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 $\chi^2$ 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 $\chi^2$ 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.
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. A recent systematic review has shown that periodontitis is highly prevalent, with approximately 10% of the global population affected by advanced periodontitis. 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. 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.

Furthermore, dental radiographs are used as an adjunct diagnostic method for the management of periodontal patient. 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. 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). 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.

Currently, two-dimensional planar images from intraoral 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. 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. 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. 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. 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.

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.

To date, there have been three systematic review articles discussing the role of CBCT in periodontitis. The first article, by Walter et al., 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., 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.
Subsequently, Anter et al.,\textsuperscript{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.\textsuperscript{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”.\textsuperscript{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.\textsuperscript{19} 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: “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)?”

\textbf{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.

\textbf{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.

\textbf{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 built on the original QUADAS tool 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. 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, 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 (Appendix 2).

Among the included publications, three publications were in vitro studies 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.
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.

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. (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 $\chi^2$ 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.
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.

| Authors          | Year | Weight | S.M.D. [95% CI]          |
|------------------|------|--------|--------------------------|
| Grimard et al.   | 2009 | 9.59%  | -0.50 [-2.56, 1.56]      |
| Pahtwa et al.    | 2009 | 75.37% | 0.07 [-0.66, 0.80]       |
| Banodkar et al.  | 2015 | 8.72%  | 0.02 [-2.14, 2.18]       |
| Li et al.        | 2015 | 6.32%  | -0.63 [-3.16, 1.90]      |

Summary Estimate
Heterogeneity: $\chi^2 = 0.4898, df = 3, \ p = 0.9211, p = 0.01%$
Test for overall effect: $Z = 0.1024, \ p = 0.9184$

Figure 4. Funnel plot of accuracy of CBCT for assessing intrabony defects
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           | 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. 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. |
| Vandenberghe et al., 35 2008    | 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 (lack of visibility, poor visibility, medium visibility, good visibility), linear bone measurements, intrabony craters, and furcation defects detection. Measurement of alveolar bone loss | |
| Takeshita et al., 19 2008      | 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 | | 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 semiconductor sensor (CMOS), panoramic radiography, and CBCT in the measurement of alveolar bone loss.

Grimald et al., 38 2009 To compare the measurements from digital introral radiographs and CBVT images to direct surgical measurements for the evaluation of regenerative treatment outcomes.

Walter et al., 27 2010 To assess the accuracy of cone beam computed tomography (CBCT) in detecting furcation involvement in maxillary molars.

Raichur et al., 36 2012 To compare the linear measurements of radiovisiography and digital volume tomo-graphy (DVT) to direct surgical measurements in the detection of periodontal infrabony defects.

Pahwa et al., 20 2014 To compare the diagnostic values of radiovisiograph and computed tomography images in comparison with direct surgical measurements for the determination of periodontal bone loss.

Qiao et al., 26 2014 To investigate the

**Human, in vivo study, randomized, controlled clinical trial of 29 patients with 35 periodontal defects**

**CBCT system:** 3DX Accuitomo 60  
**Tube voltage:** unstated  
**Filament current:** unstated  
**Acquisition time:** 18 s  
**Voxel size:** unstated

**Bone defect fill and bone defect resolution**

**Human, in vivo study, comprised of 14 patients 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)**

**Human, in vivo study, comprised of 7 patients with 28 sites of infrabony 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**

**Human, in vivo study, comprised of 15 patients 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 component was measured by subtracting (CEJ-AC) from (CEJ-BD).**

**Human, in vivo study, comprised of 15 patients with 31 sites of vertical defects**

**CBCT system:** 3D Accuitomo 60  

**The degree of furcation involvement, horizontal**

**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 surgical findings, 14.7% were underestimated, and 1.3% overestimated compared with intra-surgical findings. The measurement error was not mentioned in this article; manual calcula- tion was done resulted mean 3D measurement error for CEJ-AC = 0.16 and CEJ-BD = 0.06**

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

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Accuracy of dental CBCT in assessing FI in maxillary molars.

Banodkar et al., 2015. To evaluate the accuracy of CBCT measurements of alveolar bone defects.

Li et al., 2015. To explore the relationship between CBCT measurement and direct measurements during the surgery to correct intrabony defects.

Pajnigara et al., 2016. To evaluate the dimensions of furcation defects clinically (pre- and post-surgery), intrasurgically, and by CBCT (pre- and post-surgery).

**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 |
|-------|--------------|------------------------|
| Misch et al., 2006 | - | + | + | - | - | + |
| Vandenbergh et al., 2008 | - | + | + | - | - | + |
| Takeshita et al., 2014 | - | ? | - | - | - | ? |
| Grimard et al., 2009 | ? | + | ? | + | + | + |
| Walter et al., 2010 | ? | + | + | + | + | + |
| Raichur et al., 2012 | ? | - | ? | + | ? | ? |
| Pahwa et al., 2014 | ? | ? | + | + | ? | + |
| Qiao et al., 2014 | + | + | + | + | + | + |
| Li et al., 2015 | + | + | + | + | + | + |
| Banodkar et al., 2015 | ? | + | ? | + | ? | + |
| Pajnigara et al., 2016 | + | ? | ? | + | + | + |

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

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.
**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. The current study identified 11 studies that compared the measurement between CBCT and the clinical intrasurgical measurement or artificial osseous defect.

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 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.

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.

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.

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., 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,
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.\textsuperscript{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.\textsuperscript{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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