Assessment of alveolar bone level and furcation involvement in periodontal diseases using dental cone-beam computed tomography (CBCT): a systematic review

The advent of CBCT has contributed significantly to dental imaging. In the field of periodontics, CBCT provides a multi-planar view to assess the alveolar bone in three dimensions. This helps the dentist to make measurements at any location that could significantly improve periodontal diagnosis.

Objective: The aim of this systematic review is to evaluate the accuracy of using CBCT in the assessment of alveolar bone level and furcation involvement in periodontal diseases.

Material and Methods: PubMed, LILACS and Google Scholar databases were searched for literature related to the application of CBCT in periodontal diseases. Keywords used for the search were CBCT, furcation involvement, measurement and their synonyms.

Results: Fifteen full-text English language research papers were eligible for the systematic review using the PRISMA guidelines. Conclusion: From the results of the systematic review it can be concluded that cone-beam computed tomography imaging technique offers significantly reliable images of the furcation involvement and height of the alveolar bone.

KEYWORDS
Cone Beam Computed tomography, furcation defects, alveolar bone loss

RESUMO
O advento da Tomografia computadorizada de feixe cônico (TCFC) contribuiu significativamente para a imageologia. No campo da periodontia, a TCFC fornece uma visão multiplano para avaliar o osso alveolar em três dimensões. Isso ajuda o dentista a fazer medições em qualquer local que possa melhorar significativamente o diagnóstico periodontal. Objetivo: O objetivo desta revisão sistemática foi avaliar a precisão do uso da TCFC na avaliação do nível ósseo alveolar e do envolvimento da furca em doenças periodontais. Material e Métodos: As bases de dados PubMed, LILACS e Google Scholar foram pesquisadas na literatura relacionada à aplicação da TCFC em doenças periodontais. As palavras-chave utilizadas para a pesquisa foram TCFC, envolvimento da furca, mensuração e seus sinônimos. Resultados: Quinze trabalhos de pesquisa em inglês com texto completo foram elegíveis para a revisão sistemática usando as diretrizes do PRISMA. Conclusão: A partir dos resultados da revisão sistemática, pode-se concluir que a técnica de imagem por tomografia computadorizada de feixe cônico oferece imagens significativamente confiáveis do envolvimento da furca e da altura do osso alveolar.

PALAVRAS-CHAVE
Tomografia computadorizada de feixe côncico; Defeitos de furca; Perda óssea alveolar.
INTRODUCTION

Periodontitis is the most commonly occurring oral disease characterized by alveolar decrease in alveolar bone height [1]. Assessment of the residual alveolar bone prior to periodontal therapy provides accurate information about the hard tissue morphology leading to a more precise formulation of treatment plan [2]. Radiography plays a vital role in diagnosis of periodontal disease since they reveal the hard tissue morphology, which is a key indicator of periodontal disease [3,4]. Conventionally periapical and panoramic radiographs were used to assess the periodontal hard tissue status with practically no or limited insight into buccal and lingual alveolar bone morphology [5]. The introduction of cone beam computed tomography (CBCT) into the field of dentistry aided in overcoming the limitations of conventional imaging [6]. The main advantage of CBCT is its ability to eliminate image distortions and provide effective visualization of the anatomical structures in in all three orthogonal planes [7,8].

Recently, few clinical studies have been conducted using CBCT for determining the extent of periodontal hard tissue destruction have demonstrated positive results [9]. However a comprehensive review of such studies, taking into consideration factors such as diagnostic accuracy and precision was required. With this background a systematic review was conducted to evaluate the literature involving estimation of bony changes in periodontal disease using CBCT. The aim of our study review was to evaluate the results of clinical studies comparing CBCT based measurements of furcation dimensions with intra-surgical measurements.

MATERIALS AND METHODS

The end search date was 2nd June, 2019 across the databases. The selection process was conducted in two phases. In first phase, titles and abstracts from the selected electronic databases were reviewed by 2 authors.

Inclusion criteria

Clinical observational studies were included. Studies comparing CBCT measurements with the intra-surgical measurements of the periodontal bony defect and furcation involvement were included for the review. Clinical in vivo human studies published in English language was one of the criteria for the inclusion in systematic review.
Articles not full filling the inclusion criteria were excluded from the review. In phase 2, the full text articles obtained after filtering in phase 1 were evaluated by the same reviewers. In case of a disagreement in the selection process between the two reviewers, a third author was called in to reach a consensus. Details regarding authors, year of publication, sample size, number of examiners, type of evaluation method, type of periodontal parameter, and results were evaluated. In case of any relevant missing information the authors of the paper were contacted using email and the information was obtained.

**Exclusion criteria**

Studies published in any language other than English were not considered. Reviews, case reports, retrospective studies, letters and personal opinions pertaining to the topic were excluded from the systematic review. Studies that used other imaging techniques such as intraoral radiographs, panoramic radiograph and bitewing radiographs were not included in the review. Studies that did not compare the measurements from CBCT reconstruction to the reference standard were also not considered for the study. CBCT studies involving osseous healing after periodontal surgery, cleft palate repair, reconstructive osseous surgery and cleft palate surgery were not included in the study. CBCT studies involving the evaluation of alveolar bone in peri-implant region and orthodontics were not included in the study. The review did not involve studies carried out on CBCT evaluation of alveolar bone level in animals.

To evaluate the risk of bias at study level and at the outcome level as well as to determine the validity of the individual studies we have employed a checklist for assessing the studies used by Anter E et al. in their systematic review [11]. The checklist used in our study covered several aspects such as clarity of research question, definition of inclusion and exclusion criteria, adequacy of sample size, validity of clinical setting, adequacy of methods to eradicate bias.

**RESULTS**

The highlights of the search technique are mentioned in the flowchart. (Figure 1)
Table II – Descriptive data of the eligible articles after initial identification and screening procedures

<table>
<thead>
<tr>
<th>Authors and year</th>
<th>Sample size and sites</th>
<th>Number of observers</th>
<th>Clinical measurement tool</th>
<th>Periodontal parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pour GD et al. 2015 (12)</td>
<td>30 patients</td>
<td>Singles examiner</td>
<td>Measurements done using a periodontal probe during the surgery</td>
<td>Alveolar bone</td>
<td>In the buccal, lingual/palatal, mesial and distal surfaces, no significant difference was observed between the values obtained using CBCT and the surgical method.</td>
</tr>
<tr>
<td>Giao J et al. 2015 (13)</td>
<td>15 patients 20 sites</td>
<td>2 examiners at 1 week interval</td>
<td>CAL measured using periodontal probe graded in millimetres (Po-PUNC-T; HU-Friedy, Chicago, IL, USA), Nabers probe marked at 3 mm intervals (PQ2N; HU-Friedy).</td>
<td>Furcation involvement</td>
<td>Intra-surgical findings confirmed 82.4% of the CBCT data.</td>
</tr>
<tr>
<td>Cimbaljevic MM et al. 2015 (14)</td>
<td>15 patients 174 sites</td>
<td>One examiner evaluated the scan twice within a gap of 4 weeks</td>
<td>Evaluation of the furcation performed using a Nabers probe (PQ2N, HU-Friedy)</td>
<td>Furcation involvement</td>
<td>FI were more often detected by means of CBCT than by means of clinical examination. Agreement between the evaluation methods was present in 46.9% of cases (63.3% in maxilla, 40.5% in mandible). FI detected clinically was confirmed by means of CBCT in 24% of the evaluated sites.</td>
</tr>
<tr>
<td>Krandi et al. 2015 (15)</td>
<td>17 patients 96 furcation sites</td>
<td>Single examiner</td>
<td>Clinical measurements carried out using Nabers probe marked at 3mm intervals (H-U-Friedy)</td>
<td>Furcation involvement</td>
<td>FI was observed in all 96 furcation entrances clinically, while a Friedman I–II furcation was found in 75 sites according to the CBCT. Overall, only 29% of the clinical findings were confirmed in the CBCT, while 30.2% were overestimated and 41.7% revealed an underestimation.</td>
</tr>
<tr>
<td>Guo YJ et al. 2016 (16)</td>
<td>6 patients, 150 sites</td>
<td>4</td>
<td>A manual periodontal probe (UNC-15; HU-Friedy, Chicago, IL) graded in millimetres was used</td>
<td>Alveolar bone loss</td>
<td>No statistically significant difference was found between the surgical and CBCT measurements (p = 0.84).</td>
</tr>
<tr>
<td>Zhu J et al. 2016 (17)</td>
<td>11 patients 39 sites</td>
<td>All images were analysed twice by the same person, with a time interval of more than 1 week on the same monitor under standard conditions.</td>
<td>Nabers probe</td>
<td>Furcation involvement</td>
<td>The parameters and related methods of measurements proposed in the study showed high reproducibility. CBCT images provided more details in assessing maxillary molar FL.</td>
</tr>
<tr>
<td>Panjikarag N et al. 2016 (18)</td>
<td>40 patients 200 sites</td>
<td>CBCT measurements and clinical measurements performed by two different examiners</td>
<td>Vertical component was measured with Williams probe, Horizontal component was measured with Nabers probe</td>
<td>Furcation involvement</td>
<td>Pre-surgery clinical measurements (vertical 6.15 ± 1.71 mm and horizontal 3.05 ± 0.84 mm) and CBCT measurements (vertical 7.59 ± 1.67 mm and horizontal 4.56 ± 0.77 mm) underestimated intra-surgery measurements (vertical 8.05 ± 1.67 mm and horizontal 4.82 ± 0.87 mm) in both vertical and horizontal aspects, and the difference was statistically not significant (vertical P = 1.00).</td>
</tr>
<tr>
<td>Patmanabhan et al. 2017 (19)</td>
<td>14 patients 24 sites</td>
<td>1</td>
<td>Intramuscular measurements were done using an endodontic file and assessed with a digital vernier caliper</td>
<td>Furcation involvement</td>
<td>The CBCT versus intrasurgical furcation measurements were 23.8 ± 0.86 mm and 23.30 ± 0.89 mm for furcation height, 187 ± 0.52 mm and 184 ± 0.49 mm for furcation width, and 3.81 ± 0.52 mm and 4.05 ± 0.49 mm for furcation depth, respectively. Results showed that there was no statistical significant difference between the measured parameters, indicating that the two methods were statistically similar.</td>
</tr>
<tr>
<td>Aghanshini S et al. 2017 (20)</td>
<td>22 patients 50 sites</td>
<td>Clinical measurements and image analysis was done by 2 different examiners</td>
<td>Clinical measurements were done using Nabers probe</td>
<td>Furcation involvement</td>
<td>Thus, the results indicated that there was the highest agreement between measurements obtained using CBCT imaging techniques and true level of involvement seen during ODS (99%) when compared to clinical and ODS measurements (91%) and clinical and CBCT measurements (92%).</td>
</tr>
<tr>
<td>Zhang W et al. 2016 (21)</td>
<td>83 patients</td>
<td>Single examiner evaluated the cases 2 times within 7 months</td>
<td>Periodontal probe and Nabers probe</td>
<td>Furcation involvement</td>
<td>There were significant correlations (p &lt; 0.05) between clinical detection and intrasurgical measurements. CBCT exhibited higher correlation with clinical detection relative to intrasurgical radiography, especially at distal palatal side of maxillary first molar (p &lt; 0.05).</td>
</tr>
<tr>
<td>Parvez MF et al. 2018 (22)</td>
<td>17 subjects</td>
<td>Single examiner</td>
<td>Clinical measurements performed using curved Nabers probe marked at 3 mm intervals</td>
<td>Furcation involvement</td>
<td>There was no statistically significant difference between CBCT measurements and surgical measurements (p=0.05).</td>
</tr>
<tr>
<td>Petil SR et al. 2018 (23)</td>
<td>32 patients</td>
<td>Single examiner interpreted the images and each measurement was repeated twice by the same operator after 15 days</td>
<td>All direct surgical measurements were made with a probe (HU-Friedy)</td>
<td>Intrasutural defects</td>
<td>No significant difference was noted regarding the CBCT measurements of the facio-lingual width and M-3 with the height when compared with the measurements obtained during the surgical procedures.</td>
</tr>
<tr>
<td>Yang J et al. 2019 (24)</td>
<td>13 patients</td>
<td>3 examiners</td>
<td>Periodontal probe</td>
<td>Alveolar bone</td>
<td>Statistically significant differences were found between CBCT and CAL = 2.04 mm (P = 0.000), as well as intra-surgical evaluation (P = 0.001). All sites showed differences in CBCT versus intra-surgical measurement and versus CAL = 2.04 comparisons, except the buccal sites (P = 0.87 and 0.94 respectively).</td>
</tr>
<tr>
<td>Sneh R et al. 2019 (25)</td>
<td>10 patients</td>
<td>One examiner</td>
<td>Hard tissue measurements were recorded by a periodontal probe CP 15 UNC (HU-Friedy, Chicago, IL, USA) accurate to the nearest 0.5mm. Furcation defects (FD) were assessed using a curved Nabers probe (PQ2N, HU-Friedy).</td>
<td>Marginal bone levels and furcation involvement</td>
<td>Marginal bone levels and furcation involvement were more bone loss. Furcation defects were similar between CBCT and intra-surgical measurement.</td>
</tr>
<tr>
<td>Nayyar AS et al. 2019 (26)</td>
<td>12 patients</td>
<td>One examiner</td>
<td>It was measured using the standard UNC 15 periodontal probe</td>
<td>Bone defects</td>
<td>The CBCT measurements and clinical measurements for various sites in the anterior and posterior teeth was found to be highly significant in all the cases (P = 0.000).</td>
</tr>
</tbody>
</table>
On analysis of the data in the current review, we observed that the full text articles ranged from 2015 to 2019. The number of patients involved in the study ranged from a minimum of 10 patients in one of the studies to a maximum of 83 patients in another study. The number of examiners evaluating the clinical and radiographic measurements in these studies also showed variation. There were 9 studies with single observer. Four of the studies used 2 observers whereas 3 and 4 observers were used in one study each. Radiographic measurements of different periodontal parameters were evaluated in the studies. Furfurcation involvement was evaluated in 11 studies. Alveolar bone loss was evaluated in 4 clinical studies, whereas both furcation involvement and alveolar bone evaluation was carried out in one study. The clinical evaluation of the furcation area was carried out using Nabers probe in all the studies whereas the alveolar bone level measurements were carried out using periodontal probe (HU Friedy).

**DISCUSSION**

The application of CBCT in detection of periodontal bone levels has received significant importance in the past 5 years and the studies pertaining to this specific area of research have been reviewed systematically in three recent publications [11,27,28]. The numbers of full text articles found eligible for the review were 14, 16 and 13 in studies conducted by Anter E et al., Haas LF et al. and Choi IG et al. respectively. [11,27,28] In our systematic review 15 research studies were eligible for the final analysis. Anter E et al. used PubMed database whereas Haas LF et al. used LILACS, PubMed, Scopus and Web of Science. Choi IG et al. employed The MEDLINE and Embase databases for their article search [11,27,28]. In our systematic review we obtained articles from PubMed and Google Scholar. The detailed analysis of the results of the fifteen eligible articles in our review is presented under two broad subheadings, which are alveolar bone level evaluation and evaluation of furcation involvement.

**Alveolar bone level evaluation**

Pour GD et al. observed that there was no significant difference between the measurements using CBCT and the surgical method in the buccal, lingual/palatal, mesial and distal aspects of alveolar bone [12]. Similar results were obtained in a study conducted by Guo YJ et al. There was no significant difference ($p = 0.84$) between intra-surgical surgical and CBCT measurements in Guo YJ et al's study. Another important observation in Guo's study was statistically insignificant inter-observer ($p = 0.95$) and intra-observer ($p = 0.30$) difference among the observers [16]. Intra-bony periodontal defects study by Patil SR revealed that there was no significant difference between the CBCT measurements and intra-surgical measurements.

However a contrast results were obtained in the study conducted by Yang J et al. They found statistically significant difference between CBCT and intra-surgical measurements ($p = 0.001$) [24].

Yang J et al. stated that there could be specific reasons for the results of their study contradicting the results of those studies advocating the application of CBCT in estimating periodontal bone levels. One of the reasons stated is that most of the studies only included the premolar and molar region but seldom involved the anterior region. A study conducted by Mol et al. demonstrated that CBCT has reduced accuracy in measurements especially in the anterior region of the jaw. [29]. This could be attributed to morphology of the periodontal bone and presence of thinner buccal and lingual plates in the anterior region of the jaws [29].

Furthermore, some researchers also stated that the accuracy of measurement of bone levels may also depend on type of CBCT equipment and resolution capabilities. It has been found that measurements from the 0.25-mm resolution images will be significantly more accurate than the measurements from the 0.4-mm resolution images [30].

Another reason for inconsistencies between intra-surgical clinical bone level measurements and CBCT measurements could be due to poor accessibility in certain areas particularly in the lingual and palatal aspects [31]. The inconsistencies of CBCT in determining bone levels especially in the palatal/lingual sites of anterior teeth was highlighted in a study...
conducted by Nayyar AS et al. [26] They found that in the anterior region the mean CBCT measurement value of 4.0444 mm and the mean intra-surgical value was 4.1822 mm. The difference was statistically significant. However, there was no statistical difference between the CBCT measurements and intra-surgical measurements in the posterior teeth. Another aspect that is to be taken into consideration while employing CBCT for making alveolar bone level measurements is relatively higher radiation dose compared to intraoral periapical radiography or panoramic radiography [32].

**Evaluation of furcation involvement**

The main advantage of CBCT over the conventional two dimensional radiographic techniques is unobstructed multi-planar view of the anatomical structures. The multi-planar viewing is beneficial especially in the furcation areas (Figure 2).

Qiao et al. concluded that the CBCT images demonstrated high accuracy in evaluating furcation involvement. Another important observation in this study was that the intra-surgical measurements were most consistent with CBCT measurements in the buccal furcation followed by disto-palatal and mesio-palatal furcation.[13] The results were similar to the one observed in the study by Walter et al. [33] But some studies have found different results regarding the accuracy of CBCT in matching up to clinical measurements in different types of furcation. In a study by Cimbaljevic MM et al. it was observed that the highest agreement between clinical probing and CBCT measurements (73.7%) in furcation involvement detection was observed in the disto-palatal maxillary area. The lowest agreement (36.6%) was found in the buccal areas of the mandibular molar [14]. However the difference could be attributed to the fact that the other studies were comparing the agreement between CBCT measurements and intra-surgical management, whereas the in the study by Cimbaljevic MM et al. the agreement between CBCT measurements and clinical probing was carried out for evaluating furcation involvement. Another study conducted by Cimbaljevic MM et al. it was observed that clinical experience and CBCT expertise had no major impact on detection of furcation involvement in CBCT scans, if the interpreter has received adequate training [34]. In another study conducted by Kranti K et al., it was found that, just 28% of the clinical findings were confirmed during CBCT analysis. On the contrary 30.2% of CBCT measurements were overestimated and 41.7%were underestimated when compared to clinical measurements [15]. The results of the study by Zhu J et al. revealed that CBCT scans were more efficient in assessing maxillary furcation involvement [24]. Specific furcal parameter investigated in the study included horizontal bone loss at furcation entrance level, maximum horizontal bone loss, maximum vertical bone loss and root trunk length. The accuracy of CBCT measurements were in furcation involvement was further reinforced by results obtained in studies conducted by Parvez MF et al. and Sreih R et al. [22,25] In a study conducted by Aghanashini S et al. the furcation areas were grades from I-III during clinical, intra-surgical and CBCT
assessments. This methodology was different from majority of studies, which tended to measure the dimensions of furcation involvement rather than grade the furcation defect [20]. The results of the study however was consistent with a majority of the studies with agreement of (89%) between grading obtained using CBCT scans and intra-surgical procedures. The agreement between clinical and intra-surgical grading was (11%) whereas the agreement between clinical and CBCT measurements was (3%) [20].

Intra-surgical measurements

Endodontic file and assessed with a digital vernier caliper, Nabers probe and UNC 15 probe were the armamentarium used for the intra-surgical evaluation of periodontal defects in the clinical studies listed in our systematic review (12-26). While most of the researchers used Nabers probe and UNC 15 probe for measurement of bony defects Padmanabhan S et al. used a combination of endodontic files and digital vernier caliper [19]. In their study the height of the defect was measured from the furcation fornix to the base of the alveolar base. The width of the defect was measured between the greatest dimensions of separation between the two roots above the crest of alveolar bone. The depth of the defect was measured from the crest of alveolar bone till the interradicular bony resistance was felt.

The authors stated that the digital vernier caliper had an accuracy of up to 0.2 mm and hence was preferred over other instruments. However the results of the above mentioned study was consistent with a majority of the other studies in which Nabers probe and UNC 15 probe to carry out the intra-surgical measurements. radiographic EXAMINATIONS DO NOT

CONCLUSION

Most of the research papers state that CBCT measurements are in agreement with intra-surgical alveolar bone measurements, however, there is still some speculation regarding the accuracy of the measurements in the anterior areas with relatively thinner cortical areas. CBCT measurements were consistent with intra-surgical furcal measurements in most of the studies. However, there is evidence of some differences in areas, where accurate surgical measurements are difficult due to accessibility. Overall the efficiency of CBCT in detecting and evaluating furcation involvements remains significant however the radiation dose must be taken into account before advising for a CBCT scan in such clinical scenario.

In a recent guideline published by European Union study group on radiation protection it has been suggested that partial volume, high resolution CBCT may be indicated in only in selected cases of infra-bony defects, endo-perio lesions and furcation lesions. The guidelines stated that CBCT scans should be used in situations where clinical examinations and conventional radiographic assessment do not provide the adequate information needed for the treatment planning [35].

REFERENCES

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Shetty SR et al.
Braz Dent Sci 2020 Jul/Sep;23(3)

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Date submitted: 2019 Nov 02
Accept submission: 2020 Mar 10