetric tomography. **CEJ-AC:** Cemento-enamel junction to the alveolar crest. **CEJ-BD:** Cemento-enamel junction to base of the defect. **SD:** standard deviation; GS, gold standard. **3D:** Three-dimensional.

Table 3. Risk of bias and applicability concerns summary: review authors' judgements about each domain for each included study.

Study	Risk of Bias				Applicability Concerns		
	Patient Selection	Index Test	Reference Standard	Flow and Timing	Patient Selection	Index Test	Reference Standard
Misch *et al.*,[34] 2006	-	+	+	-	-	+	+
Vandenberghe *et al.*,[35] 2008	-	+	+	-	-	+	+
Takeshita *et al.*,[19] 2014	-	?	-	-	-	?	?
Grimard *et al.*,[3] 2009	?	+	?	+	+	+	+
Walter *et al.*,[27] 2010	?	+	+	+	+	+	+
Raichur *et al.*,[36] 2012	-	-	?	+	?	?	?
Pahwa *et al.*,[20] 2014	?	?	+	+	?	+	+
Qiao *et al.*,[26] 2014	+	+	+	+	+	+	+
Li *et al.*,[37] 2015	+	+	+	+	+	+	+
Banodkar *et al.*,[39] 2015	?	+	?	+	?	+	+
Pajnigara *et al.*,[25] 2016	+	?	?	+	+	+	+

+: low risk. **- :** high risk. **?:** unclear risk.

DISCUSSION.

In this study, CBCT was found to have relatively high accuracy as compared with the clinical intrasurgical measurement for assessing intrabony defects, with the mean CBCT measurements error of 0.03mm. Although the pooled effect of accuracy showed an underestimation of the CBCT measurement from the intrasurgical measurement, the differences are not statistically significant. Furthermore, CBCT generated data added some information that cannot be currently obtained from clinical examinations.[12] The current study identified[11] studies that compared the measurement between CBCT and the clinical intrasurgical measurement or artificial osseous defect.[19,20,25-27,34-39]

In this systematic review, both *in vitro* and clinical studies were included. There were noticeable differences in the clinical intrasurgical measurement (artificial defects versus intrasurgical measurement), the technical parameters used (voxel sizes of the scans, the type of CBCT machine, and type of CBCT images), and qualifications and the numbers of the observers who interpreted the data. It must be borne in mind that the lack of standardisation in determining the field-of-volume would significantly affect the measurement in CBCT.

These evidences were scarcely documented in the majority of primary studies. Hence, it was important to ensure that all included studies provided complete information on the mean and standard deviation values of the measurement error in producing these results as well as establishing strong evidence.

In addition, only clinical studies with intrabony defects[20,37-39] were included in the meta-analysis (n=4). In fact, it was inappropriate to perform a meta-analysis for both *in vitro* and clinical studies in this study due to the scarcity of articles discussing the research question. Furthermore, a small number of clinical studies assessing the furcation defects to be included in meta-analysis have a validation gap within this niche.

In periodontal management, accurate methods are extremely important to adequately diagnose the anatomy of intrabony and furcation defects in order to optimise treatment planning and to enable a more objective evaluation of the outcomes following periodontal surgery.[22]

In all primary studies, the quantification of measurements was based on the difference between CBCT and intrasurgical measurements (CBCT-intrasurgical measurement). Therefore, the CBCT is considered to underestimate when the value was negative and overestimate when it was positive. Nevertheless, there are a number of factors to consider when interpreting these results.

The accuracy of measurement distances on patients may be affected by a reduction in image quality due to soft tissue attenuation, restoration metallic artefacts, and patient movement. In this study, the standardised mean difference between CBCT and intrasurgical was 0.03mm. Therefore, based on this finding, it is suggested that the CBCT parameter used in the included studies is reasonable to obtain good accuracy in the measurement of periodontal defects. Accordingly, this finding is supported by a more recent review paper which summarised that CBCT provides high-resolution images in assessing the intrabony defects in three dimensions compared to conventional radiography and thus provides a better treatment outcome.[40]

However, it was noted that the field-of-view (FOV) was not explicitly mentioned in all four of primary studies. This is particularly important to prevent unnecessary radiation exposure imposed on patients should the FOV be set at moderate-to-large (diameter >16cm). As such, it is recommended for all researchers to provide the chosen FOV size in their reports as good practice. Also, the use of a small FOV may improve the spatial resolution of CBCT in certain brand devices.[41]

Notably, all clinical studies were found to use the periodontal probe as a tool for clinical intrasurgical measurement except for the study by Banodkar *et al.,*[39] who employed an endodontic reamer and digital Vernier calliper for taking this measurement. Compared to the periodontal probe, this novel approach was found to be more accurate in obtaining clinical measurements with an accuracy of up to 0.2mm.

This accuracy is comparable to the accuracy of CBCT measurements. Consequently, the periodontal probe had an accuracy of 1mm for measurement and thus the discrepancy between CBCT-based data and clinical intrasurgical measurement data may exist. For example,

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probing measurements could only be made to the nearest 0.5mm in one study, whereas CBCT measurements were able to be made to the nearest 0.01mm.[26]

Carrying out meta-analysis based on data combination from linear measurements and/or percentage agreement is known to be quite challenging given the lack of complete and detailed clinical data on the deviation of the CBCT measurement from clinical intrasurgical measurement in the literature. Hence, due to this limitation, the current study could only perform a meta-analysis of the linear measurements of intrabony defects in clinical studies.

Implications for practice

This review demonstrated that the reporting criteria utilised for CBCT analysis needed to be carefully selected. Furthermore, for dental centres considering including CBCT as part of the management of periodontitis, consideration should be given to the following aspects: It is important to describe the CBCT imaging protocol used, the reporting expertise expected, and the imaging interpretation model utilized following the acquisition of the CBCT to ensure that the test is as robust as possible.

The result of this study can potentially be used to develop a new protocol or guideline for the indication of CBCT in the management of deep intrabony and furcation defects. Also, one study showed that by using CBCT, treatment costs and time can be reduced, but this is only justified when more invasive treatment choices such as periodontal surgery are planned.[42]

Thus, employing this radiographic tool for treatment planning in selected cases may avoid redundant surgical interventions and usage of CBCT.

Implications for research

There is a clear need for good quality, larger scale prospective studies of CBCT in patients with clinical testing in confirming periodontitis. Considering the knowledge gaps identified in this review, future research efforts should be directed primarily towards randomised controlled trial design to increase the quality of the study.

These methodological additions are expected to provide the scientific community with critical information to gain better insight and understanding of the use of CBCT in the field of periodontology. Accordingly, this will be of great value to develop cost-effective and predictable clinical protocols in the future.

CONCLUSION.

Presently, clinical research is limited regarding the quantitative linear measurement of periodontal intrabony and furcation defects by CBCT. In the present study, CBCT and clinical intrasurgical measurement assessment of intrabony and furcation defects were found to be in substantial agreement.

Therefore, based on the descriptive and quantitative summaries of the overall results, it can be concluded that CBCT is highly accurate and reproducible in linear measurements for assessing intrabony defects with the weighted standardised mean difference by 0.03mm. However, it should be noted that meta-analyses of a small number of studies do not always predict the outcome of a more significant number of studies.

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