Review Article

Accuracy and precision of cone beam computed tomography in periodontal defects measurement (systematic review)

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Abstract:

Systematic review of literature was made to assess the extent of accuracy of cone beam computed tomography (CBCT) as a tool for measurement of alveolar bone loss in periodontal defect. A systematic search of PubMed electronic database and a hand search of open access journals (from 2000 to 2015) yielded abstracts that were potentially relevant. The original articles were then retrieved and their references were hand searched for possible missing articles. Only articles that met the selection criteria were included and criticized. The initial screening revealed 47 potentially relevant articles, of which only 14 have met the selection criteria; their CBCT average measurements error ranged from 0.19 mm to 1.27 mm; however, no valid meta-analysis could be made due to the high heterogeneity between the included studies. Under the limitation of the number and strength of the available studies, we concluded that CBCT provides an assessment of alveolar bone loss in periodontal defect with a minimum reported mean measurements error of 0.19 ± 0.11 mm and a maximum reported mean measurements error of 1.27 ± 1.43 mm, and there is no agreement between the studies regarding the direction of the deviation whether over or underestimation. However, we should emphasize that the evidence to this data is not strong.

Key words:

Accuracy, alveolar bone loss, cone beam computed tomography, review

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INTRODUCTION

Alveolar bone loss in periodontal defects is a common dental problem. Accurate assessment of the true extension of the periodontal defect is essential for proper formulation of a suitable treatment plan; dental radiographs are a valuable noninvasive tool used as an adjunct to clinical examination for assessment of the periodontal conditions of the teeth.[1]

Periapical and bitewing radiographs are the most commonly used radiographic techniques in assessment of the periodontium of the teeth; however, unfortunately, these techniques provide two-dimensional (2D) images lacking any information about the third dimension which hinders a true distinction between buccal and lingual cortical plates and complicates the evaluation of the periodontal defects.[2,3]

Due to this drawback, there was a need for a more accurate imaging technique to be used in assessment of periodontal conditions, with special regards to the imaging of the three-dimensional (3D) structures such as infra-bony defects, buccal and lingual cortical plates, and furcation involvement. All that drew the attention to the use of computed tomography (CT) in diagnosing periodontal problems, and it yielded good results, but unfortunately, other important factors such as cost, accessibility, and radiation dose prevent its routine use in dental clinics.[4,5]

Cone beam CT (CBCT) has recently emerged in the dental field providing another 3D alternative to medical CT. It has the great advantage of a much more reduced radiation dose which favors its use for dental and maxillofacial structures imaging, and it also provides variable fields of view; therefore, an optimum field of view (FOV) can be selected for each patient based on the task,

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for which CBCT is used and the region of interest. Moreover, it provides a submillimeter isotropic voxel resolution which allow the nonorthogonal sectioning of the obtained data sets, for that it can be used as a supplementary imaging technique in situations where traditional 2D techniques are unable to provide sufficient reliable information for periodontal assessment and treatment.[6]

To our knowledge, there have been only four review articles (and not systematic reviews) discussing the role of CBCT in diagnosis of periodontal diseases. The first was performed by Mohan *et al*., and it discussed the principles and evolution of CBCT, the differences between it and medical CT, and its advantages and limitations, and finally, its application as a diagnostic tool in periodontology and implant site assessment. They concluded that "the merits of CBCT made it as a natural fit in periodontal imaging."[7]

Furthermore, du Bois *et al*. have reviewed the imaging modalities used in diagnosis of periodontal problems including conventional and digital periapical radiographs with their limitations, panoramic radiographs, conventional CT, and finally, CBCT. They also discussed the use of CBCT in assessment of periodontal defects, furcation involvement, and periodontal regeneration, and they noted that "unless there is a sound clinical indication, CBCT should not be routinely used for assessment of periodontal problems."[8]

Aljehani has reviewed the use of CBCT in periodontal diseases diagnosis. He addressed its use in: (1) Diagnosing furcation involvement, craters, and bony defects, (2) measuring periodontal bone levels, (3) visualization of periodontal ligament space, and (4) other periodontal applications such as detection of apical periodontitis and periapical pathology. He concluded that "the CBCT does not offer a significant advantage over conventional radiography in assessment of alveolar bone loss."[9]

Acar and Kamburoglu have discussed the CBCT merits and limitations and its role in diagnosing periodontal conditions such as furcation involvement, periodontal ligament space, alveolar bone defects, soft-tissue assessment, and outcomes of regenerative periodontal therapy and bone graft. Finally, they concluded that "CBCT has obvious benefits in periodontology, but its use should be kept only when necessary to avoid radiation hazards."[10]

The question of this research is how much accuracy could be provided by CBCT in measurements of alveolar bone loss in periodontal defects?

MATERIALS AND METHODS

PubMed database was searched (from 2000 to 2015) to find potentially relevant articles for this review. On searching, we used two methods; the first by utilizing Medical Subject Headings search, in which we used the terms "cone beam computed tomography" and "alveolar bone loss," and the second method by using the standard keywords ("cone beam computed tomography" or "CBCT" or "digital volume tomography"') and "alveolar bone loss" or "periodontal defects," and then the results from the first and second search methods were combined and duplicates removed. Hand search of open access journals resulted in addition of two more articles: One from the Egyptian Journal of Oral and Maxillofacial Surgery and the other from the Egyptian Dental Journal [Table 1]. The last electronic search was made on April 14th 2015.

The potentially relevant articles that were found using aforementioned search strategy were first screened by titles and irrelevant titles were excluded, then the remaining articles were considered for abstract evaluation based on the following inclusion criteria:

(1) The study should be a primary article not a review. (2) It should examine the CBCT accuracy in measuring the amount of alveolar bone loss in the periodontal defect by comparing CBCT measurements with the gold standard (GS) measurements of the defects (whether they were naturally occurring or artificially made). (3) Clinical studies and *in vitro* studies are included. (4) The study should examine accuracy of CBCT in assessment of periodontal not peri-implant defects as implants could affect the accuracy of measurements by introducing some sort of artifact due to its metallic nature, and that may affect the results and need to be examined as a separate problem.[11] (5) The study should be in English.

If the title and abstract of an article did not provide sufficient information regarding the inclusion criteria to make a decision, the full text was obtained and examined. Further hand search was made including the bibliographies of all articles selected for full-text screening but it was not yielding.

For assessing the risk of bias both at study level and at outcome level and to ascertain the validity of the individual studies to be included in this review, we have used a checklist for assessing a diagnostic or predictive test developed by Leake[12] after modification. This was performed by two reviewers independently; finally, disagreements were resolved by discussion between the two reviewers; if no agreement could be reached, it was planned that a third author would decide. The following are the questions included in the checklist:

1. Was there a clear question for the study to address?
2. Did the study include different common presentations of the target disorder?
3. Were the exclusion and inclusion criteria mentioned?
4. Was the sample size sufficient?
5. Was the test clearly described?
6. Did the test report the technical parameters that may influence the results?
7. Was the test evaluated in a valid clinical setting?

Table 1: The search strategy developed using PubMed database

Search	Query	Items found
Number 1	Cone beam computed tomography (MeSH)	3853
Number 2	Alveolar bone loss (MeSH)	7781
Number 3	Number 1 and 2	112
Number 4	"Cone beam computed tomography" or "digital volume tomography"	7543
Number 5	Number 4 and periodontal defects	53
Number 6	Number 4 and alveolar bone loss	169
Number 7	Number 5 or 6	195

MeSH – Medical Subject Headings

8. Was the test measured against a valid GS?
9. Were the people assessing the results of the index diagnostic test blinded to the results of the reference standard?
10. Did the study describe the number and/or training and expertise of the persons executing and reading the index tests and the reference standard?
11. Did the results of the study clearly present the method error (minimally the mean and standard deviation values) of the index test compared to the GS?

RESULTS

The results of this search strategy are summarized in a flow diagram [Figure 1]. An electronic literature search revealed 195 articles from the PubMed database, of which 150 articles were excluded at the title stage and the remaining 45 studies full articles together with two articles obtained from hand searching were examined for the presence of the inclusion criteria. Only 14 articles were found fulfilling all the inclusion criteria and were included in the present analysis; they were published in a period ranging from 2005 to 2015.

Meanwhile, 33 articles were excluded for missing one or more of the inclusion criteria as four articles were not primary articles,[7-10] three studies were in Chinese language,[13-15] eight studies were assessing peri-implant not periodontal defects,[16-23] sixteen studies were excluded because there was no comparison between CBCT and GS measurements of the defects,[23-39] and one study was excluded because the measurements were not made on periodontal defects but alveolar bone from alveolar crest (AC) to a marker anywhere on the alveolar bone.[40]

The data extraction from the 14 included studies were made [Table 2]. Then, these studies were criticized for risk of bias assessment and scored using the previously mentioned checklist [Table 3]. We have to mention that on appraising the sample size of the studies, if it was not determined and justified by a prior power analysis, we did a *post hoc* power analysis based on the primary outcome to evaluate it. Finally, the results of the criticism revealed that only two studies scored <50%, for that it was planned to include these studies only in the qualitative analysis while when it comes to the meta-analysis, they should be excluded to avoid bias in the results; however, at the end, we found that no meta-analysis for the collected data could be made due to the lack of complete and detailed statistical presentation of the deviation of the CBCT measurements from GS in most of the articles [Table 3].

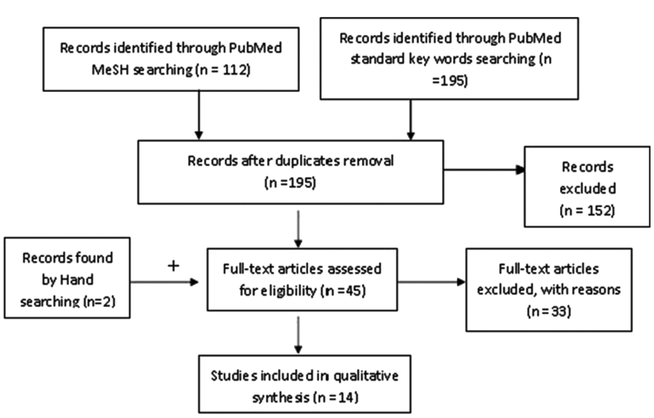

Figure 1: A flow diagram for the search strategy results

On analyzing the data pooled from the studies included in this review, we have seen that they addressed the accuracy of CBCT in assessment of different types of periodontal defects as the study by Grimard *et al*. was made on vertical periodontal defects,[41] where the measurements were taken once at the initial surgery and once at the reentry surgery while Feijo *et al*. made their study on horizontal periodontal defects.[42]

Three studies have used CBCT in assessment of dehiscence, first of which was by Mengel *et al*. who assessed both the height and width of the dehiscence and they found that the average deviation from the "GS" measurements of the height of the dehiscence was 0.28 ± 0.20 mm, and for width it was 0.21 ± 0.15 mm.[43] Further, Ising *et al*. have assessed the height of the dehiscence defects,[44] whereas Leung *et al*. did not make any measurements on the dehiscence; they only reported the specificity and sensitivity of CBCT in detecting it with no measurements.[45]

In assessment of fenestration, two studies were found; the first was by Mengel *et al*. who found that the average deviation from the GS measurements of the height of the fenestration was 0.29 ± 0.21 mm, and for width, it was 0.05 ± 0.03[43] while the second was by Leung *et al*., but they did not report in their article the amount of deviation of CBCT measurements of fenestration from the GS.[45]

Vandenberghe *et al*. addressed the accuracy of CBCT in assessment of bony and/or infra-bony craters; they also examined the accuracy of CBCT in classifying furcation involvement and the topography of the craters.[46] Meanwhile, eight studies did not determine the type of the defects they assessed and only reported that they assessed the height of the defects whether naturally present or artificially made from the cementoenamel junction (CEJ) to the AC.[47-54]

There was no agreement between the included studies in the direction of the deviation (whether over or under estimation) as five studies reported that there was more tendency for underestimation; of them, three studies did not mention the percentage of which[41,45,49] while the other two studies did as Vandenberghe *et al*. reported a 53% underestimation[46] while El Zoheiry *et al*. reported 89% and 97% underestimation depending on the type of CBCT images used.[50] However, two studies reported a higher tendency for overestimation as Vandenberghe *et al*. reported a 52% and 63% overestimation depending on the type of CBCT images used[48] while Misch *et al*. did not mention the percentage of overestimation.[47] We can see that the same group of researchers who made two different studies in the same field has attained inconsistent results regarding the direction of the deviation. However, the remaining included seven studies ignored reporting the direction of the deviation.

DISCUSSION

In trying to find an answer for our research question, we found that the mean CBCT measurements error in the included studies ranged from 0.19 ± 0.11 mm.[43] to 1.27 ± 1.43 mm,[49]

Table 2: Summary of the findings of the articles included in the study

Authors, year, and aim of the study	Study design and sample size	Type of the measurement of the defects	The results
Mengel *et al*. 2005 To investigate the accuracy and quality of the assessment of periodontal defects by IO and panoramic radiography, CT, and DVT in comparison with histology	*In vitro* study, using 6 pigs and 7 human mandibles in them 56 periodontal defects were artificially made	Height from the defect base to the occlusal plan, width from mesial to distal edge of the bone, depth from the buccal to the lingual defect limit	The mean CBCT total measurement error was 0.19±0.11 mm
Misch *et al*. 2006 To compare CBCT measurements of periodontal defects to traditional methods (periapical radiographs and periodontal probe)	*In vitro* study, 2 dry human skulls and mandibles with artificially made 21 periodontal defects	Length from CEJ-BD Length from CEJ to the crest of bone adjacent to the defect Width of the defect	The mean CBCT measurements error was: 0.41 mm (±1.19 SD) for the height and 1 mm (±0.67 SD) for the width and both were not statistically significant
Vandenberghe *et al*. 2007 To compare 2D IO digital images with 3D CBCT in assessment of periodontal bone levels and defects	*In vitro* study, using a cadaver head and dry human skull with 30 periodontal defects	CEJ-AC distance and CEJ-BD distance	The average absolute CBCT measurement error was 0.45 mm ± (0.49 SD)
Vandenberghe *et al*. 2008 To explore the diagnostic value of digital IO radiography and CBCT in the determination of periodontal bone loss, infrabony craters, and furcation involvement	*In vitro* study on one dry human skull and one human cadaver head, with 71 periodontal defects	Bone levels (CEJ-AC) and bone crater depths	The average absolute CBCT measurement error of infra-bony defects for panoramic reconstructed view was 0.47 mm while for cross-sectional images, it was 0.29 mm
Mol and Balasundaram 2008 To assess the accuracy of NewTom 9000 CBCT images in detection and quantification of periodontal bone defects in 3D	*In vitro* study using 5 dry human skulls, on which 146 sites were assessed	Measurements were made from CEJ-AC	The average absolute CBCT measurements error was 1.27 mm ± (1.43 SD)
Grimard *et al*. 2009 To compare the measurements from digital IR and CBVT images to direct surgical measurements to evaluate regenerative treatment outcomes	Randomized controlled clinical trial study using 29 patients for them 35 periodontal defects examined	From CEJ or base of restoration (if found) to the alveolar crest AC, and to the BD at the initial and reentry surgeries	The mean errors of CBVT measurements: For CEJ-AC initially, it was −0.1±1.2 mm while for reentry 0.01±0.7, for initial CEJ-BD, it was −0.9±0.8 mm and for reentry, it was −0.5±1.1 mm
Leung *et al*. 2010 to evaluate the accuracy of CBCT in diagnosing naturally occurring fenestrations and bony dehiscences and measuring their height	*In vitro* study on 13 dry human skulls of which 334 teeth were examined	From the cusp tip or mid incisal tip to the BM, and from tip to the coronal and apical ends of the fenestration	Average absolute CBCT measurements error for T-BM was 0.6±0.8
El-Zoheiry *et al*. 2011 To explore the diagnostic value of CBCT in the assessment of periodontal bone loss	*In vitro* study on 4 human dry skulls with 148 defects	Bone levels from CEJ-AC	For panoramic reconstructed view, the average absolute measurements error was 0.27 mm while for cross-sectional images, it was 0.3 mm and both were not statistically significant
Ising *et al*. 2012 To validate the use of 3D SR images to quantify the height of alveolar dehiscences	*In vitro* study using 4 human cadaver skulls on them 24 dehiscence were artificially made	Dehiscence was measured from CEJ to its most apical part	The CBCT method error on 3D SR images was 0.45 mm whereas on 2D MP images, it was 0.41 mm, and there was no statistically significant difference between them
Raichur *et al*. 2012 To compare the linear measurements of radiovisiography, DVT, and direct surgical measurements in the detection of periodontal infrabony defect	Clinical study conducted on seven patients with a sample size of 28 sites was taken for the assessment	Measurements included CEJ-AC and CEJ-BD	The measurement error was not mentioned in this article; they only reported that there was not statistically significant difference at both CEJ-AC (*P*=0.6796) and CEJ-BD (*P*=0.8792)
Fleiner *et al*. 2012 Develop a new approach for radiographically measuring circumferential periodontal bone level using CBCT and assess its accuracy	*In vitro* study using a human dry skull, 72 measurements made on 12 teeth with periodontal defects	The vertical distances between CEJ and AC	Overall deviation between radiographic and clinical GS measurements ranged between 0.36 and 0.69 mm
Ferrare *et al*. 2013 To compare CBCT and micro-CT for alveolar bone measurements	*In vitro* study on 40 teeth and alveolar bone blocks of five pigs	Measurement of bone height (CEJ-AC)	The average absolute measurement error for (CEJ-AC) measurements was 0.3 mm, and it was statistically significant

Contd...

Table 2: Contd...

Authors, year, and aim of the study	Study design and sample size	Type of the measurement of the defects	The results
Takeshita *et al*. 2014 to evaluate the diagnostic accuracy of conventional periapical radiography, digital periapical radiography, panoramic radiography, and CBCT in the measurement of alveolar bone loss	*In vitro* study on 70 teeth in 10 humane mandibles	Measurement of bone height (CEJ-AC)	The CBCT measurement error was not clearly mentioned in this article; however, they reported that according to Tukey's test for multiple comparisons the means of CBCT versus GS measurements were not statistically significant with a mean difference of 0.07457, and *P* value of 0.9759

CBCT – Cone beam computed tomography; CT – Computed tomography; IO – Intraoral; 2D – Two-dimensional; 3D – Third-dimensional; IR – Intraoral radiographs; CBVT – Cone-beam volumetric tomography; SR – Surface rendering; DVT – Digital volume tomography; CEJ-AC – Cementoenamel junction to the alveolar crest; CEJ-BD – Cemento-enamel junction to base of the defect; BM – Bone margin; GS – Gold standards; MP – Multiplanar

Table 3: Checklist scoring and critical appraisal notes of the included articles

The study authors and score	Critical appraisal notes
Mengel *et al*. 2005 (6/11)	Only mandibular defects that were assessed *In vitro* test with no soft tissue simulation The test did not report the number of observers They did not report all the technical parameters of the CBCT scanning It was not mentioned if the observers were blinded to the GS results or not
Misch *et al*. 2006 (9/11)	Periodontal defects were simulated in mandibular premolars-molars area only *In vitro* test with no soft tissue simulation
Vandenberghe *et al*. 2007 (9/11)	The selection criteria of the naturally occurring periodontal defects not mentioned It was not mentioned if the observers were blinded to the GS results or not
Vandenberghe *et al*. 2008 (8/11)	The selection criteria for the naturally occurring periodontal defects not mentioned The results are not correctly represented Depending on the last point, the power analysis for sample size could not be computed
Mol and Balasundaram 2008 (10/11)	The exposure parameters of the CBCT were not mentioned except for the voxel size
Grimard *et al*. 2009 (9/11)	The GS measurements were rounded up to the nearest mm which affects its precession The exposure parameters of the CBCT were not mentioned
Leung *et al*. 2010 (8/11)	*In vitro* test with no soft-tissue simulation It was not mentioned if the observer was blinded to the GS results The results were not completely presented
El-Zoheiry *et al*. 2011 (6/11)	*In vitro* test with no soft-tissue simulation The selection criteria for the skulls and naturally occurring periodontal defects were not mentioned It was not mentioned if the observers were blinded to the GS results or not The results are not properly presented Depending on the last-mentioned point, the power analysis for sample size could not be computed
Ising *et al*. 2012 (7/11)	Not presenting all teeth locations The exposure parameters of the CBCT were not mentioned except for the FOV and voxel size It was not mentioned if the observers were blinded to the GS results or not Sample size was insufficient according to *post hoc* power analysis giving a power of 50%
Raichur *et al*. 2012 (6/11)	It was not clear if the defects in the study were in different sites of the jaws or not The GS measurements were rounded up to the nearest mm which affects its precession It was not mentioned if the observer was blinded to the GS results or not The study did not mention the number or the expertise of the observer The results were not properly presented
Fleiner *et al*. 2012 (7/11)	*In vitro* test with no soft-tissue simulation GS measurements were rounded up to the nearest mm its precession The results were not properly represented Depending on the last point, the power analysis for sample size could not be computed
Feijo *et al*. 2012 (5/11)	Only maxillary molars defects were examined in this study The exposure parameters of CBCT scans were not mentioned except for the voxel size GS measurements were rounded up to the nearest mm which affects its precession It was not mentioned if the observer was blinded to the GS results or not The results were not properly represented Depending on the last point, the power analysis for sample size could not be computed
Ferrare *et al*. 2013 (8/11)	It was not mentioned if the observers were blinded to the GS results or not The results were not properly represented Depending on the last point, the power analysis for sample size could not be computed
Takeshita *et al*. 2014 (5/11)	Defects on mandibular teeth only were examined in this study No selection criteria were mentioned It was not clear where exactly the measurements were made interproximal, was it buccal or lingual? *In vitro* test with no information mentioned about soft-tissue simulation It was not mentioned if the observer was blinded to the GS results or not The results were not properly presented

GS – Gold standard; CBCT – Cone beam computed tomography; FOV – Fields of view with the later exceeding the 0.5 mm value which is considered the clinically acceptable discrepancy in measurements.[2,3]

However, in the included studies, we tried to highlight, analyze, and compare the factors which were considered variables that may have an impact on the CBCT accuracy in assessment of periodontal defects, and we found that the reported accuracy of CBCT measurements is definitely dependent on the accuracy of the GS measurements as lack of accuracy in the GS will generate a bias in the results. We considered that for the GS to be valid, it should be recorded using a tool which provides measurements with submillimeter accuracy. Accordingly, we considered that GS recorded with a digital caliper directly on the defect in eight studies is a valid one.[44-50,54]

Moreover, two other different tools with submillimeter accuracy were used for GS measurements, the first was a reflecting stereomicroscope with measuring ocular tool and it was used by Mengel *et al*.;[43] the accuracy of this tool had been examined, especially for dental research purposes, and it was proved to be accurate with a high precession.[55,56] The second tool was micro-CT which was used by Ferrare *et al*.,[51] but being another imaging modality, it has its own error and deviation from the real measurements, as when examined by Kim *et al*., they found an error of 0.22 ± 0.635 mm.[57]

Meanwhile, the remaining four studies have utilized the manual periodontal probe with an accuracy of 1 mm to assess the GS measurements of the periodontal defects which were rounded up to the nearest millimeter.[41,42,52,53] The usage of both micro-CT and manual periodontal probe as a tool for GS measurements could introduce a bias in the results.

We also found that of the 14 selected studies, only three *in vivo* studies were found,[41,42,52] of them only the first one was a randomized clinical trial. While the greatest number of the studies was *in vitro* ones that were done in a more controlled environment under almost idealized conditions. For instance five studies of them used dry skulls and mandibles with no soft tissue simulation,[45,47,50,51,53] and eight studies utilized radio-opaque markers (Gutta-percha fragments or metallic balls) to facilitate identification of the CEJ.[43,44,46-50,54] And these could not be considered as valid clinical settings, for-that the reproducibility of the results of these studies is questionable and need to be assessed *in vivo* adequately, which could represent an inherent weakness of evidence.

Another factor that could have an impact on the accuracy of CBCT in measurements of periodontal defects is the tooth location, and we found two of the included studies were discussing this factor. The first was conducted by Mol and Balasundaram who found that the highest deviation from the GS measurements was at the lower anterior teeth with an average absolute error of 1.95 ± 1.89 mm which was significantly larger than for other teeth groups, whereas the lowest deviation was at the upper premolars teeth with an average absolute error of 0.91 ± 0.75 mm.[49]

The second study was by Ising *et al*. who found that the lowest average error was 0.33 mm for the incisors, and the highest average error was 0.74 mm for the premolars while for the canines, it was 0.62 mm; however, there was no statistically significant difference between them.[44] We can see that the results of the two studies are inconsistent; however, on revising the scoring and critical appraisal notes of both, we found that the sample size in the second study was not sufficient.

Not only the difference in tooth location but also the difference in surface location on the tooth could impact the reported accuracy of CBCT measurements as study by Feijo *et al*. compared the measurements error between mesial and distal aspects of the involved teeth; they were 0.75 ± 0.59 mm and 1.14 ± 0.88 mm, respectively, and the difference between them was not statistically significant ($P = 0.063$) while when they compared the measurements error between palatal and vestibular aspects for the same teeth, they found a statistically significant difference ($P = 0.008$) as the errors were 1.29 ± 1.04 mm and 0.58 ± 0.39 mm, respectively,[42] and that coincides with the results of Fleiner *et al*. who reported that there was a tendency toward better results of vestibular measurement sites compared to lingual or palatal sites.[53]

Three studies have been found comparing the accuracy of the CBCT measurements of the periodontal defects on different CBCT image types. The first was performed by Vandenberghe *et al*. who used panoramic reconstructed view with a default slice thickness of 5.2 mm and cross-sectional slices of 0.4 mm thickness, and the authors concluded that the cross-sectional images provide more accurate assessment of periodontal bone loss,[46] also El Zoheiry *et al*. utilized panoramic reconstructed view with slice thickness of 5.1 mm and cross-sectional slices of 0.32 mm, and they had the same conclusion as that of the previously mentioned study.[50]

Finally, Ising *et al*. compared the accuracy of CBCT measurements of periodontal defects on 3D surface rendering images and 2D multiplanar reformatted images and they found that the difference between them was not statistically significant; the authors concluded that both image types have a similar level of accuracy in assessment of periodontal dehiscence.[44]

Now after discussing the factors that were considered variables impacting the reported accuracy of CBCT in measurements of alveolar bone level, and on trial to link our search results with the clinical situations, we have to clarify the nonmentioned aspects about CBCT. As despite of its great merits, CBCT still suffer from some limitations; the most important one is the higher radiation dose it provides compared to the other radiographic techniques such as digital and conventional periapical and panoramic radiographs used in alveolar bone loss measurements.[6,58]

The effective dose from single intraoral radiography ranged from one to 20 μSv depending on the film/digital sensors used, collimation, focus skin distance, and tube voltage[59-61] while the effective doses reported in panoramic radiography were ranged from 4 to 30 μSv.[61,62] Whereas, for dental CBCT, the effective dose varied widely among the machines and depending on the size of the FOV used; however, when a limited FOV is used, the effective dose could be <100 μSv.[58,60]

Depending on the previously mentioned facts and obeying as low as reasonably achievable concept, the CBCT should be the technique of choice only when it provide an important information that could not be supplied by other radiographic technique with a lower radiation dose, and this what was concluded by the previously made four review articles discussing role of CBCT in periodontology.[7-10] However, our review was a focused one aiming only to identify the degree of accuracy of CBCT in measurement of alveolar bone loss in periodontal defects. And answering this search question requires a valid meta-analysis for the data pooled from the studies discussing this point.

Unfortunately, many obstacles have been found on our trial to make a meta-analysis for the collected data, first of which is the statistical presentation of the results. As the descriptive analysis for numerical values such as method errors should include the minimum, maximum, mean, and standard deviation of the value, together with the precise *P* value,[63] and this was not present in most of the papers. In addition, almost one-half of included studies did not report whether their CBCT measurements errors were statistically significant or not, anyway the other half reported that they were not statistically significant.

Another great obstacle is the high heterogeneity between the studies which could be due to the difference between them in their purposes; hence, there were differences in the technical parameters used such as the voxel sizes of the scans, the type of the CBCT machine, and type of CBCT images used for measurements; there were also differences in the qualifications and the numbers of the observers who interpreted the radiographic data in the different studies. Another important point could be considered a source of heterogeneity is the inclusion of both *in vivo* and *in vitro* studies in our work due to the scarcity of articles discussing our search point.

Since no valid meta-analysis could be made, we could not reach a strong evidence-based answer for our search question. All we could reach is a wide range of the reported CBCT measurements error with its lower limit indicating very high accuracy of CBCT and encouraging its use when high precession in assessment of alveolar bone loss is needed, while the upper limit of this range indicating inadequate precession and accuracy based on what was considered by Mol 2004 and Brägger 2005 as a clinically acceptable discrepancy in measurements for alveolar bone loss assessment.

CONCLUSIONS

Under the limitation of the number and strength of the available studies, we can conclude that CBCT provides an assessment of alveolar bone loss in periodontal defect with a minimum reported mean measurements error of 0.19 ± 0.11 mm and maximum reported mean measurements error of 1.27 ± 1.43 mm, and there is no agreement between the studies regarding the direction of the deviation whether over- or under-estimation. However, we should emphasize that the evidence to this data is not strong. For that, we have no recommendation regarding the usefulness of CBCT in assessment of alveolar bone loss when high precession is needed, the only recommendations we have are that:

- More clinical studies are required to establish the precession of the CBCT in assessment of alveolar bone loss in periodontal defects
- The future studies should properly present their results with complete information on the minimum, maximum, mean, and standard deviation values of the measurement error and the precise *P* value, to facilitate the data pooling in a valid meta-analysis which could help other researchers to establish strong evidence.

Finally, we want to declare that there was no conflict of interest for any of the authors of this article.

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Conflicts of interest

There are no conflicts of interest.

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